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AQUATIC MOLLUSCA OF THE WHITE RIVER NATIONAL WILDLIFE REFUGE, ARKANSAS, U.S.A.

Mark E. Gordon[1], Stephen W. Chordas III[2], George L. Harp[3], and Arthur V. Brown[4]

ABSTRACT – Forty-nine species of freshwater Mollusca were collected during surveys of aquatic habitats within the White River National Wildlife Refuge, Arkansas. Critical review of other recent studies resulted in the identification of five additional species, increasing the known molluscan fauna of the refuge to 54 species. This assemblage represents 88.5% of molluscan species recorded for the Mississippi Alluvial Valley portion of the White River drainage basin. Examination of both large and small aquatic habitats and sympatric distribution of northern and southern elements of the Interior Basin fauna enhanced the observed species richness in this area.

Key words: Unionoidea, Prosobranchia, Pulmonata, White River, Mississippi Alluvial Valley.

INTRODUCTION

The molluscan fauna of the White River system of Arkansas and Missouri may be the most speciose of the western tributaries of the Mississippi River. Approximately 100 species are known historically (Gordon, 1982); however, the distribution of species has not been well documented within the basin. Gordon (1982) reviewed recent studies of the White River's fauna and found that only a few localized investigations had been conducted within the Mississippi Alluvial Valley portion of the drainage. Subsequently, additional faunal surveys have considered this region (*e.g.*, Bates & Dennis, 1983; Clarke, 1985; Miller & Harris, 1987) but also have tended to be rather limited in scope. None of the previous studies considered the fauna of the various aquatic habitats that occur within the adjacent lowland hardwood forest. Our investigation surveyed the aquatic molluscan fauna of the mainstem of the White River and the lowland forest within the White River National Wildlife Refuge.

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MATERIALS AND METHODS

The White River National Wildlife Refuge is located near the confluence of the White and Mississippi rivers and includes portions of Arkansas, Desha, Monroe, and Phillips counties, Arkansas. Within the refuge, large river habitat is represented by the mainstem of the White River, a former channel of the Mississippi River (Gordon, 1982); smaller lotic and lentic systems are dispersed throughout remnant stands of lowland hardwood forest. Molluscs were sampled from 31 sites distributed among accessable aquatic habitats within the refuge (Fig. 1; Appendix 1) during October 1987, July 1988, and from October 1989 through September 1990. A collection was made at the confluence of the White and Mississippi rivers, Desha County. Each site was visited twice at different times of the year to counter possible seasonal occurences of species. Sampling was qualitative (*e.g.*, visual searching, groping, digging, netting, sieving) and continued until no additional taxa could be located. Voucher material was deposited in the Academy of Natural Sciences of Philadelphia and the University of Colorado Museum.

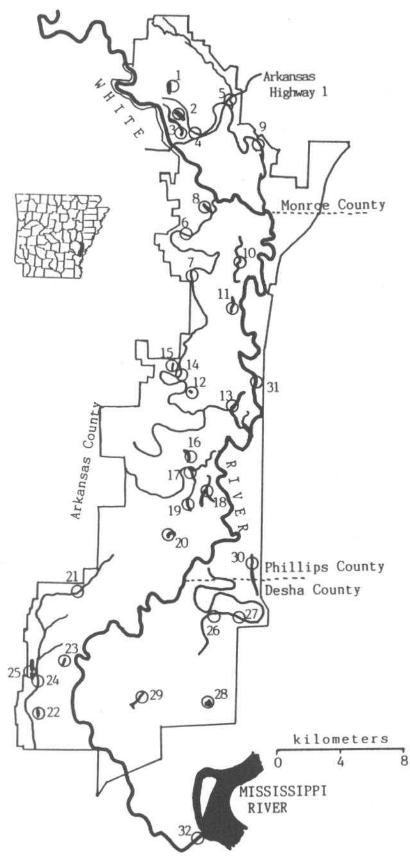

FIG 1. Collection localities within the White River National Wildlife Refuge, Arkansas.

RESULTS

Forty-nine species of freshwater Mollusca (30 unionoid mussels, three heterodont clams, seven prosobranch and nine pulmonate gastropods: Table 1) were found within the White River National Wildlife Refuge. Live individuals of all species were observed and a wide range of sizes among most species was indicative of successful reproduction and recruitment within the study area. Twenty-seven of the mussel species inhabited the mainstem of the White River and displayed a tendency to be aggregrated on the downstream side of sand bars. *Pleurocera canaliculatum* (Say 1821), a prosobranch characteristic of large river habitats, occurred in some smaller habitats in addition to the mainstem. The fauna of side channels, creeks, ox-bow lakes, ponds, and small impoundments was composed primarily of gastropods and heterodont clams, but also supported fourteen species of mussels, including three species which were collected only in these habitats (*Ligumia subrostrata* (Say 1831), *Toxolasma parvum* (Barnes 1823), *T. texasensis* (Lea 1857)). *Corbicula fluminea* (Müller 1774) was fairly ubiquitous throughout the refuge. Our record for *Valvata bicarinata* Lea 1841 is the first reported occurrence of this species in Arkansas.

DISCUSSION

The White River within the refuge previously has been studied by Kraemer & Gordon (1981) and Bates & Dennis (1983). Three of the 27 species reported by Kraemer & Gordon (1981: *Probythinella lacustris* (Baker 1928), *Somatogyrus* sp., *Lampsilis siliquoidea* (Barnes 1823)) and two of the 22 species recorded by Bates & Dennis (1983: *Quadrula metanevra* (Rafinesque 1820), *Anodonta suborbiculata* Say 1831) were not found during our survey. Two species listed within the refuge by Bates & Dennis (1983) do not occur in that region of Arkansas. *Lampsilis clarkiana* (Lea 1852) is a junior synonym of *L. altilis* (Conrad 1834) of the Alabama River system (*fide* Frierson, 1927); *Carunculina glans* (Lea 1834) (=*Toxolasma* cf. *lividium* (Rafinesque 1831)) inhabits only the Interior Highlands in Arkansas (Gordon, unpubl. data). Bates & Dennis (1983) supplemented their report with an illustrated guide to the taxa collected during their survey (see Ecological Consultants, Inc., 1984). Figured shells of *L. clarkiana* and *C. glans* in Ecological Consultants, Inc. (1984: Plates VII and X, respectively) represent misidentified specimens of *L. hydiana* (Lea 1838) and of a

TABLE 1. Mollusca of the White River National Wildlife Refuge, Arkansas (see Fig. 1 for site localities).

Taxa Site:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Gastropoda (PROSOBRANCHIA)																
Campeloma crassulum Rafinesque					X	X	X		X					X		
Cincinnatia cincinnatiensis (Anthony)	X	X	X	X	X											
Pleurocera canaliculatum (Say)					X	X	X		X					X		
Valvata bicarinata Lea				X												
Valvata tricarinata (Say)				X												
Viviparus intertextus (Say)	X			X			X				X				X	
Viviparus subpurpureus (Say)	X												X	X		
Gastropoda (PULMONATA)																
Ferrissia fragilis (Tryon)		X						X								
Ferrissia rivularis (Say)	X		X	X			X				X	X				
Fossaria obrussa (Say)																
Gyraulus parvus (Say)																
Laevapex fuscus (Adams)		X														
Micromenetus dilatatus (Gould)	X		X					X								
Physella sp. 1	X	X	X	X		X		X			X		X	X	X	X
Physella sp. 2				X								X				
Planorbella trivolvis (Say)				X	X							X				
Bivalvia (UNIONOIDEA)																
Amblema plicata (Say)												X				X
Arcidens confragosus (Say)																
Ellipsaria lineolata (Rafinesque)																
Elliptio dilatata (Rafinesque)																
Fusconaia ebena (Lea)																
Fusconaia undata (Barnes) [1]																
Lasmigona complanata (Barnes)																
Lampsilis cardium Rafinesque																
Lampsilis hydiana (Lea)																
Lampsilis teres (Rafinesque) [2]							X									
Leptodea fragilis (Rafinesque)						X	X				X		X	X		
Ligumia recta (Lamarck)																
Ligumia subrostrata (Say)				X						X		X				
Megalonaias nervosa (Rafinesque)																
Obliquaria reflexa Rafinesque							X									
Obovaria jacksoniana Frierson																
Obovaria olivaria (Rafinesque)																
Plectomerus dombeyanus (Valenciennes)													X			
Potamilus ohiensis (Rafinesque)																
Potamilus purpuratus (Lamarck)																
Pyganodon grandis (Say)																
Quadrula cylindrica (Say)																
Quadrula nodulata (Rafinesque)													X			
Quadrula pustulosa (Lea)												X				
Quadrula quadrula (Rafinesque)																
Toxolasma parvum (Barnes)	X	X									X					
Toxolasma texasensis (Lea)													X			
Tritogonia verrucosa (Rafinesque)												X				
Truncilla truncata Rafinesque																
Uniomerus tetralasmus (Say)																
Bivalvia (HETERODONTA)																
Corbicula fluminea (Müller)	X	X	X		X	X	X	X	X	X	X	X	X	X	X	
Musculium securis (Prime)			X			X						X				
Musculium transversum (Say)	X					X			X		X			X	X	

TABLE 1. (cont.)

Taxa	Site: 17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Gastropoda (PROSOBRAHCHIA)																
Campeloma crassulum	X		X	X											X	
Cincinnatia cincinnatiensis																
Pleurocera canaliculatum	X		X												X	
Valvata bicarinata																
Valvata tricarinata																
Viviparus intertextus					X	X	X				X					
Viviparus subpurpureus	X		X	X											X	X
Gastropoda (PULMONATA)																
Ferrissia fragilis								X								
Ferrissia rivularis																
Fossaria obrussa					X											
Gyraulus parvus												X				
Laevapex fuscus												X				
Micromenetus dilatatus																
Physella sp. 1		X	X	X	X	X	X	X		X	X	X	X	X		
Physella sp. 2									X	X	X					
Planorbella trivolvis		X	X	X	X	X	X			X	X	X		X		
Bivalvia (UNIONOIDEA)																
Amblema plicata															X	
Arcidens confragosus															X	X
Ellipsaria lineolata															X	
Elliptio dilatata															X	
Fusconaia ebena															X	
Fusconaia undata [1]															X	
Lasmigona complanata															X	
Lampsilis cardium															X	
Lampsilis hydiana															X	
Lampsilis teres [2]															X	
Leptodea fragilis			X											X	X	X
Ligumia recta															X	
Ligumia subrostrata																
Megalonaias nervosa															X	
Obliquaria reflexa															X	X
Obovaria jacksoniana															X	
Obovaria olivaria															X	
Plectomerus dombeyanus															X	X
Potamilus ohiensis															X	X
Potamilus purpuratus		X													X	X
Pyganodon grandis									X						X	
Quadrula cylindrica															X	
Quadrula nodulata															X	
Quadrula pustulosa															X	
Quadrula quadrula		X													X	
Toxolasma parvum		X	X													
Toxolasma texasensis		X														
Tritogonia verrucosa															X	
Truncilla truncata															X	X
Uniomerus tetralasmus															X	
Bivalvia (HETERODONTA)																
Corbicula fluminea	X			X		X							X	X	X	X
Musculium securis					X			X								
Musculium transversum					X			X						X	X	

[1]*Fusconaia undata* exhibited a wide range of shapes, including some which approached that of the so-called *F. selecta* (Wheeler 1912).

[2]Both typical (unrayed) and rayed (form *fallaciosa* Smith 1899, *non teres sensu* Stansbery [personal communications to numerous individuals: see Buchanan, 1979, and Oesch, 1984] *nec* Rafinesque 1820) specimens of *Lampsilis teres* were observed.

female *T. texasensis* (note: the figure of *C. parva* on Plate X is a male *T. texasensis*), respectively. Consequently, 54 species of aquatic molluscs are now known from the refuge.

Resident species typically are tolerant of fine particle substrates and high detrital loads inherent to most habitats within the refuge. While some taxa appear to be fairly broad habitat generalists (*e.g.*, *Campeloma crassulum* Rafinesque 1819, *Viviparus subpurpureus* (Say 1829), *Corbicula fluminea*), several species typical of large river environments (*e.g.*, *Pleurocera canaliculatum*, *Fusconaia ebena* (Lea 1831), *Potamilus ohiensis* (Rafinesque 1820)) also occurred in other habitats, indicative that distributions may have been affected historically by flooding and stream meander typical within the Mississippi Alluvial Valley prior to instigation of flood control management (*e.g.*, dams, levees). However, most of the gastropods and three mussels are more characteristic of the smaller lotic or lentic habitats generally found in the lowland forest. This component of the fauna contributed significantly to the higher number of species we recovered relative to prior studies. Based on critical review of available data (*i.e.*, Stein & Stansbery, 1980; Kraemer & Gordon, 1981; Bates & Dennis, 1983; Ecological Consultants, 1984; Clarke, 1985; Miller & Harris, 1987; data herein), 88.5% of the species that have been reported from the lower White River basin inhabit the refuge, indicating that it contains diverse habitat representative of most aquatic ecosystems within the region.

The lower White River drainage possesses a fauna composed predominantly of widely-distributed Interior Basin species but is augmented by southern faunal elements (*Plectomerus dombeyanus* (Valenciennes 1833), *Obovaria jacksoniana* Frierson 1912, *Potamilus purpuratus* (Lamarck 1819), *Toxolasma texasensis*, and *Lampsilis hydiana*; see Gordon, 1985). This faunal transitional zone represents one of the few areas where the northern *L. siliquoidea* is distributed sympatrically with the southern *L. hydiana*. Species richness also is affected by faunal mixing in the vicinity of the confluence with the Black River. As the approximate boundary between the Ozark Plateaus and the Mississippi Alluvial Valley, a few Interior Highlands endemics (*e.g.*, *Cyprogenia aberti* (Conrad 1850), *Ptychobranchus occidentalis* (Conrad 1836)) persist in habitats more characteristic of lowland species (*e.g.*, *Plectomerus dombeyanus*).

High species richness and its utilization as a major commercial source for mussels (Coker, 1919; Brann, 1947; Gordon, 1980; Harris &

Gordon, 1990) denote the importance of the White River as molluscan habitat. Unfortunately, it has suffered the fate of most large rivers in the United States and has been subjected to extensive basin modification (see Gordon, 1982). The White River within the Mississippi Alluvial Valley is managed for barge traffic with some dredging and other operations required annually to maintain the present channel, often to the demise of mussel populations, including federally-endangered species (Miller & Harris, 1987). Dredging and so-called bank stabilization (*i.e.*, removal of riparian vegetation and rip-rapping of river banks) have contributed to the environmental degradation of the refuge through physical destruction of habitat and increased erosion and siltation. The combination of increasing physical disturbance and the often indiscriminant collecting related to the recently revitalized freshwater mussel shell industry seriously threatens the faunal integrity of this already stressed system. The White River National Wildlife Refuge should be managed to preserve its diverse aquatic habitats and associated benthos, such as molluscs.

ACKNOWLEDGMENTS

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APPENDIX 1. Gazetteer of collecting sites, White River National Wildlife Refuge, Arkansas.

Site no.	Locality
1	Swan Lake, Monroe County, T3S R1W Sec. 29 (NE ¼), mud substrate with leaf and woody detritus, sparse macrophytes.
2	Buck Lake, Monroe County, T3S R1W Sec. 33 (NW ¼), mud substrate, some leaf detritus among tree roots.
3	Little Moon Lake, Monroe County, T3S R1W Sec. 33 (NW ¼), rocky substrate with considerable amounts of mud, leaf and wood detritus and some root snags, steep banks.
4	Waters Bayou, Monroe County, T3S R1W Sec. 34 (SW ¼), steep clay banks, sparse macrophytes, large amounts of woody detritus and root snags.
5	Indian Bayou, Monroe County, T3S R1W Sec. 26, rocky substrate with mud, riffle-pool morphology, sparse macrophytes in pools.
6	Big Island Chute, Arkansas County, T4S R1W Sec. 21 (SE ¼), riffle-pool morphology, gravel substrate embedded in clay, leaf and woody detritus in pools.
7	H-landing, Arkansas County, T4S R1W Sec. 33 (SE ¼), rocky substrate embedded in clay, silty pools, large amounts of woody detritus, some root snags, steep banks.
8	Little White Lake, Arkansas County, T4S R1W Sec. 14 (SE ¼), clay and silt substrate, large amounts of leaf and woody detritus.
9	Indian Bay, Monroe County, T4S R1W Sec. 1 (NE ¼), muddy substrate with occasional rocky material, spotty detrital accumulations, steep banks.
10	Big Horseshoe Lake, Arkansas County, T4S R1W Sec. 35 (NE ¼), sandy substrate, no macrophytes or detrital accumulations, some root snags, steep banks.
11	Lake Gut, Arkansas County, T5S R1W Sec. 2 (SE ¼), muddy substrate, macrophyte beds, large areas of leafy detritus, root snags.
12	Burnt Lake, Arkansas County, T5S R1W Sec. 27 (NW ¼), muddy substrate, large amounts of leaf detritus, some woody material.

13 Escrogens Lake, Arkansas County, T5S R1W Sec. 35 (NE ¼), hard clay to soft muddy substrates, large amounts of leaf and woody detritus, no macrophytes.

14 Essex Bayou, Arkansas County, T5S R1W Sec. 21 (SE ¼), mud substrate, large amounts of leaf and woody detritus, no macrophytes, root snags, steep banks.

15 Hurricane Pond, T5S R1W Sec. 21 (NW1/4), substrate of very soft black organic ooze, copious amounts of leaf and woody detritus, root snags, no macrophytes.

16 Columbus Lake, Arkansas County, T6S R1W Sec. 3 (SW ¼), hard clay to semi-soft mud substrates, some leaf detritus, large amounts of woody detritus, root snags, no macrophytes.

17 Prairie Bayou, Arkansas County, T6S R1W Sec. 10 (NW ¼), mud to clay substrate, macrophyte beds, root snags, little detritus present.

18 H-Lake, Arkansas County, T6S R1W Sec. 15 (N ½), water very turbid, muddy substrate, thick deposition of detritus, root snags.

19 Prairie Lake, Arkansas County, T6S R1W Sec. 16 (SE ¼), water turbid, clay substrate, slight detrital accumulations.

20 Wolf Lake, Arkansas County, T6S R1W Sec. 28 (NW ¼), clay substrate, macrophytes present, leaf and woody detritus, root snags.

21 Wolf Bayou, Arkansas County, T7S R2W Sec. 2 (NE ¼), at flood gate, clay to muddy substrates, scattered leafy detrital accumulations, no macrophytes.

22 Beaver Pond #1, Arkansas County, T7S R2W Sec. 34 (NE ¼), black ooze to clay substrates, large amounts of leaf and woody detritus, macrophyte beds present.

23 Beaver Pond #2, Arkansas County, T7S R2W Sec. 14 (SE ¼), clay to mud substrate, leaf and woody detritus, sparse macrophytes.

24 Honey Locust Bayou, Arkansas County, T7S R2W Sec. 22 (SE ¼), mud substrate, large amount of leaf and woody detritus.

25 Reservoir, Arkansas County, T7S R2W Sec. 22 (SW1/4), soft mud to hard clay substrates, leaf detritus, sparse woody detritus, macrophyte beds present.

26 Scrubgrass Bayou #1, Desha County, T7S R1W Sec. 11 (SE ¼), clay substrate, leaf detritus, macrophyte beds.

27 Scrubgrass Bayou #2, Desha County, T7S R1W Sec. 11 (NW ¼), hard clay substrate, leaf and woody detritus, root snags, sparse macrophytes.

28 Alligator Lake, Desha County, T7S R1W Sec. 34 (NE ¼), muddy substrate, large amounts of leaf and woody detritus, macrophyte beds and root snags present.

29 East Moon Lake, Desha County, T7S R1W Sec. 29 (SW ¼), soft mud to hard clay substrates, large amounts of leaf and woody detritus, sparse, macrophytes, root snags.

30 Borrow Pit, Phillips County, T6S R1W Sec. 36 (SE ¼), soft mud to hard clay substrate, large amounts of leaf and woody substrate, root snags, macrophytes present.

31 Hudson's Landing, Phillips County, T5S R1W Sec. 24 (SE ¼), mainstem of White River, large lowland river with sand bars, sandy substrate with gravel and some mud, areas of leaf and woddy detrital accumulation, macrophytes only in a few backwater areas, steep banks.

32 Mouth of White River, Desha County, T8S R1W Sec. 35, mainstem of White River immediately upstream from confluence with Mississippi River, sandy substrate, sandbars present, accumulations of large woody detritus, steep banks with some rip-rapping.

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CHANGES IN THE FRESHWATER SNAIL FAUNA IN AN OVER-INDUSTRIALIZED AREA IN POLAND

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ABSTRACT – Our investigations of the freshwater snails of the Upper Silesian Industrial Region of southern Poland during 1976-1990 showed a qualitative and quantitative decrease in the snail fauna which paralleled the increase of industrialization of the area. The decrease in the snail fauna is probably due to the increasing amount of toxic pollutants in the snail habitats. The diminished industrial activity observed in the final period of our study (1986-1990) has not led to the regeneration of the original snail fauna.

Key words: Freshwater snails, pollution, Silesia, Poland.

The Upper Silesian Industrial Region of southern Poland covers 1375 km^2 of the Silesian Upland. In this Region occur 68% of the coal mines and 58% of the iron plants in Poland. During the 1976-1985 period, the natural environment of the Region was devastated by increasing industrial activity, mainly by coal mining and iron metallurgy. During this period, and until 1990, we investigated the qualitative and quantitative changes in the freshwater snail fauna of the Region, investigating 43 water bodies. The area we studied is completely devoid of natural lentic environments. The only water bodies are sinkhole ponds and sand pits, both of anthropogenic origin.

The years 1976-1980 experienced the most intensive industrialization; during 1981-1985 there was some stabilization of the unfavorable environmental conditions, and more recently there has been some improvement, caused mostly by the recession of industry. From 1976 until 1985, we observed increasing pollution of the water and bottom sediments with toxic compounds. In these years, according to Fjerdingstad's (1964) classification, the water bodies became chemiobiontic, and some became chemotoxic as well. In the last period of our investigations, pollution declined.

The freshwater snail fauna (20 species in 1976) of the region we studied is not as rich as the snail fauna of neighboring areas, where 32 species have been recorded (Strzelec, 1993). In our area, the freshwater snail fauna is composed mostly of common, ubiquitous species (Table 1). Single individuals of some species could have been introduced by water birds, because the Upper Silesian Industrial Region lies in the route of bird migrations. These individually introduced

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TABLE 1. The presence and abundance of freshwater snails in the Upper Silesian Industrial Region.

Species	Time period 1976-1980	1981-1985	1986-1990
Viviparus contectus (Mill.)	+*	–	–
Valvata piscinalis (O.F. Müller)	+	–	–
Potamopyrgus jenkinsi (E.A. Smith)	–	+	++++
Bithynia tentaculata (Linnaeus)	+	+	+
Aplexa hypnorum (Linnaeus)	+	+	+
Physa fontinalis (Linnaeus)	+	+	–
Physa (Physella) acuta Draparnaud	+	++	–
Lymnaea stagnalis (Linnaeus)	+++	+++	+++
Lymnaea (Radix) peregra (O.F. Müller)	++++	++++	+++
Lymnaea (Radix) auricularia (Linnaeus)	++	++	–
Lymnaea (Stagnicola) corvus Gmelin	++	++	+
Lymnaea (Fossaria) truncatula (O.F. Müller)	++	+	–
Planorbis planorbis (Linnaeus)	++++	+++	++
Anisus spirorbis (Linnaeus)	+	++	++
Anisus vortex (Linnaeus)	++	+	–
Anisus contortus (Linnaeus)	++	++	++
Gyraulus albus (O.F. Müller)	++	+	++++
Gyraulus (Armiger) crista (Linnaeus)	++	++	+++
Hippeutis complanatus (Linnaeus)	+	+	+
Segmentina nitida (O.F. Müller)	+	++	++
Planorbarius corneus (Linnaeus)	+++	+++	++
Number of species	20	19	14
Number of specimens collected	43392	30637	24471

*+ = < 1%; ++ = 1-10%; +++ = 10. 1-20%; ++++ = > 20% of each collection.

snails may appear from year to year, but because of inappropriate habitat conditions, they cannot establish persistent populations.

In the first period of our investigations (1976-1980), we found 20 species of freshwater snails. In the second period (1981-1985), we found 19 species, and in the third period (1986-1990) we found only 14 species. Presumably this qualitative decrease indicates the prolonged influence of unfavorable conditions on the snails. The disappearance of two of the prosobranch species, and the decrease in numbers of individuals of some of the pulmonate species (e.g., *Planorbis planorbis* and *Anisus vortex)* was due most likely to the increasing toxicity of bottom sediments. It is interesting that at the same time two species (*Potamopyrgus jenkinsi* and *Gyraulus albus)* increased in numbers, and in the third period of our investigation they became the dominate snail species. The increase in numbers of these two species may have been caused by the diminished competition by species being affected by pollution.

In a previous study (Strzelec & Krodkiewska, in press), the authors found that the appearance of the introduced exotic snail species, *Potamopyrgus jenkinsi,* can cause the extinction of some snail species in small water bodies. *Potamopyrgus jenkinsi* shows considerable resistance to industrial pollutants, and can therefore colonize aquatic environments unfavorable to other snails.

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Walkerana, 1993-1994, 7(17/18): 15-22

ESTUDIO MORFOMÉTRICO EN DOS POBLACIONES DEL GÉNERO *POMACEA* (PROSOBRANCHIA: AMPULLARIIDAE) DE CUBA

Alfredo Gutiérrez[1], Gloria Perera[1], Mary Yong[1] y Jorge Sánchez[1]

RESUMEN – Se realizó un estudio morfométrico en condiciones de laboratorio con dos formas del género *Pomacea* en Cuba (poblaciones El Rubio y Valle Grande). A 68 individuos de ambas poblaciones (28 de El Rubio y 40 de Valle Grande), se le tomaron 9 medidas conquiométricas y del opérculo con las cuales se calcularon 6 índices. Se determinaron las variaciones para estos índices entre ambos sexos y entre poblaciones mediante pruebas univariadas y además se realizó un Análisis de Componentes Principales con las medidas absolutas. La población de El Rubio presentó mayor dimorfismo sexual debido a la presencia de 3 índices con diferencias estadisticamente significativas (ancho/largo de la concha, ancho/largo de la abertura y ancho/largo del opérculo), mientras que Valle Grande presentó solamente un índice con dimorfismo sexual (ancho/largo de la abertura). Al comparar entre sí las poblaciones, 5 de los 6 índices presentaron diferencias significativas. Estas variaciones fueron más pronunciadas para los índices ancho/largo de la abertura y del opérculo, así como para el largo de la vuelta del cuerpo/largo de la concha. El Análisis de Componentes Principales mostró también una separación clara de los individuos de ambos grupos.

Palabras clave: *Pomacea paludosa, P. poeyana*, Ampullariidae (Pilidae), morfometría.

INTRODUCCIÓN

El género *Pomacea* (Familia Ampullariidae [= Pilidae]) en Cuba, ha recibido la atención de los investigadores desde hace varios años y algunos trabajos han sido publicados sobre dicho grupo (Pilsbry, 1927; Ferrer *et al.*, 1989; Perera *et al.*, 1991a,b; Perera & Yong, 1991).

En el catálogo de los moluscos de Cuba (Aguayo & Jaume, 1954) se señala la presencia de 3 especies: *Pomacea cubensis* Morelet 1840, *Pomacea paludosa* Say 1829 y *Pomacea poeyana* Pilsbry 1927. Sin embargo, la descripción de las mismas se basa en caracteres puramente descriptivos de la concha, que son bastante similares en ambas especies, siendo el estatus de dicha clasificación realmente dudoso, según informan para *Pomacea cubensis* los dos autores del catálogo.

Por otra parte, los individuos pertenecientes a este género constituyen los moluscos fluviales más extendidos en Cuba y además los de

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mayor tamaño, teniendo gran importancia desde el punto de vista médico y económico (Perera & Yong, 1991; Perera *et al.*, 1991b).

Nuestro estudio se propone analizar las diferencias existentes entre dos formas del género *Pomacea* (las cuales podrían corresponder a *Pomacea paludosa* y *Pomacea poeyana*) con respecto a la morfometría de la concha y el opérculo mediante pruebas univariadas y multivariadas.

MATERIALES Y MÉTODOS

Los individuos seleccionados procedían de dos localidades: El Rubio, ubicada hacia el este de la provincia La Habana, municipio Santa Cruz del Norte y caracterizada por ser un lago artificial de gran volumen de agua con predominio de plantas como *Typha dominguensis* y gramíneas en las orillas. Los ejemplares de *Pomacea* presentes se distinguen por una concha globosa y una espira baja y cónica. La otra población fue Valle Grande, que está localizada en el límite oeste de Ciudad de La Habana, municipio Lisa y es una arrocera con predominio de gramíneas. Los individuos se caracterizan por una concha menos globosa y una espira más pronunciada.

En El Rubio fueron analizados 28 individuos (11 machos y 17 hembras) y en Valle Grande se colectaron 40 (22 machos y 18 hembras). Para la determinación del sexo según la presencia de saco penial, los moluscos fueron anestesiados con Nembutal al 0.05% y después de transcurridas 24 horas fueron extraídos de la concha luego de ser sumergidos en agua a 70°C.

A todos los individuos se le midieron las siguientes variables morfométricas de la concha y el opérculo. Las medidas están expresadas en milímetros y fueron tomadas con un pie de rey (0.1 mm de precisión):

1. Largo de la Concha (LC)
2. Ancho de la Concha (AC)
3. Largo de la Abertura (LA)
4. Ancho de la Abertura (AA)
5. Largo de la Vuelta del Cuerpo (LVC)
6. Diámetro del Núcleo (DN)
7. Diámetro de la Primera Vuelta (D1V)
8. Largo del Opérculo (LO)
9. Ancho del Opérculo (AO)

Con las variables anteriores se calcularon los siguientes índices:

1. Forma de la Concha = AC/LC
2. Forma de la Abertura = AA/LA
3. Forma del Opérculo = AO/LO
4. Diámetro relativo de la Primera Vuelta = D1V/LC
5. Diámetro relativo del Núcleo = DN/LC
6. Largo relativo de la Vuelta del Cuerpo = LVC/LC

Con los índices se realizaron pruebas de comparación de medias entre sexos y poblaciones (Prueba t de Student). Con las medidas absolutas, se aplicó un Análisis de Componentes Principales (ACP) para conocer el grado de separación y las variables más influyentes.

Los especimenes de referencia (voucher specimens) fueron depositados en la colección del Laboratorio de Malacología del Instituto Pedro Kouri, Centro Colaborador de la Organización Mundial de la Salud para el adiestramiento e investigacón en Malacología Médica y control biológico de hospederos intermediarios.

RESULTADOS

La Tabla 1 muestra los resultados obtenidos de las comparaciones entre sexos y poblaciones para los índices calculados.

El dimorfismo sexual es mucho más evidente morfométricamente en la población de Valle Grande, donde los tres primeros índices mostraron diferencias estadísticamente significativas, siendo la forma de la abertura la que presentó mayores diferencias y fue esta variable además la única que mostró diferencias significativas entre sexos en la población de El Rubio.

Sólo un índice no mostró diferencias significativas al comparar entre si las dos poblaciones [DN/LC (diámetro relativo de la primera vuelta)], mientras que la forma del opérculo (AO/LO), la forma de la abertura (AA/LA) y el largo relativo de la vuelta del cuerpo (LVC/LC), mostraron gran diferenciación ($p < 0.001$). Esta última variable presentó un escaso sobrelapamiento entre poblaciones y este sobrelapamiento fue debido fundamentalmente a los machos (Fig. 1).

Los valores propios (eigenvalues) calculados para las dos primeras componentes del ACP realizado se muestran en la Tabla 2, siendo estas dos componentes suficientes para explicar la totalidad de toda la variación observada (95.8%). Los valores medios y desviaciones típicas para cada variable, y los factores de carga (charge factors o eigenvectors) para cada componente se presentan en la Tabla 3. La primera componente presentó los mayores factores de carga para el largo de la concha y de la vuelta del cuerpo, así como para el ancho de la concha. La segunda componente presentó los valores más altos para el ancho de la abertura y para el ancho del opérculo. El diagrama de dispersión sobre estas dos componentes (Fig. 2) presentó una evidente separación de los dos grupos, ubicándose ambos centroides en cuadrantes opuestos.

DISCUSIÓN

El dimorfismo sexual en ampuláridos ha sido estudiado en especies como *Marisa cornuarietis* (Demian & Ibrahim, 1972) y *Pomacea canaliculata* (Cazzaniga, 1990). Para ambas especies se plantea que

TABLA 1. Valores medios y desviaciones típicas por sexos para 6 índices morfométricos en dos poblaciones de *Pomacea* y resultados del test estadístico t de student.

Indice	El Rubio						Valle Grande							
	Macho (N = 11)		Hembra (N = 17)		entre sexos		Macho (N = 22)		Hembra (N = 18)		entre sexos		entre poblaciones	
	Media	s	Media	s			Media	s	Media	s				
AC/LC	0.890	2.52	0.900	1.93	-0.41	ns	0.870	3.51	0.850	1.87	3.21	*	3.39	**
AA/LA	0.600	2.46	0.570	2.06	2.43	*	0.700	4.13	0.620	2.52	7.55	***	-8.12	***
AO/LO	0.610	1.91	0.600	1.75	1.09	ns	0.680	3.02	0.640	2.55	4.51	***	-8.85	***
DV/LC	0.100	0.95	0.110	0.77	-0.92	ns	0.110	1.65	0.110	1.59	-0.37	ns	-0.05	ns
DN/LC	0.054	0.39	0.054	0.55	-0.07	ns	0.049	0.66	0.052	0.71	-1.19	ns	2.37	*
LVC/LC	0.940	1.31	0.940	0.87	0.97	ns	0.890	3.90	0.890	1.08	-0.04	ns	6.674	***

ns = $p > 0.05$; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

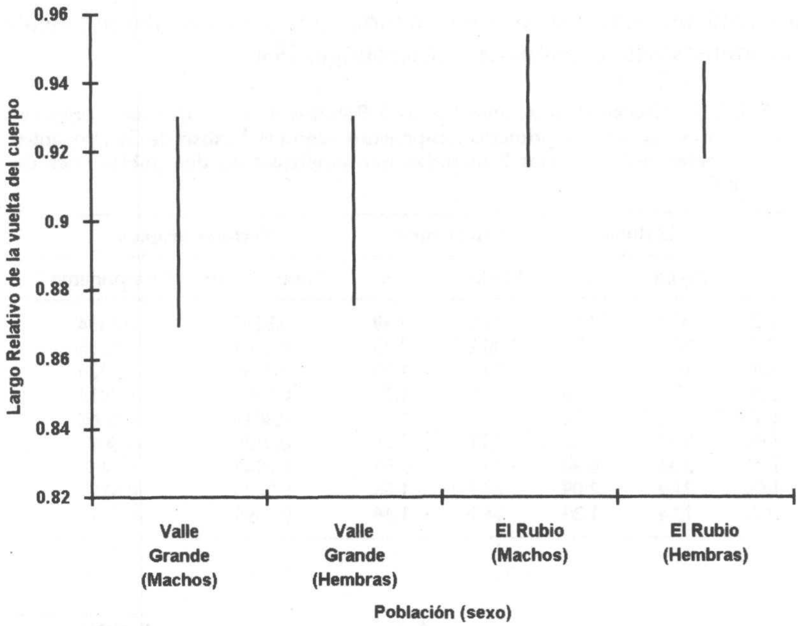

FIG. 1. Rango de amplitud del índice Largo Relativo de La Vuelta del Cuerpo, por sexos, en dos poblaciones del género *Pomacea* en Cuba.

la forma de la abertura es la variable que más diferencias sexuales presenta, lo cual es atribuído al desarrollo del complejo penial en los machos formando un abultamiento debajo del borde del manto que provoca la expansión del peristoma. También se han encontrado diferencias sexuales en cuanto a la forma del opérculo y al peso de la concha (Cazzaniga, 1990).

TABLA 2. Valores propios y porcentajes calculados para las dos primeras componentes según el Análisis de Componentes Principales realizado con 9 medidas morfométricas en dos poblaciones de *Pomacea*.

Componentes	I	II
Valores propios	40.236	3.253
Porcentajes (%)	88.6	7.2
Acumulados (%)	88.6	95.8

La población de El Rubio presentó menor cantidad de variables dimórficas que la de Valle Grande pero en ambas se corroboran las diferencias sexuales en cuanto a la forma de la abertura, pudiendo este carácter ocasionar errores cuando se toma como diagnóstico en consideraciones taxonómicas. (Cazzaniga, 1990).

TABLA 3. Medias, desviaciones típicas y Factores de carga (Vectores propios) calculados para las dos primeras componentes según el Análisis de Componentes Principales realizado con 9 medidas morfométricas en dos poblaciones de *Pomacea*.

	El Rubio		Valle Grande		Vectores propios	
	Media	s	Media	s	Componente 1	Componente 2
LC	32.2	2.99	34.5	2.69	0.5115	0.3494
AC	28.5	2.72	30.2	2.35	0.4509	0.1255
LA	16.2	2.56	25.2	1.95	0.3536	-0.5725
AA	15.7	1.60	17.6	1.73	0.2885	0.3914
LVC	30.2	2.82	30.9	1.86	0.4641	0.0562
DN	1.72	0.01	1.71	0.25	0.0120	-0.0001
DV	3.34	0.30	3.62	0.55	0.0342	0.0460
LO	21.9	2.09	20.7	1.58	0.2723	-0.6125
AO	13.4	1.39	14.1	1.46	0.1896	-0.0343

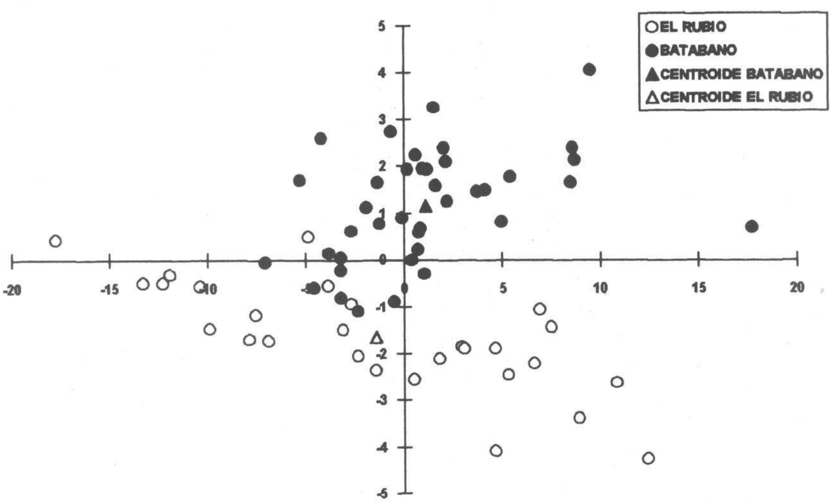

FIG. 2. Diagrama de dispersión sobre las dos primeras componentes del Análisis de Componentes Principales realizado con 9 variables morfométricas en dos poblaciones de *Pomacea*.

Las comparaciones entre poblaciones demuestran claramente que ambos grupos son entidades morfométricamente diferentes y que los índices correspondientes a la forma de la abertura, a la forma del opérculo y al largo relativo de la vuelta del cuerpo son los que más contribuyen a la variación. Este último índice podría servir para discernir a simple vista y de forma rápida cada grupo, ya que su sobrelapamiento es mínimo y el mismo está determinado por la mayor variabilidad morfométrica en los machos de la población de Valle Grande (Fig. 1). La validez de esta variable como carácter diagnóstico se corrobora con el ACP, ya que la longitud absoluta de la vuelta del cuerpo produjo uno de los mayores factores de carga en la primera componente.

La forma de la concha y de la abertura, así como la altura de la espira, entre otros caracteres morfológicos han sido indicados como de importancia en la distinción de especies en esta familia (Keawjam & Upatham, 1990) por lo que se pudiera pensar que ambas formas pertenecen a especies diferentes, pero atendiendo a la gran dificultad sistemática de este género creemos que los datos existentes hasta el momento son insuficientes y que son necesarios estudios enzimáticos y de la anatomía interna.

AGRADECIMIENTOS

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A MORPHOMETRIC STUDY OF TWO POPULATIONS OF THE GENUS *POMACEA* (PROSOBRANCHIA: AMPULLARIIDAE) IN CUBA

ABSTRACT — A morphologic study of two forms (populations of El Rubio and Valle Grande) of the genus *Pomacea* was carried out under laboratory conditions. Sixty-eight individuals of both populations (28 from El Rubio and 40 from Valle Grande) were measured for nine conchiometric and opercular variables, from which six ratios were calculated. The variations for these ratios among sexes and among populations were determined by univariate statistical tests. Also a Principal Component Analysis (PCA) was performed for the absolute values of the variables measured. The Valle Grande population showed a greater sexual dimorphism due to the presence of three ratios with statistically significant differences (width/length of the shell, width/length of the aperture and width/length of the operculum), while the El Rubio population showed only one ratio with sexual dimorphism (width/length of the aperture). When comparing both populations, five ratios showed statistically significant differences. These variations were greater for the width/length of the aperture, the width/length of the operculum and the bodywhorl length/shell length ratios. The PCA also showed a clear separation between individuals in both groups

Key Words: *Pomacea paludosa, P. poeyana*, Ampullariidae (Pilidae), morphometry.

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EVIDENCIA DE FORMAS DIFERENTES EN DOS POBLACIONES DE *MELANOIDES TUBERCULATA* EN CUBA. ESTUDIO MORFOMÉTRICO

José R. Ferrer[1], Gloria Perera[1], Mary Yong[1], Alfredo Gutiérrez[1] y Jorge Sánchez[1]

RESUMEN - Se realizó el estudio de la morfometría de los juveniles de dos poblaciones de *Melanoides tuberculata* presentes en Cuba. Fueron medidos el largo y el ancho de la concha así como el diámetro del núcleo, la primera media vuelta y la primera vuelta en los juveniles, observándose diferencias significativas entre ambas poblaciones las cuales se separan claramente en el análisis de componentes principales. Esto parece indicar que nos encontramos ante la presencia de morfos diferentes en esta especie. La población de Batabanó presenta una mayor eficiencia reproductiva que la población de *Melanoides tuberculata* de Hanabanilla.

Palabras clave: *Melanoides tuberculata*, morfos, Cuba.

INTRODUCCIÓN

Melanoides tuberculata (Müller) es un molusco prosobranquio que se reportó por primera vez en Cuba en el lago Hanabanilla por Perera *et al.* (1987). El mismo ha sido utilizado con éxito como agente de control biológico contra los hospederos intermediarios de *Schistosoma mansoni* los cuales son diferentes especies de planórbidos pertenecientes al género *Biomphalaria* (Perera *et al.*, 1989; Pointier, 1989a, 1993; Pointier & Guyard, 1992; Pointier & McCullough, 1989; Prentice, 1983).

Pointier (1989b) ha planteado la existencia de diferentes morfos de esta especie en Martinica y Guadalupe. También han sido estudiadas las características de la historia de vida de tres morfos de esta especie partenogénetica y se ha hecho referencia a su estrategia reproductiva por Pointier *et al.* (1991). En el presente trabajo se reporta la existencia de una segunda población de *Melanoides tuberculata* en la región de Batabanó al sur de la provincia de la Habana y se pretende demostrar la existencia de formas diferentes entre esta nueva población y la anteriormente reportada en el lago Hanabanilla.

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MATERIALES Y METODOS

Los moluscos fueron colectados en dos localidades diferentes, las cuales se encuentran situadas en la parte central del país (Hanabanilla) y al sur de la provincia de La Habana (Batabanó).

Descripción de los hábitats

Hanabanilla: lago artificial que se encuentra en la región central de Cuba y está situado a 350 m sobre el nivel del mar, el cual se nutre de diferentes ríos y arroyos que descienden de las montañas, por lo que la temperatura del agua es más fría que en otros lagos del país. La vegetación acuática es abundante y está compuesta por *Elodea densa* (Planch.) Casp., *Cabomba* sp. y el alga *Pitophora* sp. Dentro de la fauna malacológica acompañante encontramos a *Pomacea paludosa* (Say), *Tarebia granifera* (Lamarck), *Planorbella duryi* (Wetherby), *Physa cubensis* (Pfeiffer) y *Pyrgophorus coronatus* (Guilding).

Batabanó: Zanja de desagüe de aproximadamente 2 metros de ancho, con agua corriente y fondo arenoso. El agua está poluída, presentando niveles elevados de nitratos, nitritos y amonio. La vegetación está compuesta por *Elodea densa* y el alga *Pitophora* sp. La malacofauna esta representada por *Pomacea paludosa* y *Physa cubensis.*

Ambas localidades fueron muestreadas y se trasladaron al laboratorio 50 moluscos adultos de cada población que fueron colocados en acuarios de 20 x 20 x 15 cm con temperatura constante de 26°C y fotoperíodo de 12 horas; además se les añadió *Elodea densa* y algas cianofitas cultivadas en el laboratorio para su alimentación, y todas las semanas fué renovada el agua declorinada. Semanalmente fueron extraídos los juveniles (nuevos nacidos) a los que se les midió el largo y ancho de la concha con un pie de rey con error de 0,05 mm, así como diferentes parámetros de la protoconcha bajo el microscopio estereoscopio como son, el diámetro del núcleo, la primera 1/2 vuelta y la primera vuelta de la concha según el método descrito por Verduin (1977); todos los valores obtenidos se expresaron en mm. Se trabaja con los nuevos nacidos debido a que ha sido demostrada la diferencia biométrica entre los machos y las hembras adultos (Jean-Gilles, 1989). Con estas variables medidas en los juveniles se aplicó un análisis multivariado de Componentes Principales (PCA). Además se determinó el índice l/a (largo/ancho) y el índice n/a x 10^2 (núcleo/ancho) los cuales se utilizaron en la comparación de la morfometría de la concha en los juveniles por medio de la prueba "t". Por último se determinó la producción de juveniles en ambas poblaciones.

Los especimenes de referencia (voucher specimens) fueron depositados en la colección del Laboratorio de Malacologia del IPK, Centro Colaborador de la Organizacion Mundial de la Salud para el adiestramiento e investigacón en Malacologia Médica y control biológico de hospederos intermediarios.

RESULTADOS

El análisis de componentes principales realizado con las mediciones de la concha de los recién nacidos demuestra claramente la separación existente entre los individuos de las dos poblaciones los cuales se agrupan en dos conjuntos bien definidos (Fig. 1): hacia la izquierda la población de Hanabanilla y hacia la derecha, con menos dispersión, los de Batabanó. Se observa también un cierto sobrelapamiento entre los dos grupos. Al aplicarse la prueba "t" entre los dos índices de las dos poblaciones, se observó que existen diferencias

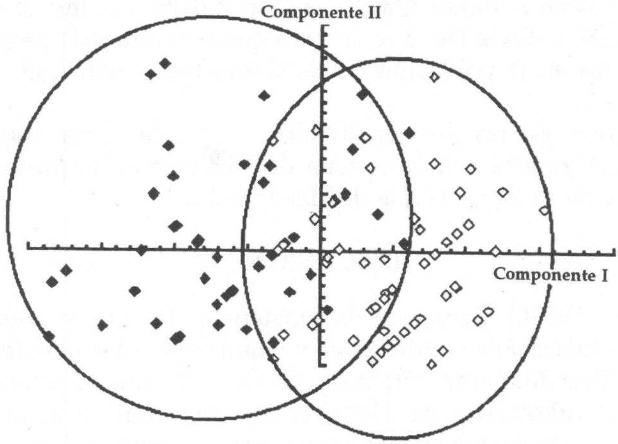

FIG 1. Representación gráfica por individuos de los resultados obtenidos del Análisis de Componentes Principales realizado con las variables medidas de las conchas de los recién nacidos de *Melanoides tuberculata*, demostrándose la separación existente entre los individuos de las dos poblaciones los cuales se agrupan en dos conjuntos bien definidos. ♦ = Población de juveniles de Hanabanilla; ◊ = población de juveniles de Batabanó.

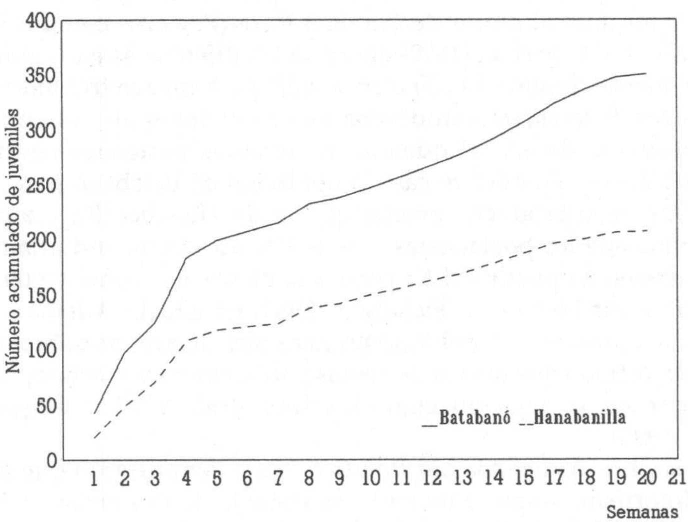

FIG. 2. Número acumulado de juveniles de *Melanoides tuberculata* de las poblaciones de Batabanó y Hanabanilla. Se observa como la descendencia obtenida a partir de la población de Batabanó es mayor que la de Hanabanilla.

significativas en el índice l/a (t = 2,45; p < 0,05) y el índice n/a (t < 7,02; p < 0,001). En la Fig. 2 se observa que el acumulado de juveniles por semanas en la población de Batabanó fué mayor que en la de Hanabanilla.

Los adultos de las dos localidades estudiadas presentaron una media de la longitud de la concha de 18,8 mm en la población de Batabanó y de 16,31 mm en la de Hanabanilla.

DISCUSIÓN

Pointier (1989b) demostró la existencia de cuatro morfos de *Melanoides tuberculata* en Martinica y Guadalupe a los que denominó Pointe-à-Pitre, Madame, Falaise y Gosier. Asimismo plantea que *Melanoides tuberculata* de Hanabanilla corresponde al morfo de Madame. Al comparar las dos poblaciones de este tiárido presentes en Cuba, se observó que existe una diferenciación morfométrica entre ellas lo que fue corroborado mediante el Análisis de Componentes Principales, además de las diferencias observadas en la comparación de los índices. Lo anteriormente señalado parece indicar, que la población de Batabanó corresponde a otro morfo el cual pudiera ó no coincidir con los anteriormente descritos por Pointier (1989b), pudiendo ser semejante al morfo de Pointe-à-Pitre (Pointier, comunicación personal). Pointier *et al.* (1992) encontraron diferencias en la producción de nuevos nacidos así como en la talla que alcanzan tres morfos de *Melanoides tuberculata* estudiados en condiciones de laboratorio, probablemente debido al número de hembras partenogéneticas de cada población. En nuestro caso la población de Batabanó parece ser más eficiente reproductivamente que la de Hanabanilla y aunque conocemos que las poblaciones de este tiárido son mayoritariamente partenogenéticas puede existir presencia de machos como ya ha sido observado por Livshits & Fishelson (1983) en Israel. Además de la presencia de machos en poblaciones naturales de este prosobranquio, se ha demostrado que dentro de ciertas poblaciones los machos pueden participar en la reproducción (Livshits *et al.*, 1984; Hodgson & Heller, 1990).

Los estudios realizados por Pointier (1992) demostraron que existe un polimorfismo importante en la morfología de la concha en *Melanoides tuberculata* de Martinica y Guadalupe. Si tenemos en cuenta que esta es una especie de reciente aparición en las Antillas (década del 70) y mucho más reciente en Cuba (1983), es significativo el hecho de que la segunda población que aparece en nuestro país presente diferencias morfométricas con la anteriormente reportada.

Teniendo en cuenta la mayor reproducción que presentan los moluscos de Batabanó, pudiera considerarse que éstos podrían jugar un rol más eficiente en el control de los hospederos de esquistosomiasis, a la hora de evaluar cuál es la población más indicada a introducir para efectuar el control biológico.

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EVIDENCE OF DIFFERENT FORMS IN TWO POPULATIONS OF *MELANOIDES TUBERCULATA* IN CUBA. MORPHOMETRIC STUDY.

ABSTRACT – A morphometric study of the juveniles of two populations of *Melanoides tuberculata* in Cuba compared the length and the width of the shell, the diameter of the nuclear whorl, the length of the first half whorl and the length of the first whorl. There were significant differences between both populations, which are clearly separated in the Principal Component Analysis. These findings suggest the presence of two different morphs of this species in Cuba. The population of Batabanó shows a greater reproductive efficiency than the population of Hanabanilla.

Key words: *Melanoides tuberculata*, morphs, Cuba.

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FOSSARIA VIATRIX ORBIGNY, HOSPEDERO INTERMEDIARIO DE *FASCIOLA HEPATICA* LINNAEUS EN TABASCO, MÉXICO

Luis José Rangel-Ruiz[1]

RESUMEN – Se registra por primera vez a *Fossaria viatrix* como hospedero intermediario de *Fasciola hepatica*, para México, en particular para el Estado de Tabasco en los municipios de Jalapa, Tacotalpa y Teapa. Se colectaron 2,840 caracoles de los cuales solo 23 estuvieron parasitados. Las prevalencias encontradas en *F. viatrix* variaron de 0.29 a 1.51% en los ranchos de "San Ramón" 2a. sección y "El Paraíso." En todos los caracoles parasitados se encontraron redias y cercarias maduras e inmaduras. No se encontró ningún otro tipo de cercaria diferente a *F. hepatica*.

Las especies de caracoles que fueron recolectadas y revisadas junto con *F. viatrix* fueron: *Drepanotrema lucidum* (Pfeiffer), *Biomphalaria obstructa* (Morelet), *Stenophysa impluviata* (Morelet), *Pomacea flagellata* (Say). Ninguna de estas especies resultó parasitada con formas larvarias de digéneos.

Mediante infecciones experimentales se confirmó a *Fossaria viatrix* como hospedero natural de *Fasciola hepatica*, alcanzando prevalencias de 48.0 y 52.0% para caracoles de laboratorio procedentes de poblaciones silvestres de Jalapa (Ejido el Guanal 2a. Sección) y Teapa (Rancho "El Paraíso") respectivamente.

Palabras claves: *Fasciola hepatica*, *Fossaria viatrix*, Tabasco, México.

INTRODUCCIÓN

La fasiolasis es una enfermedad ampliamente distribuida y es ocasionada principalmente por dos especies del género *Fasciola* estas especies son transmitidas exclusivamente por caracoles de la familia Lymnaeidae.

Fasciola gigantica es un parásito que es transmitido por caracoles pertenecientes al grupo de *Lymnaea (= Radix) auricularia* Linnaeus. En la región Etiópica, *L. (= Radix) natalensis* es la principal especie de este grupo. En Asia este papel es asumido por *L.* (= *R.*) *rubiginosa*. La distribución de *Fasciola hepatica* en América del Norte es tan amplia como la de *L. (= Fossaria) truncatula* Müller, *L. (= Pseudosuccinea) columella* Say, *L. (= Fossaria (Bakerilymnaea) bulimoides* Lea y *L. (= Fossaria (Bakerilymnaea)) cubensis* Pfeiffer, todas estas especies han sido encontradas como los hospederos intermediarios de este parásito. En América del Sur está demostrado que *L. cousini* y *L. (= Fossaria) viatrix* Orbigny son las especies que actúan como hospe-

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deros intermediarios. *Lymnaea (= Austropeplea) tormentosa* juega este papel en Australia en la Región Oceánica (Hubendick, 1951; Boray & McMichael, 1961; Over, 1982).

En América Central y las islas del Caribe también han sido registradas algunas especies de limnéidos. *Lymnaea (= Fossaria (Bakerilymnaea)) cubensis* y *Lymnaea (= Pseudosuccinea) columella* son los hospederos intermediarios de *Fasciola hepatica* en Cuba, Costa Rica y Puerto Rico (Brenes *et al.*, 1967; De León 1972; Larramendi *et al.*, 1981).

En México son escasos los registros de limneidos hospederos intermediarios de *Fasciola hepatica*. Trejo *et al.* (1989) determinaron en nueve estados de la República Mexicana la presencia de seis especies: *Lymnaea palustris, L. (= Fossaria (Bakerilymnaea)) bulimoides; L. (= Fossaria (Fossaria)) humilis* Say; *L. (= Fossaria) obrussa* Say, *L. (Galba) cubensis (= Fossaria (Bakerilymnaea) cubensis)* y *L. (G.) truncatula* Müller *(= Fossaria (Fossaria) truncatula)*. Landeros *et al.* (1981) en la cuenca lechera de Tulancingo, Hidalgo establecen como hospederos naturales a *L. cubensis (= Fossaria (Bakerilymnaea) cubensis); L. (= Fossaria (Fossaria)) humilis;* y *L. (= Fossaria (Bakerilymnaea)) bulimoides*. Gómez-Agudelo *et al.* (1978) consideran a *Lymnaea (Galba) cubensis (= Fossaria (Bakerilymnaea) cubensis)* como el hospedero intermediario de *F. hepatica* en el altiplano central de México.

A partir de 1989 el Laboratorio de Parasitología de la División Académica de Ciencias Biológicas, de la Universidad Juárez Autónoma de Tabasco comenzó a desarrollar estudios relacionados con la fasciolasis bovina en el estado de Tabasco. Como primer paso se determinó la importancia económica de esta parasitosis encontrando que en 1988, y tan sólo en el Frigorífico y Empacadora de Tabasco se perdieron $1,626,339,000.00 (N$1,626,339.00) por decomiso de hígados. Por otro lado, se determinó la distribución geográfica de la infección con base en su prevalencia, observándose que los valores altos se registran en las regiones de la Chontalpa y Sierra, y dentro de ésta última los municipios de Jalapa, Tacotalpa y Teapa (Rangel & Martínez, 1994). Con base en la información anterior decidimos identificar la o las especies de caracoles que son hospederos intermediarios de *Fasciola hepatica*.

MATERIAL Y MÉTODOS

Durante el período de Marzo de 1988 a Febrero de 1989 se realizó la búsqueda de caracoles en ranchos de los municipios de Jalapa, Tacotalpa y Teapa. Estos ranchos se encontraron localizados en zonas caracterizadas por una orografia de tipo montañosa, planicie con pendientes poco pronunciadas o con pequeños lomeríos.

Los caracoles fueron transportados al laboratorio en recipientes de plástico con agua declorinada y se les dejó reposar dos horas antes de su revisión. Fueron identificados y cada especie colocada por separado en frascos de vidrio de 50 ml para su observación. El agua de los frascos con caracoles fue examinada bajo un microscopio estereoscópico para detectar la liberación de larvas de tremátodos. Si este examen resultó negativo a la infección, los caracoles fueron sacrificados entre dos portaobjetos para detectar la presencia de infecciones inmaduras.

Cuando se encontraron formas larvarias intramoluscos, éstas fueron observadas "in vivo," se fotografiaron, se identificaron y posteriormente se fijaron con formaldehido 10% caliente.

Cincuenta caracoles de primera generación (obtenidos en laboratorio) de cada una de las poblaciones de Jalapa (Ejido el Guanal 2a. Sección) y de Teapa (Rancho "El Paraíso"), fueron expuestos en un promedio de cinco o seis miracidios de *Fasciola hepatica* por caracol durante 30 minutos y examinados después de 50 días.

Las formas larvarias fueron identificadas con base a las descripciones presentadas por Taylor (1965) y Cruz-Reyes (1986), así como, por comparación con formas larvarias obtenidas mediante las infecciones experimentales.

RESULTADOS

Durante el año de muestreo se revisaron un total de 40 ranchos, 17 en el municipio de Jalapa, 12 en el de Tacotalpa y 11 en el de Teapa. Sólo en siete ranchos se encontraron caracoles limnéidos parasitados con formas larvarias de *Fasciola hepatica,* dos en Jalapa, uno en Tacotalpa y cuatro en Teapa (Tabla 1). Estos siete ranchos estuvieron caracterizados por tener planicies con pendientes poco pronunciadas o presentar pequeños lomeríos y por tener áreas de inundación temporal. El pH encontrado varió de 6.2 a 8.1.

TABLA 1. Localidades en donde se registra a *Fossaria viatrix* infectada con *Fasciola hepatica* en tres municipios de la Región de la Sierra.

Nombre	Municipio	Superficie	pH
1) Rancho (sin nombre) *	Jalapa	A	8.1
2) Rancho (sin nombre) **	Jalapa	B	8.0
3) Rancho San Carlos	Tacotalpa	B	6.2
4) Rancho El Paraíso	Teapa	A	6.4
5) Rancho San Ramón 1a. Secc.	Teapa	A	6.6
6) Rancho San Ramón 2a. Secc.	Teapa	A	6.8
7) Rancho El Bajio	Teapa	A	6.8

*Ejido el Guanal segunda sección; Ejido Pueblo Nuevo. A = Planicie con pendientes poco pronunciadas, B= Plana con pequeñas lomerias.

La especie de caracol encontrada en estos tres municipios fue identificada como *Fossaria viatrix* (Fig. 1). Durante el estudio se colectó en los tres municipios un total de 2,840 caracoles de los cuales sólo 23 estuvieron parasitados. Las prevalencias encontradas en *F. viatrix* variaron de 0.29 a 1.51% (rancho "San Ramón" segunda sección y rancho "El Paraíso" respectivamente) (Tabla 2).

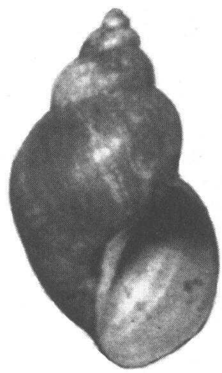

FIG. 1. Fotografía de la concha de *Fossaria viatrix* vista ventral.

TABLA 2. Prevalencia de *Fasciola hepatica* en *Fossaria viatrix* en tres municipios de la Región de la Sierra.

Rancho	Municipio	H. Exa.	H. Inf.	Prev. (%)
1) Sin nombre	Jalapa	368	2	0.54
2) Sin nombre	Jalapa	184	1	0.54
3) San Carlos	Tacotalpa	385	2	0.52
4) El Paraiso	Teapa	859	13	1.51
5) San Ramón 1a. Secc.	Teapa	482	3	0.62
6) San Ramón 2a. Secc.	Teapa	343	1	0.29
7) El Bajio	Teapa	219	1	0.46

H. Exa. = Hospederos examinados, H. Inf. = Hosp. infectados, Prev. = Prevalencia.

En los caracoles parasitados siempre se encontraron redias y cercarias maduras e inmaduras (Fig. 2 y 3). Sólo unas pocas cercarias que fueron emitidas lograron enquistarse en papel celofán (Fig. 4), sin embargo, el bajo número de metacercarias enquistadas no permitió realizar infecciones en el laboratorio. Las formas larvarias observadas en infecciones naturales fueron idénticas a las obtenidas por medio de las infecciones experimentales y nunca se encontró ningún otro tipo de cercaria diferente a *Fasciola hepatica* en los caracoles revisados.

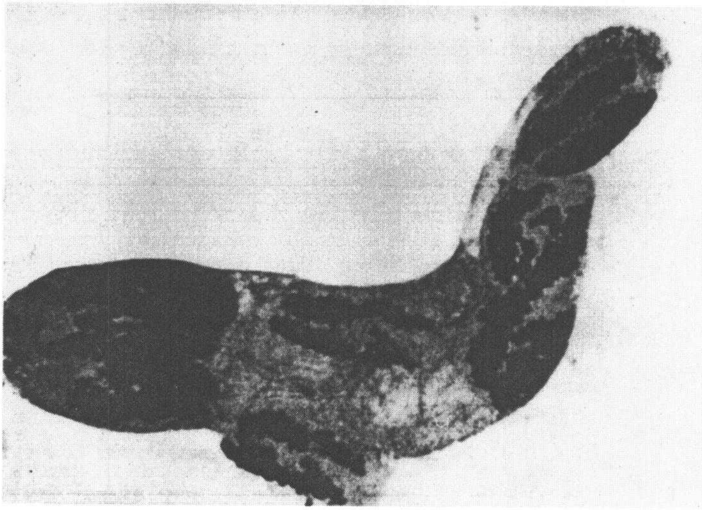

FIG. 2. Fotografía de la redia de *Fasciola hepatica* encontrada en *Fossaria viatrix* en el muncipio de Teapa, Tabasco.

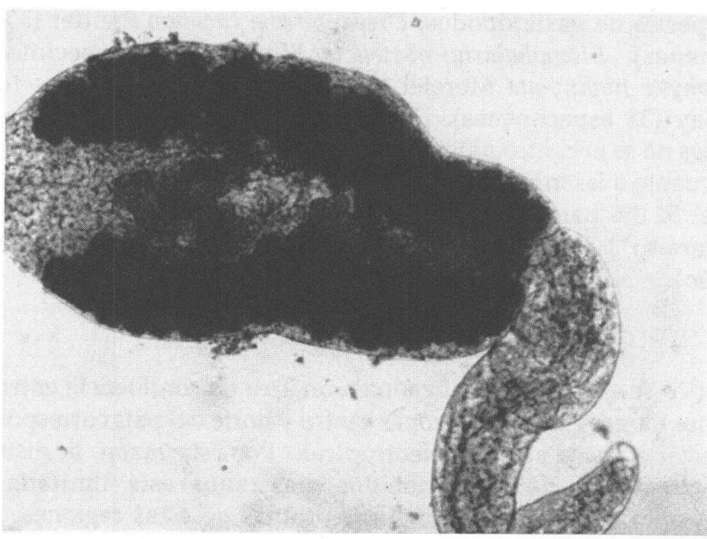

FIG. 3. Fotografía de la cercaria de *Fasciola hepatica* encontrada en *Fossaria viatrix* en el muncipio de Teapa, Tabasco.

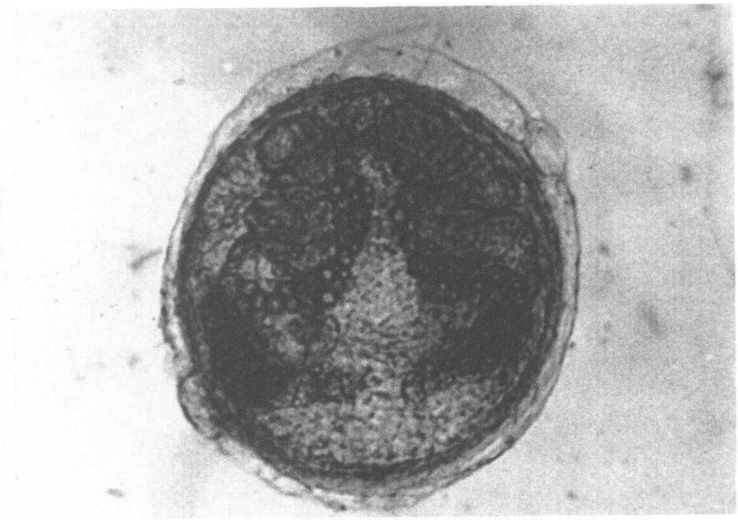

FIG. 3. Fotografía de una metacercaria enquistada de *Fasciola hepatica* liberada de *Fossaria viatrix*, colectada en el muncipio de Teapa, Tabasco.

Además de *Fossaria viatrix* se recolectaron y revisaron las siguientes especies de gasterópodos: *Drepanotrema lucidum* Pfeiffer (302 especímenes), *Biomphalaria obstructa* Morelet (459 especímenes), *Stenophysa impluviata* Morelet (258 especímenes) y *Pomacea flagellata* Say (38 especímenes). En la revisión parasitológica de estas especies no se encontró ninguna forma larvaria intramolusco.

En cuanto a las infecciones experimentales se encontró una prevalencia del 52.0% para los caracoles de la población de Teapa (Rancho "El Paraiso") y de 48.0% para la de Jalapa (Ejido el Guanal 2a. Sección).

DISCUSIÓN

México se encuentra localizado en un área de confluencia entre dos regiones biogeográficas, las zonas centro y norte del país corresponden a la Neártica y la sur a la Neotropical. Por esta razón, la distribución geográfica de los limnéidos mexicanos está limitada por condiciones ecológicas y climáticas propias de estas regiones. Dos especies se distribuyen en la Región Neotropical de México: *Lymnaea (= Pseudosuccinea) columella* (Say) y *Lymnaea (= Fossaria) viatrix* (Orbigny). *Fossaria viatrix* se encuentra distribuída en la región

Neotropical desde México, algunas islas del Caribe, hasta América del Sur en Chile y Argentina (Paraense, 1982).

En la actualidad la mayoría de los registros de limnéidos como hospederos intermediarios de *Fasciola hepatica,* en México, están ubicados en la región Neártica. Las seis especies registradas hasta el momento son: *Lymnaea palustris; Fossaria (Bakerilymnaea) cubensis; Fossaria (Bakerilymnaea) bulimoides; Fossaria (Fossaria) humilis; Fossaria obrussa;* y *Fossaria (Fossaria) truncatula* (Cómez-Agudelo *et. al.*, 1978; Landeros *et al.*, 1981; Trejo *et al.*, 1989).

A pesar de que *Fossaria viatrix* ha sido registrada para México en Chapala en el Estado de Jalisco, Teoloyucan en Veracruz y Ciudad del Carmen en Campeche (Paraense, 1982) éste constituye el primer registro de este caracol como hospedero intermediario de *Fasciola hepatica.* Además de una extensión de un rango geográfico a Tabasco principalmente en los municipios de Jalapa, Tacotalpa y Teapa. *Fossaria viatrix* es un hospedero importante de *F. hepatica* en paises de América del Sur como Argentina (Bacigalupo, 1932), Bolivia (Ueno *et al.*, 1975), Chile (Tagle, 1944) y Uruguay (Nari & Cardozo, 1976; Nari *et al.*, 1983).

Los valores de prevalencia encontrados en estas localidades son semejantes a los registrados para otras especies de limnéidos, por ejemplo, en Piquete municipio de Paraiba do Sul, Brasil, tasas de infección de 1.22% y 0.14% fueron obtenidas en *Lymnaea (= Pseudosuccinea) columella* infectados naturalmente por *Fasciola hepatica* (Ueta, 1980); *Stagnicola (= Fossaria (Bakerilymnaea)) bulimoides techella* en el sur de Colorado, fue encontrada infectada naturalmente, alrededor de 1,000 caracoles fueron sacrificados y la incidencia de infección fue alrededor de 0.1% (Wilson & Samson, 1971). Gómez-Agudelo *et al.* (1978) encuentran a *Lymnaea (Galba) cubensis (= Fossaria (Bakerilymnaea) cubensis)* naturalmente infectada con *F. hepatica,* con una prevalencia de 95%, en un pequeño charco junto a un canal de riego en "La Magdalena," cerca de Texcoco (Estado de México).

En todos los caracoles parasitados siempre se encontraron redias y cercarias maduras e inmaduras (Fig. 2 y 3); sólo unas pocas cercarias que fueron emitidas se lograron enquistar (Fig. 4). En la revisión parasitológica de todas las especies de gasterópodos, solo *Fossaria viatrix* se encontró parasitada con *Fasciola hepatica,* esto sugiere una fuerte especificidad hospedatoria.

Resulta importante realizar estudios para determinar el efecto que tienen otras especies de caracoles sobre *Fossaria viatrix*, ya que algunas especies de caracoles pueden actuar como competidores o depredadores, ejerciendo un control biológico natural, el cual bajo ciertas circunstancias, pudiera ser empleado para reducir las poblaciones de *F. viatrix* y consecuentemente las tasas de infección de *Fasciola hepatica.*

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FOSSARIA VIATRIX ORBIGNY, INTERMEDIATE HOST OF *FASCIOLA HEPATICA* LINNAEUS IN TABASCO, MEXICO

ABSTRACT – The snail *Fossaria viatrix* is recorded for first time as an intermediate host of *Fasciola hepatica* in Mexico, particularly for Tabasco State in the municipalities of Jalapa, Tacotalpa and Teapa. From 2,840 snails collected, only 23 were parasitized. Prevalences of *F. hepatica* in *F. viatrix* ranged from 0.29-1.51%. All infected snails were parasitized by mature and inmature redial and cercarial stages. No other species of larval digeneans were found. This study revealed that although *F. viatrix, Drepanotrema lucidum* (Pfeiffer), *Biomphalaria obstructa* (Morelet), *Stenophysa impluviata* (Morelet) and *Pomacea flagellata* (Say) were found in the same habitat, only *F. viatrix* harbored intramolluscan stages of *F. hepatica*.

Experimental infection of laboratory-reared snails confirm that *Fossaria viatrix* is the natural host of *Fasciola hepatica* in Tabasco, with prevalence values of 48.0% (public land: the Guanal "second section") and 52.0% (Ranch "El Paraiso").

Key words: *Fasciola hepatica, Fossaria viatrix*, Tabasco, Mexico.

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PREVALENCE OF LARVAL HELMINTHS OF FRESHWATER SNAILS IN THE MIDSTREAM REACHES OF THE TACHIA RIVER, TAIWAN, REPUBLIC OF CHINA

David Chao[1]

ABSTRACT – A survey of larval helminth infections among freshwater snails of the midstream reaches of Tachia River was conducted from October, 1988 to September, 1989. A total of 425 live snails were collected and carefully examined for parasites. Results showed that 17.6% of the snails examined were infected with larval helminths. Among 99 *Radix auricularia swinhoei* snails, 46 were infected with metacercariae of flukes and four were infected with two types of cercariae. Third-stage larvae of *Parastrongylus cantonensis* were found in eight and metacercariae were detected in two of 17 *Gyraulus spirillus* snails. Cercarial larvae have also been observed in two of 170 *Thiara granifera* snails. These cercariae were not infective to mice at the dose of 200 per mouse. Of 77 *Melanoides tuberculata* examined, one was infected with cercariae and 12 were infected with sporocysts of flukes. Parasitic larval helminths could not be detected in 62 *Thiara scabra*. Further studies on their final hosts and the transmission dynamics of these parasites are essential to the evaluation of their influence on the prevalence of snail-transmitted infections in man or other animals.

Key words: larval helminths, snails, Tachia River, Taiwan.

INTRODUCTION

More than 15 species of freshwater snails are known to serve as hosts of larval helminths in Taiwan (Pace, 1973; Lo, 1974). Due to their medical and economic importance, and also due to their value as bioindicators in water pollution, many aspects of their biology have been studied. However, there are no recent studies concerning snails or their parasites occurring in Tachia River. The present study provides information on the prevalence of helminth larvae in freshwater snails of the midstream reaches of Tachia River.

MATERIALS AND METHODS

Tachia River is the richest water resource of all 129 rivers in Taiwan. It supplies water for drinking, irrigation, hydroelectric power, and other uses for the millions of people that live in central Taiwan.

Field surveys of freshwater snails at eight different loci of the midstream Tachia River were conducted between October, 1988, and September, 1989. Fig. 1 shows these eight collecting sites. Snail collection was done in water bodies by using snail forceps and col-

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lecting scoopnets. The snails were identified and classified mainly according to the taxonomic characters described by Pace (1973).

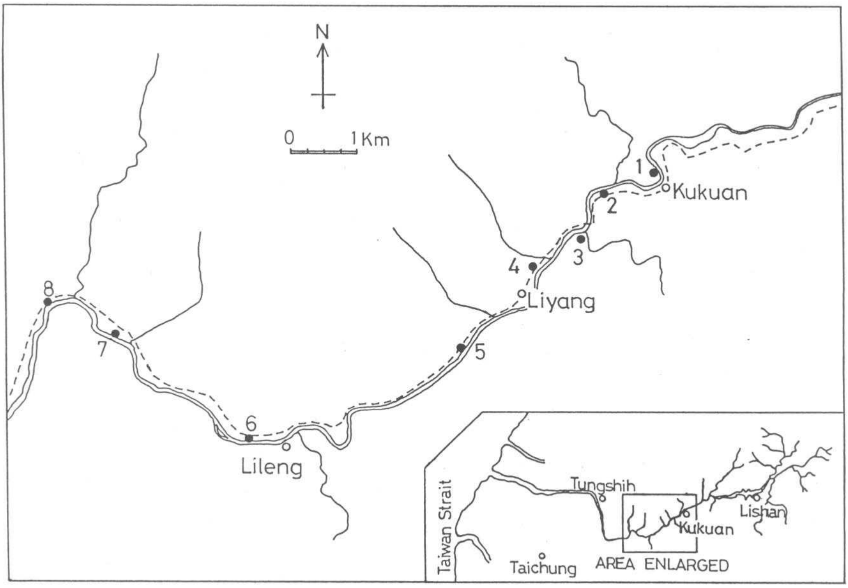


FIG 1. Map of study area showing the eight snail collecting localities.

Groups of mollusks were kept in large beakers containing filtered, aerated water and examined for parasitic larval helminths. They were first examined for cercarial emergence by constant changing and checking the aerated water under a dissecting microscope. If cercariae were detected, the snails were observed individually for three consecutive days. The number of cercaria-shedding snails were calculated for the positive rates. Cercariae were first identified according to the molluscan hosts. They were then fixed in 10% formalin, placed under a coverglass for microscopic measurements, and then classified according to their diagnostic features as described by Yamaguti (Yamaguti, 1975). Those snails negative for cercariae were examined for helminth larvae as follows: small-sized snails were crushed between two glass plates and examined under a dissecting microscope. The large-sized snails were crushed and homogenized in a blender. Artificial gastric juice (0.6% pepsin-HCl, pH 2) was used to digest the molluscan tissues for 1-3 hours. Tissue mixtures were transferred to conical graduates and diluted with aerated water. The precipitates were examined under a dissecting microscope. Helminth larvae were classified according to Yamaguti (1975) after fixation and staining. Larvae which lacked taxonomically important characteristics were conditionally designated as type A, B, C, etc.

Nematodes resembling third-stage larvae of *Parastrongylus cantonensis* (Chen) recovered after digestion were inoculated into adult male BALB/c mice by stomach intubation. The mice were killed after 14 days and their brains were examined for the presence of fifth-stage larvae. Trematode larvae were fed to BALB/c mice and their viscera were examined 21 days afterwards for the presence of adult flukes.

RESULTS

Five species of snails were found along the study area. These were *Gyraulus spirillus* (Gould), *Melanoides tuberculata* (Müller), *Radix auricularia swinhoei* (Adams), *Thiara granifera* (Lamarck) and *Thiara scabra* (Müller). Parasitological examinations of a total of 425 live snails revealed that 17.6% were infected with helminths. Table 1 shows the parasitic helminths obtained from these snails.

TABLE 1. Helminth infections in snails of Tachia River.

Snail species	Location	Number examined	Parasite* (number infected)
Gyraulus spirillus	1	1	PC (1)
	2	9	PC (7)
	3	4	MA (2)
	4	1	—
	5	2	—
Melanoides tuberculata	4	3	—
	5	10	XB (1)
	6	43	SU (12)
	7	19	—
	8	2	—
Radix auricularia swinhoei	1	27	MB (9), XA (3)
	2	15	MB (6), OC (1)
	3	16	EU (4), MB (5)
	4	28	MB (17), MC (3)
	5	11	MB (2)
	6	2	—
Thiara granifera	1	70	—
	2	64	HT (2)
	3	11	—
	4	4	—
	5	6	—
	6	3	—
	7	12	—
Thiara scabra	1	44	—
	2	15	—
	5	2	—
	6	1	—

*Parasite: PC, third-stage larvae of *Parastrongylus cantonensis*; EU, metacercariae of unidentified echinostome; MA, MB, and MC, type A, B, and C metacercariae other than echinostome; HT, OC, XA, and XB, cercariae of Haplorchis taichiui, ophthalmocercariae, and type A and B xiphidiocercariae.
— = not infected.

Young adults of *Parastrongylus cantonensis* were recovered from the mice, but on autopsy no trematodes were recovered from those animals receiving metacercariae. Fig. 2 shows the helminth larvae found in Tachia River.

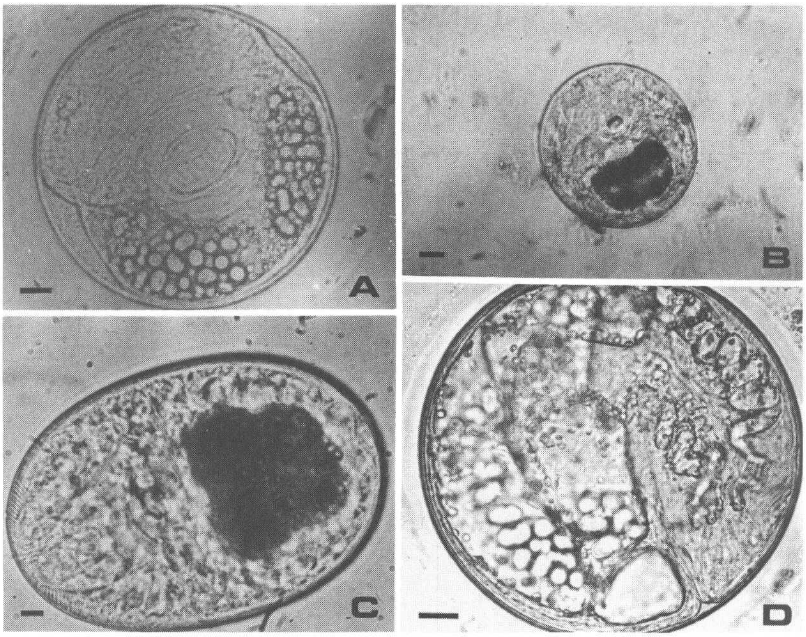
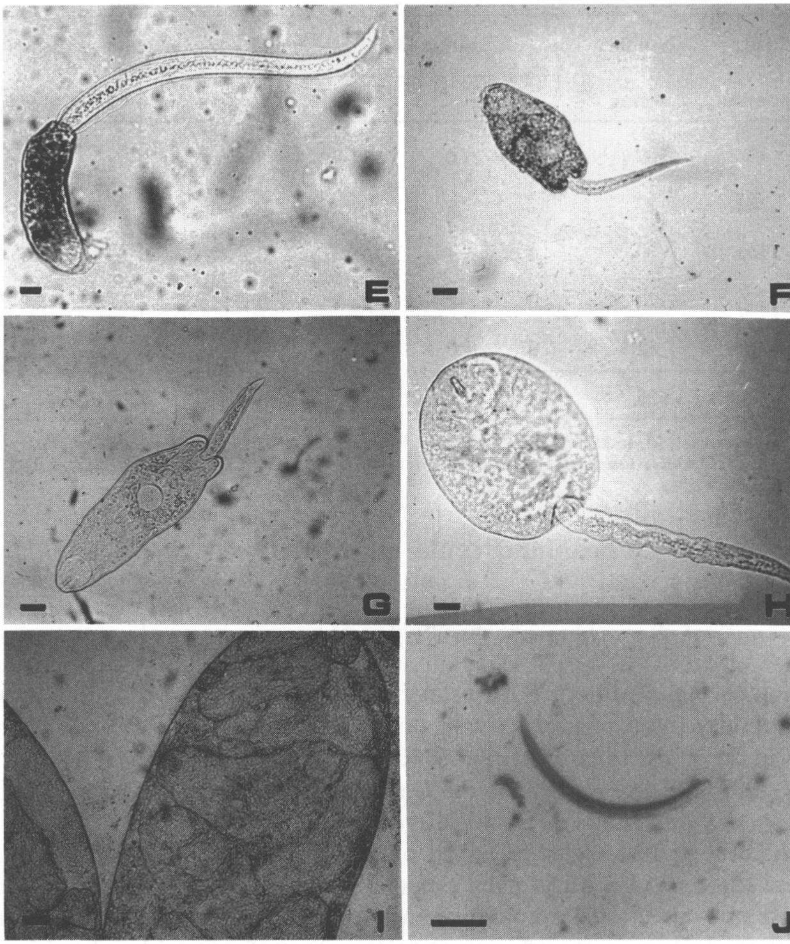


FIG 2. Parasitic larval helminths found in snails of Tachia River. **A**, Metacercaria of an unidentified echinostome; **B-D**, Type A, B, and C metacercariae, respectively. (Bar = 10 μm.) [Continued on p. 43.]

The highest parasitic infection rate was observed in the planorbid species, *Gyraulus spirillus*, with a prevalence rate of 58.8% (Table 2). In addition to trematodes, results of this study also indicate that *G. spirillus* can serve as a nature intermediate host of *Parastrongylus cantonensis* with a relatively high infection rate of 47.1%. About half of the *Radix auricularia swinhoei* snails were infected (50.5%). Two types of cercariae and three types of metacercarial larvae were observed in these snails. Among 99 snails, 46 were infected with metacercariae, three with xiphidiocercous larvae and one with op-



(FIG. 2, continued). **E-H**, Cercarial larvae of *Haplorchis pumilio*, ophthalmocercariae, and type A and B xiphidiocercariae, respectively; **I**, Sporocysts of an unknown trematode; **J**, Third-stage larva of *Parastrongylus cantonensis*. (E - I, bar = 10 µm; J, bar = 100 µm).

thalmocercous larvae of flukes. *Haplorchis taichiui* (Nishig) larvae have been observed in two of 170 *Thiara granifera* snails. These cercariae were not infective to mice at the dose of 200 per mouse. Of 77 *Melanoides tuberculata* examined, one was infected with xiphidiocercarial larvae and 12 were infected with sporocysts of flukes.

TABLE 2. Final larval stages of helminths found in snails of Tachia River

Snail species	Number exam.	Trematode*			Nematode	Total	Infection rate (%)
		S	C	M	L3		
Gs	17	0	0	2	8	10	58.8
Mt	77	12	1	0	0	13	16.9
Ras	99	0	4	46	0	50	50.5
Tg	170	0	2	0	0	2	1.2
Ts	62	0	0	0	0	0	0
Total	425	12	7	48	8	75	17.6

*S, sporocyst; M, metacercaria; C, cercaria; L3, third-stage larvae; Gs, *Gyraulus spirillus*; Mt, *Melanoides tuberculata*; Ras, *Radix auricularia swinhoei*; Tg, *Thiara granifera*; Ts, *Thiara scabra.*

Parasitic larval helminths could not be detected in the 62 *Thiara scabra.*

DISCUSSION

Larval helminths of Formosan freshwater snails have been investigated by many workers (Nakagawa, 1915; Tsuchimochi, 1926; Pace, 1973; Lo, 1974, 1976; Fischthal & Kuntz 1975; Lu & Su, 1988; Chao, *et al.*, 1992). However, this is the first report on larval parasites found in freshwater snails of Tachia River.

A total of 10 species of larval parasites were recovered from five host snail species during the present study. Among those collected were nine species of trematodes and one species of nematode. Of the trematode larvae found, one species was metacercariae of echinostomes, three species were metacercariae of other flukes, and four species were cercariae of flukes. The sporocysts of flukes detected in *Melanoides tuberculata* might represent a newly infected batch of parasites which were not yet fully developed in their snail hosts. They were discovered at the same place of the river. Migrating birds were probably their infection source. *Melanoides tuberculata* has become a very widely distributed species. More than 50 different forms of cercariae have been recovered from this species (Ismail *et al.*, 1988). Two unknown types of cercariae have been described from this species in Taiwan (Lo, 1974). The xiphidiocercariae found in this study were different from those two unknown types of cercariae.

Gyraulus spirillus was found to harbour third-stage larvae of *Parastrongylus cantonensis*. The author suggested that the distribution of this nematode larva in freshwater snails along the river depends on the presence of rat hosts. It was limited to the two loci around the Kukuan Hotel area, and not found at the other loci.

In addition to physical and chemical environments of the river, interspecies and intraspecies competition, predation and parasitism may be more important to the distribution of the snails. Parasitic pathogens can serve as selective forces in snail populations (Lively, 1898; Jong-Brink, 1990). The differences in the parasitic infections among snails collected from different loci showed that the parasites are locally adapted to the snail. Studies on the geographical distribution and the relation between larval parasites and snail hosts may be useful in providing information on the vertebrate hosts, life cycles, epidemiology and transmission related behavior of parasites (Lively 1989). Freshwater snails generally harbor a wide range of parasites. The literature on the possible relation between diseases and water pollution has been comprehensively reviewed by Khan & Thulin (1991). Pollutants might influence the prevalence, intensity and pathogenicity of a parasite. Further, infected snails may show inverted susceptibility to pollutants.

The failure to recover flukes in the experimentally infected mice indicates that these trematodes may be parasites of other animals. Some larval trematodes require a period of maturation in a suitable host such as fish before they are able to infect mice. The helminths occurring in Tachia River will require further study to determine their veterinary and medical importance to the local animals and to man.

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TERRESTRIAL GASTROPODS OF MACKINAC ISLAND, MICHIGAN, U.S.A.

Timothy A. Pearce[1]

ABSTRACT

ABSTRACT – Thirty-six species of land gastropods are reported from 14 localities. Eighteen species are first records for the island, and 10 of those are new county records. Two exotic species, *Polygyra septemvolva* and *Bradybaena similaris*, do not appear to be established, and are unlikely to survive the Michigan winter outside of a greenhouse.

Key words: Land snail, distribution, Great Lakes islands.

INTRODUCTION

Faunal surveys repeated at intervals provide important baseline information for the study of invasions and extinctions. Previous surveys by Archer (1934, gastropods) and Getz (1987, slugs) documented 23 species of land gastropods on Mackinac Island, Mackinac County, Michigan. In summer 1992, during field work as part of a study on terrestrial gastropod zoogeography on the islands of the Great Lakes, I discovered 18 species of terrestrial gastropods on Mackinac Island that had not been reported previously, including 10 county records that were not listed previously in Hubricht (1985). Here I list the species I found along with their localities and habitats.

METHODS

On 15 July 1992, I collected or observed land gastropods at 14 localities on Mackinac Island (Fig. 1). I visually searched for land gastropods under logs and in leaf litter, and on the ground while walking, and I also collected leaf litter for later sieving and sorting.

A description of the localities is as follows. Localities in the "Species accounts, localities and habitats" section refer to these locality descriptions.

1. At the Butterfly House in town. 45°51'00"N, 84°36'35"W; UTM 685500 m E, 5080000 m N; elev. 186 m. The proprietor carries butterflies and potted plants (*Lantana*, *Buddleia*) to Florida in the fall and from Florida in the spring. Visual search only on soil of the potted plants inside butterfly house, and outside butterfly house on rock retaining wall by the street.
2. At Arch Rock. 45°51'30"N, 84°36'25"W; UTM 685700 m E, 5080700 m N; elev. 183-213 m. Vegetation includes cedar, beech and wild parsnip. Visual search only.

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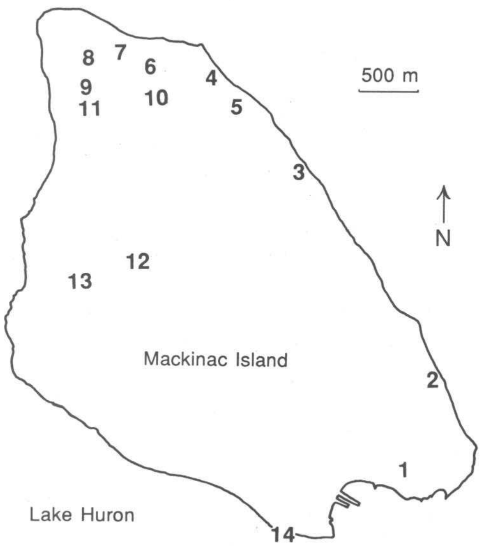

FIG. 1. Mackinac Island, Michigan, showing 14 localities where I collected or observed terrestrial gastropods.

3. At mile marker 2 on the E shore of Mackinac Island. 45°52'25"N, 84°37'10"W; UTM 684700 m E, 5082400 m N; elev. 178 m. At a swampy area of cedar, leatherleaf, birch, and moss. Leaf litter sample only.

4. Just inland from where Scott's Shore Road meets Lake Shore Road. 45°52'50"N, 84°37'45"W; UTM 684050 m E, 5083250 m N; elev. 181 m. In a forested area of yew, cedar, and moss. Some places are low and moist. Visual search and leaf litter sample.

5. Along Scott's Road from Scott's Shore Road to Tranquil Bluff Trail to the SE. Ca. 45°52'40"N, 84°37'35"W; UTM ca. 686300 m E, 5083000 m N; elev. 187 m. Beech maple woods. Visual search only.

6. On Tranquil Bluff Trail, West of Eagle Point Cave. 45°52'55"N, 84°38'15"W; UTM 683400 m E, 5083500 m N; elev. 201 m. In beech and sugar maple woods with deep leaf litter. Visual search and leaf litter sample.

7. Along Tranquil Bluff Trail. 45°53'00"N, 84°38'25"W; UTM 683200 m E, 5083600 m N; elev. 201 m. Abundant depredated shells. Vegetation includes beech, sugar maple, and moss. Visual search and leaf litter sample.

8. Along Tranquil Bluff trail. 45°52'55"N, 84°38'30"W; UTM 683000 m E, 5083600 m N; elev. 201 m. Beech and sugar maple. Visual search only.

9. At junction of Tranquil Bluff trail and Porter Hank's Trail. 45°52'45"N, 84° 38'35"W; UTM 683000 m E, 5083200 m N; elev. 201 m. Beech and sugar maple. Visual search only.

10. At junction of Porter Hank's trail and Swamp Trail. 45°52'45"N, 84°38'10"W; UTM 683500 m E, 5083300 m N; elev. 204 m. An area of beech and sugar maple trees, and limestone rocks. Visual search and leaf litter sample.

11. At junction of British Landing Nature Trail and Scott's Road, at the NW end of the Nature Trail. 45°52'40"N, 84°38'35"W; UTM 682900 m E, 5083100 m N; elev. 192 m. Beech and sugar maple. Visual search only.

12. At Cave of the Woods (at Crack in the Island). 45°51'55"N, 84°38'20"W; UTM

683200 m E, 5081700 m N; elev. 223 m. Beech trees and abundant limestone, many macrosnails but few microsnails, leaf litter is sparse. Visual search only.

13. At a field on the W end of the landing strip. 45°51'50"N, 84°38'30"W; UTM 683000 m E, 5081600 m N; elev. 223 m. Vegetation is foxglove, grass, and other forbs. Visual search only.

14. At the boardwalk in the town. 45°50'45"N, 84°37'20"W; UTM 684400 m E, 5079600 m N; elev. 178 m. Along the beach, in leaf litter on sand. Visual search only.

Voucher specimens of the species are deposited in the University of Michigan Museum of Zoology, Mollusk Division as lot numbers 253586 to 253621.

SPECIES ACCOUNTS, LOCALITIES AND HABITATS

Accounts of the species, including localities and habitats, follow.

Carychium exile canadense Clapp 1906. Locality 3 (UMMZ 253586). In cedar swamp. Not previously reported; represents a county record not previously reported by Hubricht (1985).

Cochlicopa lubrica (Müller 1774). Localities 2, 3, 14 (UMMZ 253587). In moist areas.

Columella edentula (Draparnaud 1805). Localities 7 (UMMZ 253588), 10. In beech-maple forest.

Gastrocopta tappaniana (C.B. Adams 1842). Locality 3 (UMMZ 253589). In cedar swamp. Not previously reported; represents a county record not previously reported by Hubricht (1985).

Pupilla muscorum (Linnaeus 1758). Locality 14 (UMMZ 253590). Along the lake shore.

Vertigo ovata Say 1822. Locality 3 (UMMZ 253591). In cedar swamp. Not previously reported; represents a county record not previously reported by Hubricht (1985).

Vertigo ventricosa (E.S. Morse 1865). Locality 3 (UMMZ 253592). In cedar swamp.

Strobilops labyrinthica (Say, 1817). Localities 2, 3 (UMMZ 253593), 4. Associated with cedar.

Vallonia costata (Müller 1774). Localities 2, 13, 14 (UMMZ 253594). In open or disturbed areas.

Vallonia excentrica Sterki 1893. Localities 1, 3 (UMMZ 253595). In town, and in cedar swamp. Not previously reported; represents a county record not previously reported by Hubricht (1985).

cf. *Catinella avara* (Say 1824). Locality 3 (UMMZ 253596). In cedar swamp. Not previously reported.

Succinea ovalis Say 1817. Localities 6, 7, 12 (UMMZ 253597). In beech-maple forest.

Anguispira alternata (Say 1816). Localities 2, 4, 5, 6 (UMMZ 253598), 7, 10, 11, 12. In beech-maple forest. Of the shells I collected, 36 of 89 (40%) lacked the dark brown transverse markings of typical *A. alternata*. I have not seen such unmarked individuals on the mainland or on other islands. Archer (1934) noted finding albinos. Eleven of 39 shells I found were greenish rather than the darker brown typical of *A. alternata*. These shells may correspond to the shells Archer called albinos. Three of the 11 greenish shells had the dark brown transverse markings of typical *A. alternata*. Perhaps these color and pattern variations are genetic mutations peculiar to Mackinac Island. Researchers working on genetics of *Anguispira alternata* may be able to use these mutations as genetic markers.

Discus catskillensis (Pilsbry 1896). Localities 4, 6 (UMMZ 253599), 7, 10. In beech-maple forest.

Helicodiscus shimeki Hubricht 1962. Localities 3, 4, 6 (UMMZ 253600), 7, 10. Associated with cedar, and in beech-maple forest. Not previously reported, but the shells that Archer (1934) reported as *H. parallelus* (Say 1817) may have been *H. shimeki*, since *Helicodiscus shimeki* was not recognized as distinct from *H. parallelus* until 1962.

Punctum minutissimum (I. Lea 1841). Localities 3 (UMMZ 253601), 4, 7. Associated with cedar, and in beech-maple forest. Not previously reported.

Arion cf. *hortensis* complex. Locality 2 (UMMZ 253602). In an area disturbed by human activity. This species is introduced from Europe. The single specimen is immature, so on dissection I was unable to confirm which species in the *A. hortensis* complex it is. It is not *A. owenii* Davies 1979 because it lacks the vertical foot fringe lines. It may be *A. distinctus* Mabille 1868 or *A. hortensis* Férussac 1819. See Davies (1977, 1979) for discussion of the *Arion hortensis* complex. Getz (1987) reported "*A. hortensis*" from Mackinac Island, but did not verify by dissection which species of the *A. hortensis* complex he had (Pearce & Blanchard, 1992).

Arion cf. *subfuscus* (Draparnaud 1805). Locality 6 (UMMZ 253603). In beech-maple forest. Not previously reported. A species introduced from Europe. Getz (1987) expected to find this species on the island, although he did not find it during his survey.

Arion cf. *sylvaticus* Lohmander 1937. Locality 6 (UMMZ 253604). In beech-maple forest. Not previously reported. A species introduced from Europe. Getz (1987) reported finding the related species *Arion fasciatus*.

Glyphyalinia indentata (Say 1823). Localities 7, 10 (UMMZ 253605), 12. In beech-maple forest, perhaps especially in areas rich in limestone. Although previously reported from Mackinac Island by Archer (1934), it was not reported from Mackinac County by Hubricht (1985).

Glyphyalinia cf. *rhoadsi* (Pilsbry 1899). Locality 10 (UMMZ 253606). In beech-maple forest rich in limestone. Not previously reported; represents a new county record not previously reported by Hubricht (1985).

cf. *Nesovitrea electrina* (Gould 1841). Locality 4 (UMMZ 253607). Among yew and cedar.

Oxychilus alliarius (J.S. Miller 1822). Locality 2 (UMMZ 253608). In an area disturbed by human activity. Not previously reported. A species introduced from Europe.

Paravitrea multidentata (A. Binney 1840). Localities 4 (UMMZ 253609), 6, 7, 10. In beech-maple forest.

Striatura exigua (Stimpson 1850). Localities 4, 6 (UMMZ 253610), 7, 10. In beech-maple forest. Not previously reported.

Striatura ferrea E.S. Morse 1864. Localities 4 (UMMZ 253611), 6. In yew and cedar woods, and in beech-maple forest. Not previously reported; represents a new county record not previously reported by Hubricht (1985).

Striatura milium (E.S. Morse 1864). Localities 3 (UMMZ 253612), 4, 6, 7, 10. In cedar forest and in beech-maple forest. Not previously reported; represents a new county record not previously reported by Hubricht (1985).

Vitrina limpida Gould 1850. Localities 10, 13 (UMMZ 253613). In beech-maple forest and in grassy field. Not previously reported.

Zonitoides arboreus (Say 1816). Localities 6 (UMMZ 253614), 7, 10. In beech-maple forest.

cf. *Zonitoides nitidus* (Müller 1774). Locality 3 (UMMZ 253615). In cedar swamp. Not previously reported.

Deroceras cf. *laeve* (Müller 1774). Locality 1 (UMMZ 253616). In residential area of town. Getz (1987) also reported finding *D. laeve* only in downtown Mackinac Island. Hubricht (1985) did not report *D. laeve* from Mackinac County.

Limax maximus Linnaeus 1758. Locality 4 (UMMZ 253617). In forest of yew and cedar. A species introduced from Europe.

Neohelix albolabris (Say 1816). Localities 2, 6, 7, 8, 9, 10, 11, 12 (UMMZ 253618). In beech-maple forest. An abundant large snail. Many shells had been depredated, apparently by small mammals.

Polygyra septemvolva (Say 1818). Locality 1 (UMMZ 253619). At the Butterfly House. Not previously reported. This exotic species was apparently transported from Florida to Mackinac Island with plants. I found shells only. This species does not appear to be established away from the Butterfly house. Furthermore, as it is native to the southern United States, it is not likely to survive the Michigan winter outside a greenhouse. Not reported from Mackinac County by Hubricht (1985).

Stenotrema fraternum (Say 1824). Localities 7, 10, 12 (UMMZ 253620). In beech-maple forest. Perhaps especially found in areas rich in limestone.

Bradybaena similaris (Férussac 1821). Locality 1 (UMMZ 253621). At the Butterfly House. Not previously reported. This pest species has been spread to many tropical areas, and was apparently transported from Florida to Mackinac Island with plants. Although I found living individuals, this species does not appear to be established away from the Butterfly House. Furthermore, as it is restricted elsewhere to warmer climates, it is not likely to survive the Michigan winter outside a greenhouse.

Five species of terrestrial gastropods noted on Mackinac Island by Archer (1934) and Getz (1987) that I did not find are *Helicodiscus parallelus, Arion fasciatus* (Nilsson 1822), *Philomycus carolinianus* (Bosc 1802), *Euconulus polygyratus* (Pilsbry 1899), and *Deroceras reticulatum* (Müller 1774).

Some species that are common on the adjacent mainland are unexpectedly absent from Mackinac Island. Although the large snail *Mesodon thyroidus* (Say 1816) occurs together with the large snail *Neohelix albolabris* on the mainland of Northern Michigan (Burch & Jung, 1988; personal observation), I found *N. albolabris* to be abundant on Mackinac Island, but I did not find *M. thyroidus*. Similarly, on a number of other islands in northern Lake Michigan I have noted the presence of *N. albolabris* but absence of *M. thyroidus* (unpublished data). This pattern, which deserves further study, may reflect different colonizing abilities or extinction susceptibilities between the two species, or different dispersal histories since the retreat of the most recent glaciation. Another species that is common on the mainland but absent from Mackinac Island and a number of other islands in Northern Lake Michigan is the carnivorous snail, *Haplotrema concavum* (Say 1821).

Of the introduced gastropods on the island, finding the slugs *Limax maximus* and *Arion* spp. is not a surprise, but finding snails from the southern United States, *Polygyra septemvolva* and *Bradybaena similaris,* is a surprise. The snails must have been carried from Florida to Mackinac Island, most likely on plants displayed in the Butterfly House on the Island. The snails are unlikely to become established on Mackinac Island, because they are not likely to survive Michigan winters.

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A NEW GENUS AND SPECIES OF CHAROPIDAE (GASTROPODA, ENDODONTOIDEA, STYLOMMATOPHORA), *RETIDISCUS RETICULATUS*, FROM SOUTHERN BRAZIL

Álvaro L. Müller da Fonseca[1,2] and José W. Thomé[1,2]

ABSTRACT – The new genus and species ***Retidiscus reticulatus* Fonseca & Thomé** are proposed for specimens from Rio Grande do Sul, southern Brazil. These new taxa belong to the entodontoid family Charopidae, subfamily Rotadiscinae. Analysis of the shell with the scanning electron microscope revealed distinct characteristics. The shell is small (1.7 mm in diameter), with reticulate sculpture. The apex has up to 20 spiral nuclear microstriae crossed by radial riblets (one riblet every 15 μm). The spiral postnuclear microstriae are conspicuous, and are crossed by thin radial intercostate microriblets. There are 32 ribs per millimeter on the last (body) whorl. Especially noteworthy is the peculiar striation pattern in the nuclear and the postnuclear microsculpture, and the very small size of the shell.

Key words: *Reticulatus reticulatus*, Endodontoidea, Charopidae, Rotadiscinae, southern Brazil, shell morphology.

INTRODUCTION

There are many genera of land micromolluscs in the entodontoid land snail family Charopidae. In southern South America, the genera *Radiodiscus* Pilsbry & Ferris 1906 and *Radioconus* Baker 1930, with a large number of species, and *Stephanoda* Albers 1860 and *Stephadiscus* Hilton Scott 1981, with fewer species, are the most reported (see Stuardo & Vega, 1985; Fonseca & Thomé, 1993a).

We have been studying specimens of micromolluscs from southeast and northeast hillsides of the State Rio Grande do Sul, Brazil. The purpose of this paper is to describe one of the previously undescribed species, a member of the family Charopidae, and to assign it to a new genus, also herein described.

Retidiscus gen. n.

Type species: *Retidiscus reticulatus* Fonseca & Thomé

Diagnosis: a genus of the subfamily Rotadiscinae, with more or less rectangular reticulated nuclear sculpture and conspicuous postnuclear spiral microstriation, crossed by very thin radial microriblets.

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Description: patuliform shell, with the average diameter of the Rotadiscinae – an average major diameter of 1.7 mm; an average shell height of 1.0 mm, with up to four whorls showing regular growth; umbilicus relatively broad (¼ of the major diameter); thin spiral nuclear microstriae crossed by radial riblets; postnuclear ribs comprising a triad of vertical laminas (the central one is higher than the lateral ones); postnuclear spiral microsculpture crossed by thin radial microriblets.

Discussion: this genus has sculpture, size and shape that relate it to the Charopidae, with some features convergent with those of the Endodontidae. But the absence of apertural barriers, so characteristic of the Endodontidae (Solem, 1973), the type of nuclear sculpture, not described for the Endodontidae (Solem, 1976, 1982), as well as the shell dimensions and conchometric ratios, confirm the classification of *Retidiscus* in the Charopidae. [Characteristics given by Solem (1982) for the Charopidae are: the depressed spire and very diminutive shell diameter, diameter/umbilicus ratio (D/U), spire height/major diameter ratio (He/D), pattern of whorl width increment (W1stw/D), type of nuclear sculpture, and number of ribs on the last whorl.]

Distinctive features, mainly the reticulate aspect of the nuclear and post-nuclear sculpture, although similar to the nuclear sculpture of *Radiodiscus* and *Microcharopa*, do not have conspicuous striae arranged with open-ended ridges, broadly undulated and crossed by deep sulci (as in *Radiodiscus* and *Microcharopa*). These characters separate *Retidiscus* from species with shell features described by Pilsbry (1948) and Solem (1977) for the genera *Radiodiscus* and *Radioconus*, and from the genus *Microcharopa*. The dimensions and ribs are similar to *Radiodiscus* and *Radioconus*, but the nuclear and postnuclear sculpture are very distinct from the other genera of Rotadiscinae, *e.g.*, the spiral nuclear microstriae crossed by radial riblets, leading to a reticulate pattern in the apex. This sculpture, according to Hilton Scott (1981), relate to the genus *Stephanoda*, but the dimensions and postnuclear sculpture of *Retidiscus* are distinctly different. Finally, spiral postnuclear microstriae are larger than radial riblets, with one crossing over the other. This results in a reticulate pattern in *Retidiscus* gen. n., which is different from other genera where the spiral striation is less conspicuous.

Retidiscus reticulatus sp. n.

(Figs. 1-6)

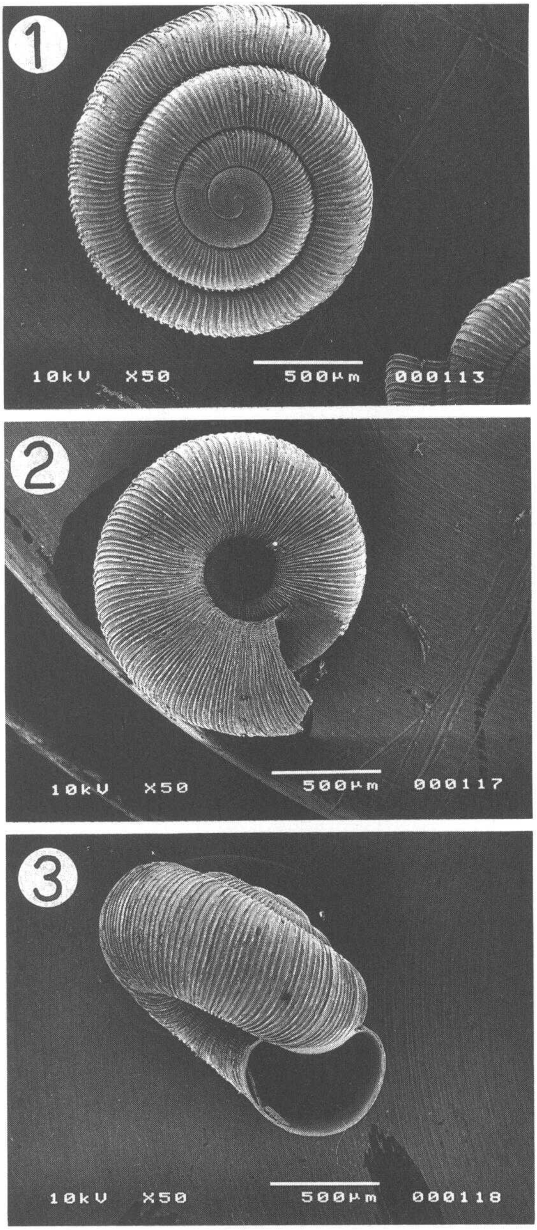
Diagnosis: small shell (1.7 mm in diameter), with reticulate sculpture; apex with up to 20 spiral nuclear microstriae crossed by radial riblets (one riblet every 15 μm); conspicuous spiral postnuclear microstriae crossed by thin radial intercostate microriblets; 32 ribs per millimeter on the last (body) whorl.

Description: shell with up to four whorls, showing regular growth; lurid (pale yellow) to cupreous-like surface, slightly transparent; nuclear shell, 1⅔ of the first whorls, slightly spirally striated (19 to 21 microstriae) crossed by tenuous radial riblets (one riblet every 15 μm), resulting in characteristic reticulations; postnuclear whorls convexly rounded and slightly flat; spire low (⅛ of the height); the last third of the last whorl gradually descending to the aperture; deep and slightly concave suture; ribs formed by a triad of laminae, one central and two lateral (paracostate); with about 32 slightly sigmoidal ribs per millimeter on the last whorl; the postnuclear spiral microsculpture (six microstriae per 50 μm) is crossed by thinner radial and less crowned intercostate microriblets (about six); umbilicus broad (¼ of the major diameter), regularly conic, decoiling in ventral view; aperture bean-shaped with smooth outline (peristome). This species has conchometric ratios as follows: H/D = 0.588; D/U = 3.8; W1stw/D = 0.26; He/D = 0.07; that make it close to the Charopidae, like also the number of whorls (four), type of nuclear sculpture and type of nuclear striae, number of ribs on the last (body) whorl (± 110), conical-patuloid shaped shell, very low spire (He/D = 0.07) and very minute diameter. These data can be compared with the characteristics presented by Solem (1982, pp. 38-44) for the families Charopidae and Endodontidae.

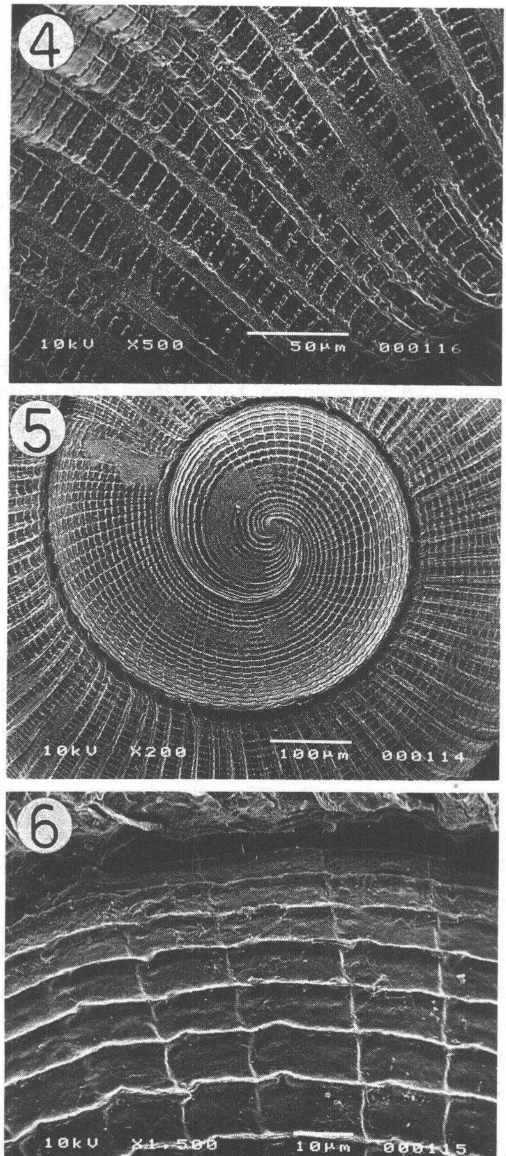
Holotype measurements: major diameter = 1.7 mm; minor diameter = 1.5 mm; umbilicus diameter = 0.45 mm; height = 1.0 mm; spire height = 0.12 mm; apertural height = 0.45 mm; apertural width = 0.7 mm.

Type locality: Parque Saint-Hilaire, Viamão, Rio Grande do Sul, Brazil.

The specimens examined were collected within the humid substrate (leaf mold) on the soil around the base of big trunks, in four localities from subtropical forests during the summer and autumn.



FIGS. 1-3. *Retidiscus reticulatus* gen. n. sp. n. FIG. 1. Paratype, dorsal (top) view. FIG. 2. Ventral (basal) view. FIG. 3. Lateral (side) view.



FIGS. 4-6. *Retidiscus reticulatus* gen. n. sp. n. FIG. 4. Detail of the postnuclear microsculpture, showing broken major ribs, radial riblets and spiral microstriae. FIG. 5. Nuclear shell, top view. Fig. 6. Detail of the reticulate nuclear microsculpture.

Material examined: Brazil, Rio Grande do Sul, Viamão, Parque Saint-Hilaire, holotype MCNZ (Museu de Ciências Naturais da Fundação Zoobotânica do Rio Grande do Sul, Porto Alegre, Brazil) 33487a and two specimen paratypes MCNZ 33487b, 13.I.1993, leg. Álvaro Fonseca; Brazil, Rio Grande do Sul, São Francisco de Paula, road RS-20, five specimen paratypes MCNZ 33486, 14.V.1993, leg. Álvaro Fonseca; Brazil, Rio Grande do Sul, Viamão, Parque Saint-Hilaire, 11 specimen paratypes MCNZ 33488, 30.I.1993, leg. Álvaro Fonseca; Brazil, Rio Grande do Sul, Camaquã, Localidade dos Galpões, four specimen paratypes MCNZ 33489, 16.IV.1994, leg. Álvaro Fonseca.

Discussion: *Retidiscus reticulatus* has similarities to species of the genera *Radiodiscus* and *Radioconus*, but differs from species in those two genera by the nuclear reticulations and the postnuclear intercostate microsculpture. The major ribs of *Retidiscus reticulatus*, consisting of a triad of laminae, are similar to those of *Radiodiscus*. *Retidiscus reticulatus* is distinct from species of *Stephanoda* and *Stephadiscus* in the nuclear microsculpture features, in the number of laminas of the major ribs, and in the shell dimensions.

DISCUSSION

Radiodiscus, according to Solem (1977), has the nuclear (embryonic) shell with spiral microribs (microstriae) crossed by radial striae (although Fonseca & Thomé (in press) prefer to name them sulcs or grooves in this genus). The ribs (costae) are three vertical laminae (triad), whose central lamina is higher. Solem (1982) described a species very similar to species of *Radiodiscus*, *Microcharopa mimula* from Viti Levu, Fiji Islands, but having some significant differences from *Radiodiscus*, such as major number of whorls, ribs and major diameter. Baker (1927) and Pilsbry (1948) did not show any significant conchological difference between *Radiodiscus* and *Radioconus*, but the South American species classed as *Radioconus*, according Haas (1959), have higher isolated ribs and nuclear striation without radial striae.

Hilton Scott (1981) stated that species with shells sculptured with only radial microribs belong to *Stephadiscus*, and those with both spiral and radial microribs should be placed in the genus *Stephanoda*. Both of these genera are placed in the subfamily Amphidoxinae, in which the minimum shell diameter is always more than the maximum diameter of shells of the subfamily Rotadiscinae (*Radio-*

discus, Radioconus). Otherwise, according to Fonseca & Thomé (in press), a diminutive species having spiral and radial sculpture on the embryonic shell, but with postnuclear sculpture similar to *Radiodiscus,* cannot belong to *Stephanoda.*

Fonseca & Thomé (1993a,b) proposed a classification for some genera of South American Endodontoidea (based on characteristics reported in the original description of these genera, as well as other features presented by Solem (1973, 1976, 1977, 1982), Pilsbry (1948), Hilton Scott (1981), and assertions by Stuardo & Vega (1985) and other authors), with *Stephanoda* Albers 1860, *Ptychodon* Ancey 1888, *Radiodiscus* Pilsbry & Ferris 1906, *Radioconus* Baker 1930, *Radiodomus* Baker 1930, *Austrodiscus* Parodiz 1957, and *Trochogyra* Weyrauch 1965 included in the Charopidae, and *Zilchogyra* Weyrauch 1956 placed in the Helicodiscidae. Fonseca & Thomé (1993a,b) presented characteristics that define these genera. One of these, *Radiodiscus,* shows undulate nuclear spiral striae, as Solem (1977) also described, crossed by radial sulci, the conical-patuloid shaped shell has a broad and perspective umbilicus, the major shell diameter varys from 1.3 to 2.2 mm, the height is about 1.00 mm and the spire is not prominent; the dense post-nuclear sculpture is composed of thin ribs and intercostate microsculpture consisting of microribs and microstriae; shell having an aperture with thin and sharp peristome without apertural barriers. Fonseca & Thomé (1993b) defined *Radiodiscus,* based on considerations of Baker (1927), Pilsbry (1948) and Haas (1959). *Retidiscus* has nuclear cord-like striae, a conical-patuloid shell, and post-nuclear sculpture similar to *Radiodiscus,* but also with higher and inclined lamina-like ribs, the major shell diameter varying from 1.5 to 2.5 mm, the shell having prominent or depressed spire and a height of about 1.2 mm, and umbilicus and aperture both similar to but broader than that of *Radiodiscus.*

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SAMPLING FRESHWATER MUSSEL POPULATIONS: THE BIAS OF MUSKRAT MIDDENS

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ABSTRACT – Shells of freshwater mussels collected from middens of muskrats (*Ondatra zibethicus*) often are used in unionid survey work as indicative of the *in situ* population. The relative abundance of mussel species in samples collected from middens was compared with adjacent beds in the lower Muskingum River in Ohio. All samples from middens differed significantly in both mussel diversity and relative abundance from the beds from which they were derived. Samples collected from muskrat middens represent a biased sample that may lead to erroneous conclusions concerning population and community structure of the parent bed.

Key words: Unionidae, predation, Muskingum River, Ohio, muskrat.

INTRODUCTION

Muskrats (*Ondatra zebithicus* (Linnaeus 1758)) are important predators on freshwater mussels (Lee, 1886; Apgar, 1887), including endangered taxa. Muskrats in one lake in Alberta ate an average of 350 mussels a day in the autumn, and over 37,000 a year (Hanson *et al.*, 1989; Convey *et al.*, 1989). Middens often contain hundreds or thousands of shells, usually in good condition. Sampling middens is time and labor efficient when compared to diving, brailing, or other methods that require finding living individuals *in situ*. When available, material from middens often is included in a survey.

There is, however, some evidence to suggest that muskrats are selective in their mussel predation. Bovbjerg (1956), working with a small sample size, found that the relative abundance of mussel species found in muskrat middens differed from that in a nearby stream for several species. Neves & Odom (1989) compared middens during different seasons of the year with quadrat studies of eight species of mussels living in the North Fork Holston River, Virginia. Five species were present in approximately the same relative abundance in both middens and quadrats. Individuals of *Pleurobema oviforme* (Conrad 1834) and the federally endangered *Fusconaia cuneolus* (Lea 1840) were more abundant in middens, however, than in

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the mussel beds. Muskrats avoided the smallest species available, *Medionidus conradicus* (Lea 1834). Elsewhere, Bruenderman & Neves (1993) found juveniles of *Fusconaia cuneolus* to be more common in middens than in collections of live individuals from the Clinch River, Virginia. Conversely, Hanson *et al.*, (1989) found that muskrats primarily ate the largest mussel individuals.

During the fall of 1992, the lower 54 km of the Muskingum River in Ohio were surveyed for mussels by brail, diving, and midden collection (Ecological Specialists, Inc., 1993). This river reach harbors one of the densest and most diverse mussel populations left in North America, with beds having up to 124 individuals per m^2 comprising 34 species. Middens were common, frequently large, and located next to identified beds. The large sample size and high diversity enables one to ascertain the importance of differential muskrat predation on a greater scale than was available to Bovbjerg (1956) and Neves & Odum (1989).

METHODS

The lower Muskingum River is a reach impounded by locks and dams. The average depth is 3-5 m, and the river width is 0.24 km.

The river bank is wooded to the west, with small cottages on the east bank. Middens were found primarily on the west bank. During low water, sand and gravel shoals are emergent below the dams.

The Muskingum River was sampled during 23 September to 30 October 1992 from river mile 34.1 to the mouth. Beds were located by brailing, and sampled quantitatively and qualitatively by divers using a surface air compressor. The quantitative work consisted of forty 0.25 m^2 quadrats placed at random along five 33.3 m, randomly spaced, transect lines within a bed. Each quadrat was excavated to a depth of 15-20 cm. Qualitative work consisted of a diver collecting all specimens found within 1-2 hours. Because the results consisted of all individuals encountered, whether within a quadrat (quantitative) or without (qualitative), these data were combined for this analysis. No evidence was found that individual mussel species were not randomly distributed throughout the mussel bed. The study area was defined as the whole mussel bed, not a quadrat, and only the sum numbers of individuals of each species present in the bed were used, regardless of how obtained. Muskrat middens were found next to these beds and all shells found in middens were identified to species and counted.

Middens were of two types, defined as home base and feeding site middens. Home base middens consisted of large middens associated with the muskrat's burrow, usually among the exposed roots of trees lining the shore. Feeding site middens were found along the shore and on exposed shoals. These were smaller middens that probably represented a single night of predation.

The middens used in this study were chosen by two criteria: size and proximity to a bed. The four largest middens, or series of feeding site middens on a single island, were chosen to obtain sufficient numbers for detailed analysis. These middens clearly were associated with existing beds (Beds 3 and 5 of the survey), being located on the nearest shore or on islands within a bed.

Because the purpose of this study was to compare midden diversity with that of the parent bed, it was necessary to reconstruct the diversity of the parent bed. Thus the total for a given bed was the sum of all *in situ* individuals as well as all material collected from the nearby muskrat middens (Table 1). *In situ* material was used from both quantitative and qualitative diving studies. The material collected by brailing is not included, but represents a negligible fraction of the total number found. The number of muskrats responsible for the middens is not known.

Because the relative abundances of species between a midden and the total for the bed are assumed to be covariant, data were compared with a pairing design test, a type of t-test. The more typically used group comparison test increases the likelihood of accepting a false null hypothesis in this case (Woolf, 1968). The data for each species were expressed as a percentage of the total untransformed numbers and arcsin transformed.

RESULTS

A total of 11,139 individuals of 34 unionid species were found in the survey, including living specimens of the U. S. federally endangered *Cyprogenia stegaria* (Rafinesque, 1820), and ten species listed as endangered by the State of Ohio. The data set used here represents 7,581 individuals of 32 species.

The most abundant mussel species were *Quadrula pustulosa* (Lea 1831) *Obliquaria reflexa* Rafinesque 1820, *Quadrula quadrula* (Rafinesque 1820), *Pleurobema cordatum* (Rafinesque 1820), and *Amblema plicata* (Say 1817) (Table 1). The hypothesis that the mussel species relative abundance from middens was the same as the parent bed was rejected in all cases ($P < 0.05$). Muskrats did not remove mussels at random from the mussel beds. In every case, the relative abundances of the dominant mussel species collected from middens differed from those of their parent beds.

Two of the dominant species were found to be underrepresented in middens: *Amblema plicata* and *Pleurobema cordatum*. *Amblema* is a heavy species when adult that may be too heavy for a muskrat to handle, and was underrepresented by at least a factor of ten in three of the middens. However, it was accurately represented in one midden, mostly as juveniles. There was no indication that this species was more common near that midden than any other. The reasons why *Pleurobema cordatum* was not selected are unknown. The most massive North American species, *Megalonaias nervosa* (Rafinesque 1820), also may be underrepresented, but was too rare in the study for this conclusion to be drawn.

Three taxa were over represented: *Leptodea fragilis* (Rafinesque 1820), *Obliquaria reflexa* and *Quadrula pustulosa*. *Leptodea* was over represented by a factor of two in three of the middens, but underrepresented by a factor of four in the fourth midden. These species

TABLE 1. Mussel species and numbers found in each midden and in parent bed. * = species not found in bed.

Taxa	Bed 3				Bed 5							
	Midden 1		Total		Midden 1		Midden 2		Midden 3		Total	
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Actinonaias ligamentina	1	0.09	4	0.14	0	0.00	0	0.00	0	0.00	3	0.06
Alasmidonta marginata				*	0	0.00	0	0.00	0	0.00	1	0.02
Amblema plicata	9	0.79	353	12.38	2	0.27	4	0.81	155	11.23	504	10.66
Anodonta grandis	1	0.09	4	0.14	1	0.13	1	0.20	3	0.22	5	0.11
Anodonta imbecillis	1	0.09	1	0.04	0	0.00	0	0.00	1	0.07	1	0.02
Cyprogenia stegaria	*	*	*	*	2	0.27	0	0.00	0	0.00	6	0.13
Ellipsaria lineolata	5	0.44	16	0.56	53	7.07	19	3.84	42	3.04	150	3.17
Fusconaia flava	*	*	*	*	0	0.00	1	0.20	0	0.00	1	0.02
Fusconaia maculata	1	0.09	7	0.25	0	0.00	0	0.00	0	0.00	2	0.04
Lampsilis radiata luteola	*	*	*	*	0	0.00	1	0.20	0	0.00	1	0.02
Lampsilis ventricosa	0	0.00	3	0.11	0	0.00	0	0.00	2	0.14	8	0.17
Lasmigona complanata	0	0.00	2	0.07	0	0.00	0	0.00	5	0.36	18	0.38
Lasmigona costata	0	0.00	2	0.07	0	0.00	0	0.00	0	0.00	1	0.02
Leptodea fragilis	29	2.56	46	1.61	2	0.27	14	2.83	36	2.61	51	1.08
Megalonaias nervosa	0	0.00	1	0.04	2	0.27	0	0.00	2	0.14	19	0.40
Obliquaria reflexa	430	37.89	856	30.01	306	40.80	250	50.51	568	41.16	1610	34.05
Obovaria subrotunda	3	0.26	8	0.28	19	2.53	4	0.81	1	0.07	25	0.53
Plethobasus cyphyus	*	*	*	*	1	0.13	0	0.00	0	0.00	2	0.04
Pleurobema cordatum	42	3.70	202	7.08	3	0.40	35	7.07	127	9.20	781	16.52
Pleurobema rubrum	*	*	*	*	0	0.00	0	0.00	0	0.00	1	0.02
Pleurobema sintoxia	1	0.09	5	0.18	2	0.27	0	0.00	0	0.00	6	0.13

TABLE 1 (continued)

Taxa	Bed 3				Bed 5							
	Midden 1		Total		Midden 1		Midden 2		Midden 3		Total	
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Potamilus alatus	5	0.44	16	0.56	2	0.27	13	2.63	26	1.88	51	1.08
Potamilus ohiensis	0	0.00	2	0.07	0	0.00	0	0.00	5	0.36	7	0.15
Quadrula metanavra	0	0.00	1	0.04	43	5.73	0	0.00	2	0.14	61	1.29
Quadrula pustulosa	576	50.75	1222	42.85	199	26.53	99	20.00	209	15.14	695	14.70
Quadrula quadrula	15	1.32	52	1.82	111	14.80	41	8.28	166	12.03	638	13.49
Strophitus undulatus	0	0.00	2	0.07	*	*	*	*	*	*	*	*
Truncilla donaciformis	16	1.41	47	1.65	0	0.00	13	2.63	25	1.81	71	1.50
Truncilla truncata	*	*	*	*	2	0.27	0	0.00	5	0.00	10	0.21
Totals	1135		2852		750		495		1380		4729	

* = species not found in bed.

represent both thin and thick shelled species, as well as sculptured and unsculptured, and are of medium size when adults (70-120 mm). With the possible exception of their taste to the muskrat, these species have little in common that would suggest a cause for their over representation.

DISCUSSION

Marinelli & Messier (1993) summarized the data on the home range size of muskrats in their study and others. Home range size varied between 0.03 and 4.24 ha. This is substantially smaller than the mussel beds on which the Muskingum River muskrats fed. It is unlikely that the muskrats responsible for the middens bypassed the adjacent bed to travel to a farther one and then transport the shells back. There seems little question that the shells in a midden came from the adjacent bed.

It also is unlikely that the shells within a midden were not gathered the same year that the survey was conducted. Winter and spring high water wash away middens made the previous summer and autumn and new middens are constructed each year (personal observations). The shells within the middens are, therefore, concurrent to those collected in the diving survey.

Muskrats appear to sample mussel beds in a non-random manner. Middens on the Muskingum River often contain many juvenile mussels (< 40 mm). Heavy, older individuals presumably are too cumbersome to carry and were passed over. It did not matter if the shells were thin or thick, or sculptured or smooth. Species seemed to be favored or avoided for reasons not yet known. Taste may be a factor.

Although Hanson *et al.* (1989) and Convey *et al.* (1989) found that muskrats selected the largest mussels, their study area did not have the massive species of the Muskingum River, such as *Megalonaias nervosa*. Indeed, Narrow Lake supports only the thin-shelled *Anodonta grandis simpsoniana*. That species is much lighter than most unionids of the same size, and apparently was manageable at large sizes (up to 90 mm long) by muskrats.

The results support the conclusion of Bovbjerg (1965) and Neves & Odum (1989) that muskrats selectively prey on certain unionid species in a mussel bed. This study addresses a widespread and common practice among field malacologists interested in unionid diversity: the use of muskrat middens as estimates of mussel populations. The results indicate that muskrats are biased collectors and that their middens do not represent the actual diversity or relative abundance *in situ.* Results of other studies suggest that there is a further bias in the sizes of individuals of a species found in middens (Hanson *et al.*, 1989; Bruenderman & Neves, 1993). Interpretations and generalizations about a unionid population based on midden material are apt to be incorrect.

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A SEARCH FOR ADDITIONAL POPULATIONS OF *POTAMILUS CAPAX* IN THE ST. FRANCIS AND CACHE RIVER WATERSHEDS, ARKANSAS AND MISSOURI, U.S.A.

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ABSTRACT – The Tennessee Valley Authority conducted a second mussel survey in 1987 in the St. Francis River watershed, Arkansas and Missouri, and sampled a few sites in the Cache River watershed, Arkansas. The purposes of this survey were to identify additional populations of *Potamilus capax*, a federally-listed endangered species, and to collect abundance information on this species. The survey included qualitative sampling at 256 sites in selected reaches totaling approximately 380 miles of stream and ditch habitat. Quantitative samples were taken at 42 sites.

Thirty-five mussel species were found alive in the St. Francis River watershed and 19 species were found alive at the Cache River sites. *Potamilus capax* was found alive in nine reaches of the St. Francis watershed, most of which have continuous contact with the St. Francis Floodway. The atypical distribution of this species in the watershed would seem to match that of a migratory fish host (as yet unidentified). Distribution patterns of other mussels in the St. Francis watershed reflect general habitat similarity throughout the system. Evidence of past mussel assemblages indicates how much the stream habitat has been degraded during this century.

Abundance information collected for *Potamilus capax* indicated the species averaged 0.03/m^2 where it occurred. This value is similar to results from the complementary survey conducted in 1986. Length data on *P. capax* in four well-represented areas suggested that two of them were established populations, one (in a relatively new ditch) was growing rapidly, and the other may not be well established.

Key words: *Potamilus capax*, St. Francis River, Cache River, Arkansas, Missouri.

INTRODUCTION

In the fall of 1986, Tennessee Valley Authority (TVA) biologists conducted a freshwater mussel survey in the St. Francis River system, Arkansas and Missouri, for the Memphis District, U.S. Army Corps of Engineers (USACE) (Ahlstedt & Jenkinson, 1991). That survey, which included approximately 250 miles (mostly river mainstem), was intended to identify upstream and downstream limits on the range of the endangered fat pocketbook pearly mussel, *Potamilus capax*, within the watershed. The report on that survey (Ahlstedt & Jenkinson, 1991) reviewed recent mussel distribution literature on the St. Francis watershed and presented results that indicated *P. capax* was more

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widespread and more abundant than previously thought. They speculated that surveys of additional reaches of the St. Francis watershed would reveal other areas populated by the fat pocketbook.

Using this information, the USACE prepared a Scope of Work for a survey of approximately 350 miles, primarily of tributaries in the St. Francis watershed. This survey was designed to extend the 1986 survey and required the use of similar sampling techniques and levels of effort. The focus of this survey, like the one in 1986, was the distribution and abundance of *Potamilus capax*. Subsequently, the USACE requested that 30 additional miles of State Line Outlet Ditch habitat be sampled because *P. capax* had been found in that part of the watershed.

The primary purpose of this report is to present results of the survey called for in the USACE Scope of Work. It also uses information accumulated during this and several previous surveys to identify mussel distribution patterns in the St. Francis River system.

PROJECT AREA

Most of the St. Francis River watershed is located on the Mississippi River floodplain in northeast Arkansas and southeast Missouri (Fig. 1). This watershed, bounded on the west by Crowleys Ridge and on the east by the Mississippi River, has been substantially altered by local interests and the USACE to protect adjacent agricultural land. Most natural stream channels have been straightened or dredged and many ditches and levees have been built over the years to control flooding. These water control structures have substantially altered the drainage pattern to the point that there have been many channel diversions, one stream now crosses over another, and the watershed has been divided into two parallel basins between Marked Tree (River Mile 155) and Huxtable Dam (River Mile 12).

The USACE Scope of Work for the 1987 survey called for mussel sampling to be conducted in 66 identified reaches, most of which are located in smaller tributaries of the St. Francis system. The Scope of Work also called for sampling in Reeses Fork, a minor connection between the Cache and White rivers further west in Arkansas. These reaches included approximately 350 miles of stream and ditch habitat, ranging from the lower L'Anguille River near the mouth of the St. Francis to several ditches on the Arkansas-Missouri State line. The subsequent USACE request added three reaches (30 miles) in the State Line Outlet Ditch basin.

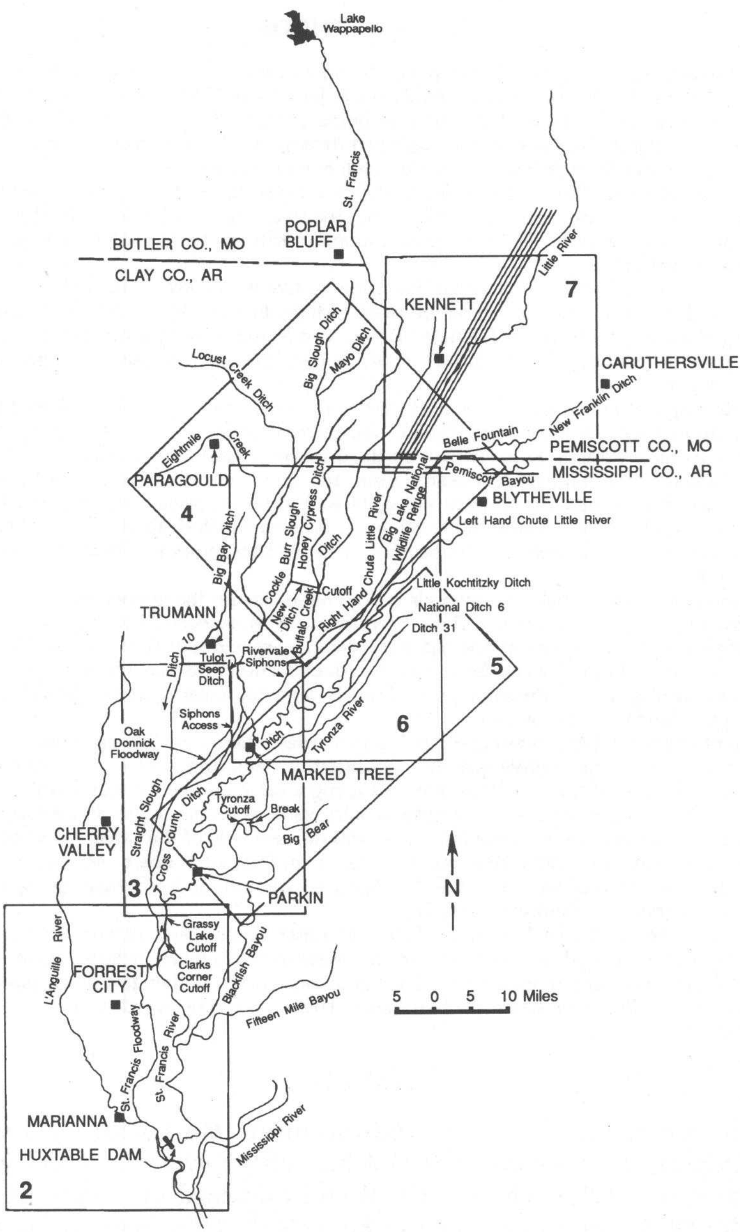

FIG. 1. The St. Francis River watershed, Arkansas and Missouri. Outlined areas are presented in more detail on Figs. 2-7, as indicated.

STUDY METHODS

Methods used during this survey were the same as those employed during the 1986 TVA study of the St. Francis River (Ahlstedt & Jenkinson, 1991). Access points were examined to locate boat launch and takeout points prior to the field effort. Information gathered during the access survey also helped determine which reaches would have to be floated to visit three or four sites within each five-mile reach.

Specific sampling sites were chosen in the field based upon the apparent quality of mussel habitat, uniform spacing of sites within the river reach, and accessibility by land or water. Large scale (7.5 minute series) topographic maps were used for navigation and site description.

When a sampling site was selected, the three- to five-man crew conducted a qualitative search for live and fresh-dead mussels. Methods typically employed included feeling along the substrate with hands or feet, raking, and collecting dead shells along the banks. Where necessary, snorkel or SCUBA equipment was used to perform an adequate search.

Collecting continued in all habitats at the site until the crew leader was satisfied that no additional species were being found. All mussels found were sorted by species, identified, and counted. Records kept on the qualitative search included the site location; number of man-minutes of search time; and numbers of live, fresh-dead (shells with shiny nacre), and relicts (dull nacre) of each mussel species encountered. Live individuals were returned to suitable habitat at the site. Fresh-dead and unusual relict shells were labeled and returned to the TVA Fisheries Laboratory in Norris, Tennessee, for storage.

Identification of virtually all mussels encountered during the survey was made by the leader of each field crew. These identifications were based upon considerable experience with all genera represented, augmented by specific study of species likely to occur in the St. Francis watershed. Species identification and synonymies had been clarified during an examination of St. Francis material housed at the Museum of Zoology, Ohio State University.

Quantitative sampling was conducted only at sites where live *Potamilus capax* were found during the qualitative search. Quantitative sampling consisted of carefully searching for mussels in 1 x 10 m intervals along a cable laid across the width of the river or ditch. Typically, two biologists would wade, snorkel, or use SCUBA equipment to find mussels within one-half meter (m) on each side of the cable. A complete quantitative search included two transects, spaced at least 20 m apart. Mussels found in each 10 m interval were identified to species, counted, and recorded along with substrate composition and water depth.

All live and unbroken fresh-dead *Potamilus capax* encountered during the survey were measured using dial or vernier calipers. Measurements taken included maximum anterior-posterior length, maximum height from anterior of umbos to ventral margin, and maximum thickness across the two shells. These data were recorded to the nearest 0.1 mm.

RESULTS

This survey was conducted in two segments. Most of the work was accomplished by two crews of TVA biologists between August 3 and September 2, 1987. The additional area examined in the State Line Outlet Ditch basin was surveyed by a single TVA crew during the week of October 26 -30, 1987.

Qualitative collections were made at 256 sites (Table 1, Figs. 2-8), where a total of 15,708 live and fresh-dead mussels were found (Table 2). Quantitative samples taken at 42 of these sites yielded a total of 3,961 live mussels (Table 3). Measurements were taken on 586 live and fresh-dead *Potamilus capax* found at these sites (Table 4).

Separate habitat descriptions, collection notes, and results tables are provided for each of nine major geographic areas or subwatersheds examined. Also provided are detailed qualitative and quantitative results from each group of collections. Measurements of the *Potamilus capax* specimens and general discussion of the data collected from all the sites are presented in the Discussion section.

L'Anguille River

Six sites were examined in the downstream part of this extensive watershed: three in the L'Anguille River between its mouth to the St. Francis Floodway and Marianna, two in the river mainstem upstream from Marianna, and one in a tributary (Larkin Creek) near its mouth (Fig. 2). All collections were made under what appeared to be low flow conditions, but visibility was never more than 10 cm.

Habitat at all mainstem sites was fairly consistent. The banks were high, rather steep, and stepped off quickly into water a meter or more in depth. Along the banks the substrate typically was thick silt, often overlain by partially or completely submerged trees. In the center of the river where the water was 1.5 to 2 m deep, the substrate was either thick silt or, occasionally, firm sand and gravel. Larkin Creek was quite small (less than 3 m wide), but still had high, steep banks. The substrate in this creek was silt and hard-packed clay.

Fifteen mussel species were found at the four downstream river sites (Table 5). No mussels were found in Larkin Creek and none were found in shallow water at Route 70 bridge (site 5). At the downstream sites, *Anodonta grandis* was by far the most abundant species, followed in order by *Arcidens confragosus, Lampsilis teres* form *anodontoides, Lasmigona complanata* and *Amblema plicata*. Single specimens of *Anodonta imbecillis, Potamilus capax, P. purpuratus, Quadrula apiculata* and *Truncilla truncata* were found. Quantitative samples taken at the most downstream site yielded 0.17 mussels/m^2 (Table 6).

St. Francis Floodway - Main Channels

Twenty-one sites were visited this year in two mainstem sections of the lower St. Francis Floodway: 7 sites in a 10-mile reach upstream

TABLE 1. Locations of collection sites visited during the St. Francis and Cache River watershed survey, August-October 1987.

Site Number	Location	County	State
	L'Anguille River		
1	0.5 miles above its mouth to St. Francis Floodway	Lee	AR
2	0.9 miles east-northeast of Marianna	Lee	AR
3	At Rt. 79 bridge 1.4 miles northeast of Marianna	Lee	AR
4	0.7 miles north-northwest of Wrightland Bridge		
5	At Rt. 70 bridge	St. Francis	AR
6	Larkin Creek at bridge 2.0 miles northwest of Wright and bridge over L'Anguille	St. Francis	AR
	St. Francis Floodway - Main Channels		
Madison Area			
7	0.4 miles northeast of Rt. 50 bridge in Madison	Cross	AR
8	1.4 miles northeast of Rt. 50 bridge in Madison	Cross	AR
9	2.0 miles north of Rt. 50 bridge in Madison	Cross	AR
10	0.5 miles above I-40 Bridge above Madison	Cross	AR
11	2.0 miles below Clarks Corner Cutoff	Cross	AR
12	1.0 miles below Clarks Corner Cutoff	Cross	AR
13	0.1 miles below Clarks Corner Cutoff	Cross	AR
Straight Slough			
14	Above confluence with Cross County Ditch	Cross	AR
15	0.5 miles above Cross County Ditch	Cross	AR
16	1.0 miles above Cross County Ditch	Cross	AR
17	2.5 miles above Cross County Ditch	Cross	AR
18	3.5 miles above Cross County Ditch	Cross	AR
19	3.0 miles south-southeast of Rt. 42 bridge	Cross	AR
20	2.5 miles south-southwest of Rt. 42 bridge	Cross	AR
21	1.6 miles downstream from Rt. 42 bridge	Cross	AR
22	1.1 miles downstream from Rt. 42 bridge	Cross	AR
23	Downstream from Rt. 42 bridge	Cross	AR
24	1 mile above Rt. 42 bridge	Cross	AR
25	2.8 miles north-northeast from Rt. 42 bridge	Cross	AR
26	1 mile above Sugar Creek	Cross	AR
27	2.5 miles east-southeast of Bay Village	Cross	AR
	Western Ditches		
Ditch 10			
28	Above confluence of Ditch 9 above Rt. 69 bridge west of Stacey	Poinsett	AR
29	Below bridge east of Little Bay Ditch 9	Poinsett	AR

TABLE 1 (cont.)

Site Number	Location	County	State
Little Bay Ditch 9			
30	At bridge east of Shady Grove	Poinsett	AR
31	At bridge north of Shady Grove	Poinsett	AR
Tulot Seep Ditch (Ditches 123 and 103)			
32	Ditch 123 above bridge south of Anderson Tully (Stewart)	Poinsett	AR
33	Ditch 103 at bridge south of Payneway below Rt. 63 bridge	Poinsett	AR
34	Below Rt. 63 bridge at Payneway	Poinsett	AR
35	North of Payneway off levee road across from Floodway Dam Ditch 60	Poinsett	AR
36	At railroad crossing bridge south of Tulot	Poinsett	AR
Ditch 60 Connector to Ditch 61			
37	Connecting ditch between Ditch 60 and 61 on east bank below Rt. 63 bridge	Poinsett	AR
38	Connecting ditch between Ditch 60 and 61 on east bank below Rt. 63 bridge	Poinsett	AR
39	Ditch 61 just upstream from connector to Ditch 60	Poinsett	AR
40	At road culvert 1.3 miles west of Lester	Greene	AR
41	At road bridge 1.7 miles southwest of Dixie	Greene	AR
42	At road 2.1 miles southeast of Schug	Greene	AR
Thompson Creek Ditch			
43	At bridge 1.8 miles west of Lester	Greene	AR
44	Below mouth of Main Ditch	Greene	AR
45	3.7 miles east of Brookland	Greene	AR
Eightmile Creek Ditch			
46	At bridge east of Schug	Greene	AR
47	At bridge east of Mulbery Church	Greene	AR
48	At Rt. 135 road crossing	Greene	AR
49	At Rt. 412 bridge in Paragould	Greene	AR
50	At Rt. 49 bridge above Paragould	Greene	AR
Locust Creek Ditch			
51	1 mile above Lake Ditch south of Coffman	Greene	AR
52	Above Rt. 412 bridge crossing	Greene	AR

TABLE 1 (cont.)

Site Number	Location	County	State
Locust Creek Ditch (cont.)			
53	West of Bard	Greene	AR
54	East of Morning Star	Greene	AR
55	Henderson Creek, tributary to Locust Creek Ditch west of Bard	Greene	AR
Big Slough Ditch			
56	At Rt. 139 bridge crossing north of Fritz	Clay	AR
57	At bridge crossing east of White Walnut Creek	Clay	AR
58	At Rt. 90 bridge crossing near Hargrove Corner	Clay	AR
59	At bridge crossing 2.0 miles north-northeast of Hargrove Corner	Clay	AR
60	At county road bridge, 2.0 miles southeast of Greenway	Clay	AR
61	At county road bridge east of Greenway	Clay	AR
Mayo Ditch			
62	At county road bridge north of Middle Bark Camp Island	Greene	AR
63	At county road bridge north of Bark Camp Island	Greene	AR
64	At Rt. 139 bridge, 0.6 miles south of Mounds	Greene	AR
	St. Francis River Channel		
65	2 miles below Rt. 79 bridge south of Raggio	Lee	AR
66	0.5 miles below Rt. 79 bridge	Lee	AR
67	Above Rt. 79 bridge at Cow Bayou Bar	Lee	AR
68	North of Tongin	Lee	AR
69	Cutoff above Old River Channel	St. Francis	AR
70	At Council Bar	St. Francis	AR
71	1.4 miles southwest of Joyland	Poinsett	AR
72	0.9 miles south-southwest of Joyland	Poinsett	AR
73	0.7 miles south-southwest of Joyland	Poinsett	AR
74	0.5 miles east-northeast of Joyland	Poinsett	AR
75	At Yellow Banks west of Mt. Olive	Poinsett	AR
76	Downstream from mouth of Ditch 1	Poinsett	AR
77	Above mouth of Ditch 1	Poinsett	AR
78	Below Neiswander Church	Poinsett	AR
79	North of Neiswander Church	Poinsett	AR
80	Below Rt. 63 bridge	Poinsett	AR
81	Above Rt. 63 bridge	Poinsett	AR
82	Below Rt. 63B bridge at Marked Tree	Poinsett	AR

TABLE 1 (cont.)

Site Number	Location	County	State
St. Francis River Channel (cont.)			
83	At sand bar upstream from Rt. 63B bridge at Marked Tree	Poinsett	AR
84	1 mile below railroad bridge	Poinsett	AR
85	Just above railroad bridge	Poinsett	AR
86	At mouth of Left Hand Chute Little River	Poinsett	AR
87	Below Siphons Access above Marked Tree	Poinsett	AR
88	Below Siphons Access above Marked Tree	Poinsett	AR
89	At Siphons Access above marked Tree	Poinsett	AR
	Lower Eastern Tributaries		
Blackfish Bayou			
90	At Rawlinson	St. Francis	AR
91	Above Rt. 38 bridge	St. Francis	AR
92	Below bridge crossing southwest of Rt. 50	St. Francis	AR
93	At bridge crossing south of Rt. 50	St. Francis	AR
94	At Rt. 50 bridge crossing	St. Francis	AR
Fifteen Mile Bayou			
95	Above Rt. 38 bridge crossing	St. Francis	AR
96	North of Rt. 38	St. Francis	AR
Tyronza River			
97	1 mile above confluence with St. Francis River near Parkin	Cross	AR
98	North of Smithdale	Cross	AR
99	2.0 miles below Rt. 184 bridge crossing	Crittenden	AR
100	1.0 miles below Rt. 184 bridge crossing	Crittenden	AR
101	At Rt. 184 bridge crossing north of Norvell	Crittenden	AR
102	In field access west of Three Forks	Crittenden	AR
103	At Rt. 42 bridge crossing	Crittenden	AR
104	Tyronza cutoff at bridge west of King Soloman Cemetery and Rt. 149	Crittenden	AR
105	Tyronza cutoff at Rt. 149 bridge	Crittenden	AR
106	At Rt. 14 bridge, 1.6 miles north-northeast of Dyess	Mississippi	AR
107	At county bridge 2.0 miles northeast of Dyess	Mississippi	AR
108	Ditch 31 at bridge 1.2 miles east of Halftown	Mississippi	AR
109	Ditch 40 at Rt. 181 bridge crossing	Mississippi	AR
110	Ditch 40 at Rt. 158 bridge crossing	Mississippi	AR

TABLE 1 (cont.)

Site Number	Location	County	State
Big Creek			
111	At Rt. 149 bridge crossing northeast of Three Forks	Crittenden	AR
112	At confluence of upper Tyronsa River south of Rt. 42	Crittenden	AR
113	At Rt. 118 bridge crossing	Crittenden	AR
114	Below Deer Bayou south of Heafer	Crittenden	AR
115	At Rt. 42 bridge crossing east of Heafer	Crittenden	AR
116	At Rt. 42 bridge west of Turrell	Crittenden	AR
Ditch No. 1			
117	At confluence with St. Francis River	Poinsett	AR
118	At Rt. 149 bridge crossing south of Marked Tree	Poinsett	AR
119	At Rt. 308 bridge crossing	Poinsett	AR
120	At Rt. 135 bridge crossing north of Spear Lake	Poinsett	AR
121	At bridge south of Rt. 14	Mississippi	AR
122	2.8 miles southwest of Hall Town	Mississippi	AR
123	Tributary to National Ditch 6 at bridge crossing near Hall Town	Mississippi	AR
124	Tributary to National Ditch 6 at Rt. 140 bridge crossing	Mississippi	AR
	Left Hand Chute Little River and Buffalo Creek Ditch		
Left Hand Chute Little River			
125	Just above confluence with St. Francis River	Poinsett	AR
126	At Rt. 140 bridge crossing, 1.5 miles north-northeast of Marked Tree	Poinsett	AR
127	At bridge 0.7 miles east-northeast of Marked Tree	Poinsett	AR
128	Where Rt. 308 turns east, 1.5 miles northeast of Marked Tree	Poinsett	AR
129	At bridge crossing, 2.3 miles northeast of Marked Tree	Poinsett	AR
130	At bridge crossing, 3.7 miles northeast of Marked Tree	Poinsett	AR
131	1.7 miles southwest of Lepanto	Poinsett	AR
132	At Rt. 140 bridge (North) in Lepanto	Poinsett	AR
133	Along dirt road, 2.4 miles south of Rivervale	Poinsett	AR
134	At Rt. 135 bridge crossing, 2.0 miles north of Lepanto	Poinsett	AR
135	Along Rt. 135, 0.5 miles from center of Lepanto	Poinsett	AR
136	At upstream southeast edge of Lepanto	Poinsett	AR
137	At Rt. 14 bridge crossing, 3.0 miles east of Lepanto	Mississippi	AR

TABLE 1 (cont.)

Site Number	Location	County	State
Left Hand Chute Little River (cont.)			
138	2.0 miles northeast of Lepanto	Mississippi	AR
139	At bridge 2.5 miles southwest of West Ridge	Mississippi	AR
140	At Rt. 77 bridge crossing in Bondsville	Mississippi	AR
141	At bridge 1.2 miles northeast of Bondsville	Mississippi	AR
142	At bridge 3.0 miles northeast of Bondsville	Mississippi	AR
143	At Rt. 140 bridge crossing, 2.2 miles southeast of Etowah	Mississippi	AR
144	1.7 miles southwest of Carrol Corner	Mississippi	AR
145	At Rt. 77 bridge crossing	Mississippi	AR
146	Unnamed ditch to LHCLR, 1.8 miles south-southeast of Rivervale	Poinsett	AR
Lower Buffalo Creek Ditch Complex			
147	New ditch at bridge 3.2 miles south-southeast of Rivervale	Poinsett	AR
148	New ditch 0.6 miles south-southeast of Rivervale	Poinsett	AR
149	Ditch north of Left Hand Chute just below Rivervale	Poinsett	AR
150	Unnamed ditch flowing under Right Hand Chute at Rivervale	Poinsett	AR
151	Unnamed ditch at powerline crossing, 1.0 mile north of Rivervale	Poinsett	AR
152	Unnamed ditch at Stier, Rt. 135 at Craighead County line	Poinsett	AR
153	Buffalo Creek Ditch off Rt. 158 bridge crossing	Mississippi	AR
154	Buffalo Creek Ditch at bridge west of Milligan	Mississippi	AR
155	Buffalo Creek Ditch east of Hancock	Mississippi	AR
156	Buffalo Creek Ditch at bridge east of Vail	Mississippi	AR
157	Unnamed ditch at Rt. 135 access, 0.8 miles southeast of Rivervale	Poinsett	AR
236	At Rt. 18 bridge crossing	Mississippi	AR
	Right Hand Chute Little River Complex		
158	Iron Mines Creek off levee road west of Red Oak Church	Poinsett	AR
159	Right Hand Chute Little River off levee road west of Red Oak Church	Poinsett	AR
160	Iron Mines Creek north of Siphons Access	Poinsett	AR
161	Right Hand Chute Little River north of Siphons Access	Poinsett	AR
162	Iron Mines Creek off levee road north of Rt. 140	Poinsett	AR

TABLE 1 (cont.)

Site Number	Location	County	State
Right Hand Chute Little River Complex (cont.)			
163	Right Hand Chute Little River off levee road north of Rt. 140	Poinsett	AR
164	Right Hand Chute Little River below bridge south of Rivervale	Poinsett	AR
165	Dry Ditch (no name) 2 miles south of Rivervale	Poinsett	AR
166	Right Hand Chute Little River right channel below Rt. 135 bridge at Rivervale	Poinsett	AR
167	Right Hand Chute Little River above bridge at Rivervale	Poinsett	AR
168	Right Hand Chute Little River 2 miles above bridge at Rivervale	Poinsett	AR
169	Right Hand Chute Little River west of diversion ditch above Rivervale	Mississippi	AR
170	Right Hand Chute Little River east of Buffalo Creek Church above Rivervale	Mississippi	AR
171	Right Hand Chute Little River just downstream from mouth of Ditch 1, 1.2 miles south of Mandalay	Mississippi	AR
172	Ditch 1 above mouth to RHCLR, 1.3 miles south-southeast of Mandalay	Mississippi	AR
173	RHCLR at mouth of Ditch 2, 1.1 miles south-southeast of Mandalay	Mississippi	AR
174	Ditch l, 2.3 miles southeast of Mandalay	Mississippi	AR
175	RHCLR 2.2 miles east-southeast of Mandalay	Mississippi	AR
176	RHCLR, 0.8 miles southwest of Mandalay	Mississippi	AR
177	Ditch l, 0.7 miles south-southwest of Floodway	Mississippi	AR
178	RHCLR, 0.2 miles downstream from Rt. 77 Floodway bridge	Mississippi	AR
179	RHCLR, 0.1 miles upstream from Floodway (Rt. 77) bridge	Mississippi	AR
180	Ditch l at mouth to RHCLR, 0.4 miles southeast of Floodway	Mississippi	AR
181	Ditch 1, 1.6 miles east-northeast of Floodway	Mississippi	AR
182	RHCLR 1.9 miles northeast of Floodway	Mississippi	AR
183	Ditch 3, 2.5 miles south-southwest of Big Lake Dam	Mississippi	AR
184	RHCLR, 2.0 miles south-southwest of Big Lake Dam	Mississippi	AR
185	RHCLR above mouth of Ditch 81	Mississippi	AR
186	RHCLR, 0.5 miles south of Big Lake Dam	Mississippi	AR
187	RHCLR, downstream from Big Lake Dam under powerline	Mississippi	AR
188	RHCLR just below Big Lake Dam	Mississippi	AR
189	Lateral off of Ditch l, east of Peach Orchard	Pemiscott	MO
190	Ditch 1 above Rt. EE bridge east of Peach Orchard	Pemiscott	MO

TABLE 1 (cont.)

Site Number	Location	County	State
Right Hand Chute Little River Complex (cont.)			
191	Ditch 83 at Rt. EE bridge east of Peach Orchard	Pemiscott	MO
	State Line Outlet Ditch Basin		
Belle Fountain Main Ditch			
192	Above and below confluence of Pemiscot Bayou	Dunklin	MO
193	Below powerline crossing west of Rt. TT bridge	Dunklin	MO
194	Above powerline crossing west of Rt. TT bridge	Dunklin	MO
195	Above and below Main Ditch 1 west of Rt. TT bridge	Dunklin	MO
196	At Rt. TT bridge crossing	Dunklin	MO
197	At Rt. TT bridge crossing	Dunklin	MO
198	At bridge south of Shady Grove Church	Dunklin	MO
199	Below Rt. NN bridge crossing	Dunklin	MO
200	At bridge south of Rt. M and west of Hermondale	Pemiscott	MO
201	At bridge north of Hermondale	Pemiscott	MO
202	At Rt. 61 bridge crossing	Pemiscott	MO
203	At Rt. 559 bridge crossing	Pemiscott	MO
204	At bridge crossing southwest of Cooter	Pemiscott	MO
Pemiscot Bayou Ditch 29			
205	Above mouth of Pemiscot Bayou (Ditch 29)	Mississippi	AR
206	At Rt. 151N bridge above Calumet	Mississippi	AR
207	At Rt. 181N bridge	Mississippi	AR
208	At Rt. 150E bridge above Blytheville Air Force Base	Mississippi	AR
209	At Rt. 150 bridge spur north of Yarbro	Mississippi	AR
210	At Rt. 61 bridge northeast of Yarbro	Mississippi	AR
211	At I-55 bridge	Mississippi	AR
New Franklin Ditch 5			
212	At Rt. 554 bridge	Pemiscott	MO
213	At Rt. E bridge east of Cooter	Pemiscott	MO
214	Ditch 3 at bridge north of Cooter	Pemiscott	MO
215	At Rt. H bridge south of Acorn Corner	Pemiscott	MO
216	At bridge east of Rt. H below Acorn Corner	Pemiscott	MO
217	At Rt. 164 bridge	Pemiscott	MO
218	At Rt. D bridge	Pemiscott	MO

TABLE 1 (cont.)

Site Number	Location	County	State
Main Ditch 6			
219	At Missouri Rt. E bridge west of I-55	Pemiscott	MO
220	At bridge 1.0 miles southwest of Steele	Pemiscott	MO
221	At Rt. 61 bridge, north edge of Steele	Pemiscott	MO
222	At bridge east of Kings Chapel	Pemiscott	MO
223	At bridge east of Rt. 2	Pemiscott	MO
224	At Rt. J bridge southeast of Braggadiocio	Pemiscott	MO
225	At bridge north of Shade	Pemiscott	MO
Ditch 9			
226	At Rt. M west of West Hermondale	Pemiscott	MO
227	Below Channel at Rt. 164W bridge	Pemiscott	MO
228	At bridge east of the town of Channel	Pemiscott	MO
229	At bridge south of Rt. 164	Pemiscott	MO
230	At Rt. 164 bridge west of Denton	Pemiscott	MO
231	At bridge east of Rt. NN	Dunklin	MO
232	At Rt. 164 bridge	Dunklin	MO
	Upper Eastern Tributaries		
Cockle Burr Slough Ditch			
233	At bridge west of Rt. 139	Craighead	AR
234	Above bridge at Rt. 139 and 18	Craighead	AR
235	At bridge west of Delfore	Craighead	AR
236	[locality follows site no. 157]		
Upper Buffalo Creek Ditch			
237	1 mile below Rt. 119 bridge crossing	Mississippi	AR
238	At lateral Ditch 12	Mississippi	AR
239	Off Rt. 119	Mississippi	AR
Honey Cypress Creek Ditch 12			
240	At new bridge east of Rt. 110 below Leachville	Mississippi	AR
241	At bridge east of Rt. 77	Mississippi	AR
242	At bridge east of Rt. 77	Mississippi	AR
243	At new bridge west of Buckeye	Mississippi	AR
244	At bridge west of Pawheen	Mississippi	AR
245	At bridge east of Rt. 77	Mississippi	AR
246	Dredge Boat Creek Ditch 12 at bridge east of Rt. 119	Mississippi	AR

TABLE 1 (cont.)

Site Number	Location	County	State
Cane Island Slough Ditch			
247	At mouth of Little Slough Ditch	Craighead	AR
248	At bridge, 1.6 miles east of Lake City	Craighead	AR
249	At Rt. 18 bridge crossing	Craighead	AR
Varney River Ditch			
250	At Osbunds Harvesting Rt. A bridge	Dunklin	MO
251	At dirt road bridge	Dunklin	MO
252	At Rt. A bridge	Dunklin	MO
	Cache River		
253	At former channel outlet 2.0 miles north of Rt. 79 bridge in Clarendon	Monroe	AR
254	Reeses Fork 2.3 miles north-northwest of Rt. 79 bridge in Clarendon	Monroe	AR
255	Reeses Fork 3.0 miles northwest of Rt. 79 bridge in Clarendon	Monroe	AR
256	Reeses Fork 2.9 miles northwest of Rt. 79 bridge in Clarendon	Monroe	AR

from Madison (sites 7-13, Fig. 2), and 14 sites spaced along a 10-mile reach of Straight Slough upstream from its confluence with Cross County Ditch (sites 14-27, Fig. 3). Water levels were down and collecting conditions were excellent in both areas. Visibility was 20-30 cm at best.

Aquatic habitat in these two areas was not the same. The reach from Madison upstream to Clarks Corner Cutoff appeared to be a relatively unmodified old river channel. High banks either dropped off into the water or to bankside sand or gravel bars. The river typically was rather wide (70 m), less than 1 m deep, and had a substrate composed of stable or shifting sand. On the outside of bends there usually was a band of firm clay or gravel that could contain many mussels.

Straight Slough was a large, straight manmade ditch. The banks were high and steep, with little or no marginal strip along the water's edge. The channel was 30 to 50 m wide and nearly uniform in depth (30-70 cm). At its downstream end, the substrate was relatively firm mud. Further upstream the substrate gradually changed into shifting or firm sand with patches of mud along the banks. Gravel substrates

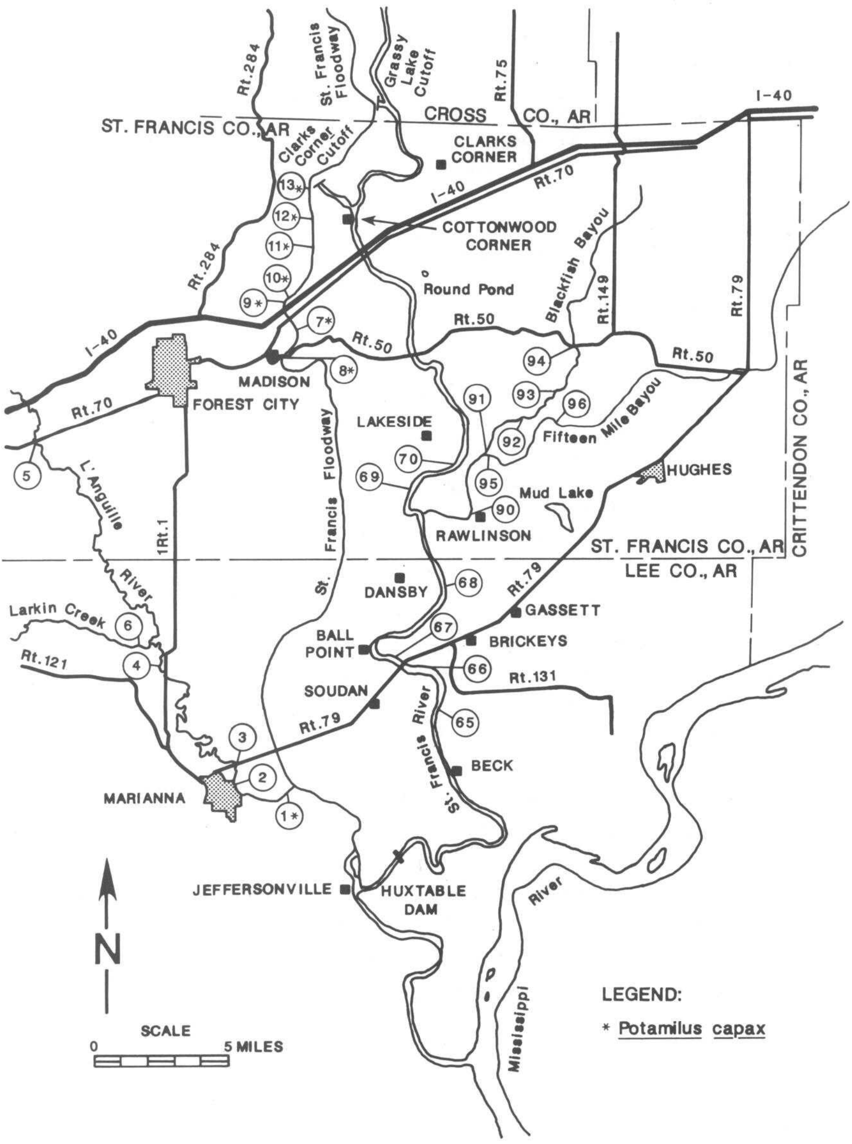

FIG. 2. Collection sites visited during 1987 in the L'Anguille River, Madison reach of the St. Francis Floodway, Lower St. Francis River, and Blackfish Bayou drainage. Stars identify sites where *Potamilus capax* was found.

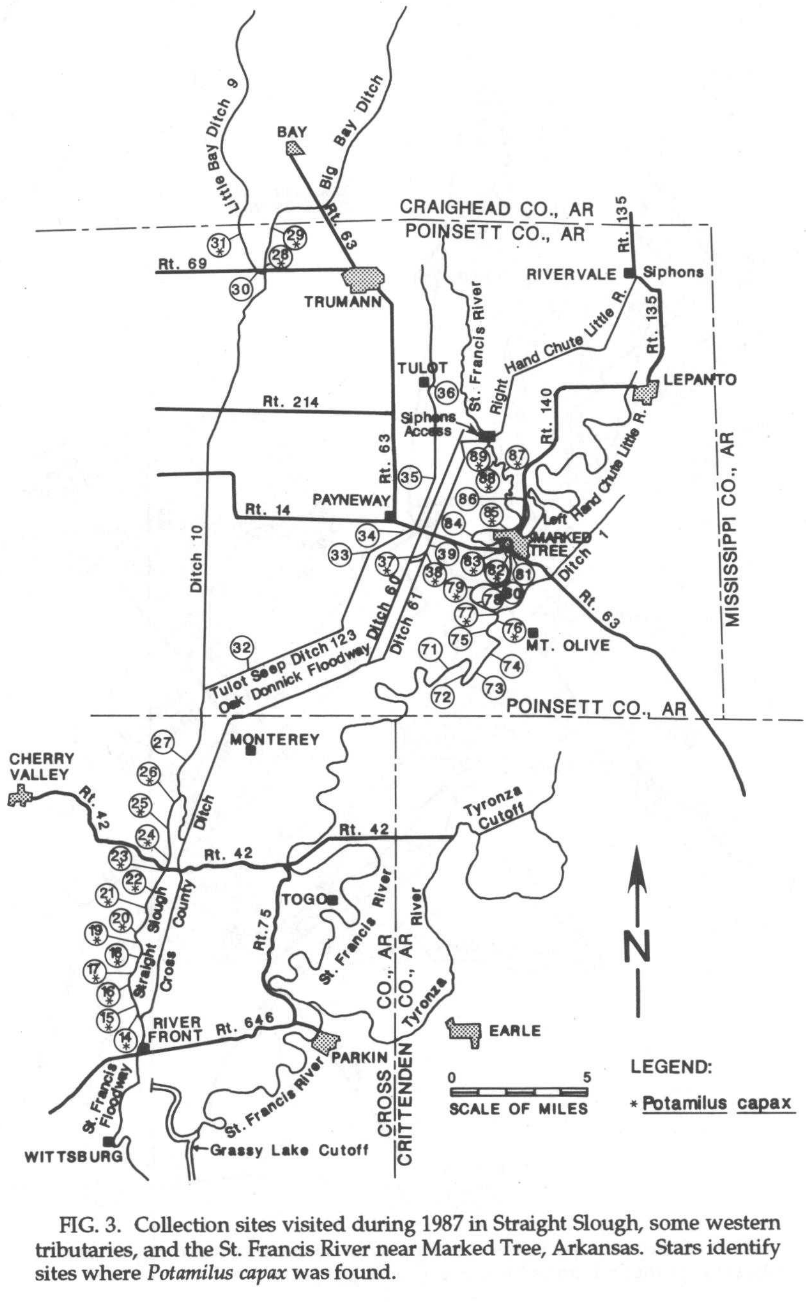

FIG. 3. Collection sites visited during 1987 in Straight Slough, some western tributaries, and the St. Francis River near Marked Tree, Arkansas. Stars identify sites where *Potamilus capax* was found.

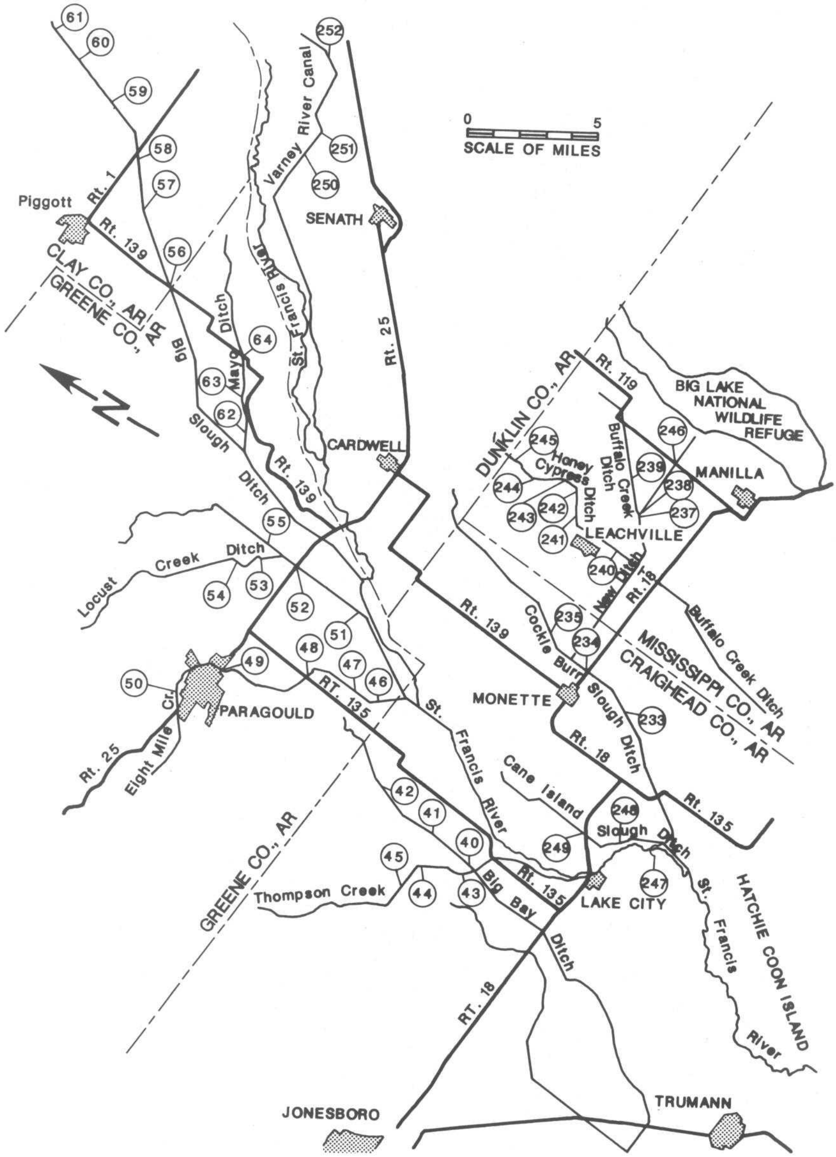

FIG. 4. Collection sites visited during 1987 in northwestern and upper eastern tributaries of the St. Francis River and Floodway system.

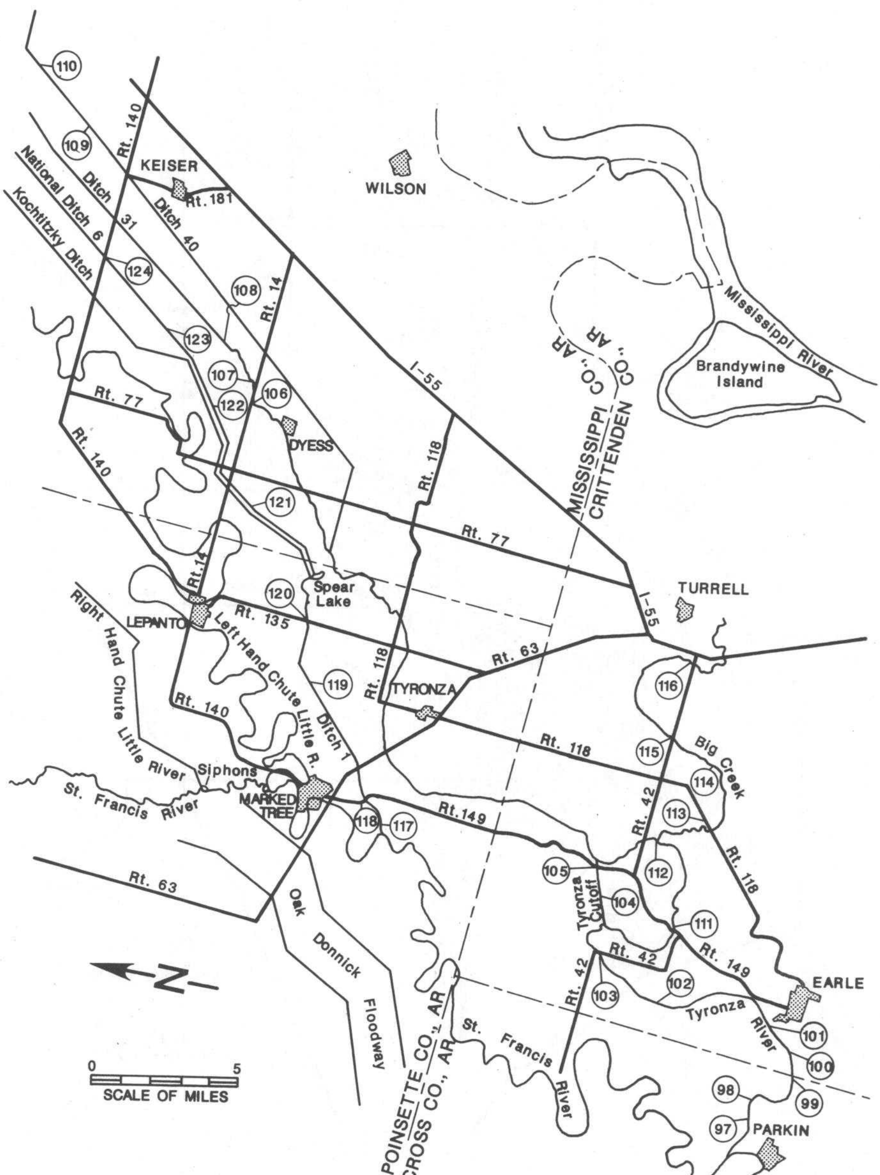

FIG. 5. Collection sites visited during 1987 in the Tyronza River and Ditch 1 drainage basins.

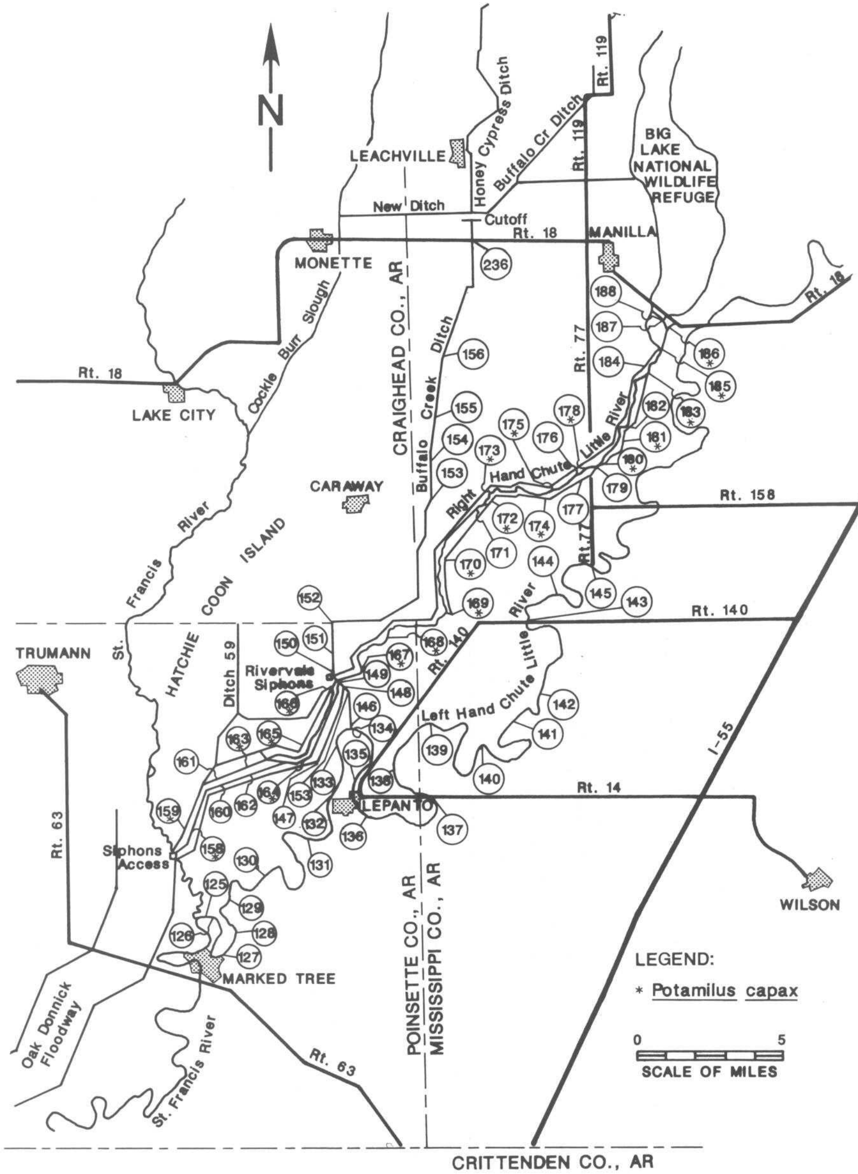

FIG. 6. Collection sites visited during 1987 in Left Hand Chute, Lower Buffalo Creek Ditch, and lower Right Hand Chute Little River. Stars identify sites where *Potamilus capax* was found.

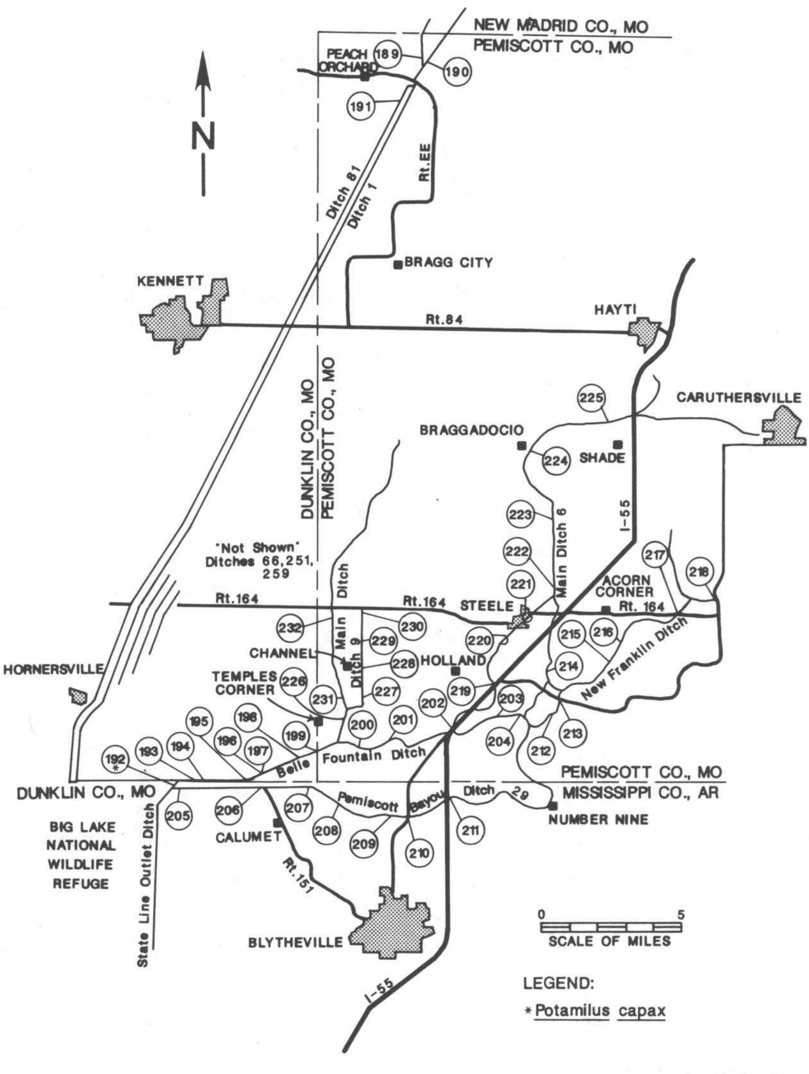

FIG. 7. Collection sites visited during 1987 in the State Line Outlet Ditch basin. A star indicates the site where *Potamilus capax* was found.

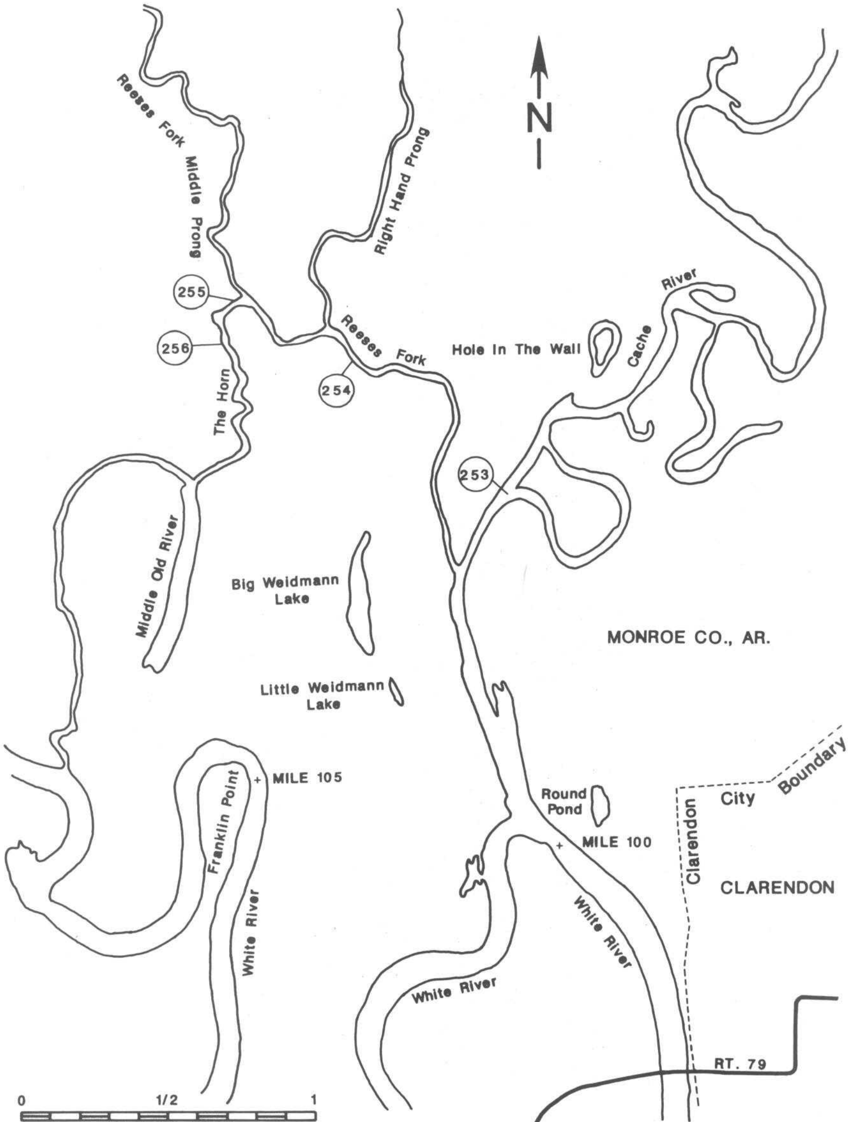

FIG. 8. Collection sites visited during 1987 in the Cache River basin.

TABLE 2. Summary of live and fresh-dead mussel records from the St. Francis and Cache River watershed survey, August-October, 1987.

Species	Site Number						
	1-6	7-27	28-64	65-89	90-124	125-157, 236	158-191
Amblema plicata	14	1412	166	1380	1545	431	213
Anodonta grandis	131	48	38	102	58	253	91
Anodonta imbecillis	1	3	17	5	7	4	7
Anodonta suborbiculata	10	4	1	2	10		2
Arcidens confragosus	22	7	10	10	24	14	3
Cyprogenia aberti		2					
Fusconaia ebena		37		3			
Fusconaia flava		108	33	123	35	18	21
Lampsilis radiata hydiana				1	1		
Lampsilis teres f. *anodontoides*	19	76	43	91	55	23	32
Lampsilis teres f. *teres*			3	4	7		
Lampsilis ovata		4	34	4	3	11	31
Lasmigona complanata	15	12	10	16	25	52	56
Leptodea fragilis		69	116	225	136	42	127
Megalonaias nervosa		135		83	125	41	5
Obliquaria reflexa		48	9	40	26	5	44
Obovaria olivaria							
Ellipsaria lineolata		26					
Plectomerus dombeyanus		3		3	2		
Pleurobema rubrum		354		20			
Potamilus capax	1	254	176	45			129
Potamilus ohiensis	3	66	21	87	36	56	124
Potamilus purpuratus	1	95	67	254	173	74	139
Quadrula apiculata	1				1		
Quadrula metanevra		4		2			
Quadrula nodulata		47	6	41	82	19	100
Quadrula pustulosa	2	682	4	573	206	29	80
Quadrula quadrula	13	632	53	82	116	27	65
Strophitus undulatus			3	1	5	1	
Toxolasma texasensis			7	9	31	3	11
Tritogonia verrucosa		50	1	78	86	20	7
Truncilla donaciformis		1		3	4		6
Truncilla truncata	1	5		6	19	1	
Uniomerus declivus			2		7		
Uniomerus tetralasmus			13				
Villosa lienosa	5				1		
Totals							
Specimens	239	4184	833	3293	2826	1125	1293
No. Species	15	27	23	29	28	21	21
Sites Visited	6	21	37	25	35	34	34
Specimens/Site	39.83	199.24	22.51	131.72	80.74	33.09	38.03

TABLE 2. (Cont.)

Species	St. Line Outlet Sites 192-232	Up East Tribs. Sites 233-252 (-236)	St. Francis System Grand totals	St. Francis System Percent	Cache R. System Sites 253-256	Cache R. System Percent of total
Amblema plicata	125	63	5349	35.69	78	10.90
Anodonta grandis	201	87	1009	6.73	6	0.84
Anodonta imbecillis	4	3	51	0.34		
Anodonta suborbiculata	5	4	38	0.25		
Arcidens confragosus	107	4	201	1.34		
Cyprogenia aberti			2	0.01		
Fusconaia ebena			40	0.27	21	2.94
Fusconaia flava		11	349	2.33	1	0.14
Lampsilis hydiana			2	0.01		
Lampsilis teres f. anodontoides	23	2	364	2.43	17	2.38
Lampsilis teres f. teres	3		17	0.11		
Lampsilis ovata	4	5	96	0.64	7	0.98
Lasmigona complanata	72	10	268	1.79		
Leptodea fragilis	122	12	849	5.66	121	16.91
Megalonaias nervosa			389	2.59	23	3.22
Obliquaria reflexa	10		182	1.21	28	3.92
Obovaria olivaria					3	0.42
Ellipsaria lineolata			26	0.17		
Plectomerus dombeyanus	1		9	0.06	142	19.86
Pleurobema rubrum			374	2.49		
Potamilus capax	2		607	4.05		
Potamilus ohiensis	31	5	429	2.86	18	2.52
Potamilus purpuratus	76	9	888	5.92	16	2.24
Quadrula apiculata	3	3	9	0.06		
Quadrula metanevra			6	0.04		
Quadrula nodulata	20		315	2.10	4	0.56
Quadrula pustulosa	1	29	1606	10.72	138	19.30
Quadrula quadrula	70	9	1067	7.12	74	10.35
Strophitus undulatus		6	16	0.11		
Toxolasma texasensis	6	12	79	0.53	4	0.56
Tritogonia verrucosa	23		265	1.77	8	1.12
Truncilla donaciformis	5		19	0.13		
Truncilla truncata			32	0.21	6	0.84
Uniomerus declivus	4	7	20	0.13		
Uniomerus tetralasmus	1		14	0.09		
Villosa lienosa			6	0.04		
Totals						
Specimens	919	281	14993	100.00	715	100.00
No. Species	24	18	35		19	
Sites Visited	41	19	252		4	
Specimens/Site	22.41	14.79	59.50		178.75	

TABLE 3. Summary of quantitative samples (mussels/m^2) taken in each watershed area, St. Francis River System, August-October 1987.

Species	L'Anguille River	Floodway channels	Western ditches	St. Francis River	Right Hand Chute	Average per m^2	No. of spec.
Amblema plicata		0.67*	0.10	0.18	0.00	0.38	1371
Anodonta grandis	0.12	0.00	0.01	0.01	0.01	0.01	25
Anodonta imbecillis			0.01			0.00	1
Anodonta suborbiculata		0.00			0.00	0.00	3
Arcidens confragosus		0.00		0.02		0.00	9
Cyprogenia aberti		0.00				0.00	2
Fusconaia ebena		0.02				0.01	37
Fusconaia flava		0.06		0.02		0.03	113
Lampsilis teres f. anodontoides		0.03	0.01	0.01	0.00	0.02	55
Lampsilis ovata		0.00	0.02			0.00	5
Lasmigona complanata	0.02	0.00		0.01	0.01	0.00	18
Leptodea fragilis		0.02	0.01	0.11	0.01	0.03	94
Megalonaias nervosa		0.07		0.05		0.04	149
Obliquaria reflexa		0.02		0.00	0.01	0.02	53
Ellipsaria lineolata		0.01				0.01	26
Plectomerus dombeyanus				0.00		0.00	1
Pleurobema rubrum		0.18		0.00		0.10	355
Potamilus capax		0.03	0.04	0.01	0.02	0.03	92
Potamilus ohiensis	0.02	0.01	0.01		0.01	0.01	33
Potamilus purpuratus		0.03	0.01	0.06	0.02	0.03	95
Quadrula apiculata	0.02					0.00	1
Quadrula metanevra		0.00				0.00	4
Quadrula nodulata		0.01	0.01	0.01	0.02	0.01	51
Quadrula pustulosa		0.31		0.07	0.00	0.19	669
Quadrula quadrula		0.31	0.01	0.03	0.01	0.18	627
Tritogonia verrucosa		0.02		0.05	0.00	0.02	64
Truncilla donaciformis		0.00			0.00	0.00	3
Truncilla truncata		0.00				0.00	5
Totals							
Number per Square Meter	0.17	1.85	0.23	0.63	0.12	1.11	
Number of Samples (10 m^2)	6194	14	30	113	357		
Specimens found	10	3590	32	190	139		3961
Species Included	4	25	11	17	15		28

*All calculated values in the table have been rounded to two decimal places. These rounding errors make some summations appear to be incorrect.

TABLE 4. Lengths of *Potamilus capax* specimens encountered alive or as fresh-dead shells in each watershed area, St. Francis River system, August-October 1987.

		Length Increments in Millimeters											
Drainage Basins	Mean	30	40	50	60	70	80	90	100	110	120	130	Specimens
L'Anguille River	111.70									1			1
Floodway Main Channels	101.90			1	3	13	46	62	36	39	33	10	243
Western Ditches	79.77		5	8	14	74	41	23	4	5	2		176
St. Francis River	90.12	1	3			4	12	15	6	1	2	1	45
Right Hand Chute	97.55	1		3	3	9	23	31	26	3	14	6	119
State Line Outlet Ditch	99.00						1			1			2
Totals	93.47	2	8	12	20	100	123	131	72	50	51	17	586

TABLE 5. Site by site counts of all mussels found in the L'Anguille River watershed, August 1987.

Species	Site						Totals	No. sites
	1	2	3	4	5	6		
Amblema plicata	1	11	2	-	-	-	14	3
Anodonta grandis	61	54	16	-	-	-	131	3
Anodonta imbecillis	1	-	-	-	-	-	1	1
Anodonta suborbiculata	5	2	3	-	-	-	10	3
Arcidens confragosus	1	20	1	-	-	-	22	3
Lampsilis teres f. *anodontoides*	2	11	5	1	-	-	19	4
Lasmigona complanata	2	10	3	-	-	-	15	3
Potamilus capax	1	-	-	-	-	-	1	1
Potamilus ohiensis	1	2	-	-	-	-	3	2
Potamilus purpuratus	1	-	-	-	-	-	1	1
Quadrula apiculata	1	-	-	-	-	-	1	1
Quadrula pustulosa	-	1	1	-	-	-	2	2
Quadrula quadrula	1	11	1	-	-	-	13	3
Truncilla truncata	-	-	1	-	-	-	1	1
Villosa lienosa	-	4	1	-	-	-	5	2
Total Specimens	78	126	34	1	0	0	239	
Species Included	12	10	10	1	0	0	15	

TABLE 6. Quantitative sampling results (mussels/m^2) from the L'Anguille River watershed, August 1987.

Species	Site 1	Average per m^2	No. specimens
Anodonta grandis	0.12*	0.12	7
Lasmigona complanata	0.02	0.02	1
Potamilus ohiensis	0.02	0.02	1
Quadrula apiculata	0.02	0.02	1
Totals			
Number Per Square Meter	0.17	0.17	
Number of Samples (10 m^2)	6	6	
Specimens Found	10		10
Species Included	4		4

*All calculated values in the table have been rounded to two decimal places. These rounding errors make some summations appear to be incorrect.

were rare.

Twenty-five mussel species were found in the Madison reach and 16 species were found in Straight Slough (Table 7). Mussels were far more abundant in the Madison reach (Table 8). The most abundant species in the Madison reach was *Amblema plicata,* followed in order by *Quadrula pustulosa, Q. quadrula, Pleurobema rubrum* and *Potamilus capax.* The most abundant species in Straight Slough was *P. capax,* followed by *Anodonta grandis, Potamilus purpuratus, P. ohiensis* and *Q. quadrula.* As indicated in Table 7, several species were represented by only a few individuals in one or both of these reaches. *Potamilus capax* occurred at all but one of these sites.

Mussels were particularly abundant at the three downstream sites near Madison (sites 7, 8, 9). At all three sites, firm clay or gravel substrate adjacent to one bank was packed with mussels. At sites 7 and 8, the band of firm clay adjacent to the left (descending) bank changed fairly quickly to shifting sand substrates that did not contain many mussels. At site 9, the firm gravel along the right bank passed through a slow transition to packed sand and mussel shells (both live and dead) before becoming shifting sand near the left shoreline. Live mussels were packed into this site across more than half the width of the river.

Western Ditches

Thirty-seven sites were examined in 10 western ditches or small streams that drain into the St. Francis Floodway or the St. Francis

TABLE 7. Site by site counts of all mussels found in the St. Francis Floodway-Main Channels, August 1987.

	Madison Area									Straight Slough							
Species Site	7	8	9	10	11	12	13	Subtotal	Percent	14	15	16	17	18	19	20	21
Amblema plicata	361	155	836	43	7	-	4	1406	36.11	-	1	-	-	-	-	-	-
Anodonta grandis	-	-	-	-	-	-	-	-	0.00	6	22	3	5	5	-	2	2
Anodonta imbecillis	-	-	-	-	-	-	1	1	0.03	-	-	-	-	-	1	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	0.00	-	3	-	1	-	-	-	-
Arcidens confragosus	1	2	1	-	-	-	-	4	0.10	2	1	-	-	-	-	-	-
Cyprogenia aberti	-	-	2	-	-	-	-	2	0.05	-	-	-	-	-	-	-	-
Fusconaia ebena	5	-	31	-	-	-	1	37	0.95	-	-	-	-	-	-	-	-
Fusconaia flava	4	4	99	-	-	-	-	107	2.75	-	-	-	-	-	-	-	-
Lampsilis teres f. *anodontoides*	2	9	39	9	9	4	2	74	1.90	-	1	-	-	-	-	-	-
Lampsilis ovata	2	1	-	-	1	-	-	4	0.10	-	-	-	-	-	-	-	-
Lasmigona complanata	1	-	-	-	-	-	-	1	0.03	1	4	1	1	1	-	-	-
Leptodea fragilis	15	12	16	3	-	1	1	48	1.23	2	-	3	2	2	1	1	1
Megalonaias nervosa	4	7	124	-	-	-	-	135	3.47	-	-	-	-	-	-	-	-
Obliquaria reflexa	2	12	26	1	-	1	5	47	1.21	-	-	-	-	-	-	-	-
Ellipsaria lineolata	-	-	26	-	-	-	-	26	0.67	-	-	-	-	-	-	-	-
Plectomerus dombeyanus	-	-	-	3	-	-	-	3	0.08	-	-	-	-	-	-	-	-
Pleurobema rubrum	-	2	352	-	-	-	-	354	9.10	-	-	-	-	-	-	-	-
Potamilus capax	31	5	21	52	15	17	24	165	4.24	10	4	3	3	10	4	5	7
Potamilus ohiensis	8	4	1	4	1	2	14	34	0.87	2	5	-	2	9	3	3	1
Potamilus purpuratus	12	11	31	-	-	2	4	60	1.54	5	6	-	5	4	3	6	-
Quadrula metanevra	-	-	4	-	-	-	-	40	0.10	-	-	-	-	-	-	-	-
Quadrula nodulata	2	17	4	7	7	-	1	38	0.98	-	-	-	-	1	1	1	-
Quadrula pustulosa	48	118	496	14	-	3	2	681	17.51	-	-	-	-	-	-	1	-
Quadrula quadrula	37	48	520	-	-	-	2	607	15.60	-	1	-	-	3	1	1	2
Tritogonia verrucosa	7	2	39	-	-	-	2	50	1.29	-	-	-	-	-	-	-	-

TABLE 7. (cont.)

Species	Madison Area									Straight Slough							
	Site 7	8	9	10	11	12	13	Subtotal	Percent	14	15	16	17	18	19	20	21
Truncilla donaciformis	-	-	1	-	-	-	-	1	0.03	-	-	-	-	-	-	-	-
Truncilla truncata	4	-	1	-	-	-	-	1	0.03	-	-	-	-	-	-	-	-
Total specimens	546	409	2670	136	40	30	63	3890	100.00	28	48	10	19	35	14	20	13
Species included	18	16	21	9	6	7	13	25		7	10	4	7	8	7	8	5

TABLE 7. (cont.)

Species	Straight Slough								Total	No. sites
	Site 22	23	24	25	26	27	Subtotal	Percent		
Amblema plicata	-	1	1	1	2	-	6	2.07	1412	11
Anodonta grandis	-	-	-	3	-	-	48	16.55	48	8
Anodonta imbecillis	-	-	-	1	-	-	2	0.69	3	3
Anodonta suborbiculata	-	-	-	-	-	-	4	1.38	4	2
Arcidens confragosus	-	-	-		-	-	3	1.03	7	5
Cyprogenia aberti	-	-	-	-	-	-	-	0.00	2	1
Fusconaia ebena	-	-	-	-	-	-	-	0.00	37	3
Fusconaia flava	-	-	-	-	1	-	1	0.34	108	4
Lampsilis teres f. *anodontoides*	-	1	-	-	-	-	2	0.69	76	9
Lampsilis ovata	-	-	-	-	-	-	-	0.00	4	3
Lasmigona complanata	1	-	1	-	1	-	11	3.79	12	9
Leptodea fragilis	1	3	2	1	2	-	21	7.24	69	18
Megalonaias nervosa	-	-	-	-	-	-	-	0.00	135	3
Obliquaria reflexa	-	-	-	-	1	-	1	0.34	48	7
Ellipsaria lineolata	-	-	-	-	-	-	-	0.00	26	1
Plectomerus dombeyanus	-	-	-	-	-	-	-	0.00	3	1
Pleurobema rubrum	-	-	-	-	-	-	-	0.00	354	2
Potamilus capax	7	11	10	5	10	-	89	30.69	254	20
Potamilus ohiensis	-	2	2	-	3	-	32	11.03	66	17
Potamilus purpuratus	1	2	-	3	-	-	35	12.07	95	14
Quadrula metanevra	-	-	-	-	-	-	-	0.00	4	1
Quadrula nodulata	-	-	3	1	2	-	9	3.10	47	12
Quadrula pustulosa	-	-	-	-	-	-	1	0.34	682	7
Quadrula quadrula	1	4	5	1	5	1	25	8.62	632	15
Tritogonia verrucosa	-	-	-	-	-	-	-	0.00	50	4

TABLE 7. (cont.)

Species	Straight Slough								Percent	Total	No. sites
	Site	22	23	24	25	26	27	Subtotal			
Truncilla donaciformis		-	-	-	-	-	-	-	0.00	1	1
Truncilla truncata		-	-	-	-	-	-	-	0.00	5	2
Total specimens		11	24	24	16	27	1	290	100.00	4184	
Species included		5	7	7	8	9	1	16		27	

TABLE 8. Quantitative sampling results (mussels/m²) from the St. Francis Floodway—Main Channels, August 1987.

Species	Site	Madison Reach									Straight Slough			
		7	8	9	10	11	12	13	Average per m²	No. specimens	14	15	17	18
Amblema plicata		2.02*	1.05	11.93	0.10	0.02	-	0.02	1.20	1295	-	-	-	-
Anodonta grandis		-	-	-	-	-	-	-	-	-	0.01	0.03	0.02	-
Anodonta suborbiculata		-	-	-	-	-	-	-	-	-	-	0.01	-	-
Arcidens confragosus		0.01	0.01	0.01	-	-		-	0.00	4	-	-	-	-
Cyprogenia aberti		-	-	0.03	-	-	-	-	0.00	2	-	-	-	-
Fusconaia ebena		0.04	-	0.44	-	-	-	0.01	0.03	37	-	-	-	-
Fusconaia flava		0.03	0.03	1.41	-	-	-	-	0.10	107	-	-	-	-
Lampsilis teres f. *anodontoides*		-	0.05	0.53	0.00	0.01	-	0.01	0.04	49	-	-	-	-
Lampsilis ovata		-	0.01	-	-	0.00	-	-	0.00	2	-	-	-	-
Lasmigona complanata		0.01	-	-	-	-	-	-	0.00	1	-	-	-	0.01
Leptodea fragilis		0.09	0.09	0.23	0.00	-	0.01	0.01	0.04	43	-	-	-	-
Megalonaias nervosa		0.03	0.05	1.77	-	-	-	-	0.12	135	-	-	-	-
Obliquaria reflexa		0.01	0.08	0.37	0.00	-	-	0.03	0.04	44	-	-	-	-
Ellipsaria lineolata		-	-	0.37	-	-	-	-	0.02	26	-	-	-	-
Pleurobema rubrum		-	0.01	5.03	-	-	-	-	0.33	354	-	-	-	-
Potamilus capax		0.02	0.03	0.26	0.02	0.01	0.02	0.06	0.42	45	0.02	0.01	0.01	-
Potamilus ohiensis		0.03	0.03	0.01	-	0.00	-	0.04	0.02	15	-	-	0.01	-
Potamilus purpuratus		0.06	0.08	0.44	-	-	-	0.02	0.50	54	-	-	-	0.01
Quadrula metanevra		-	-	0.06	-	-	-	-	0.00	4	-	-	-	-
Quadrula nodulata		-	0.11	0.06	0.01	0.00	-	0.01	0.02	24	-	-	-	0.01
Quadrula pustulosa		0.23	0.76	7.09	0.02	-	0.01	0.01	0.60	643	-	-	-	-
Quadrula quadrula		0.21	0.34	7.43	-	-	-	0.01	0.56	599	-	-	-	0.01
Tritogonia verrucosa		0.04	0.01	0.56	-		-	0.01	0.04	48	-	-	-	-
Truncilla donaciformis		-	-	0.01	-	-	-	-	0.00	1	-	-	-	-
Truncilla truncata		0.03	-	0.01	-	-	-	-	0.00	5	-	-	-	-

TABLE 8. (cont.)

Species / Site	Madison Reach									Straight Slough			
	7	8	9	10	11	12	13	Average per m^2	No. Specimens	14	15	17	18
Totals													
Number Per Square Meter	2.84	2.74	38.06	0.18	0.06	0.03	0.24	3.28		0.03	0.05	0.05	0.05
Number of Samples (10 m^2)	14	14	7	21	20	16	16	180		10	10	8	8
Specimens Found	397	384	2664	37	13	5	38		3558	3	5	4	4
Species Included	15	16	21	7	6	3	12	23		2	3	3	4

*All calculated values in the table have been rounded to two decimal places. These rounding errors make some summations appear to be incorrect.

TABLE 8. (cont.)

Species	Site	Straight Slough										Area Totals	
		19	20	21	22	23	24	25	26	Average per m^2	No. Specimens	Average per m^2	No. Specimens
Amblema plicata		-	-	-	-	-	-	-	0.01	0.00	1	0.67	1296
Anodonta grandis		-	0.02	-	-	-	-	-	-	0.01	7	0.00	7
Anodonta suborbiculata		-	-	-	-	-	-	-	-	0.00	1	0.00	1
Arcidens confragosus		-	-	-		-	-	-	-	-	-	0.00	4
Cyprogenia aberti		-	-	-	-	-	-	-	-	-	-	0.00	2
Fusconaia ebena		-	-	-	-	-	-	-	-	-	-	0.02	37
Fusconaia flava		-		-	-	-	-	-	-	-	-	0.06	107
Lampsilis teres f. *anodontoides*		-	-	-	-	-	-	-	-	-	-	0.03	49
Lampsilis ovata		-	-	-	-	-	-	-	-	-	-	0.00	2
Lasmigona complanata		-	-	-	-	-	-	-	-	0.00	1	0.00	2
Leptodea fragilis		0.02	0.02	-	-	-	-	-	-	0.00	2	0.02	45
Megalonaias nervosa		-	-	-	-	-	-	-	-	-	-	0.07	135
Obliquaria reflexa		-	-	-	-	-	-	-	0.01	0.00	1	0.02	45
Ellipsaria lineolata		-	-	-	-	-	-	-	-	-	-	0.01	26
Pleurobema rubrum		-	-	-	-	-	-	-	-	-	-	0.18	354
Potamilus capax		0.02	0.02	-	0.03	0.07	0.02	0.02	0.02	0.02	16	0.03	61
Potamilus ohiensis		0.05	0.03	-		-	-	-	-	0.01	6	0.01	22
Potamilus purpuratus		0.02	0.02	-	0.02	-	-	0.02	-	0.01	5	0.03	59
Quadrula metanevra		-	-	-	-	-	-	-	-	-	-	0.00	4
Quadrula nodulata		-	-	-	-	-	-	0.02	0.02	0.00	4	0.01	28
Quadrula pustulosa		-	-	-	-	-	-	-	-	-	-	0.33	643
Quadrula quadrula		-	-	0.03	0.02	-	-	0.02	0.04	0.01	8	0.31	607
Tritogonia verrucosa		-	-	-	-	-	-	-	-	-	-	0.02	48
Truncilla donaciformis		-	-	-	-	-	-	-	-	-	-	0.00	1
Truncilla truncata		-	-	-	-	-	-	-	-	-	-	0.00	5

TABLE 8 (cont.)

Species / Site	Straight Slough 19	20	21	22	23	24	25	26	Average per m^2	No. Specimens	Area Totals Average per m^2	No. Specimens
Totals												
Number Per Square Meter	0.10	0.08	0.03	0.07	0.07	0.02	0.10	0.11	0.06		1.85	
Number of Samples (10 m^2)	6	6	6	6	6	8	4	8	86		194	
Specimens Found	6	5	2	4	4	2	4	9		52		3590
Species Included	4	4	1	3	1	1	4	5	11			25

River (sites 28-64, Figs. 3 and 4). Most of these waterways had been dredged, cleared of snags, and had the trees cut back from along the banks.

Habitat in these ditches ranged from sloping muddy banks with soft mud and sand substrates across the width of the channels (Tulot Seep Ditch, Little Bay Ditch 9 and Ditch 10) to steep-sided banks with hard-packed clay, gravel, and coarse sand substrate (Big Bay Ditch, Eightmile Creek and Locust Creek).

Twenty-three mussel species were found in these tributaries (Table 9). In soft mud and sand habitats, mussels were randomly scattered. Mussels were rare or absent in some areas, especially the steep-sided, gully-like streams such as Eightmile Creek (sites 46-50), Locust Creek Ditch (sites 51-55), and Thompson Creek (sites 43-45). Tulot Seep Ditch (sites 32-36) contained the most species (18), followed by the channel connecting Ditches 60 and 61 (sites 37-39, 15 species), and Mayo Ditch (sites 62-64, 13 species).

The most abundant species in these streams were *Potamilus capax* and *Amblema plicata,* followed by *Leptodea fragilis, Potamilus purpuratus* and *Quadrula quadrula.* Uncommon species in these streams were *Anodonta suborbiculata, Tritogonia verrucosa* and *Uniomerus declivus.*

Quantitative samples were taken at four ditch sites in this area (Table 10). Mussel density ranged from 0 (sites 29 and 31) to 0.52/m^2 (site 38). *Amblema plicata* was the most abundant species in the quantitative samples.

Potamilus capax was found in four of these ditches: Ditch 10 (sites 28 and 29), Little Bay Ditch 9 (site 31), Tulot Seep Ditch (site 32), and especially the channel connecting Ditches 60 and 61 (sites 37 and 38, Table 9).

St. Francis River Channel

Twenty-five sites were examined in two sections of the St. Francis River: six sites from below Route 79 bridge upstream to Council Bar (sites 65-70, Fig. 2) and 19 sites from Joyland upstream to the siphons near Marked Tree (sites 71-89, Fig. 3). The downstream section was surveyed at access points while the upstream reach was surveyed by boat.

Habitat at the downstream St. Francis River sites consisted of wide sloping banks and waist-deep mud overlain with tree limbs, leaves, and flocculent silt. The lower reach also was impounded by Huxtable Dam. At the upstream sites, the St. Francis was largely riverine, with sloping muddy banks and shifting sand across the width of the

TABLE 9. Site by site counts of all mussels found in the Western Ditches, St. Francis Watershed, August 1987.

	Ditch 10		Little Bay		Tulot Seep Ditch					60-61 Connector			Big Bay Ditch		
Species Site	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Amblema plicata	3	1	-	-	7	5	8	1	2	111	22	-	-	1	1
Anodonta grandis	12	-	-	1	1	2	1	3	1	-	-	-	-	6	6
Anodonta imbecillis	5	-	1	-	-	-	1	1	-	1	1	-	4	2	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arcidens confragosus	1	-	-	-	-	2	1	-	2	-	1	-	-	-	-
Fusconaia flava	-	-	-	-	-	1	1	1	-	-	1	-	-	-	-
Lampsilis teres f. *anodontoides*	1	1	2	-	9	5	8	1	1	6	2	-	-	-	-
Lampsilis teres f. *teres*	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	2	-	-	-	6	11	-	-	-	1	4	-	-	1	-
Lasmigona complanata	-	-	-	-	1	1	2	-	-	-	-	-	-	1	-
Leptodea fragilis	3	6	-	1	9	1	-	-	1	69	19	-	-	2	-
Obliquaria reflexa	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-
Potamilus capax	1	3	-	6	1	-	-	-	-	113	52	-	-	-	-
Potamilus ohiensis	-	-	3	1	-	-	-	-	-	-	14	-	-	-	-
Potamilus purpuratus	1	1	-	-	9	3	4	-	2	37	7	-	-	-	-
Quadrula nodulata	-	-	-	-	-	1	-	-	-	1	4	-	-	-	-
Quadrula pustulosa	-	-	-	-	1	1	-	-	-	1	-	-	-	-	-
Quadrula quadrula	2	1	2	1	2	5	1	-	3	2	6	-	-	2	-
Strophitus undulatus	-	-	-	-	1	1	-	-	1	-	-	-	-	-	-
Toxolasma texasensis	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-
Tritogonia verrucosa	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Uniomerus declivus	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-
Uniomerus tetralasmus	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-
Total Specimens	31	13	8	12	50	40	28	7	13	344	135	0	16	16	7
Species Included	10	6	4	7	13	14	10	5	8	11	14	0	2	8	2

TABLE 9. (cont.)

Species	Site	Thompson Creek			Eightmile Creek Ditch					Locust Creek Ditch					Big Slough	
		43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
Amblema plicata		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta grandis		-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Anodonta imbecillis		-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Anodonta suborbiculata		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arcidens confragosus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia flava		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis teres f. *anodontoides*		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis teres f. *teres*		-	-	-	-	-	-		-	-	-	-	-	-	-	-
Lampsilis ovata		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona complanata		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis		-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Obliquaria reflexa		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamilus capax		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamilus ohiensis		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamilus purpuratus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula nodulata		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula pustulosa		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula quadrula		-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Strophitus undulatus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toxolasma texasensis		-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Tritogonia verrucosa		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uniomerus declivus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uniomerus tetralasmus		-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Total Specimens		0	0	1	0	0	0	0	1	0	0	0	0	4	0	0
Species Included		0	0	1	0	0	0	0	1	0	0	0	0	4	0	0

TABLE 9. (cont.)

Species	Site	Big Slough Ditch				Mayo Ditch				
		58	59	60	61	62	63	64	Total	No. sites
Amblema plicata		-	-	-	-	-	4	-	166	12
Anodonta grandis		-	-	-	-	4	-	-	38	11
Anodonta imbecillis		-	-	-	-	-	-	-	17	9
Anodonta suborbiculata		-	-	-	-	1		-	1	1
Arcidens confragosus		-	-	-	-	1	2	-	10	7
Fusconaia flava		-	-	-	-	-	29	-	33	5
Lampsilis teres f. *anodontoides*		-	-	7	-	-	-	-	43	11
Lampsilis teres f. *teres*		-	-	-	-	-	-	-	3	2
Lampsilis ovata		2	2	4	-	-	-	1	34	10
Lasmigona complanata		1	-	-	-	1	3	-	10	7
Leptodea fragilis		3	-	-	-	1	-	-	116	12
Obliquaria reflexa		-	-	-	-	-	6	-	9	3
Potamilus capax		-	-	-	-	-	-	-	176	6
Potamilus ohiensis		-	-	-	-	3	-	-	21	4
Potamilus purpuratus		1	-	-	-	2	-	-	67	10
Quadrula nodulata		-	-	-	-	-	-	-	6	3
Quadrula pustulosa		-	-	-	-	-	1	-	4	4
Quadrula quadrula		-	-	-	-	-	25	-	53	13
Strophitus undulatus		-	-	-	-	-	-	-	3	3
Toxolasma texasensis		-	-	3	-	-	-	-	7	5
Tritogonia verrucosa		-	-	-	-	-	-	-	1	1
Uniomerus declivus		-	-	-	-	-	-	-	2	2
Uniomerus tetralasmus		-	-	-	-	-	-	-	13	2
Total Specimens		7	2	14	0	13	70	1	833	
Species Included		4	1	3	0	7	7	1	23	

TABLE 10. Quantitative sampling results (mussels/m²) from the Western Ditches, St. Francis watershed, August 1987

Site Species	28	29	31	38	Average per m^2	No. specimens
Amblema plicata	-	-	-	0.23*	0.10	14
Anodonta grandis	0.02	-	-	-	0.01	1
Anodonta imbecillis	-	-	-	0.02	0.01	1
Lampsilis teres f. *anodontoides*	-	-	-	0.02	0.01	1
Lampsilis ovata	-	-	-	0.05	0.02	3
Leptodea fragilis		-	-	0.02	0.01	1
Potamilus capax	-	-	-	0.08	0.04	5
Potamilus ohiensis		-	-	0.03	0.01	2
Potamilus purpuratus		-	-	0.02	0.01	1
Quadrula nodulata		-	-	0.02	0.01	1
Quadrula quadrula		-	-	0.03	0.01	2
Totals						
Number per square meter	0.02	0.00	0.00	0.52	0.23	
Number of samples (10 m²)	4	2	2	6	14	
Specimens found	1	0	0	31		32
Species included	1	0	0	10		11

*All calculated values in the table have been rounded to two decimal places. These rounding errors make some summations appear to be incorrect.

channel.

Ten mussel species were found at the six downstream sites, while 27 species were found at the upstream sites (Table 11). Downstream, the most abundant species were *Potamilus purpuratus* and *Anodonta grandis*. Few specimens of *Anodonta imbecillis* and *Quadrula quadrula* were found. The most abundant species at the upstream sites was *Amblema plicata*. Other common species were *Quadrula pustulosa, Potamilus purpuratus, Leptodea fragilis, Fusconaia flava* and *Anodonta grandis*. Few specimens of *Plectomerus dombeyanus, Lampsilis hydiana, Strophitus undulatus, Anodonta suborbiculata* and *Quadrula metanevra* were present in this area. Only three live *Plectomerus dombeyanus* were found throughout this river reach, but relict (old-dead) shells were observed at many sites.

Quantitative samples were taken at four of the upstream sites (Table 12). Because *Potamilus capax* was not present at the downstream sites, no quantitative samples were taken. Mussel density ranged from 0 (site 89) to 1.22/m² (site 82). *Amblema plicata* was the most abundant species in the quantitative samples.

Potamilus capax was found only from below Ditch 1 (site 16) upstream to the siphons (site 89). A total of 45 specimens were found at

TABLE 11. Site by site counts of all mussels found in the St. Francis River Channel, August 1987.

Species / Site	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
Amblema plicata	-	-	-	-	-	-	48	351	113	120	87	18	63	51	63
Anodonta grandis	4	7	16	10	2	4	1	2	5	3	3	2	4	1	1
Anodonta imbecillis	-	-	-	1	-	-	-	-	-	-	2	-	1	-	-
Anodonta suborbiculata	-	-	-	2	-	-	-	-	-		-	-	-	-	-
Arcidens confragosus	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-
Fusconaia ebena	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-
Fusconaia flava	-	-	-	-	-	-	1	86	-	1	15	2	-	-	5
Lampsilis hydiana	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Lampsilis teres f. anodontoides	-	1	6	11	-	4	3	-	2	-	5	1	17	1	1
Lanpsilis teres f. teres	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-
Lampsilis ovata	-	-	-	-	-	-	-	-	2	1	-	-	-	1	-
Lasmigona complanata	-	-	-	-	-	-	-	-	2	1	3	1	-	-	-
Leptodea fragilis	-	5	6	6	-	-	4	6	8	12	13	15	26	5	-
Megalonaias nervosa	-	-	-	-	-	-	4	13	9	3	8	-	4	-	2
Obliquaria reflexa	-	-	1		-	4	1		-	4	1	5	1	-	-
Plectomerus dombeyanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Pleurobema rubrum	-	-	-	-	-	-	-	14	-	-	5	-	-	-	-
Potamilus capax	-	-	-	-	-	-	-	-	-	-	-	1	2	-	2
Potamilus ohiensis	1	8	-	-	2	3	2	-	6	1	3	-	5	3	1
Potamilus purpuratus	3	4	8	22	12	43	12	9	18	14	1	2	3	-	6
Ouadrula metanevra	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Quadrula nodulata	-	-	-	-	-	-	2	-	3	-	-	5	3	-	1
Quadrula pustulosa	-	-	-	-	-	-	15	90	10	16	98	36	31	16	27
Quadrula quadrula	-	-	1	-	-	-	3	20	3	1	5	8	4	-	1
Strophitus undulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toxolasma texasensis	1	5	3	-	-	-	-	-	-	-	-	-	-	-	-
Tritogonia verrucosa	-	-	-	-	-	-	2	7	10	-	10	1	1	-	10
Truncilla donaciformis	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total specimens	9	30	41	52	16	58	99	599	191	178	264	98	168	78	121
Species included	4	6	7	6	3	5	14	11	13	13	18	14	16	7	13

TABLE 11. (cont.)

Species / Site	80	81	82	83	84	85	86	87	88	89	Total	No. Sites
Amblema plicata	23	203	64	23	88	11	41	13	-	-	1380	17
Anodonta grandis	4	8	2	2	4	2	13	-	2	-	102	23
Anodonta imbecillis	-	-	-	-	-	-	-	-	1	-	5	4
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	2	1
Arcidens confragosus	-	2	2	1	-	3	-	-	-	-	10	6
Fusconaia ebena	-	-	-	-	-	-	-	-	-	-	3	2
Fusconaia flava	-	3	3	1	3	3	-	-	-	-	123	11
Lampsilis hydiana	-	-	-	-	-	-	-	-	-	-	1	1
Lampsilis teres f. anodontoides	1	2	8	6	1	16	-	3	2	-	91	19
Lampsilis teres f. teres	-	-	1	-	-	-	-	-	-	-	4	3
Lampsilis ovata	-	-	-	-	-	-	-	-	-	-	4	3
Lasmigona complanata	1	-	5	-	-	1	-	2	-	-	16	8
Leptodea fragilis	2	10	13	13	19	39	-	10	8	5	225	20
Megalonaias nervosa	-	-	3	2	7	12	13	3	-	-	83	13
Obliquaria reflexa	2	4	4	5	1	2	-	5	-	-	40	14
Plectomerus dombeyanus	-	1	1	-	-	-	-	-	-	-	3	3
Pleurobema rubrum	-	-	1	-	-	-	-	-	-	-	20	3
Potamilus capax	-	-	2	3	-	12	-	9	5	9	45	9
Potamilus ohiensis	1	4	4	4	14	1	3	10	2	9	87	21
Potamilus purpuratus	2	2	16	14	12	17	8	23	2	1	254	24
Quadrula metanevra	-	-	-	-	-	-	-	-	-	-	2	1
Quadrula nodulata	3	8	-	9	4	2	-	1	-	-	41	11
Quadrula pustulosa	7	61	8	57	80	20	-	1	-	-	573	16
Quadrula quadrula	2	2	7	13	4	3	-	3	2	-	82	17
Strophitus undulatus	-	1	-	-	-	-	-	-	-	-	1	1
Toxolasma texasensis	-	-	-	-	-	-	-	-	-	-	9	3
Tritogonia verrucosa	1	4	14	4	5	7	1	1	-	-	78	15
Truncilla donaciformis	1	-	-	-	-	1	-	-	-	-	3	3
Truncilla truncata	2	4	-	-	-	-	-	-	-	-	6	2
Total specimens	52	319	158	157	242	152	79	84	24	24	3293	
Species included	14	16	18	15	13	17	6	13	8	4	29	

TABLE 12. Quantitative sampling results (mussels/m²) from the St. Francis River channel, August 1987.

Species \ Site	82	85	87	89	Average per m²	No. specimens
Amblema plicata	0.56*	0.09	-	-	0.18	54
Anodonta grandis	0.01	0.01	-	-	0.01	2
Arcidens confragosus	0.02	0.03	-	-	0.02	5
Fusconaia flava	0.04	0.03	-	-	0.02	6
Lampsilis teres f. *anodontoides*	0.01	0.02	-	-	0.01	3
Lasmigona complanata	0.05	-	-	-	0.01	4
Leptodea fragilis	0.09	0.25	-	-	0.11	32
Megalonaias nervosa	0.04	0.11	-	-	0.05	14
Obliquaria reflexa	-	0.01	-	-	0.00	1
Plectomerus dombeyanus	0.01	-	-	-	0.00	1
Pleurobema rubrum	0.01	-	-	-	0.00	1
Potamilus capax	-	0.02	-	-	0.01	2
Potamilus purpuratus	0.14	0.06	0.02	-	0.06	18
Quadrula nodulata	-	0.02	-	-	0.01	2
Quadrula pustulosa	0.06	0.16	-	-	0.07	21
Quadrula quadrula	0.06	0.03	0.02	-	0.03	9
Tritogonia verrucosa	0.11	0.06	-	-	0.05	15
Totals						
Number per square meter	1.22	0.90	0.03	0.00	0.63	
Number of samples (10 m²)	8	10	6	6	30	
Specimens found	98	90	2	0		190
Species included	14	14	2	0		17

*All calculated values in the table have been rounded to two decimal places. These rounding errors make some summations appear to be incorrect.

nine sites in this reach. This species was relatively common in the river channel between the siphons and Marked Tree, but became increasingly rare downstream.

Lower Eastern Tributaries

Thirty-five sites were examined in eight lower eastern tributaries of the St. Francis River (sites 90-124, Figs. 2, 5). Although included in the Scope of Work, Kochtitsky Ditch was not sampled because it was dry and overgrown with vegetation. Most of the length of these watercourses had either been dredged, straightened, or cleared of snags.

Habitat in these areas varied primarily with stream size. Larger watercourses (Tyronza River, Blackfish Bayou, Fifteen Mile Bayou, and Ditch 1) had steep sloping muddy banks that interfaced with soft mud and shifting sand in the channel. Habitat in smaller ditches (Ditch 31, National Ditch 6) consisted of low, grass-covered banks with hard-packed clay and gravel substrates, typically colonized by emergent vegetation.

Twenty-eight mussel species were found in this area (Table 13). The vast majority of individuals and species occurred in narrow bands where the shifting sand in the channel met the mud or clay of the banks. This was especially true in the Tyronza River where *Amblema plicata* was abundant in these bankside bands.

The Tyronza River (sites 97-107) had the most diverse species assemblage (23), followed by 17 species in National Ditch 6 (sites 123-124), and 16 species each in Big Creek (sites 111-116) and Ditch 1 (sites 117-122).

The most abundant species in these watercourses was *Amblema plicata.* Other common species included *Quadrula pustulosa, Potamilus purpuratus, Leptodea fragilis* and *Megalonaias nervosa.* One or two individuals of four species were found (*Villosa lienosa, Lampsilis hydiana, Quadrula apiculata* and Plectomerus *dombeyanus*). Many relict specimens of *Plectomerus dombeyanus* were observed in the Tyronza River and Ditch 1. *Potamilus capax* was not found at any of the sampling sites in this area.

Several piles of mussel shells were seen along the lower Tyronza River. Most of these shells were *Amblema plicata* or *Megalonaias nervosa.* Apparently, the Tyronsa River still supports a limited commercial mussel fishery.

Left Hand Chute Little River and Lower Buffalo Creek Ditch

Twenty-two collections were made in the lower 30 miles of Left Hand Chute Little River (sites 125-146) and twelve collections were made in Lower Buffalo Creek Ditch (sites 147-157 and 236, Fig. 6). This reach of Left Hand Chute appeared to be a naturally meandering stream that had not been channelized, but had received considerable sedimentation in recent years.

The sequence of connected channels here called Lower Buffalo Creek Ditch (referred to as "unnumbered ditch" in Ahlstedt & Jenkinson, 1991) seem to be parts of several drainage ditches constructed over a long period of time. The mouth of this system now flows into the St. Francis River just downstream from the siphons at Marked Tree by way of a ditch constructed since 1978. Upstream, this ditch flows under (no water-to-water contact) Right Hand Chute Little River at Rivervale through a culvert dated 1924 (Fig. 6). The upstream end of the system now drains part of western Mississippi County, Arkansas. The former upstream portion of Buffalo Creek

TABLE 13. Site by site counts of all mussels found in the Lower Eastern Tributaries, St. Francis River System, August 1987.

	Blackfish Bayou					15 Mile		Tyronza River							
Species Site	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104
Amblema plicata	7	-	12	11	23	-	10	51	46	149	128	220	236	78	16
Anodonta grandis	2	9	1	1	-	2	2	-	-	-	-	-	-	2	2
Anodonta imbecillis	-	-	1	-	-	1	-	-	-	1	-	-	-	-	-
Anodonta suborbiculata	5	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Arcidens confragosus	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-
Fusconaia flava	-	-	-	-	-	-	-	-	-	2	-	1	25	1	-
Lampsilis hydiana	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Lampsilis teres f. *anodontoides*	-	-	2	-	-	12	-	-	4	8	4	1	-	1	2
Lampsilis teres f. *teres*	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Lampsilis ovata	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-
Lasmigona complanata	-	-	3	1	-	-	-	2	1	-	-	-	1	3	1
Leptodea fragilis	2	3	2	4	4	5	1	4	5	22	8	10	4	4	1
Megalonaias nervosa	-	-	2	5	14	-	1	10	9	8	6	20	29	3	-
Obliquaria reflexa	-	-	-	-	-	-	-	-	2	16	-	-	-	-	-
Plectomerus dombeyanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamilus ohiensis	6	-	3	5	2	-	-	3	1	5	-	4	2	-	
Potamilus purpuratus	2	4	10	8	5	1	2	16	11	19	12	27	7	14	3
Quadrula apiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula nodulata	-	-	1	-	1	-	2	-	8	35	-	1	1	-	9
Quadrula pustulosa	-	-	1	2	2	-	-	1	4	26	-	7	71	16	1
Quadrula quadrula	3	-	12	-	-	1	3	1	2	4	-	1	9	4	3
Strophitus undulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toxolasma texasensis	5	4	-	-	-	14	-	1	-	-	-	-	-	-	-
Tritogonia verrucosa	-	-	-	1	-	-	-	2	4	7	30	4	13	5	-
Truncilla donaciformis	-	-	-	-	-	-	-	-	1	3	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	1	7	-	-	-	2	-
Uniomerus declivus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa lienosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total specimens	32	22	50	38	51	37	21	91	100	312	190	296	399	134	38
Species included	8	5	12	9	7	8	7	10	15	15	8	11	12	13	9

TABLE 13. (cont.)

Species / Site	Tyronza River						Big Creek						Ditch 1		
	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119
Amblema plicata	3	-	-	1	-	-	19	7	-	2	16	-	2	3	246
Anodonta grandis	1	-	-	3	-	-	19	6	-	1	-	1	2	-	-
Anodonta imbecillis	-	-	-	-	1	3	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Arcidens confragosus	-	-	-	6	-	-	-	1	-	1	-	-	-	-	-
Fusconaia flava	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-
Lampsilis hydiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis teres f. *anodontoides*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Lampsilis teres f. *teres*	-	-	-	-	-	-	-	-	-	-	2	2	-	-	2
Lampsilis ovata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasmigona complanata	2	-	-	2	-	-	-	-	-	1	-	-	-	-	-
Leptodea fragilis	2	-	-	1	-	-	2	-	-	1	10	-	-	-	-
Megalonaias nervosa	1	-	-	-	-	-	5	5	-	-	-	-	1	-	5
Obliquaria reflexa	3	-	-	2	-	-		-	-	-	-	-	-	-	-
Plectomerus dombeyanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamilus ohiensis	-	-	-	-	-	-	1	-	-	-	2	2	-	-	-
Potamilus purpuratus	2	-	-	1	-	-	1	1	-	2	1	1	-	-	-
Quadrula apiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula nodulata	6	-	-	-	-	-	-	-	-	1	4	-	-	-	2
Quadrula pustulosa	-	-	1	-	-	-	-	-	-	-	52	-	-	-	4
Quadrula quadrula	2	-	-	1	-	2	-	-	-	1	31	1	-	-	2
Strophitus undulatus	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Toxolasma texasensis	-	-	-	-		-	-	-	-	1	-	6	-	-	-
Tritogonia verrucosa	-	-	-	-	-	-	-	-	-	-	7	-	-	-	1
Truncilla donaciformis	-	-	-	-	-	-	-	-	-	-	-		-	-	-
Truncilla truncata		-	-	-		-	-	-	-	-	9	-	-	-	-
Uniomerus declivus	-	-	-	-	3	4	-	-	-	-	-	-	-	-	-
Villosa lienosa	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Total specimens	23	0	2	18	4	10	50	20	0	11	135	13	5	3	266
Species included	10	0	2	9	2	4	7	5	0	9	11	6	3	1	8

TABLE 13. (cont.)

Species	Site	Ditch 1					Total	No.
		120	121	122	123	124		
Amblema plicata		23	172	17	17	30	1545	27
Anodonta grandis		3	1	-	-	-	58	17
Anodonta imbecillis		-	-	-	-	-	7	5
Anodonta suborbiculata		-	-	-	-	-	10	3
Arcidens confragosus		-	4	1	5	4	24	9
Fusconaia flava		-	1	-	3	-	35	8
Lampsilis hydiana		-	-	-	-	-	1	1
Lampsilis teres f. anodontoides		-	12	-	4	-	55	12
Lampsilis teres f. teres		-	-	-	-	-	7	4
Lampsilis ovata		-	-	-	1	-	3	3
Lasmigona complanata		-	1	1	3	3	25	14
Leptodea fragilis		-	32	1	6	2	136	24
Megalonaias nervosa		-	-	-	-	1	125	17
Obliquaria reflexa		-	3	-	-	-	26	5
Plectomerus dombeyanus		-	-	-	2	-	2	1
Potamilus ohiensis		-	-	-	-	-	36	12
Potamilus purpuratus		-	16	1	4	2	173	26
Quadrula apiculata		-	-	-	1	-	1	1
Quadrula nodulata		-	9	-	1	1	82	15
Quadrula pustulosa		-	7	1	6	4	206	17
Quadrula quadrula		-	8	-	20	5	116	21
Strophitus undulatus		-	1	-	3	-	5	3
Toxolasma texasensis		-	-	-	-	-	31	6
Tritogonia verrucosa		2	5	1	4	-	86	14
Truncilla donaciformis		-	-	-	-	-	4	2
Truncilla truncata		-	-	-	-	-	19	4
Uniomerus declivus		-	-	-	-	-	7	2
Villosa lienosa		-	-	-	-	-	1	1
Total specimens		28	272	23	80	52	2826	
Species included		3	14	7	15	9	28	

Ditch has been diverted into Cockle Burr Slough Ditch through a new channel that runs north of Route 18. Collection sites for that portion of the drainage are covered as part of the Upper Eastern Tributaries area.

Aquatic habitat throughout Left Hand Chute was virtually uniform: well-defined banks bordering water less than 2 m deep over a heavy silt substrate. Mussels found in this reach typically were scattered at random, "floating" on the surface of the silt. Habitat in Buffalo Creek Ditch also was uniform, but here steep banks dropped off into water typically 1 m deep over sand substrates. Any mussels present appeared to be randomly scattered in stable or shifting sand.

Twenty-one mussel species were found in these watersheds: 19 in Left Hand Chute and 17 in Lower Buffalo Creek Ditch (Table 14). Four species were found in Left Hand Chute but not in Buffalo Creek Ditch (*Anodonta imbecillis, Quadrula apiculata, Toxolasma texasensis* and *Truncilla truncata*) while two species (*Obliquaria reflexa* and *Strophitus undulatus*) were found in Buffalo Creek but not in Left Hand Chute. In all, 913 live and fresh-dead mussels were found at the 22 Left Hand Chute sites (an average of 41.5 specimens per site). The 12 Buffalo Creek Ditch sites yielded 212 live or fresh-dead specimens (17.7 per site).

In both drainages, *Amblema plicata* was the most abundant species and *Anodonta grandis* was second. Other abundant species in Left Hand Chute were *Potamilus purpuratus, P. ohiensis* and *Megalonaias nervosa.* In Buffalo Creek Ditch, other abundant species were *Lasmigona complanata, Quadrula pustulosa* and *Leptodea fragilis.* At the other end of the spectrum, single individuals of *Lampsilis ovata, Quadrula apiculata* and *Truncilla truncata* were found in Left Hand Chute. *Strophitus undulatus* was the only species represented by a single individual in Buffalo Creek Ditch. *Potamilus capax* was not found in either drainage this year and no quantitative samples were taken.

At several sites on Left Hand Chute, relict shells were found either far underneath the surface of the substrate or in eroding bankside deposits. Samples of these relict shells were collected at two locations (sites 129 and 131). Tentative identifications and counts of these relicts are presented in Table 15. Differences in species composition and relative abundance between these relict samples and the extant fauna of Left Hand Chute are covered as part of the Discussion.

TABLE 14. Site by site counts of all mussels found in Left Hand Chute and Lower Buffalo Creek Ditch, August 1987.

	Left Hand Chute Little River														
Species Site	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139
Amblema plicata	17	56	46	55	18	17	16	12	53	6	2	2	8	13	4
Anodonta grandis	16	11	21	10	21	8	1	6	7	-	18	3	5	7	2
Anodonta imbecillis	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-
Arcidens confragosus	-	-	-	1	2	-	-	1	1	-	-	1	-	1	1
Fusconaia flava	-	-	-	-	2	-	3	-	-	-	-	-	-	-	-
Lampsilis teres f. *anodontoides*	-	-	7	7	-	-	2	-	-	-	1	1	1	-	-
Lampsilis ovata	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Lasmigona complanata	-	1	1	-	3	3	2	4	2	1	2	-	-	1	3
Leptodea fragilis	-	-	2	1	8	1	-	-	1	-	2	2	-	1	-
Megalonaias nervosa	6	29	1	-	1	-	-	-	-	-	-	-	-	-	-
Obliquaria reflexa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamilus ohiensis	-	1	7	6	2	2	2	-	2	-	5	2	6	6	2
Potamilus purpuratus	3	9	3	11	13	4	2	1	1	-	-	-	1	4	1
Quadrula apiculata	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Quadrula nodulata	-	-	1	-	1	-	-	6	2	-	1	-	2	-	-
Quadrula pustulosa	-	-	-	1	3	2	1	3	-	1	-	-	-	1	-
Quadrula quadrula	-	-	-	-	1	-	-	3	-	1	-	-	-	2	5
Strophitus undulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toxolasma texasensis	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-
Tritogonia verrucosa	-	1	-	3	2	2	-	1	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total specimens	42	108	91	98	78	39	29	37	69	9	32	12	23	36	18
Species included	4	7	11	11	14	8	8	9	8	4	8	7	6	9	7

TABLE 14. (cont.)

Species / Site	Left Hand Chute Little River									Lower Buffalo Creek Ditch							
	140	141	142	143	144	145	146	Subtotal	Percent	147	148	149	150	151	152	153	154
Amblema plicata	-	2	9	14	8	-	-	358	39.21	-	-	8	-	3	-	24	25
Anodonta grandis	4	17	11	18	23	11	-	220	24.10	1	-	1	-	-	-	-	2
Anodonta imbecillis	-	-	-	1	-	-	-	4	0.44	-	-	-	-	-	-	-	-
Arcidens confragosus	-	1	1	-	-	-	-	10	1.10	-	1	-	-	-	-	-	1
Fusconaia flava	-	-	-	1	-	-	-	6	0.66	2	-	-	-	-	-	3	2
Lampsilis teres f. *anodontoides*	-	1	-	-	-	-	-	20	2.19	2	-	1	-	-	-	-	-
Lampsilis ovata	-	-	-	-	-	-	-	1	0.11	-	-	4	-	-	-	3	3
Lasmigona complanata	-	-	3	4	2	1	2	35	3.83	-	-	3	-	-	-	1	5
Leptodea fragilis	-	3	1	1	4	1	3	31	3.40	4	-	1	-	1	-	-	-
Megalonaias nervosa	1	-	-	-	-	-	-	38	4.16	-	-	2	-	-	-	-	-
Obliquaria reflexa	-	-	-	-	-	-	-	-	0.00	4	-	1	-	-	-	-	-
Potamilus ohiensis	1	4	3	1	2	-	-	54	5.91	-	-	-	-	-	-	-	-
Potamilus purpuratus	2	2	4	3	1	1	2	68	7.45	-	-	1	-	-	-	2	2
Quadrula apiculata	-	-	-	-	-	-	-	1	0.11	-	-	-	-	-	-	-	-
Quadrula nodulata	-	-	1	-	2	-	-	16	1.75	2	-	-	-	1	-	-	-
Quadrula pustulosa	-	-	1	1	-	-	-	14	1.53	-	-	1	-	1	-	3	5
Quadrula quadrula	-	1	4	3	2	2	-	24	2.63	1	-	1	-	-	-	1	-
Strophitus undulatus	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	1
Toxolasma texasensis	-	-	-	-	-	-	-	3	0.33	-	-	-	-	-	-	-	-
Tritogonia verrucosa	-	-	-	-	-	-	-	9	0.99	-	-	2	-	-	-	3	3
Truncilla truncata	-	-	1	-	-	-	-	1	0.11	-	-	-	-	-	-	-	-
Total specimens	8	31	39	47	44	16	7	913	100.00	16	1	26	0	6	0	40	49
Species included	4	8	11	10	8	5	3	19		7	1	12	0	4	0	8	10

TABLE 14. (cont.)

Species	Site 155	156	157	236	Subtotal	Percent	Total	No. sites
	Lower Buffalo Creek Ditch							
Amblema plicata	1	6	6	-	73	34.43	431	26
Anodonta grandis	2	16	11	-	33	15.57	253	26
Anodonta imbecillis	-	-	-	-	-	0.00	4	3
Arcidens confragosus	-	1	1	-	4	1.89	14	13
Fusconaia flava	1	1	3	-	12	5.66	18	9
Lampsilis teres f. *anodontoides*	-	-	-	-	3	1.42	23	9
Lampsilis ovata	-	-	-	-	10	4.72	11	4
Lasmigona complanata	3	3	2	-	17	8.02	52	22
Leptodea fragilis	2	-	3	-	11	5.19	42	19
Megalonaias nervosa	-	-	1	-	3	1.42	41	7
Obliquaria reflexa	-	-	-	-	5	2.36	5	2
Potamilus ohiensis	1	1	-	-	2	0.94	56	19
Potamilus purpuratus	-	-	1	-	6	2.83	74	23
Quadrula apiculata	-	-	-	-	-	0.00	1	1
Quadrula nodulata	-	-	-	-	3	1.42	19	10
Quadrula pustulosa	1	3	1	-	15	7.08	29	16
Quadrula quadrula	-	-	-	-	3	1.42	27	13
Strophitus undulatus	-	-	-	-	1	0.47	1	1
Toxolasma texasensis	-	-	-	-	-	0.00	3	3
Tritogonia verrucosa	-	-	3	-	11	5.19	20	9
Truncilla truncata	-	-	-	-	-	0.00	1	1
Total specimens	11	31	32	0	212	100.00	1125	
Species included	7	7	10	0	17		21	

TABLE 15. Counts of old-dead (relict) shells collected from two sites on Left Hand Chute Little River. Site numbers are the same as those previously listed.

	Site 129		Site 131	
Species	Valves	Percent	Valves	Percent
Fusconaia flava	120	50.43	2	3.85
Quadrula pustulosa	37	15.55	4	7.69
Amblema plicata	29	12.18	5	9.62
Fusconaia ebena	13	5.46	6	11.54
Plectomerus dombeyanus	9	3.78		0.00
Obliquaria reflexa	5	2.10		0.00
Obovaria sp. (*jacksoniana?*)	5	2.10		0.00
Quadrula nodulata	4	1.68	1	1.92
Cyprogenia aberti	4	1.68		0.00
Quadrula quadrula	3	1.26		0.00
Pleurobema rubrum	2	0.84	30	57.69
Truncilla truncata	2	0.84	3	5.77
Tritogonia verrucosa	2	0.84		0.00
Obovaria olivaria	1	0.42		0.00
Truncilla donaciformis	1	0.42		0.00
Megalonaias nervosa	1	0.42		0.00
Potamilus purpuratus		0.00	1	1.92
Total number of valves	238	100.00	52	100.00
Species included	16		8	
Pleurocera sp. (heavy, low spire)	1			
Pleurocera sp. (high spire, striate)			7	
Campeloma sp.			26	

Right Hand Chute Drainage

The Iron Mines Creek-Right Hand Chute Little River system consisted of a braided series of natural and manmade channels between the siphons at Marked Tree and Big Lake National Wildlife Refuge (Fig. 6). North of the Big Lake Refuge, much of the waterflow was contained in five large, parallel ditches (Fig. 7). In 1987, 34 sites were visited in this system: 31 in the Iron Mines Creek-Right Hand Chute complex (sites 158-188, Fig. 6) and three at adjacent sites on two of the upstream ditches (sites 189-191, Fig. 7).

Habitat throughout this system varied primarily with channel size and constancy of flow. Large channels (usually manmade) were relatively wide (60-70 m) and 2 m or more deep, with substantial flow and firm sand substrates. Smaller channels were as little as 4 m wide and less than 30 cm deep, with little or no obvious flow and flocculent silt substrates. Because of the braided nature of the channels between the Marked Tree siphons and Big Lake Refuge, both large and small channel habitats could occur side by side. The upstream ditches sampled all were of modest size (10-15 m wide) with obvious flow and firm sand substrates.

These collections produced live or fresh-dead specimens of 21 species: 20 in the downstream reach and 16 at the three upstream sites (Table 16). Five species were present downstream, but absent at the upstream sites (*Anodonta suborbiculata, Arcidens confragosus, Megalonaias nervosa, Potamilus capax* and *Toxolasma texasensis*). *Fusconaia flava* was the single species present at the upstream sites but absent throughout the downstream reach.

The five most abundant species in the downstream channels were *Amblema plicata, Potamilus capax, Potamilus ohiensis, Potamilus purpuratus* and *Leptodea fragilis.* At the upstream sites, *Quadrula pustulosa* was most abundant, followed by *Amblema plicata, Potamilus purpuratus, Leptodea fragilis* and *Lampsilis ovata.* In the downstream channels, four species were represented by five or fewer live or fresh-dead individuals (*Anodonta imbecillis, Anodonta suborbiculata, Arcidens confragosus* and *Truncilla donaciformis*). At the upstream sites, two of the same species (*Anodonta imbecillis* and *Truncilla donaciformis*) and *Tritogonia verrucosa* were represented by such low numbers.

Quantitative samples were taken at 14 sites in the Iron Mines Creek-Right Hand Chute complex (Table 17). At the upstream sites, no quantitative samples were taken because *Potamilus capax* was not present.

Mussel density varied considerably among sites, ranging from 0 (sites 164 and 175) to $0.45/m^2$ (site 166). *Potamilus capax* was the most abundant species in these quantitative samples.

State Line Outlet Ditch Basin

Forty-one sites were examined in six ditch systems which drain into the Right Hand Chute Little River at Big Lake (sites 192-232, Fig. 7). These small ditches resemble free-flowing streams given their canopy cover and stabilized streambanks; however, each is relatively straight and flat-bottomed. The upper portion of Main Ditch 6 was not sampled because it was dry and covered with emergent vegetation.

Substrates varied from soft mud throughout (New Franklin Ditch 5, Main Ditch 6, and Ditch 9) to mud banks with shifting sand or hard-packed clay out in midchannel (Belle Fountain Ditch and Pemiscot Bayou Ditch 29). Main Ditch 6 (sites 214-225) was practically dry, but had a mixture of gravel, sand and mud substrate. Most of the streams

TABLE 16. Site by site counts of all mussels found in the Right Hand Chute Drainage, August-September 1987.

Species	Site	Iron Mines Creek — Right Hand Chute Little River														
		158	159	160	161	162	163	164	165	166	167	168	169	170	171	172
Amblema plicata		57	-	1	3	-	5	-	6	-	12	-	-	-	-	1
Anodonta grandis		14	-	-	-	-	-	-	2	4	-	-	-	-	-	-
Anodonta imbecillis		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arcidens confragosus		-	-	-	-	-	-	-	1	2	-	-	-	-	-	-
Fusconaia flava		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis teres f. *anodontoides*		2	-	-	-	-	-	-	1	2	1	4	-	-	1	1
Lampsilis ovata		1	-	-	-	-	-	-	-	-	-	1	1	1	-	-
Lasmigona complanata		2	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Leptodea fragilis		1	3	-	-	-	5	1	4	2	8	4	2	6	-	3
Megalonaias nervosa		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Obliquaria reflexa		-	-	-	-	-	-	-	-	-	3	-	-	1	-	-
Potamilus capax		7	1	-	-	-	22	5	11	15	4	15	7	9	-	1
Potamilus ohiensis		14	2	-	-	-	-	-	3	12	3	4	7	13	-	-
Potamilus purpuratus		1	2	-	1	-	4	-	12	16	1	8	5	4	-	4
Quadrula nodulata		44	1	-	-	-	2	1	17	1	5	9	1	-	-	-
Quadrula pustulosa		3	-	-	2	-	1	-	1	-	1	1	-	-	-	-
Quadrula quadrula		14	3	-	-	-	1	-	2	1	1	2	-	-	-	-
Toxolasma texasensis		9	-	-	-	-	-	-	1	1	-	-	-	-	-	-
Tritogonia verrucosa		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Truncilla donaciformis		-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Total specimens		172	12	1	6	0	40	7	61	56	39	48	24	36	1	10
Species included		14	6	1	3	0	7	3	12	10	10	9	7	7	1	5

TABLE 16. (cont.)

Species	Site	Right Hand Chute Little River														
		173	174	175	176	177	178	179	180	181	182	183	184	185	186	187
Amblema plicata		1	-	1	1	1	-	-	1	-	12	31	11	3	3	5
Anodonta grandis		-	-	-	1	-	-	-	-	-	2	2	3	8	15	8
Anodonta imbecillis		-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Anodonta suborbiculata		-	-	-	-	-	-	-	-	-	-	-	-	1	1	-
Arcidens confragosus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia flava		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis teres f. *anodontoides*		-	-	-	-	-	-	-	-	1	-	1	-	1	-	1
Lampsilis ovata		-	-	-	-	-	2	-	-	3	-	-	-	-	-	-
Lasmigona complanata		-	-	1	-	-	-	-	-	8	1	6	1	4	5	-
Leptodea fragilis		10	-	8	2	3	6	1	2	10	-	4	-	3	3	1
Megalonaias nervosa		-	-	-	-	-	-	-	-	-	5	-	-	-	-	-
Obliquaria reflexa		2	-	1	-	-	-	-	1	5	-	9	-	-	1	-
Potamilus capax		3	1	4	-	-	5	-	9	4	-	1	-	3	2	-
Potamilus ohiensis		2	1	8	-	-	4	1	1	13	-	6	-	-	10	-
Potamilus purpuratus		1	2	4	2	1	1	-	2	3	-	8	-	4	4	6
Quadrula nodulata		-	-	-	1	-	-	-	3	1	-	2	1	-	2	-
Quadrula pustulosa		-	-	-	-	1	-	-	1	3	-	4	-	3	-	3
Quadrula quadrula		-	-	1	-	-	1	-	-	2	2	4	-	1	6	1
Toxolasma texasensis		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tritogonia verrucosa		-	-	-	-	-	-	-	-	1	-	-	-	3	-	1
Truncilla donaciformis		-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Total specimens		19	4	30	7	6	19	2	20	54	22	78	16	34	53	26
Species included		6	3	9	5	4	6	2	8	12	5	12	4	11	12	8

TABLE 16. (cont.)

	Upper Ditches					
Site	188	189	190	191	Total	No. sites
Amblema plicata	7	2	38	11	213	22
Anodonta grandis	21	-	3	8	91	13
Anodonta imbecillis	-	-	2	1	7	4
Anodonta suborbiculata	-	-	-	-	2	2
Arcidens confragosus	-	-	-	-	3	2
Fusconaia flava	-	-	18	3	21	2
Lampsilis teres f. *anodontoides*	1	2	13	-	32	14
Lampsilis ovata	-	1	13	8	31	9
Lasmigona complanata	22	-	-	5	56	11
Leptodea fragilis	2	2	19	12	127	27
Megalonaias nervosa			-	-	5	1
Obliquaria reflexa	5	-	14	2	44	11
Potamilus capax	-	-	-	-	129	20
Potamilus ohiensis	1	6	13	-	124	20
Potamilus purpuratus	9	4	16	14	139	27
Quadrula nodulata	1	-	5	3	100	18
Quadrula pustulosa	1	1	41	13	80	16
Quadrula quadrula	12	-	-	11	65	17
Toxolasma texasensis	-	-	-	-	11	3
Tritogonia verrucosa	1	-	-	1	7	5
Truncilla donaciformis	-	-	2	-	6	3
Total specimens	83	18	197	92	1293	
Species included	12	7	13	13	21	

TABLE 17. Quantitative sampling results (mussels/m^2) from the Right Hand Chute drainage, August 1987.

Species Site	163	164	166	167	168	169	170	173	175
Amblema plicata	-	-	-	0.02*	-	-	-	-	-
Anodonta grandis	-	-	0.33	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-		-	-	-	-	-
Lampsilis teres f. *anodontoides*	-	-	0.02	-	-	-	-	-	-
Lasmigona complanata	-	-	-	-	-	-	-	-	-
Leptodea fragilis	0.01	-	0.02	0.01	-	-	0.01	0.01	-
Obliquaria reflexa	-	-	-	0.01	-	-	0.01	0.01	-
Potamilus capax	0.01	-	0.17	0.02	0.02	0.01	-	0.01	-
Potamilus ohiensis	-	-	0.03	-	-	-	0.03	-	-
Potamilus purpuratus	0.01	-	0.15	0.01	0.02	-	-	-	-
Quadrula nodulata	0.01	-	0.02	0.02	0.09	0.01	-	-	-
Quadrula pustulosa	-	-	-	-	0.01	-	-	-	-
Quadrula quadrula	0.01	-	0.02	-	0.01	-	-	-	-
Tritogonia verrucosa	-	-	-	-	-	-	-	-	-
Truncilla donaciformis	-	-	-	-	-	-	0.02	-	-
Totals									
Number per square meter	0.04	0.00	0.45	0.09	0.15	0.02	0.07	0.04	0.00
Number of samples	14	6	6	12	10	10	10	8	4
Specimens found	5	0	27	11	15	2	7	3	0
Species included	5	0	8	6	5	2	4	3	0

*All calculated values in the table have been rounded to two decimal places. These rounding errors make some summations appear to be incorrect.

TABLE 17. (cont.)

Species	Site 178	180	181	185	186	Average per m²	No. specimens
Amblema plicata		0.01			-	0.00	4
Anodonta grandis		-	-	0.02	0.05	0.01	8
Anodonta suborbiculata	-		-	0.02	0.01	0.00	2
Lampsilis teres f. *anodontoides*	-		0.01	-		0.00	2
Lasmigona complanata	-		0.10	0.05	0.01	0.01	11
Leptodea fragilis		0.01	0.09		0.03	0.01	16
Obliquaria reflexa	-	0.01	0.04			0.01	7
Potamilus capax	0.02	0.03	0.02	-	0.01	0.02	24
Potamilus ohiensis	-	0.01			0.02	0.01	8
Potamilus purpuratus	-	0.03	0.01	0.02	-	0.02	17
Quadrula nodulata		0.04	0.01	-	0.02	0.02	20
Quadrula pustulosa		0.01	0.04		-	0.00	5
Quadrula quadrula	0.02		0.01	0.02	0.03	0.01	9
Tritogonia verrucosa	-	-	0.01	-	-	0.00	1
Truncilla donaciformis	-		-		-	0.00	2
Totals							
Number per square meter	0.05	0.17	0.35	0.15	0.18	0.12	
Number of samples	4	7	8	4	10	113	
Specimens found	2	12	28	6	18		136
Species included	2	8	10	5	8		15

(ditches) sampled in this area were clogged with fallen trees, and beaver dams were common throughout the area.

Twenty-five mussel species were found in this area (Table 18), typically scattered at random across the substrate. At sites where shifting sand was present in the channel (Belle Fountain Ditch), most mussels were found in mud bars along the banks.

Belle Fountain Ditch (sites 192-204) included the most species (17), followed by Pemiscot Bayou Ditch 29 (sites 205-211, 14 species) and Main Ditch 6 (sites 219-225, 13 species).

The most abundant species were *Anodonta grandis, Amblema plicata, Leptodea fragilis* and *Arcidens confragosus.* Few *Plectomerus dombeyanus, Quadrula pustulosa* and *Uniomerus declivus* were found.

Potamilus capax was collected at only one location (site 192) in the extreme lower portion of Belle Fountain Ditch. The two fresh-dead specimens found did not meet the criterion to start taking quantitative samples.

Upper Eastern Tributaries

Twenty sites were examined in five upper eastern tributaries to the St. Francis River (sites 233-235 and 237-252, Fig. 4). All of these watercourses appeared to be dredged channels.

These tributaries had gently sloping, grass- and tree-covered banks with soft mud (ooze) to shifting sand substrates. In Cockle Burr Slough, the largest ditch sampled in this area, the substrate changed from waist-deep mud at downstream sites to mud banks with mid-channel patches of shifting sand at upstream sites. The remaining ditches (upper Buffalo Creek, Honey Cypress Creek, Cane Island Slough, and Varney River) all had thick mud substrates with occasional patches of sand, large amounts of submerged vegetation, and beaver dams. Upstream sites on upper Buffalo Creek Ditch (sites 238 and 239) and Dredge Boat Creek (site 246) had virtually no flow and were stagnant.

Eighteen mussel species were found in these tributaries (Table 19). Most were found scattered across the mud bottom. At sites with shifting sand in the channel and mud along the banks (Cockle Burr Slough and Honey Cypress Creek), mussels occurred in a band at the sand-mud transition.

Cockle Burr Slough (sites 233-235) and Varney River (sites 250-252) both contained 12 mussel species. Upper Buffalo Creek Ditch (sites 237-239) and Cane Island Slough (sites 246-249) each yielded seven

TABLE 18. Site by site counts of all mussels found in State Line Outlet Ditch basin, August and October 1987.

Species	Belle Fountain Main Ditch													Pemiscot	
Site	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206
Amblema plicata	1	9	-	9	18	-	25	25	8	6	3	1	3	-	5
Anodonta grandis	1	-	-	-	-	2	-	-	-	3	1	-	2	2	6
Anodonta imbecillis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodonta suborbiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Arcidens confragosus	-	-	-	-	-	1	-	-	1	-	1	-	4	-	12
Lampsilis teres f. *anodontoides*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis teres f. *teres*	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Lampsilis ovata	-	-	1	-	-	-	1	-	-	-	-	1	-	-	-
Lasmigona complanata	6	1	-	11	2	2	-	-	-	-	-	2	1	5	11
Leptodea fragilis	19	4	9	2	7	4	2	4	1	1	4	-	2	6	5
Obliquaria reflexa	5	1	-	-	-	1	1	-	-	-	-	-	-	-	-
Plectomerus dombeyanus	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Potamilus capax	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamilus ohiensis	4	-	1	1	-	-	-	-	2	-	-	-	1	4	1
Potamilus purpuratus	12	4	4	11	2	1	3	2	1	3	2	-	1	5	1
Quadrula apiculata	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-
Quadrula nodulata	13	1	-	-	-	1	-	-	-	-	1	1	1	2	-
Quadrula pustulosa	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Quadrula quadrula	17	1	1	-	1	1	1	4	2	2	5	4	7	-	2
Toxolasma texasensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tritogonia verrucosa	1	-	4	5	5	4	2	1	-	1	-	-	-	-	-
Truncilla donaciformis	1	-	1	1	-	1	-	1	-	-	-	-	-	-	-
Uniomerus declivus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uniomerus tetralasmus	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total specimens	83	21	21	40	35	18	35	38	15	17	17	10	22	28	43
Species included	13	7	7	7	6	10	7	7	6	7	7	6	9	9	8

TABLE 18. (cont.)

Species	Site	Pemiscot Bayou					New Franklin Ditch							Main Ditch 6		
		207	208	209	210	211	212	213	214	215	216	217	218	219	220	221
Amblema plicata		1	-	-	1	-	1	3	-	-	-	-	-	-	-	-
Anodonta grandis		4	4	9	11	14	-	5	2	10	7	3	12	1	1	1
Anodonta imbecillis		-	-	-	-	-	-		-	-	-	-	-	1	-	-
Anodonta suborbiculata		-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Arcidens confragosus		1	9	10	14	7	4	-	-	8	-	-	-	5	-	1
Lampsilis teres f. *anodontoides*		2	-	2	-	2	-	6	-	1	-	-	-	1	2	-
Lampsilis teres f. *teres*		-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Lampsilis ovata		-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Lasmigona complanata		9	5	4	8	-	1	1	-	1	-	-	-	-	-	-
Leptodea fragilis		3	4	3	8	1	2	12	-	3	2	1	-	2	1	-
Obliquaria reflexa		1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plectomerus dombeyanus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamilus capax		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamilus ohiensis		1	-	1	-	2	-	3	-	2	-	1	-	-	-	-
Potamilus purpuratus		2	-	3	5	-	1	4	-	1	-	-	-	-	2	-
Quadrula apiculata		-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Quadrula nodulata		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula pustulosa		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula quadrula		1	-	3	4	-	1	3	-	-	-	-	-	2	1	-
Toxolasma texasensis		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tritogonia verrucosa		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Truncilla donaciformis		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uniomerus declivus		-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Uniomerus tetralasmus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total specimens		25	22	35	51	26	11	37	2	27	9	5	12	12	10	2
Species included		10	4	8	7	5	7	8	1	8	2	3	1	6	8	2

TABLE 18. (cont.)

Species	Site	Main Ditch 6				Ditch 9							Total	No. sites
		222	223	224	225	226	227	228	229	230	231	232		
Amblema plicata		-	-	-	-	-	-	-	-	-	4	2	125	18
Anodonta grandis		26	3	12	4	1	6	-	-	-	45	3	201	29
Anodonta imbecillis		-	-	-	1	-	2	-	-	-	-	-	4	3
Anodonta suborbiculata		1	-	-	-	-	2	-	-	-	-	-	5	4
Arcidens confragosus		6	4	4	8	-	-	-	-	-	6	1	107	20
Lampsilis teres f. *anodontoides*		-	-	-	-	-	-	-	-	-	4	3	23	9
Lampsilis teres f. *teres*		-	-	-	-	-	-	-	-	-	-	-	3	2
Lampsilis ovata		-	-	-	-	-	-	-	-	-	-	-	4	4
Lasmigona complanata		2	-	-	-	-	-	-	-	-	-	-	72	17
Leptodea fragilis		3	-	-	-	-	-	-	-	-	7	-	122	28
Obliquaria reflexa		-	-	-	-	-	-	-	-	-	-	1	10	6
Plectomerus dombeyanus		-	-	-	-	-	-	-	-	-	-	-	1	1
Potamilus capax		-	-	-	-	-	-	-	-	-	-	-	2	1
Potamilus ohiensis		2	-	-	-	-	-	-	-	-	2	3	31	16
Potamilus purpuratus		-	-	-	-	-	-	-	-	-	4	2	76	23
Quadrula apiculata		-	-	-	-	-	-	-	-	-	-	-	3	3
Quadrula nodulata		-	-	-	-	-	-	-	-	-	-	-	20	7
Quadrula pustulosa		-	-	-	-	-	-	-	-	-	-	-	1	1
Quadrula quadrula		-	-	1	-	-	-	-	-	-	1	5	70	23
Toxolasma texasensis		-	-	-	-	-	6	-	-	-	-	-	6	1
Tritogonia verrucosa		-	-	-	-	-	-	-	-	-	-	-	23	8
Truncilla donaciformis		-	-	-	-	-	-	-	-	-	-	-	5	5
Uniomerus declivus		1	-	-	1	-	1	-	-	-	-	-	4	4
Uniomerus tetralasmus		-	-	-	-	-	-	-	-	-	-	-	1	1
Total specimens		41	7	17	14	1	17	0	0	0	73	20	919	
Species included		7	2	3	4	1	5	0	0	0	8	8	24	

TABLE 19. Site by site counts of all mussels found in the Upper Eastern Tributaries, August 1987.

		Cockle Burr			Buffalo Creek Ditch					Honey Cypress Creek					Cane Island
Species	Site	233	234	235	237	238	239	240	241	242	243	244	245	246	247
Amblema plicata		-	2	10	-		1	1	5	24	2	15	1	-	-
Anodonta grandis		7	4	-	-	-	1	-	-	-	-	-	-	29	6
Anodonta imbecillis		-	-	-	-	-	-	-	-	-	-		1	-	-
Anodonta suborbiculata		4	-	-	-	-	-	-	-	-	-	-	-	-	-
Arcidens confragosus		-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia flava		-	-	-	-	-	-		2	6	-	1	-	-	-
Lampsilis teres f. *anodontoides*		-	-	-	-	1	-	-	-	-	-	-	-	-	-
Lampsilis ovata		-	3	-	-	-	1	-	-	-	-	-	-	-	-
Lasmigona complanata		1	1	6	-	-	-	-	-	-	-	-	-		1
Leptodea fragilis		-	7	-	-	1	3	-	-	-	-	-	-	-	-
Potamilus ohiensis		3	-	-	-	-	-	-	-	-	-	-	-	-	2
Potamilus purpuratus		-	-	1	-		1	-	-	-	-	1	-	-	-
Quadrula apiculata		-	-	1	-	-	-	-	-	-	-	-	-	-	-
Quadrula pustulosa		-	-	-	-	-	2	1	-	2	-	-	-	-	-
Quadrula quadrula		-	5	1	-	-	-	-	-	-	-	-	-	-	-
Strophitus undulatus		-	-	2	-	-	-	-	-	2	1	-	1	-	-
Toxolasma texasensis		7	3	-	-	-	-	-	-	-	-	-	-	1	1
Uniomerus declivus		-	-	-	-	-	-	-	-	-	-	-	-	7	-
Total specimens		22	25	21	0	2	9	2	7	34	3	17	3	37	10
Species included		5	7	6	0	2	6	2	2	4	2	3	3	3	4

TABLE 19. (cont.)

Species	Site	Cane Island		Varney River				
		248	249	250	251	252	Total	No. sites
Amblema plicata		-	-	-	2	-	63	10
Anodonta grandis		10	7	7	4	12	87	10
Anodonta imbecillis		1	-	-	-	1	3	3
Anodonta suborbiculata		-	-	-	-	-	4	1
Arcidens confragosus		-	-	1	-	3	4	2
Fusconaia flava		-	-	1	-	1	11	5
Lampsilis teres f. *anodontoides*		-	1	-	-	-	2	2
Lampsilis ovata		-	-	-	1	-	5	3
Lasmigona complanata		-	-	-	1	-	10	5
Leptodea fragilis		-	-	-	-	1	12	4
Potamilus ohiensis		-	-	-	-	-	5	2
Potamilus purpuratus		-	-	-	4	2	9	5
Quadrula apiculata		-	-	-	1	1	3	3
Quadrula pustulosa		-	-	24	-	-	29	4
Quadrula quadrula		-	-	1	1	1	9	5
Strophitus undulatus		-	-	-	-	-	6	4
Toxolasma texasensis		-	-	-	-	-	12	4
Uniomerus declivus		-	-	-	-	-	7	1
Total specimens		11	8	34	14	22	281	
Species included		2	2	5	7	8	18	

species, while six species were found in Honey Cypress Creek (sites 240-245). In all, 281 mussels were examined from these ditches.

The most abundant species in this area was *Anodonta grandis*, especially in Cane Island Slough and Varney River. *Amblema plicata* was common in Honey Cypress Creek. Uncommon species in this area were *Lampsilis teres, Anodonta imbecillis* and *Quadrula apiculata*. *Potamilus capax* was not encountered at any site in this area.

Cache River

In compliance with the Scope of Work for this project, four sites were examined in and around Reeses Fork, Monroe County, Arkansas. Reeses Fork is (or has been) a secondary connection between the White River and the Cache River upstream from their confluence near Clarendon (Fig. 8). Three collections were made in Reeses Fork (sites 254, 255, and 256) and one was made in the Cache River just upstream from the mouth of Reeses Fork (site 253).

In mid-August 1987, the Cache River mouth of Reeses Fork was a small, entrenched channel that meandered through a second-growth woodland. The banks were 2-4 m high and dropped fairly quickly into water that ranged between 0.2 and 3 m in depth. When sampled, the water level was quite low and there was no surface flow from either the Middle Prong or Right Hand Prong of Reeses Fork. The substrate typically was shifting sand (site 254 was an exposed sand bar); however, clay outcrops with sharp rocky (marl ?) inclusions were present at site 255. Fallen trees occurred all along the stream. Collections were made no further upstream than site 256 because the channel was blocked there by fallen trees and the remains of a collapsed logging road culvert.

The mainstem Cache River collection (site 253) was made at the downstream end of a standing-water meander and the channel apparently constructed to bypass it. Firm sand was the substrate on the main channel margin, but considerably more silt was present around the corner in the meander. Water depth was 2 m across the mouth of the meander.

Nineteen mussel species were found at these collection sites (Table 20). Most abundant was *Plectomerus dombeyanus*, followed in order by *Quadrula pustulosa, Leptodea fragilis, Amblema plicata* and *Quadrula quadrula*. Less than five specimens of *Fusconaia flava, Obovaria olivaria, Quadrula nodulata, Toxolasma texasensis* and *Truncilla truncata* were collected. No specimens of *Potamilus capax* were found.

TABLE 20. Site by site counts of all mussels found in the Cache River watershed, August 1987.

	Cache R.	Reeses Fork				
Species Site	253	254	255	256	Total	No. sites
Amblema plicata	48	21	6	3	78	4
Anodonta grandis	5	-	1		6	2
Fusconaia ebena	-	16	4	1	21	3
Fusconaia flava	-	1		-	1	1
Lampsilis teres f. *anodontoides*	2	7	5	3	17	4
Lampsilis ovata		3	4	-	7	2
Leptodea fragilis	3	101	16	1	121	4
Megalonaias nervosa	9	13	1	-	23	3
Obliquaria reflexa	1	23	4	-	28	3
Obovaria olivaria	-	2	1	-	3	2
Plectomerus dombeyanus	67	36	38	1	142	4
Potamilus ohiensis	1	7	3	7	18	4
Potamilus purpuratus	-	10	4	2	16	3
Quadrula nodulata	2	1	1	-	4	3
Quadrula pustulosa	5	102	23	8	138	4
Quadrula quadrula	46	23	4	1	74	4
Toxolasma texasensis	4	-		-	4	1
Tritogonia verrucosa	1	2	5	-	8	3
Truncilla truncata	-	4	2	-	6	2
Total specimens	194	372	122	27	715	
Species included	13	17	17	9	19	

DISCUSSION

Mussel Distribution

This survey has provided freshwater mussel distribution and abundance information for parts of the St. Francis River watershed that had not been examined in such detail previously. When combined with data from the 1986 TVA survey (Ahlstedt & Jenkinson, 1991) and from other recent surveys of the watershed (Stansbery & Stein, 1982; Bates & Dennis, 1983; Clarke, 1985; and Harris, 1986), these results can be used to describe mussel distribution patterns throughout the system.

As indicated in Results and Table 2, we have chosen to examine our 1987 collection data from the St. Francis River system as samples from nine geographic areas or actual subwatersheds. These watershed areas typically contain fairly uniform habitat conditions and mussel communities. This approach also can be expanded to form the basis for a discussion of mussel distribution patterns throughout the river system.

Expanding these nine watershed areas to cover the remainder of the river system downstream from Wappapello Dam requires that the Floodway area be extended downstream to the mouth of the river and that two additional areas be added: the Sunken Lands ≅ the St. Francis River between the Marked Tree siphons (River Mile 155) and U.S. Route 62 bridge (River Mile 229), and the river mainstem between U.S. Route 62 and Wappapello Dam (River Mile 305). The resulting 11 watershed areas in the St. Francis River system are illustrated on Fig. 9.

Table 21 summarizes presence/absence information in the 11 watershed areas from this and the five other recent St. Francis River surveys. For this compilation, location information from the various surveys has been used to place collection sites within our watershed areas. Also, species names presented in the various reports have been listed as the synonyms we prefer to use.

In Table 21, the final column under each watershed is a composite list of species that have been reported from that area. While 46 species have been reported from the entire river system, composite lists for the 11 watershed areas range from 16 to 38 species. The 14 species found in at least 10 of the 11 watershed areas are those that typically occur in muddy or sandy habitats. The 18 species found in less than five of the areas typically occur in gravel or other firm substrates. In general, there does not seem to be any substantial increase in species number with stream size. This observation also has been made by Stansbery & Stein (1982).

Principal Components Analysis

A search for trends in the distribution of mussel species throughout the St. Francis system was conducted using principal components analysis (PCA). As used here, PCA is a non-parametric, exploratory technique that sorts out a series of independent factors which represent relationships in the data (Echelle & Schnell, 1976). This analysis technique also calculates weightings that indicate how strongly each species conforms to each factor. A strong positive or negative weighting for some factor indicates that a species follows that trend in the data set. The ecological meaning of each factor must be inferred using other information.

Table 22 presents the results of a PCA of the mussel presence/absence data from St. Francis watershed sites visited during the 1986

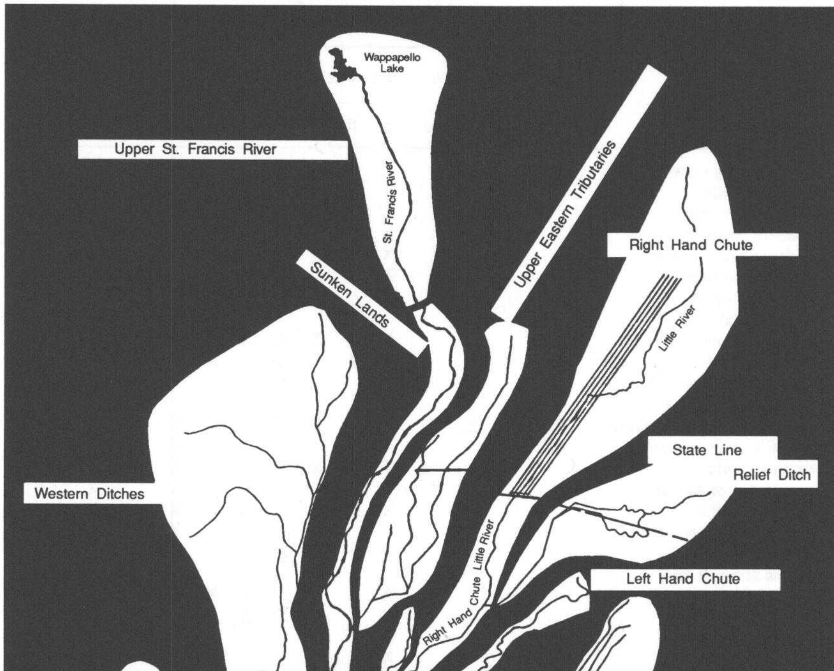

FIG. 9. Exploded view of the St. Francis River system to separate the eleven geographic or subwatershed areas discussed in the text.

TABLE 21. Summary of recent mussel survey results (presence/absence) for eleven geographic areas or subwatersheds of the St. Francis River System.

	L'Anguille River				Lower St. Francis River							Western Trib.			
Species	S*	B	T	Co	S	B	C	H	A	T	Co	B	A	T	Co
Actinonaias ligamentina															
Amblema plicata		X	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	X
Anodonta imbecillis			X	X	X					X	X		X	X	X
Anodonta suborbiculata			X	X	X		X			X	X		X	X	X
Arcidens confragosus			X	X	X	X	X	X		X	X		X	X	X
Cyprogenia aberti										X	X				
Elliptio dilatatus															
Fusconaia ebena					X	X	X	X	X	X	X				
Fusconaia flava					X	X	X	X		X	X			X	X
Lampsilis hydiana					X			X			X				
Lampsilis siliquoidea															
Lampsilis teres f. *anodontoides*			X	X	X	X	X	X	X	X	X		X	X	X
Lampsilis teres f. *teres*					X						X			X	X
Lampsilis ovata					X	X	X	X		X	X		X	X	X
Lasmigona complanata			X	X	X		X	X	X	X	X		X	X	X
Leptodea fragilis					X	X	X	X	X	X	X		X	X	X
Leptodea leptodon							X				X				
Ligumia recta								X			X				
Ligumia subrostrata ?							X				X				
Megalonaias nervosa					X	X	X	X	X	X	X				
Obliquaria reflexa					X	X	X	X	X	X	X		X	X	X
Obovaria jacksoniana					X						X				
Ellipsaria lineolata					X	X		X		X	X				
Plectomerus dombeyanus					X	X	X	X		X	X				
Pleurobema cordatum						X	X				X				
Pleurobema rubrum								X		X	X				
Pleurobema sintoxia					X		X				X		X		X
Potamilus capax			X	X	X	X	X	X	X	X	X		X	X	X
Potamilus ohiensis			X	X	X	X	X	X	X	X	X		X	X	X
Potamilus purpuratus		X	X	X	X	X	X	X	X	X	X		X	X	X
Quadrula apiculata			X	X	X						X				
Quadrula metanevra					X	X	X			X	X				
Quadrula nodulata					X	X	X	X	X	X	X		X	X	X
Quadrula pustulosa		X	X	X	X	X	X	X	X	X	X		X	X	X
Quadrula quadrula			X	X	X	X	X	X	X	X	X		X	X	X
Strophitus undulatus					X									X	X
Toxolasma parvus											X				
Toxolasma glans															
Toxolasma texasensis													X	X	X
Tritogonia verrucosa		X		X	X	X	X	X	X	X	X			X	X
Truncilla donaciformis					X	X				X	X		X		X
Truncilla truncata			X	X	X	X	X	X	X	X	X		X		X
Uniomerus declivus					X									X	X
Uniomerus tetralasmus													X	X	X
Villosa lienosa			X	X									X		X
Totals															
Species encountered	0	5	15	16	32	23	26	24	17	27	38	0	22	23	27
Sites visited	2	8	6		24	19	93	1	19	21		9	26	37	

*Abbreviations - see bottom of next page.

TABLE 21. (cont.)

	St. Francis River				Lower E. Tribs					L.H. Ch./Buff. Cr.		
Species	S	B	A	T	Co	C	T	Co	B	A	T	Co
Actinonaias ligamentina												
Amblema plicata	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
Anodonta imbecillis			X	X	X	X	X	X			X	X
Anodonta suborbiculata				X	X		X	X		X		X
Arcidens confragosus	X	X	X	X	X	X	X	X			X	X
Cyprogenia aberti			X		X							
Elliptio dilatatus												
Fusconaia ebena	X	X	X	X	X							
Fusconaia flava	X	X	X	X	X	X	X	X		X	X	X
Lampsilis hydiana	X		X	X	X		X	X				
Lampsilis siliquoidea												
Lampsilis teres f. *anodontoides*	X	X	X	X	X	X	X	X	X	X	X	X
Lampsilis teres f. *teres*	X		X	X	X		X	X				
Lampsilis ovata	X	X	X	X	X	X	X	X		X	X	X
Lasmigona complanata	X	X	X	X	X		X	X		X	X	X
Leptodea fragilis	X	X	X	X	X	X	X	X	X	X	X	X
Leptodea leptodon												
Ligumia recta			X		X							
Ligumia subrostrata ?												
Megalonaias nervosa	X	X	X	X	X	X	X	X			X	X
Obliquaria reflexa	X	X	X	X	X		X	X		X	X	X
Obovaria jacksoniana												
Ellipsaria lineolata			X		X							
Plectomerus dombeyanus	X	X	X	X	X	X	X	X				
Pleurobema cordatum		X			X	X		X	X			X
Pleurobema rubrum			X	X	X							
Pleurobema sintoxia	X		X		X							
Potamilus capax	X		X	X	X					X		X
Potamilus ohiensis	X	X	X	X	X		X	X		X	X	X
Potamilus purpuratus	X	X	X	X	X	X	X	X	X	X	X	X
Quadrula apiculata							X	X			X	X
Quadrula metanevra	X	X	X	X	X							
Quadrula nodulata	X	X	X	X	X		X	X			X	X
Quadrula pustulosa	X	X	X	X	X	X	X	X	X	X	X	X
Quadrula quadrula	X	X	X	X	X	X	X	X			X	X
Strophitus undulatus				X	X		X	X			X	X
Toxolasma parvus	X				X							
Toxolasma glans												
Toxolasma texasensis	X			X	X		X	X			X	X
Tritogonia verrucosa	X	X	X	X	X		X	X			X	X
Truncilla donaciformis			X	X	X		X	X		X		X
Truncilla truncata	X	X	X	X	X		X	X	X		X	X
Uniomerus declivus							X	X				
Uniomerus tetralasmus												
Villosa lienosa							X	X				
Totals												
Species encountered	26	21	30	29	35	14	28	29	7	14	21	26
Sites visited	10	15	35	25		69	35		10	3	34	

Abbreviations: A - Ahlstedt & Jenkinson, 1987; B - Bates & Dennis, 1983; C - Clarke, 1985; Co - Composite list for this area; H - Harris, 1986; S - Stansbery & Stein, 1982; T - This study.

TABLE 21. (cont.)

Species	Right Chute				Sunk. Lnds.			St. Line Out.			Up. E. Tribs		
	B	A	T	Co	B	A	Co	B	T	Co	B	T	Co
Actinonaias ligamentaria													
Amblema plicata		X	X	X	X	X	X		X	X		X	X
Anodonta grandis		X	X	X	X	X	X		X	X		X	X
Anodonta imbecillis			X	X					X	X		X	X
Anodonta suborbiculata		X	X	X	X	X	X		X	X		X	X
Arcidens confragosus		X	X	X		X	X		X	X		X	X
Cyprogenia aberti													
Elliptio dilatatus													
Fusconaia ebena						X	X						
Fusconaia flava			X	X	X	X	X					X	X
Lampsilis hydiana													
Lampsilis siliquoidea													
Lampsilis teres f. *anodontoides*			X	X	X	X	X		X	X	X	X	X
Lampsilis teres f. *teres*						X	X		X	X			
Lampsilis ovata			X	X	X	X	X		X	X	X	X	X
Lasmigona complanata		X	X	X	X	X	X		X	X	X	X	X
Leptodea fragilis		X	X	X	X	X	X		X	X		X	X
Leptodea leptodon													
Ligumia recta													
Ligumia subrostrata ?													
Megalonaias nervosa			X	X	X	X	X						
Obliquaria reflexa			X	X	X	X	X		X	X			
Obovaria jacksoniana													
Ellipsaria lineolata													
Plectomerus dombeyanus					X	X	X		X	X			
Pleurobema cordatum					X		X						
Pleurobema rubrum						X	X						
Pleurobema sintoxia													
Potamilus capax		X	X	X					X	X			
Potamilus ohiensis		X	X	X	X	X	X		X	X		X	X
Potamilus purpuratus		X	X	X	X	X	X		X	X		X	X
Quadrula apiculata									X	X		X	X
Quadrula metanevra						X	X						
Quadrula nodulata		X	X	X	X	X	X		X	X			
Quadrula pustulosa			X	X	X	X	X		X	X		X	X
Quadrula quadrula		X	X	X	X	X	X		X	X	X	X	X
Strophitus undulatus												X	X
Toxolasma parvus													
Toxolasma glans					X		X						
Toxolasma texasensis			X	X		X	X		X	X		X	X
Tritogonia verrucosa			X	X	X	X	X		X	X			
Truncilla donaciformis			X	X	X		X		X	X			
Truncilla truncata					X	X	X						
Uniomerus declivus						X	X		X	X			
Uniomerus tetralasmus									X	X			
Villosa lienosa													
Totals													
Species encountered	0	11	21	21	21	25	28	0	24	24	4	17	17
Sites visited	4	2	34		6	35		4	41		28	19	

Abbreviations: A - Ahlstedt & Jenkinson, 1987; B - Bates & Dennis, 1983; C - Clarke, 1985; Co - Composite list for this area; H - Harris, 1986; S - Stansbery & Stein, 1982; T - This study.

TABLE 21. (cont.)

Species	Upper St. Francis B	A	Co	No. Areas/Species
Actinonaias ligamentina	X	X	X	1
Amblema plicata	X	X	X	11
Anodonta grandis	X	X	X	11
Anodonta imbecillis		X	X	10
Anodonta suborbiculata				10
Arcidens confragosus	X	X	X	11
Cyprogenia aberti	X	X	X	3
Elliptio dilatatus	X		X	1
Fusconaia ebena				3
Fusconaia flava	X	X	X	9
Lampsilis hydiana				3
Lampsilis siliquoidea	X		X	1
Lampsilis teres f. *anodontoides*	X	X	X	11
Lampsilis teres f. *teres*		X	X	7
Lampsilis ovata	X	X	X	10
Lasmigona complanata	X	X	X	11
Leptodea fragilis	X	X		10
Leptodea leptodon				1
Ligumia recta				2
Ligumia subrostrata ?				1
Megalonaias nervosa	X	X	X	7
Obliquaria reflexa	X	X	X	9
Obovaria jacksoniana				1
Ellipsaria lineolata				2
Plectomerus dombeyanus	X	X	X	6
Pleurobema cordatum	X		X	6
Pleurobema rubrum		X	X	4
Pleurobema sintoxia		X	X	4
Potamilus capax				7
Potamilus ohiensis		X	X	11
Potamilus purpuratus	X	X	X	11
Quadrula apiculata				6
Quadrula metanevra	X	X	X	4
Quadrula nodulata				8
Quadrula pustulosa	X	X	X	11
Quadrula quadrula	X	X	X	11
Strophitus undulatus	X	X	X	6
Toxolasma parvus				2
Toxolasma glans				1
Toxolasma texasensis				8
Tritogonia verrucosa	X	X	X	10
Truncilla donaciformis	X	X	X	9
Truncilla truncata	X	X	X	8
Uniomerus declivus				5
Uniomerus tetralasmus				2
Villosa lienosa	X		X	4
Totals				
Species encountered	25	26	30	46
Sites visited	12	27		

Abbreviations: A - Ahlstedt & Jenkinson, 1987; B - Bates & Dennis, 1983; C - Clarke, 1985; Co - Composite list for this area; H - Harris, 1986; S - Stansbery & Stein, 1982; T - This study.

TABLE 22. Groupings of St. Francis watershed mussel species based upon principal components analysis results. Factor weightings less than ± 0.2 are not presented in the table.

Groups and species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Info. incl. (%)	21.2	8.2	8.0	5.5	4.6
Group 1					
Potamilus purpuratus	0.596	0.282	0.209	-	-
Quadrula nodulata	0.526	0.276	-	-	0.218
Leptodea fragilis	0.484	0.382	-	-	-
Lampsilis teres form *anodontoides*	0.433	0.271		0.580	0.339
Potamilus ohiensis	0.343	0.644	-	-	-0.461
Anodonta grandis	0.242	-0.220	0.720	0.314	-
Arcidens confragosus	0.411	-0.218	0.427	0.223	-
Fusconaia flava	0.527	-0.345	-0.238	-	-
Amblema plicata	0.655	-0.276	-	-	-
Quadrula pustulosa	0.658	-0.293	-0.333	-	-
Group 2					
Lasmigona complanata	0.398	-	0.518	-0.492	-
Cyprogenia aberti	0.201	-	-0.280	-	-
Ellipsaria lineolata	0.239	-	-0.215	-	-
Truncilla donaciformis	0.295	-	-0.213	-	-
Quadrula metanevra	0.340	-	-0.279	-	-
Fusconaia ebena	0.412	-	-0.216	0.217	-
Obliquaria reflexa	0.573	-	-0.322	-	-
Tritogonia verrucosa	0.636	-	-0.230	-	-
Group 3					
Truncilla truncata	0.405	-	-	-	-
Pleurobema rubrum	0.382	-	-	-	-
Lampsilis ovata	0.357	-	-	-	-
Pleurobema sintoxia	0.214	-	-	-	-
Plectomerus dombeyanus	0.208	-	-	-	-
Ungrouped					
Megalonaias nervosa	0.552	-	-	0.238	-0.242
Quadrula quadrula	0.634	-	-	-0.237	0.464
Potamilus capax	-	0.640	-	-0.258	0.275
Strophitus undulatus	-	-0.203	-	-	-
Anodonta suborbiculata	-	-	0.370	-	-
Actinonaias carinata	-	-	-0.208	-	-
Anodonta imbecillis	-	-	-	0.244	0.291
Lampsilis hydiana	-	-	-	-	-
Lampsilis teres form *teres*	-	-	-	-	-
Ligumia recta	-	-	-	-	-
Quadrula apiculata	-	-	-	-	-
Toxolasma texasensis	-	-	-	-	-
Uniomerus declivus	-	-	-	-	-
Uniomerus tetralasmus	-	-	-	-	-
Villosa lienosa	-	-	-	-	-

and 1987 TVA surveys. Data from other recent surveys of the watershed were not included because site-by-site results from those surveys were not available. As indicated in the table, the first five factors calculated by the analysis incorporated 47.6% of the information included in the data set. The remaining information is included in a long series of less important factors, not included in Table 22.

In an attempt to identify the ecological trend being represented by each PCA factor, species that received the highest weightings were contrasted with those that received the lowest weightings. Distribution patterns, specific habitat associations, fish host relationships (when known), and other characteristics were considered in this trend identification process.

Factor 1 yielded strong (greater in magnitude than ± 0.2) positive weightings for 25 of the 38 species involved. This trend appeared to sort the species according to the uniformity of their distribution and frequency of occurrence throughout the watershed. Widely distributed, frequently-found species had the highest weightings. Rarely-found species or those with disjunct distribution patterns had much lower weightings.

Factor 2 gave both positive and negative weightings. This trend seemed to sort the species based on stability of the aquatic habitat. Species with strong positive weightings all occurred at sites with unstable substrates, often in areas that had been disturbed in recent years. Species with strong negative weightings all occurred at sites that had stabilized substrates and well-established bankside vegetation.

Factor 3 gave strong positive and strong negative weightings, apparently related to the composition of site substrates. Species with strong positive weightings typically occurred in soft, silty substrates while species with strong negative weightings typically occurred in gravel or rocky substrates.

Factors 4 and 5 each gave a few strong positive and negative weightings, but we were unable to identify the basis for either trend. Stream size, flow characteristics, fish host habitat preferences, and other likely determinants of mussel distribution patterns should contribute to some factor in this type of analysis. Unfortunately, we were unable to recognize any such relationship in these weightings of the species.

In Table 22, the species are arranged in groups determined by similar weightings for one or more of the factors. The 10 species that make up Group 1 all had strong positive weightings for Factor 1 and strong weightings for Factor 2. All of these species seemed to be widely and uniformly distributed, some occurring in unstable habitats while the others occurred primarily where the habitat was stable. *Potamilus ohiensis* and *Leptodea fragilis* had the highest positive weightings for both of these factors and, during the surveys, these species were the ones expected to be found in the unstable substrates of a new ditch. Two of the five members of this group with negative weightings for Factor 2 (*Anodonta grandis* and *Arcidens confragosus*) typically were found in stable silty substrates (positive weightings for Factor 3). The other three (*Fusconaia flava, Amblema plicata* and *Quadrula pustulosa*) typically were found in firm substrates (negative weightings for Factor 3).

Group 2 consists of eight species, all of which had strong positive weightings for Factor 1 and strong weightings for Factor 3, but weak weightings for Factor 2. These mussels also were widespread and uniformly distributed; however, they occurred in either soft or firm substrates, apparently without regard to how long since these habitats had been disturbed. *Lasmigona complanata* is the single member of this group with a strong positive weighting for Factor 3, interpreted to indicate an association with soft substrates. It seemed to be present wherever soft mud substrate occurred. The seven other members of this group (with negative weightings for Factor 3) occurred in firm substrates. These species were found in clay or gravel substrates both in undisturbed reaches (the Floodway near Madison and in the St. Francis River near Parkin) and in the atypical river reach downstream from Wappapello Dam.

The six Group 3 species had strong weightings only for Factor 1. All six of these species were found in several areas of the watershed; however, none of them was represented by many individuals (between 48 and 452 mussels, or 0.16 to 1.53 percent of the combined total). The small representation within each species may have prevented stronger weightings for factors 2 or 3.

Fifteen species are listed in Table 22 as "ungrouped." These species either did not have strong weightings for any factor (eight species) or they did not share relationships with any other species. Both *Megalonaias nervosa* and *Quadrula quadrula* had strong weightings for Factors 1, 4 and 5. Both had positive weightings for Factor 1, probably indicating widespread distributions; however, they had opposite relationships for Factor 4 and for Factor 5. There does not appear to be any close relationship between the distribution patterns of these two species (at least within the St. Francis River system).

Both *Potamilus capax* and *Strophitus undulatus* had strong weightings for Factor 2 and weak weightings for Factors 1 and 3.

Potamilus capax also had strong weightings for Factors 4 and 5. According to the PCA results, neither of these species is widely or uniformly distributed in the St. Francis system, nor do they routinely occur in soft or firm substrates. The analysis suggests that *Potamilus capax* occurs in unstable habitats and *Strophitus undulatus* occurs in stable habitats.

Most of the remaining species were represented by very few individuals and, for that reason, might not have generated stronger weightings for some factors. The analysis suggests *Anodonta suborbiculata* occurs in soft substrates and *Actinonaias ligamentinata* occurs in firm substrates (both because of strong weightings for Factor 3). No information is provided concerning the eight species which had no strong weighting for any factor.

Nothing in the preceding discussion associates present mussel distribution patterns in the St. Francis River system with stream size or drainage area. The typical pattern of species number increasing with stream size recognized and confirmed by malacologists for many years (*i.e.*, Ortmann, 1925; van der Schalie & van der Schalie, 1950; Jenkinson & Heuer, 1986) apparently does not apply to this watershed. Stream size was not an apparent component in any of the factors produced by the PCA and there is no size-related trend in the numbers of species encountered in each of the subwatersheds (Table 21).

This difference between the St. Francis River and other streams probably can be attributed to two related developments: the high percentage of land involved in row crops and the extensive channelization of the streams necessary to minimize flooding in this extremely flat watershed. Every watercourse in the St. Francis system appears to have been impacted by siltation; many of them have been dredged or channelized. Aquatic habitat throughout the system is fairly uniform, with silt and sand substrates predominating. Gravel or firm mud substrates are rare; however, they are present at less-modified sites throughout the watershed. Mussel species that persist in this system do not occur in longitudinal zones; rather they are found wherever suitable habitat exists.

Historic Perspective

A seldom referenced paper (Meek, 1896) does a surprisingly good job of describing habitat conditions in the St. Francis River basin before the area was developed. In 1895, Meek collected fish at Marked Tree, Big Bay (today "Bay" is located between Trumann and Jonesboro), and fish and a few mussels at Old River near Greenway (probably southeast of Piggott). The latter two of these sites are located in the watershed area we refer to as the Sunken Lands (Fig. 9).

At that time much of the St. Francis basin consisted of large lakes "five to six miles wide and three to four times as long" connected by clear, slow-moving channels. Meek mentions sandy substrates most frequently and includes several comments about abundant aquatic vegetation and water clarity. Old River, the mussel collection site, is described as half a mile to only a few rods wide, as much as 20 feet deep in places, with little current, a sandy bottom, and only a small amount of aquatic vegetation.

Meek collected 15 species of mussels at Old River (Table 23). Abundance information presented in the table was extracted from notes in the paper; however, it is not clear whether this information is intended to apply to the collection or to the general distribution of each species. Five of these species (*Anodonta grandis, A. imbecillis, Lampsilis teres* form *anodontoides, Quadrula pustulosa* and *Tritogonia verrucosa*) still are found throughout the St. Francis watershed. Five other species (*Elliptio dilatatus, Lampsilis hydiana, Obovaria jacksoniana, Pleurobema rubrum* and *Villosa lienosa*) are rare now or no longer exist in the system.

TABLE 23. Freshwater mussels collected in 1894 by Meek from Old River, near Greenway, Arkansas. Original identifications made by C. T. Simpson, U. S. National Museum. (Adapted from Meek, 1896.)

Species reported	Current names	Abundance
Unio pyramidatus Lea	*Pleurobema rubrum*	Scarce
Unio gibbosus Barnes	*Elliptio dilatata*	Quite common
Unio parvus Barnes	*Toxolasma parva*	Scarce
Unio texasensis Lea	*Toxolasma texasensis*	Scarce
Unio tuberculatus Barnes	*Tritogonia verrucosa*	Scarce
Unio turgidus Lea	*Quadrula pustulosa*	
Unio anodontoides Lea	*Lampsilis teres* form *anodontoides*	Abundant
Unio lienosus Conrad	*Villosa lienosa*	Not common
Unio castaneus Lea	*Obovaria jacksoniana*	Common
Unio hydianus Lea	*Lampsilis hydiana*	Very abundant
Unio cerinus Conrad	*Fusconaia flava*	Abundant
Unio undulatus Barnes	*Megalonaias nervosa*	Scarce
Anodonta imbecillis Say	*Anodonta imbecillis*	Scarce
Anodonta edentula Say	*Strophitus undulatus*	Not common
Anodonta opaca Sea	*Anodonta grandis*	Scarce

Another indication of previous mussel assemblages in the watershed was encountered in the form of relict shells at several sites on Left Hand Chute Little River. As indicated in Results, two collections of relicts were made at sites between Marked Tree and Lepanto (Fig. 6). The species present in these collections (Table 15) include some that typically occur on gravel substrates (*Cyprogenia aberti, Fusconaia flava* and *Pleurobema rubrum*), a habitat type that no longer exists in Left Hand Chute. Differences in relative abundance among the species in these collections and the extant fauna of Left Hand Chute (Table 14) could indicate habitat changes over time. However, these differences also could be artifacts of the small sample sizes, missing species records (because fragile shells are rarely preserved), or selection for certain species by some previous collector (mussel fisherman?).

The habitat observations and premodification mussel species list presented by Meek (1896) and the relict collections from Left Hand Chute Little River probably represent stages in the degradation of this lowland drainage basin. If so, they document that some species have been lost from the community, some added, and some have been able to persist – but not necessarily in their original relative abundance.

Potamilus capax

When this survey was designed, its primary purpose was to locate and quantify additional *Potamilus capax* populations in the St. Francis River watershed. A secondary purpose was to collect information on the abundance of the species in areas not sampled quantitatively during 1986. The large number of *Potamilus capax* found this year (607) and the site-specific information collected with them, has added greatly to our understanding of the species and its distribution in this watershed.

Distribution

Ahlstedt & Jenkinson (1991) found *Potamilus capax* in the Lower St. Francis River, the St. Francis Floodway near Marianna, and in a variety of ditch and stream habitats near Marked Tree. One of the *P. capax* habitats near Marked Tree was the downstream two and one-half mile reach of lower Buffalo Creek Ditch (called "unnumbered ditch" in Ahlstedt & Jenkinson, 1991). As indicated in Results, in our current survey, *P. capax* was found in 10 areas:

- the downstream reach of the L'Anguille River,

- the St. Francis Floodway at Madison (previously reported by several authors),
- Straight Slough (previously reported by Clarke, 1985),
- Ditch 10 (previously reported by Ahlstedt & Jenkinson, 1991),
- Little Bay Ditch 9,
- Tulot Seep Ditch (previously reported by Ahlstedt & Jenkinson, 1991),
- the connector between Ditch 60 and 61 (previously reported by Ahlstedt & Jenkinson, 1991),
- St. Francis River from Ditch 1 upstream to the siphons [previously sampled near the siphons by Stansbery & Stein (1982) and Ahlstedt & Jenkinson (1991)],
- Iron Mines Creek-Right Hand Chute from the siphons upstream to Big Lake (Iron Mines Creek sites previously reported by Ahlstedt & Jenkinson, 1991), and
- Belle Fountain Main Ditch (not previously reported, but found by USACE and Fish and Wildlife Service personnel earlier in 1987).

Each of these areas inhabited by *Potamilus capax* has a continuous connection with the St. Francis Floodway, except the St. Francis River downstream from the siphons at Marked Tree and lower Buffalo Creek Ditch. When in operation, the siphons divert water from the Floodway system into the river channel at the mouth of Buffalo Creek Ditch. The river and Floodway systems are distinct from each other between the siphons (River Mile 155) and Huxtable Dam (River Mile 12). Water in the river is released into the Floodway at Huxtable Dam; however, there is no possibility for upstream mussel or fish passage through that structure.

The distribution pattern this substantially enlarged data set suggests (Fig. 10) is quite similar to the one presented in Ahlstedt & Jenkinson (1991). *Potamilus capax* typically occurs in the Floodway system and ditches or streams with unimpeded access to it. The fact that *P. capax* becomes increasingly rare with distance from the siphons in the St. Francis River and lower Buffalo Creek Ditch suggests the species has gained access to these reaches through the large, gravity-fed siphons. Colonization of these areas might be considered a recent event, except that Stansbery & Stein (1982) reported collecting *P. capax* downstream from the siphons in 1973.

If *Potamilus capax* has been in the St. Francis River downstream from the siphons since 1973 (at least), the species does not seem to have been able to extend its range in the river beyond the mouth of Ditch 1,

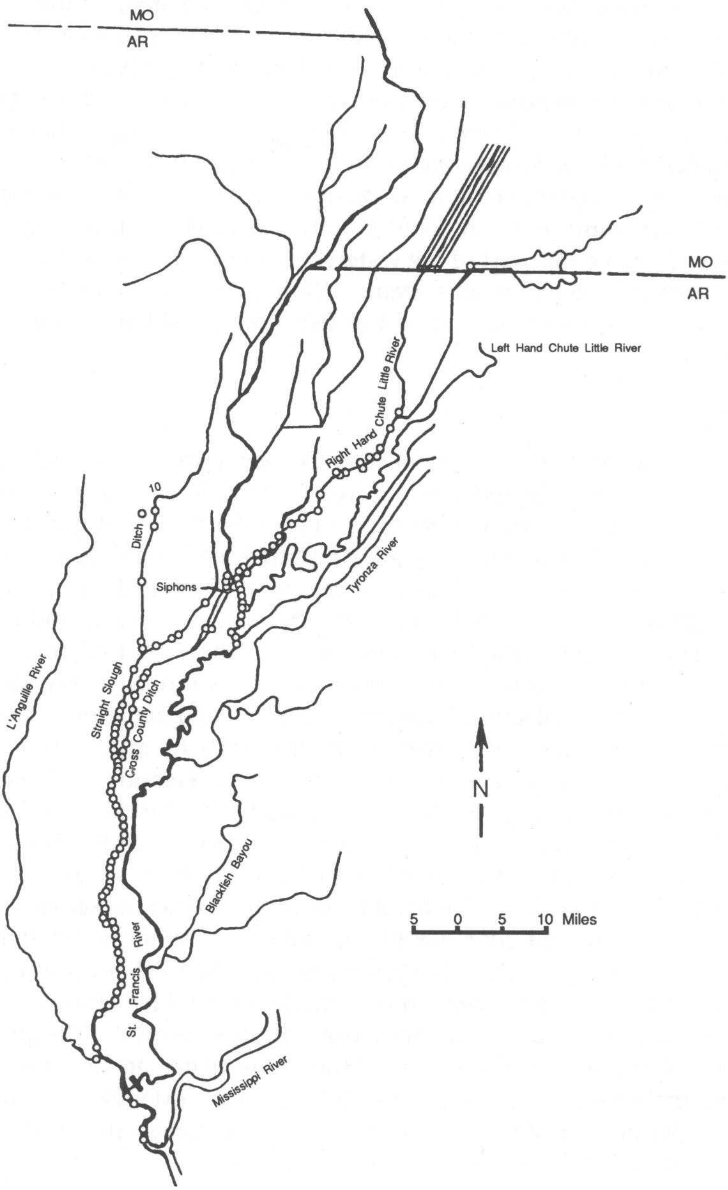

FIG. 10. Sites in the St. Francis River watershed where the fat pocketbook, *Potamilus capax*, has been found during the period 1973-1987. This figure incorporates information from several sources (see text).

upstream more than two miles in Buffalo Creek Ditch, or into adjacent tributaries like Left Hand Chute. Since these reaches appear to contain the types of substrate in which *P. capax* is normally found, this observation suggests some life cycle requirement is not being met in this part of the watershed. One obvious life cycle requirement not associated with substrate that could be affected by the water control system is fish host movement. If the host for *P. capax* was a migratory species, some infected fish could be introduced through the siphons, but would leave this part of the watershed and could not return to the river area through Huxtable Dam. While this idea seems to fit the available data, identification of the fish host would be required to confirm it.

Habitat

During this survey, the fat pocketbook was found in a broad range of substrate types. In the Madison reach of the St. Francis Floodway, *Potamilus capax* occurred in shifting sand, firm clay, and gravel. At the most downstream site on the L'Anguille River and at several sites in the St. Francis River downstream from Marked Tree, *P. capax* occurred in firm mud. In the connector between ditches 60 and 61, in Right Hand Chute Little River, and in most other areas where it was found, *P. capax* occurred in a mixture of sand, mud, and clay (called "sticky mud" in Ahlstedt & Jenkinson, 1991). Field experience gained during this and the 1986 survey suggests this sticky mud is the most likely substrate in which to expect the fat pocketbook. However, searches for the species should not be restricted to this stabilized sand substrate, because *P. capax* has been found alive in all but the most flocculent silt substrates present in the St. Francis River system.

Other characteristics of the habitats in which the fat pocketbook was found also exhibited considerable variation. Channel width ranged from less than 10 m (Ditch 10 system) to over 100 m (Madison reach). Bankside vegetation ranged from virtually none (Ditch 60-61 connector) to large trees and a nearly closed canopy (Straight Slough, St. Francis River near Marked Tree). Human influence on channel morphometry appeared to range from little or none (Madison reach, St. Francis River near Marked Tree) to recent construction (lower Buffalo Creek Ditch, Ditch 60-61 connector).

Abundance

One of the purposes of this survey was to gather quantitative information on *Potamilus capax* populations not sampled in 1986, especially those in the Madison area and Straight Slough. These data, when accompanied by quantitative information from the sites evaluated in 1986 and the areas discovered this year, will permit a complete review of *P. capax* abundance throughout the watershed.

Table 3 presents a summary of the quantitative data collected during this survey. In all of these collections, the 92 *Potamilus capax* found in the 357 10-m^2 quadrat intervals (3,570 square meters) yielded an average of 0.03 *P. capax*/m^2. Density seemed to be quite consistent in each of the watershed areas where *P. capax* was found this year. The highest density was 0.26/m^2 (18 individuals in seven transect intervals) found in the St. Francis Floodway upstream from Madison (site 9, Table 8). The lowest average density in a watershed area (0.01/m^2 in the St. Francis River) included one site with a density of 0.02/m^2, and three sites where live *P. capax* were found but not in any transect intervals.

These results are quite similar to the averages found during the 1986 TVA survey. In that study, Ahlstedt & Jenkinson (1991) reported 0.02 *P. capax*/m^2 for river sites (three individuals in 190 m^2) and 0.01/m^2 for ditch sites (six individuals in 580 m^2). The density estimates from these TVA surveys are one order of magnitude lower than the 0.16/m^2 (82 individuals in 512 m^2) reported from Madison by Harris (1986) and one order of magnitude higher than the 0.004/m^2 (226 individuals in 58,152 m of productive habitat) reported from the Madison and Straight Slough reaches by Clarke (1985).

Differences between these abundance estimates probably are most related to the intensity of each survey. Harris counted his specimens while attempting to remove all mussels from a single, small site where a boat ramp was to be built. Clarke's counts were made while sampling many large, randomly-selected sites scattered throughout a long floodway reach. The quantitative sampling included in both TVA surveys was conducted only where live *Potamilus capax* had been found during a qualitative search. When taken, the TVA quantitative samples also were restricted to one or two narrow bands across the width of each site. While the differences in field techniques used during these surveys have yielded three different estimates of fat pocketbook abundance, the results vary along expected lines given their relative intensity.

Population Structure

Length class data for the 586 live or fresh-dead *Potamilus capax* measured during this survey are presented in Table 4. As indicated in the table, at least 45 individuals were measured from each of four watershed areas. Inspection of numbers in length class intervals suggests that each of these well represented areas contains a normal distribution of shell lengths. Two of the areas have mean lengths of approximately 100 mm (101.9 mm for the Floodway Main Channels and 97.55 mm for Right Hand Chute), while one has a mean of 90.12 mm (St. Francis River), and the other has a mean of 79.77 mm (Western Ditches).

The Floodway Main Channels and Right Hand Chute areas both consist of sites that appear to have been relatively undisturbed in recent years. This observation, accompanied by the similarity of their mean length values and size class relationships suggests they both represent well-established *Potamilus capax* populations. Measurement data from the Floodway Channels collected by Clarke (1985) and Harris (1986) support this concept. Mean lengths Clarke measured were 91.94 mm in 1984 (124 individuals) and 101.70 mm in 1985 (94 individuals). The mean of 81 individuals Harris measured in 1985 was 97.21 mm.

The relatively small number of measured *Potamilus capax* from the St. Francis River between the mouth of Ditch 1 and the siphons (45 animals) had a mean length of 90.12 mm, 10 mm shorter than those from the Floodway or Right Hand Chute. The mean length of 35 individuals from this area measured in 1986 was similar, 88.11 mm (Ahlstedt & Jenkinson, 1991). The difference between these mean values and those from other areas could suggest the river habitat did not promote shell growth as much as other habitats or, perhaps, the population was not as well established as those in the Floodway system.

Ninety-four percent of the measured specimens from the Western Ditches (165 of 176 mussels, Table 9) came from the connector or between Ditches 60 and 61 (constructed in 1978). The mean length of these mussels by themselves was 79.07 mm. Mean length of 49 individuals from this same ditch measured in 1986 was 50.19 mm (Ahlstedt & Jenkinson, 1991). The differences in these mean values, accompanied by the age of this ditch, suggests this is a relatively new population, in which the individuals are growing rapidly.

SUMMARY

As anticipated, this survey of the St. Francis River system has documented the existence of several previously unknown *Potamilus capax* populations. This endangered species is now known to occur virtually throughout the length of the St. Francis Floodway and in many of its tributaries. Upstream from the Floodway, *P. capax* occurs in the Iron Mines Creek-Right Hand Chute Little River system at least as far as Big Lake Dam and the lower portion of Belle Fountain Main Ditch. The species also occurs in the St. Francis River from the siphons near Marked Tree downstream to the Mouth of Ditch 1 and in Buffalo Creek Ditch near the siphons. This distribution pattern is unlike that of any other freshwater mussel present in the St. Francis River system and seems likely to be tied to the movement pattern of a migratory fish host.

Survey results this year indicated the habitat of *Potamilus capax* was broader than indicated by Ahlstedt & Jenkinson (1991). Populations or individuals of the species were found in the full range of habitat types, from shifting sand and flocculent mud to hard clay and gravel. Results of a principal components analysis indicated *P. capax* had an affinity for unstable habitats (disturbed areas). We are still of the opinion that the most likely habitat in which to find this species is "sticky-mud" - a mixture of sand, silt, and clay.

In terms of abundance, the 92 *Potamilus capax* found in a total of 357 10-m^2 transect intervals yielded an average of 0.03/m^2. This average was consistent wherever *P. capax* occurred and is quite similar to the averages found during the 1986 TVA survey. These values are one order of magnitude lower than the 0.16/m^2 density estimate obtained during intensive work at Madison (Harris, 1986) and one order of magnitude higher than the 0.004/m^2 estimate from wide-ranging work conducted in the Madison-Straight Slough area by Clarke (1985).

Length data on 586 *Potamilus capax* suggested that two of the populations appeared to be well established, with a normal distribution of lengths around a mean of approximately 100 mm. One of these populations was in the Madison-Straight Slough reach of the Floodway and the other was in the Right Hand Chute complex. Individuals in the St. Francis River reach near Marked Tree had a mean length of approximately 90 mm, suggesting slower growth rates in that area or a relatively young population.

Measured *Potamilus capax* from the connector between Ditches 60 and 61 had a mean length of approximately 80 mm. Individuals from this ditch also had been measured in 1986 (mean 50 mm). This change in mean length, accompanied by the recent completion date of the ditch (1978), suggested this was a rapidly growing, young population.

Additional finds of *Potamilus capax* in the St. Francis River system could occur; however, they are not likely to make substantial changes in the distribution pattern. The one possible exception to this generalization is the recent discovery of *P. capax* in Belle Fountain Main Ditch, upstream from Big Lake Dam. This find suggests the species could occur in other parts of the Right Hand Chute drainage basin, possibly including the five major ditches that drain much of the Missouri bootheel.

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Once again, the field crews consisted of TVA employees. We sincerely appreciate the individual commitments that Dennis Baxter, Tom Craven, Bill Host, Johnny Miller, Larry Neill and Arnold Woodward made to this project.

Office and technical services also were provided by TVA personnel. Tom McDonough and Bob Terry improved field forms for our use, expertly managed the data set as it developed, and prepared all the output we could use. Rochelle Loy, Kathy Shirley, Carmen Lee and Laura Howard all participated in typing various iterations of the manuscript.

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CUMBERLANDIAN MOLLUSK CONSERVATION PROGRAM. ACTIVITY 8: ANALYSIS OF MACROFAUNA FACTORS

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ABSTRACT – The Cumberlandian Mollusk Conservation Program (CMCP) involved nine research activities designed to answer questions concerning the Cumberlandian mussel fauna and present or potential habitats in selected river reaches in the Tennessee River basin. The Activity 8-Analysis of Macrofauna Factors, was designed to determine the characteristics of fish and benthic faunal communities in 15 designated study areas of nine Tennessee Valley streams. Intensive fish, benthic macroinvertebrate, and mussel habitat sampling were conducted as part of this activity. This information was analyzed to produce habitat requirements for Cumberlandian species and to select transplant sites for mussel species living in the proposed impoundment area of Columbia Reservoir (Duck River, Tennessee).

Key Words: Duck River, Tennessee; fish, benthic macroinvertebrates, naiads, habitat mapping, *Lemiox rimosus, Quadrula intermedia.*

INTRODUCTION

The United States' Office of Management and Budget (OMB) asked the Tennessee Valley Authority (TVA) to investigate alternatives to the Columbia Dam and Reservoir Project, located on the Duck River in middle Tennessee. The TVA was asked if they could meet the water supply and flood control needs of the region and not violate the Endangered Species Act of 1973. After evaluation of several alternatives, TVA concluded that with an intensive conservation and relocation effort for endangered species, the original project proposal would be no more harmful to mussels than other practical alternatives (TVA, 1979).

Research plans were developed for the Cumberlandian Mollusk Conservation Program (CMCP) and included the following nine activities (TVA, 1980): 1, Mollusk Surveys; 2, Potential Fish Hosts; 3, Fish Host Identification; 4, Artificial Culture Medium; 5, Physical Habitat Analysis; 6, Limnological Analysis; 7, Plant and Plankton Analysis; 8, Macrofauna Analysis; and 9, Transplant Site Selection. Each research activity was designed to examine all aspects of the life his-

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tory of *Lemiox rimosus* (= *Conradilla caelata*) and *Quadrula intermedia* in order to describe habitat and limnological conditions necessary to maintain reproducing populations of these mussels. The general goal of the CMCP is to improve conditions for the survival of endangered and other stream dwelling mollusks that exist only in the headwaters of the Tennessee and Cumberland river systems (Jenkinson, 1980). The Activity 8-Macrofauna Analysis portion of this research was charged, "To determine the characteristics of fish and benthic faunal communities in designated study areas of the Duck, Clinch, Powell, and possibly other rivers in order to provide information that will assist in the analysis of molluscan habitat requirements." This report summarizes the findings of those efforts.

PROCEDURES

To characterize faunal communities in designated study areas of the Duck, Clinch, Powell, North Fork Holston, Nolichucky, Buffalo, Paint Rock and Elk Rivers, and Copper Creek, 15 standardized sampling sites (650-foot reaches of river) were selected and sampled for mussels, benthic macroinvertebrates, and fish. Specific locations, physical, and hydrological characteristics of individual sites are detailed in a separate report (Ostrowski & Speaks, 1983).

Mollusks

A stratified random sampling scheme was used to estimate mussel abundance (Cochran, 1977) during the period from May through October 1981. Estimates were made in both relative (number/m^2) and absolute (population estimate) terms. Total population estimates for each mussel species occurring at a site were calculated by expanding the number of each mussel species collected from all 0.25 m^2 quadrat samples to total area of the site. Because a random sampling scheme was used, each site was surveyed by field crews and the water's edge was located relative to a designated reference point established above the high water line and at the downstream end of the site. A baseline was extended upstream from this reference point. Stakes were set at 50-foot intervals along the baseline with corresponding stakes set on the opposite side of the stream.

Maps were prepared for each site with a grid (developed from reference point and baseline) of cells (five feet square) superimposed on the map. Each site was stratified into 10,000 square foot areas which were divided into 400 cells. Using a computerized random number generator program, sixteen cells within each stratum were randomly selected for search, with two replicate samples (0.25 m^2 quadrats) taken within each cell.

The cells to be sampled were located using anchor stakes set at the water's edge and in line with each pair of 50-foot interval baseline stakes (Fig. 1). Cables (marked at 5-foot intervals) strung across the stream between two pairs of corresponding stakes, were used to locate sample cells across the width of the rivers and a tape measure (50-foot) was used to locate the designated cells along the length of stream between the two cables.

A snorkeler or diver (depending upon depth of water) randomly placed the quadrat sampler on the substrate within the area of the sample cell. The sample depth was measured, and substrate characterized (*i.e.*, clay, sand, sand and gravel, cobble, etc.). All mussels within the confines of the quadrat were collected and placed in a nylon mesh collection bag. After the search was completed, mussels were sorted by species, enumerated, then returned to the substrate. A second sample, collected in the same manner, was then taken in each sample cell after moving the quadrat one-half meter toward mid-stream from the initial sample.

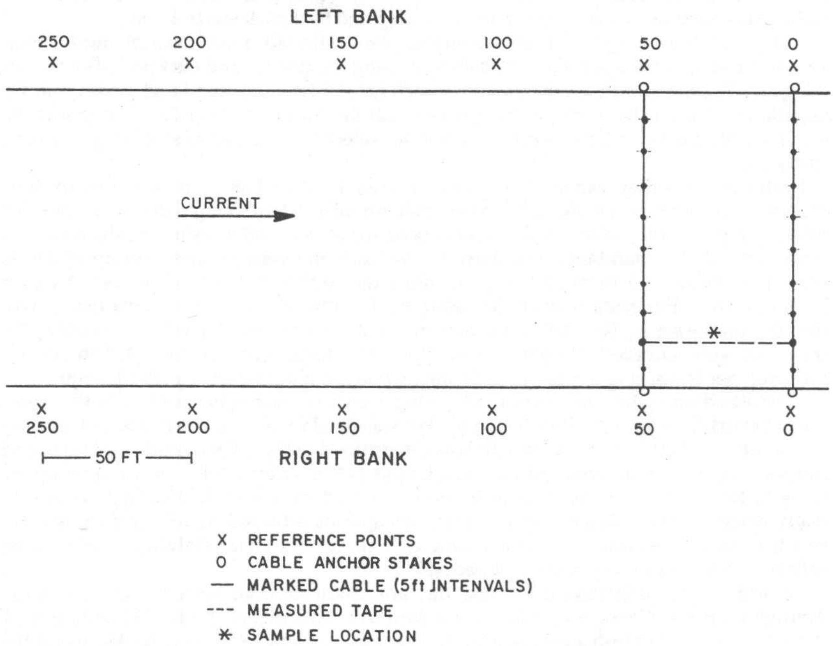

FIG. 1. Illustration of procedure used to locate sample cell at the fifteen standard sample cites.

A two-way cluster analysis of the distribution of mussels in standard sampling sites was used to examine the relationship of species within sample sites. The Jaccard coefficient of association was used to cluster sample sites and species (Jaccard, 1908): $s(j) = a / (a + b + c)$; where, a is the number of species occurring in both sample areas, b is the number of species occurring in site 1, but not site 2, and c is the number of species in site 2, but not site 1. The Jaccard coefficients were then subjected to cluster analysis using the unweighted pair-group method (Sneath & Sokal, 1973).

Benthic Macroinvertebrates

The 15 sites were sampled for benthic macroinvertebrates on a quarterly basis from July 1980 to May 1981. Both qualitative and quantitative samples were collected.

Quantitative samples were taken using an unmodified Surber square-foot sampler in shoal and riffle areas. At each site, four approximately evenly spaced samples were collected in a transect across the shoal. Qualitative samples were collected during the same field trips using D-nets, Needham scrapers, and handpicking. During qualitative sampling, an attempt was made to sample all available habitat types, including muck, vegetation, and debris. All samples were preserved in 10 percent formalin and sent to the laboratory where they were sorted and identified to the lowest possible taxon.

Fish

Fish were collected monthly during 1981 at each site during the suspected glochidia release period for Cumberlandian mollusks (May, June, and July). Three assessment techniques were used – snorkeling, haul seining, and backpack electrofishing.

Both quantitative and qualitative samples were collected in each sample area. Measured transects were systematically sampled using snorkeling and backpack electrofishing gear. Transects were established over each habitat type (*i.e.*, sand and gravel, rubble, vegetation, and/or bedrock) at the various sample locations. Backpack electrofishing and haul seining techniques were also used to collect random samples throughout each study area.

Systematic snorkel transects covering an area 4.9 x 15.2 m were sampled by four divers. The divers swam abreast in a downstream direction driving fish into a 6 m seine held stationary in the river. A 7.6 m anchored rope was used to establish the length of each transect. To maintain a standard interval and an overall transect width of 4.9 m, each diver held a 1.1 m fiberglass pole connected to the adjacent diver's pole by four links of chain. Bumping these poles along the bottom also served to drive fish downstream into the seine. Snorkel transects were conducted during daylight hours only. Six transects were sampled in each habitat type. The mean number of each fish species collected per transect was used to estimate its relative abundance at each location.

Electrofishing collections were made using a transect technique similar to that used during snorkel sampling. The electroshocker was used to drive the fish into a stationary 6 m seine. As before, transect length was determined using a 7.6 m anchored rope and transect width was determined by seine length (4.9 m allowing for positioning of the seine to form a "bag"). Six transects were sampled over each habitat type at the 15 study reaches. The mean number of each fish species collected per electrofishing transect was used to estimate relative abundance. Backpack electrofishing samples were collected during both day and night periods.

To add to the qualitative data base, day and night random seine hauls were made throughout the sampling area using a standard 6 m seine (6 mm mesh size) and/or a 9.1 m bag seine (6 mm mesh size). Additional qualitative samples were collected using the backpack electroshocker and longhandled dip nets to collect fish near the shoreline and around obstructions such as logs, tree roots, etc.

The fish assemblage within the different rivers was examined to determine the presence/absence of a potential host fish and how the relative abundance of specific fish populations correlated with the presence of mussels in a study reach. The total number of fish of a particular species collected at a study site was divided by the total fish (all species combined) collected at that site. Resulting proportions were then ranked from most abundant to least abundant by sample site. Since adequate numbers of host fish must be present to perpetuate mussel populations, only those species comprising a 0.01 ratio (one percent) of the total fish assemblage for each study site were used in the rankings. These species were ranked in decreasing order of abundance for all study reaches combined, for those reaches with *Lemiox rimosus* and *Quadrula intermedia* populations, and for those reaches that did not contain the two endangered mussels.

Most fish collected by the various techniques were identified, counted, and returned alive to the stream. Voucher specimens of each species and specimens of questionable identity were preserved in 10 percent formalin and taken to the laboratory for positive identification.

RESULTS

Mollusks

A total of 43 species of freshwater mussels was collected from all sites (Table 1). Of these, 17 species were considered as "Cumberlandian," seven of which are presently listed as Endangered by the U.S. Fish and Wildlife Service. The total number of mussels collected and dominant substrate is provided for each sample in the 15 study reaches (Appendix: Figs. A-1 through A-15).

Species composition varied greatly among stations within the same river. For example, 33 mussel species were collected from Clinch River Mile (CRM) 189.5 while only nine species were found at CRM 227.4 (Table 1). In the Duck River, 24 species were collected from Duck River Mile (DRM) 179.1, while only five species were observed at DRM 159.4, three at DRM 202.2, and one at DRM 243.1. The cold water discharged through Normandy Dam, previous pollution mishaps, and Lillards Mill Dam (prevents fish migration and thus mussel recolonization) appear to have had significant impacts on the mussel fauna from DRM 248.6 to DRM 179.3 (just upstream from Lillards Mill Dam).

Likewise, mussel abundances varied considerably among rivers (Table 2). The Clinch River at CRM 189.5 had the largest estimated number of mussels (108,343), followed by the Duck River at DRM 179.1 (75,339) and the Powell River at PRM 99.2 (54,780). Sites supporting the largest estimated populations of Cumberlandian species include: Clinch River – CRM 189.5 (43,266), Powell River – PRM 99.2 (35,988) and North Fork Holston River – NFHRM 85.2 (22,786). Species specific abundance information is presented in the Appendix (Table A-1).

Population estimates were based on randomized sampling within strata where each stratum was determined to be a transect of the river reach that contained 10,000 square feet. Since the width of the 15 study reaches varied considerably, there may be some bias introduced since substrate, flow, currents, and channel morphology could influence the populations. With all samples chosen randomly it was decided that estimates of abundance (number/m^2) would allow a realistic approach for comparison of mussel densities at the sites. These data (Table 3) indicate that the Powell River site at PRM 99.9 has the greatest mussel density per unit area (4.06 mussels/m^2) followed by the Clinch River at CRM 189.5 (3.81 mussels/m^2), the Pow-

TABLE 1. Mussel species collected at the fifteen standard sampling sites, 1981.

Species	Status	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Cumberlandia monodonta			+													
Amblema plicata			+	+		+				+	+	+		+		
Fusconaia barnesiana	C	+	+	+		+				+	+	+	+		+	+
Fusconaia cuneolus	CE		+								+					+
Fusconaia subrotunda			+							+	+					
Fusconaia cor	CE												+			+
Quadrula cylindrica			+			+					+					
Quadrula intermedia	CE									+	+					
Quadrula pustulosa		+	+			+										
Tritogonia verrucosa						+										
Megalonaias nervosa						+										
Cyclonaias tuberculata		+	+		+	+	+			+	+			+		
Elliptio crassidens			+													
Elliptio dilatata		+	+			+				+	+			+		+
Hemistena lata	E	+	+													
Lexingtonia dolabelloides	C	+			+	+	+	+								
Plethobasus cyphyus			+								+					
Pleurobema cordatum			+			+										
Pleurobema oviforme	C		+			+				+		+	+		+	+
Alasmidonta marginata			+													
Lasmigona costata			+	+		+				+	+					
Actinonaias ligamentina			+	+	+					+	+			+		
Actinonaias pectorosa	C	+	+	+		+				+	+		+			
Toxolasma lividis	C														+	
Epioblasma brevidens	C		+							+	+					
Epioblasma capsaeformis	C		+			+				+	+					+
Epioblasma triquetra			+							+	+					
Lampsilis fasciola		+	+		+	+	+			+	+	+	+	+	+	+
Lampsilis ovata			+			+				+	+	+		+	+	
Leptodea fragilis						+				+	+					
Ligumia recta			+	+						+	+					
Medionidus conradicus	C	+	+		+					+	+		+		+	+

TABLE 1. (cont.)

Species	Status	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Obovaria subrotunda		+				+									+	
Potamilus alatus			+	+		+			+	+	+			+		
Truncilla truncata			+			+										
Villosa iris	C		+			+					+	+	+		+	+
Villosa vanuxemensis	C		+	+		+						+	+		+	
Villosa perpurpurea	C															+
Cyprogenia stegaria	E		+	+												
Dromus dromas	CE									+	+					
Ptychobranchus fasciolaris			+			+				+	+		+	+	+	
Ptychobranchus subtentum	C		+							+	+		+			
Lemiox rimosus	CE		+			+										
Total number species		10	33	9	5	24	3	1	1	22	25	7	10	8	10	10

C = Cumberlandian species; E = Endangered species

TABLE 2. Population estimates* of mussels (all species and Cumberlandian species only) at each of the standard sampling sites in 1981.

River	Site	Overall	Cumberlandian
Clinch	CRM 189.5	108,343	43,266
Duck	DRM 179.1	75,339	13,203
Powell	PRM 99.2	54,780	35,988
Powell	PRM 117.4	34,974	20,161
North Fork Holston	NFHRM 85.2	24,068	22,786
North Fork Holston	NFHRM 6.2	8,317	1,458
Copper Creek	CCRM 1.9	6,089	5,073
Paint Rock	PRRM 60.0	4,820	3,811
Elk	ERM 91.4	3,971	1,898
Clinch	CRM 227.4	1,921	530
Nolichucky	NRM 27.8	1,559	0
Duck	DRM 159.4	1,030	232
Duck	DRM 202.2	464	232
Buffalo	BRM 79.9	232	0
Duck	DRM 243.1	116	116

*Estimated numbers of mussels in each 650 foot reach of river.

TABLE 3. Relative abundance estimates, for mussels at the 15 sampling sites, 1981.

River	Site	Relative abundance (No./m²)
Powell	PRM 99.2	4.06
Clinch	CRM 189.5	3.81
Powell	PRM 117.4	3.62
Duck	DRM 179.1	3.46
North Fork Holston	NFHRM 85.2	2.45
Copper Creek	CCRM 1.9	0.95
Paint Rock	PRRM 60.0	0.81
North Fork Holston	NFHRM 6.2	0.37
Elk	ERM 91.4	0.24
Nolichucky	NRM 27.8	0.14
Clinch	CRM 227.4	0.09
Duck	DRM 159.4	0.08
Duck	DRM 202.2	0.04
Buffalo	BRM 79.9	0.02
Duck	DRM 243.1	0.01

ell River at PRM 117.4 (3.62 mussels/m^2), and the Duck River at DRM 179.1 (3.46 mussels/m^2). Individual species abundance estimates are presented in the Appendix (Table A-2).

The cluster analysis of sample sites revealed three major associations based on within-group average Jaccard coefficients. The standard sampling site association complex I included all Powell and Clinch River sites in addition to the Duck River at DRM 179.1 and

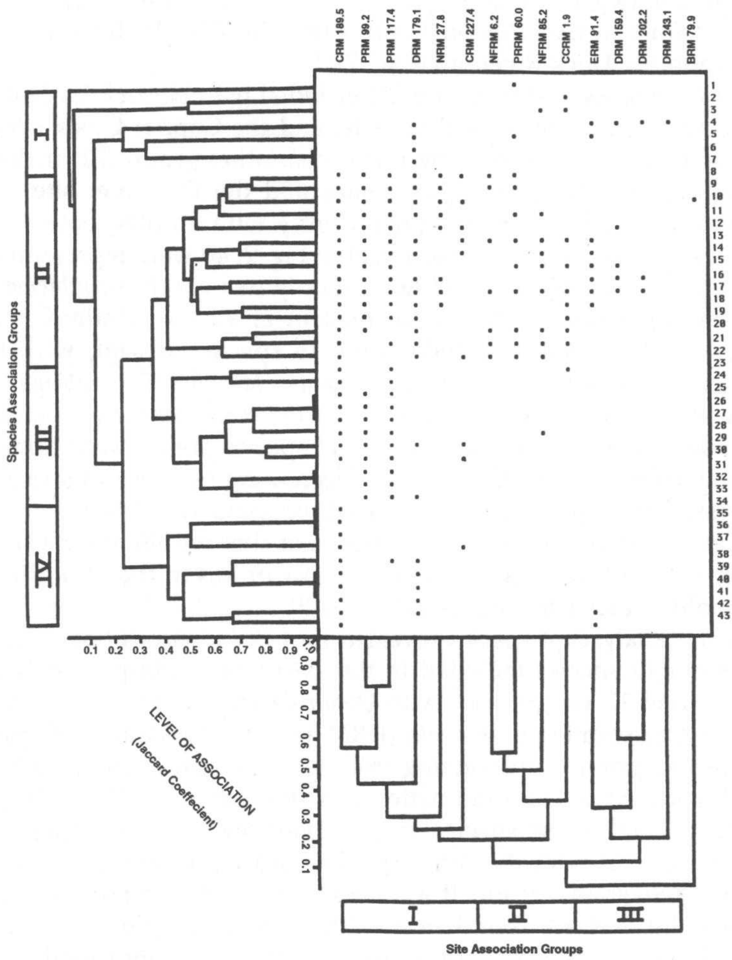

FIG. 2. Two-way cluster analysis of the distribution of 43 species of freshwater mussels (vertical axis) in the 15 standard sampling sites (horizontal axis). Numbers on the left margin refer to the following species: 1, *Carunculina moesta*; 2, *Villosa perpurpurea*; 3, *Fusconaia edgariana*; 4, *Lexingtonia dolabelloides*; 5, *Obovaria subrotunda*; 6, *Megalonaias nervosa*; 7, *Tritogonia verrucosa*; 8, *Amblema plicata*; 9, *Lampsilis ovata*; 10, *Potamilus alatus*; 11, *Ptychobranchus fasciolaris*; 12, *Actinonaias carinata*; 13, *Fusconaia barnesiana*; 14, *Actinonaias pectorosa*; 15, *Medionidus conradicus*; 16, *Cyclonaias tuberculata*; 17, *Lampsilis fasciola*; 18, *Elliptio dilatatus*; 19, *Epioblasma capsaeformis*; 20, *Pleurobema oviforme*; 21, *Villosa nebulosa*; 22, *Villosa vanuxemensis*; 23, *Fusconaia cuneolus*; 24, *Plethobasus cyphyus*; 25, *Fusconaia subrotunda*; 26, *Epioblasma brevidens*; 27, *Epioblasma triquetra*; 28, *Ptychobranchus subtentum*; 29, *Lasmigona costata*; 30, *Ligumia recta*; 31, *Quadrula intermedia*; 32, *Dromus dromas*; 33, *Leptodea fragilis*; 34, *Cumberlandia monodonta*; 35, *Elliptio crassidens*; 36, *Alasmidonta marginata*; 37, *Cyprogenia irrorata*; 38, *Quadrula cylindrica*; 39, *Pleurobema cordatum*; 40, *Truncilla truncata*; 41, *Lemiox rimosus*; 42, *Quadrula pustulosa*; 43, *Hemistena lata*.

the Nolichucky River site (Fig. 2). Of these, faunal affinity was highest for the two Powell River sites, the Clinch River at CRM 189.5, and the Duck River at DRM 179.1.

The second association group (II) included both North Fork Holston River sites, the Paint Rock River site, and the Copper Creek site, all in relatively small rivers. The third association group (III) included the remaining three Duck River sites and the Elk River site. The Buffalo River site had low faunal affinity with all other sites.

Of the 43 mussel species presented in Fig. 2, 40 were represented in site association complex I. However, only two species (*Amblema plicata* and *Potamilus alatus*) were present at all six locations in the complex. In complex II, there were 15 species present, with four species (*Fusconaia barnesiana, Lampsilis fasciola, Pleurobema oviforme* and *Villosa iris*) found at each of the four sample areas, while site association complex III had only 11 species present with none occurring throughout the 5 sites. The decreasing numbers of species in site association groups I through III, coupled with decreasing instances of individual species occurrence at sites within groups (1-121, 11-38, 111-20), suggests something is now or has in the past affected the quality of sites in complexes II and III.

Cluster analysis of species revealed four major associations (Fig. 2). There are 10 species included in the association group with *Lemiox rimosus* and 11 are grouped with *Quadrula intermedia.*

With the exception of one site (DRM 179.1), the members of species association group I are missing from site association complex I and show scattered distribution patterns in site complexes II and III (Fig. 2). In general, these species show a poor level of correlation with each other and with the other species association groups. Taxa in species association group II are eurytypic, widely distributed geographically and are found in all three site association complexes. Mussels in species association group III are primarily found in site association complex I, with two exceptions (*Ptychobranchus subtentum* and *Fusconaia cuneolus,* both Cumberlandian species associated with medium to small rivers) found in site complex II. Species group IV is characteristic of two sites, CRM 189.5 and DRM 179.1 in site association complex I. Based on abundance and species present, these two locations represent optimal mussel habitat. The two group IV species that occur in site complex III (*Quadrula pustulosa* and *Hemistena lata*) are relatively widespread and can accommodate considerable silt in their habitat.

In summary, (eurytypic) mussel species (species association group II) are more than twice as prevalent in site association complex I than in complex III. Species groups III and IV are found almost exclusively in site complex I, whereas species association group I was poorly correlated either with other mussel species or site association groups (Fig. 2).

The 11 taxa in species association group III (including *Quadrula intermedia*) and the 10 taxa in species group IV (including *Lemiox rimosus*) were closely linked with the site complex I (Fig. 2). Along with the known locations of the species of concern, site complex I contained one potential transplant site (NRM 27.8) on the Nolichucky River. The conspicuous absence of molluscan species associated with *L. rimosus* and *Q. intermedia* from sites other than site complex I suggests habitats included in site associations II and III either were not adequate for the assemblages or have been affected by physical/chemical components which excluded these species.

Benthic Macroinvertebrates

Although non-molluscan benthic fauna communities at the 15 sampled river reaches can all be described as diverse, apparently healthy communities, there are significant differences among them. Results of cluster analysis based on Jaccard coefficients (Fig. 3) indi-

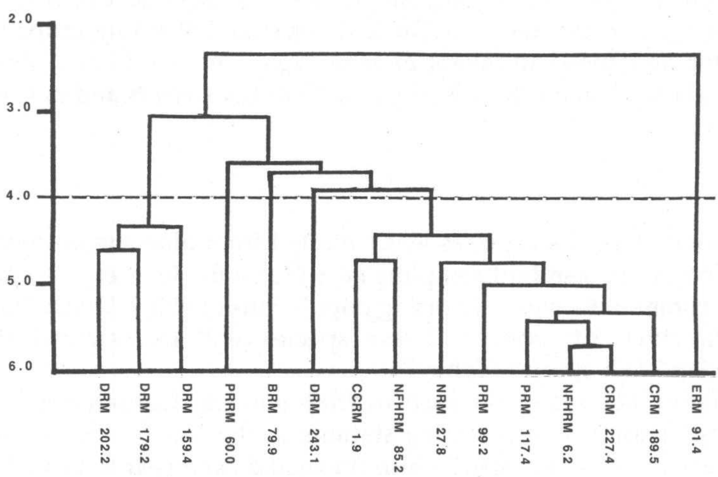

FIG. 3. Cluster analysis of the distribution of 201 taxa of benthic macroinvertebrtaes in the 15 standard sampling sites.

cate two sample site association groups if one uses a criterion of 0.4 similarity (the median value). Complex I includes all sites on the Clinch, Powell, North Fork Holston, Nolichucky, and Copper Creek. These are all tributaries of the upper Tennessee and are located in eastern Tennessee or southwest Virginia. Complex II includes the Duck River sites with the exception of mile 243.1. Four sites, DRM 243.1, BRM 79.9, ERM 91.4 and PRRM 60.0, did not have 40% similarity with either complex.

A total of 166 taxa were collected in Surber samples from the 15 study reaches during four quarters of sampling (Appendix Table A-3). Qualitative sampling added an additional 35 taxa. Species occurrence is shown in Appendix Table A-4. Coefficients of species similarity (Table 4) show that among sites sampled, none of the communities are very similar to Lillards Mill. The Hall Mill site on the Duck River most closely resembles the Lillards Mill site, the two communities sharing approximately 46% of the taxa from those sites in common. Other sites shared 43% or fewer of their taxa in common with the Lillards Mill community. Relative abundance of taxa at each site are shown in Appendix Tables A-5 and A-6.

Diversity indices (Table 5) were lowest at the Elk River (H = 3.35), Duck River Mile 243.1 (H = 3.50), Powell River Mile 117.4 (H = 3.17), North Fork Holston River Mile 6.2 (H = 3.45) and Nolichucky River Mile 27.8 (H = 3.43). Standing crops of benthic fauna (mean numbers of organisms per square-foot) and numbers of taxa (Table 5) were lowest in the Elk and the four Duck River sites. Standing crops were greater and mean numbers of taxa higher in the Clinch, Powell, North Fork Holston, Nolichucky and Paint Rock rivers and in Copper Creek.

Fish

A total of 111 fish species was collected from nine streams encompassing the 15 standard sampling sites (Table 6). Of these, 34 species were common to sites supporting populations of either *Lemiox rimosus* or *Quadrula intermedia.* These species will be referred to as "overlap" fish species (Table 7).

Relative abundance of each overlap species fluctuated not only among rivers but also among stations in the same river (Table 8). Abundance of certain species also fluctuated from year to year. Comparison of abundance estimates for *Etheostoma zonale* (known fish host for *Lemiox rimosus*) from sites sampled during Activity 2 and

TABLE 4. Coefficients of similarity of benthic macroinvertebrate communities between Lillard Mill (DRM, 179.1) and other standard sampling sites.

River	Site	Similarity coefficient
Duck	DRM 202.2	0.46
Duck	DRM 159.4	0.43
North Fork Holston	NFHRM 6.2	0.36
Buffalo	BRM 79.9	0.33
Clinch	CRM 227.4	0.32
Powell	PRM 117.4	0.30
Duck	DRM 243.1	0.29
Nolichucky	NRM 27.8	0.29
Clinch	CRM 189.5	0.29
Powell	PRM 99.2	0.27
Copper Creek	CCRM 1.9	0.26
Paint Rock	PRRM 60.0	0.25
North Fork Holston	NFHRM 85.2	0.24
Elk	ERM 91.4	0.23

TABLE 5. Diversity (H), mean number and taxa of benthic macroinvertebrate organisms per Surber square-foot sample ± standard deviation at each of 15 standard sampling sites.

Sample Site	Diversity index (H)	Mean number of taxa/sample	Mean number per ft^2
ERM 91.4	3.35	6.6 ± 3.5	24.2 ± 15.6
CRM 189.5	4.29	15.6 ± 3.6	123.8 ± 77.7
CRM 227.4	4.00	17.7 ± 6.8	297.1 ± 436.0
DRM 159.4	4.04	10.0 ± 5.2	46.8 ± 29.6
DRM 179.1	3.98	9.6 ± 5.3	53.9 ± 48.7
DRM 202.2	4.14	10.9 ± 5.4	42.1 ± 25.9
DRM 243.1	3.50	7.9 ± 3.2	41.5 ± 53.7
BRM 79.9	3.73	13.0 ± 3.7	65.5 ± 52.0
PRM 99.2	3.87	13.1 ± 5.1	178.2 ± 172.0
PRM 117.4	3.17	13.2 ± 2.7	154.4 ± 147.7
NFHRM 6.2	3.45	18.6 ± 5.2	241.8 ± 389.3
NFHRM 85.2	4.27	18.2 ± 4.7	168.5 ± 85.3
NRM 27.8	3.43	13.7 ± 3.4	290.2 ± 309.8
PRRM 60.0	4.03	17.1 ± 6.2	104.2 ± 145.3
CCRM 1.9	3.97	16.2 ± 4.1	137.2 ± 76.8

Activity 8 (1979, 1980, and 1981 mussel glochidia release periods) reveal abundance fluctuated considerably at two of the four sites sampled during both surveys (Fig. 4). Thus, consideration of abundance of a host fish species at a particular site based on only one season of data may lead to an inappropriate selection of transplant sites.

TABLE 6. Fish species collected from nine streams sampled during 1981 CMCP Activity 8.

Species	Buffalo River	Clinch River	Copper Creek	Duck River	Elk River	Nolichucky River	NF Holston River	Paint Rock River	Powell River
Ichthyomyzon bdellium		+	+	+	+	+	+		+
I. castaneus								+	
Polyodon spathula									+
Lepisosteus oculatus				+					
L. osseus		+	+	+		+		+	+
Dorosoma cepedianum	+	+	+	+				+	+
D. petenense		+							+
Oncorhynchus mykiss				+	+				
Esox masquinongy		+							
Campostoma anomalum	+	+	+	+	+	+	+	+	+
Clinostomus funduloides	+			+					
Cyprinus carpio				+	+				
Notropis amblops	+	+	+	+	+	+	+	+	+
Erimystax cahni		+							
E. dissimilis	+	+	+	+	+		+	+	+
E. insignis	+	+	+	+		+	+	+	+
Cyprinella monacha							+		
Nocomis effusus				+					
N. micropogon	+	+	+		+	+	+		+
Lythrurus ardens					+				
Notropis ariommus	+	+		+	+		+		+
N. atherinoides		+							
N. boops	+			+				+	
Luxilus coccogenis		+	+				+		+
L. cornutus	+	+	+	+	+	+	+	+	+
Cyprinella galactura	+	+	+	+	+		+	+	+
Notropis leuciodus	+	+	+			+	+	+	+
Lythrurus lirus	+		+	+				+	
Notropis photogenis	+	+	+	+	+	+	+		+
N. rubellus	+	+	+	+	+	+	+		+
Cyprinella spiloptera	+	+	+	+	+	+	+	+	+
Notropis volucellus	+	+	+		+	+			+
Cyprinella whipplei		+		+					
Notropis telescopus	+	+	+	+	+	+	+	+	+
N. (undescribed)		+		+	+		+	+	+
N. (undescribed)								+	
N. heterolepis				+					
Phenacobius uranops	+	+	+	+	+	+	+		+

TABLE 6. (cont.)

Species	Buffalo River	Clinch River	Copper Creek	Duck River	Elk River	Nolichucky River	NF Holston River	Paint Rock River	Powell River
P. crassilabrum						+			
Pimephales notatus	+	+	+	+	+			+	+
P. vigilax	+			+			+		
Rhinichthys atratulus		+							
Semotilus atromaculatus	+	+		+	+				
Hypentelium nigricans	+	+	+	+	+	+	+	+	+
Ictiobus bubalus						+			
I. niger					+				
Minytrema melanops	+			+					
Moxostoma macrolepidotum	+	+		+	+	+		+	
M. carinatum	+	+		+				+	+
M. duquesnei	+	+	+	+	+	+	+	+	+
M. erythrurum	+	+	+	+	+	+	+	+	+
Ameiurus natalis	+	+		+		+	+	+	+
Ictalurus punctatus	+	+	+	+	+	+	+	+	+
Noturus eleutherus		+	+	+			+		+
N. exilis	+								
N. flavus			+	+					
N. miurus				+					
N. flavipinnis			+						
N. insignis							+		
N. elegans				+				+	
Pylodictis olivaris	+	+		+		+			+
Anguilla rostrata								+	
Fundulus catenatus	+	+		+				+	
F. notatus				+					
F. olivaceus	+			+				+	
Gambusia affinis				+	+	+		+	
Morone chrysops								+	+
Ambloplites rupestris	+	+	+	+	+		+	+	+
Lepomis gulosus	+							+	
L. auritus		+		+		+	+		
L. cyanellus	+			+	+				
L. macrochirus	+	+	+	+	+	+	+	+	
L. megalotis	+	+	+	+	+		+	+	+
Micropterus dolomieu	+	+	+	+		+	+	+	+
M. punctulatus	+	+		+		+	+	+	+
M. salmoides	+			+			+		

TABLE 6. (cont.)

Species	Buffalo River	Clinch River	Copper Creek	Duck River	Elk River	Nolichucky River	NF Holston River	Paint Rock River	Powell River
Pomoxis annularis		+							+
P. nigromaculatus		+		+					
Ammocrypta clara									+
Etheostoma acuticeps						+			
E. blennioides	+	+	+	+	+	+	+	+	+
E. blennius	+			+	+				
E. caeruleum	+			+	+			+	
E. camurum		+		+		+	+		+
E. cinereum					+				
E. duryi				+					
E. flabellare	+			+	+			+	
E. jessiae		+	+		+	+		+	+
E. kennicotti	+			+				+	
E. luteovinctum				+					
E. maculatum		+	+			+	+		+
E. nigrum								+	
E. rufilineatum	+	+	+	+	+	+	+	+	+
E. simoterum	+	+	+	+	+	+	+	+	+
E. squamiceps				+					
E. stigmaeum	+			+					
E. tippecanoe		+		+					
E. zonale	+	+	+	+	+	+	+	+	+
E. (undescribed)			+						
E. aquali	+			+					
E. (undescribed)				+	+				
Percina aurantiaca		+	+				+		+
P. caprodes	+	+	+	+	+		+	+	+
P. copelandi		+							+
P. burtoni	+		+						
P. evides	+	+	+		+	+	+		+
P. phoxocephala				+					
P. sciera	+	+	+	+				+	+
Aplodinotus grunniens				+				+	
Cottus carolinae	+	+		+	+	+	+	+	+
Labidesthes sicculus		+		+					
Total number species	57	61	43	76	44	38	43	49	51

TABLE 7. Overlap fish species collected at the sites where *Lemiox rimosus* and *Quadrula intermedia* were present.

Fish species	*Quadrula intermedia*	*Lemiox rimosus*
Lepisosteus osseus	+	+
Dorosoma cepedianum	+	+
Campostoma anomalum	+	+
Erimystax dissimilis	+	+
E. insignis	+	
Notropis amblops	+	+
N. ariommus	+	+
Luxilus cornutus	+	+
Cyprinella galactura	+	+
Notropis photogenis	+	+
N. rubellus	+	+
Cyprinella spiloptera	+	+
Notropis telescopus	+	+
N. (undescribed)	+	+
Phenacobius uranops	+	+
Pimephales notatus	+	+
Hypentelium nigricans	+	+
Moxostoma duquesnei	+	+
M. erythrurum	+	+
Ictalurus punctatus		+
Noturus eleutherus	+	+
Ambloplites rupestris	+	+
Lepomis megalotis	+	+
Micropterus dolomieu	+	+
M. punctulatus	+	+
Etheostoma blennioides	+	+
E. camurum	+	+
E. rufilineatum	+	+
E. zonale	+	+
*E. stigmaeum or jessiae**	+	+
*E. maculatum or aquali**	+	+
Percina caprodes	+	+
P. sciera	+	+
Cottus carolinae	+	+

*Similarities in systematics and preferred habitat merit considering the two species as a species group.

Some overlap species (*i.e., Lepisosteus osseus, Dorosoma cepedianum, Ictalurus punctatus, Ambloplites rupestris, Lepomis megalotis, Micropterus dolomieu* and *M. punctulatus*) prefer habitat types other than those quantitatively sampled. Therefore, overall abundance of these species may not be accurately reflected by relative abundance

TABLE 8. Relative abundance estimates (mean number per transect) of overlap fish species at the 15 standard sampling sites. Values of 0.00 indicate that a species was collected by qualitative sampling only.

Species	Duck RM 159.4	Duck RM 179.1	Duck RM 202.2	Duck RM 243.1	Clinch RM 189.5	Clinch RM 227.4	Copper Cr. RM 1.9	Powell RM 99.2
Lepisosteus osseus	0.02	0.00	0.00		0.01	0.00	0.00	0.00
Dorosoma cepedianum	0.00	0.02	0.01		0.02	0.04	0.04	0.00
Campostoma anomalum	0.19	1.33	0.02	2.07	0.28	4.11	0.76	0.44
Notropis amblops	0.07	0.22	0.09		0.07	0.02	1.11	0.47
Erimystax dissimilis	0.16	0.83	0.69	0.03	0.35	0.30	1.19	1.37
*E. insignis**	2.75	1.05	0.19	0.01		0.54	0.67	0.39
Notropis ariommus	0.29	0.05	0.01		0.00			0.03
Luxilus cornutus	0.03	0.07	0.14	0.01	0.07	0.11	0.26	0.08
Cyprinella galactura	0.34	0.07	0.01		0.20	0.43	0.41	0.15
Notropis photogenis	0.00	0.00	0.01		0.03		0.09	0.06
N. rubellus	0.24	0.05	0.01		0.43	0.45	0.17	3.30
N. sp. cf. N. spectrunculus	1.19	2.93	0.07		0.00	0.02		0.07
Cyprinella spiloptera	0.67	0.05		0.00	0.07	0.04	0.00	0.09
Notropis telescopus	2.03	0.97	1.39	0.02	0.07	0.46	0.70	0.07
Phenacobius uranops	0.01	0.05	0.07	0.33	0.30	0.75	0.33	1.39
Pimephales notatus		0.00	0.00	0.00	0.00	0.00	0.07	0.01
Hypentelium nigricans	0.10	0.17	0.06	0.27	0.35	0.75	0.56	0.23
Moxostoma duquesnei	0.00	0.02	0.09	0.01	0.01	0.02	0.24	0.01
M. erythrurum	0.00	0.01	0.03		0.00	0.02	0.11	0.00
*Ictalurus punctatus***	0.07	0.09	0.00		0.00	0.02	0.02	0.00
Noturus eleutherus	0.91	2.77			0.59	0.26	0.13	0.09
Ambloplites rupestris	0.01	0.08	0.06		0.00	0.00	0.04	0.00
Lepomis megalotis	0.07	0.10	0.27	0.00	0.00	0.02	0.00	0.01
Micropterus dolomieu	0.06	0.05	0.02		0.01	0.04	0.00	0.00
M. punctulatus	0.02	0.11	0.05		0.01	0.00		0.01
Etheostoma blennioides	0.41	0.61	0.14	0.10	0.58	4.75	0.70	0.50
E. camurum	0.21	0.36	0.00		0.37	0.00		0.11
E. rufilineatum	2.60	2.25	0.21	0.01	1.30	12.33	3.70	12.04
E. zonale	6.69	2.17	0.38		0.17	1.02	0.13	0.26
E. stigmaeum or *jessiae****	0.01	0.45	0.06		0.00	0.00	1.11	0.02
E. maculatum or *aquali****	0.65	0.52	0.07		0.01	0.00	0.06	0.01
Percina caprodes	0.20	0.24	0.03	0.11	0.05	0.00	0.02	0.10
P. sciera	0.01	0.08	0.01		0.00	0.00	0.00	0.01
Cottus carolinae	1.03	0.17	0.21	2.69	0.00	0.05		0.30
Total number species	33	34	32	15	33	32	29	34

*Overlap species for *Q. intermedia* only; **Overlap species for *L. rimosus* only; ***Similarities in systematics and preferred habitat merit considering the two species as a species group.

TABLE 8. (cont.)

Species	Powell RM 117.4	NF Holston RM 6.2	NF Holston RM 85.2	Nolichucky RM 27.8	Paint Rock RM 60.0	Elk RM 91.4	Buffalo RM 79.9
Lepisosteus osseus	0.00			0.00	0.00		
Dorosoma cepedianum	0.00				0.01		0.02
Campostoma anomalum	0.22	0.26	0.85	0.87	0.15	0.50	1.24
Notropis amblops	1.08	0.01		0.00	0.33	0.11	1.73
H. dissimilis	0.57	0.39	0.15		0.82	1.28	0.36
*H. insignis**	1.09			4.48	0.07		0.22
Notropis ariommus	0.00	0.00				0.02	0.07
Luxilus cornutus	0.07	0.00	0.26	0.44	0.16	0.28	0.10
Cyprinella galactura	0.05	0.46	0.09		0.60	0.13	0.59
N. photogenis	0.19	0.10	0.07	0.00		0.13	0.30
N. rubellus	5.92	1.46	0.50	3.96		0.48	0.02
N. sp. cf. N. spectrunculus	0.00	1.33	0.02		1.24	0.33	
Cyprinella spiloptera	0.01	0.03	0.00	2.11	0.19	0.06	0.01
Notropis telescopus	0.03	0.77	2.80	0.02	1.05	0.19	0.24
Phenacobius uranops	2.39	0.13	0.02	1.04		1.51	0.14
Pimephales notatus	0.03	0.00			0.06	0.00	0.03
Hypentelium nigricans	0.54	0.17	0.39	0.94	0.10	1.13	0.19
Moxostoma duquesnei	0.00	0.00	0.02	0.02	0.03	0.00	0.07
M. erythrurum	0.00	0.00	0.00	0.00	0.02	0.00	0.00
*Ictalurus punctatus***	0.01		0.04	0.00	0.02	0.01	
Noturus eleutherus	0.27	0.57					
Ambloplites rupestris	0.01	0.08	0.11		0.09	0.00	0.04
Lepomis megalotis	0.00	0.00	0.00		0.47	0.00	0.00
Micropterus dolomieu	0.00	0.01	0.26	0.00	0.04		0.00
M. punctulatus	0.00	0.00		0.00	0.01		0.00
Etheostoma blennioides	0.92	0.83	0.37	3.76	0.13	2.28	0.02
E. camurum	0.07	1.15	0.30	2.09			
E. rufilineatum	9.31	7.88	4.63	0.02	2.25	0.50	0.03
E. zonale	0.71	0.42	0.00	0.59	0.10	0.43	0.58
E. stigmaeum or *jessiae****	0.32			0.00	0.53	0.00	0.07
E. maculatum or *aquali****	0.00		0.19	0.07			0.48
Percina caprodes	0.16		0.07		0.15	0.48	0.04
P. sciera	0.00				0.00		0.01
Cottus carolinae	0.32	0.10	0.17	1.31	0.36	2.39	0.30
Total number species	34	26	24	23	27	25	29

*Overlap species for *Q. intermedia* only; **Overlap species for *L. rimosus* only; ***Similarities in systematics and preferred habitat merit considering the two species as a species group.

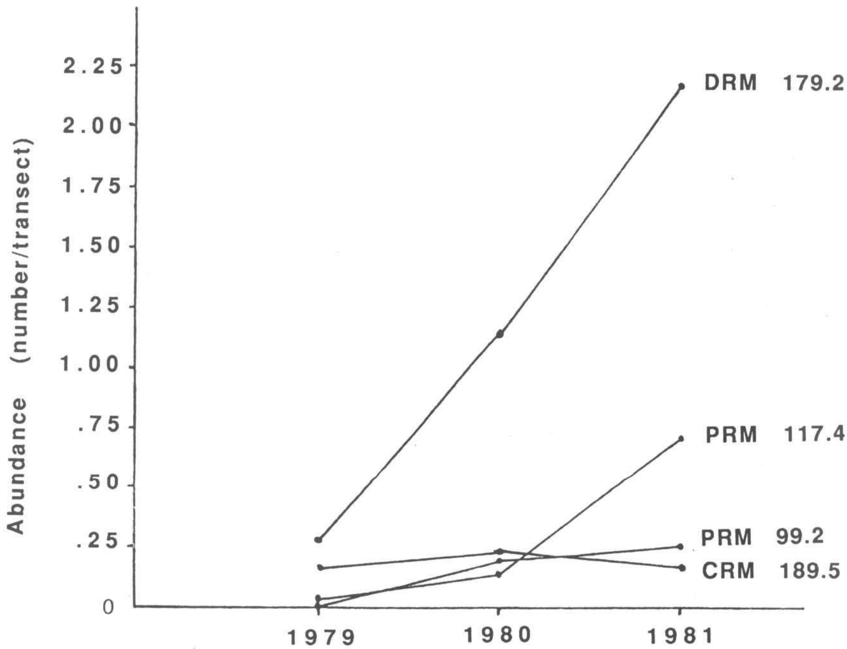

FIG. 4. Relative abundance estimates for *Etheostoma zonale* at four study sites, 1979-1981.

estimates. Abundances of overlap species are generally described for each study site in Table 9 by categorizing species according to total number collected (both quantitative and qualitative samples).

The percent of overlap species for *Lemiox rimosus* found at sampling sites without *L. rimosus* populations indicate that the largest number of *L. rimosus* overlap species (Table 10) were collected from the DRM 159.4 and PRM 117.4 sites. For *Quadrula intermedia,* the DRM 159.4 and the CRM 189.5 sites support the highest number of overlap species (Table 11).

In an analysis performed independently of the overlap species test, lists of total occurrence over all sample periods, by fish species for each site, were compiled and ranked from most abundant to least abundant. All those species that comprised at least one percent of the total number of fish for each site were then analyzed by rank to establish the most common fish species present in the 15 study reaches. Because of variation between reaches and between rivers, 64

TABLE 9. Abundance of overlap fish species for *Lemiox rimosus* and *Quadrula intermedia* at the 15 standard sampling sites based on total numbers collected (quan-titative and qualitative samples) during Activity 8. Categories: Rare (R) = 1-10, Uncommon (U) = 11-100, Common (C) = 101-400, Abundant (A) = 401-1,000, Super Abundant (SA) = over 1,000.

Species	Duck RM 159.4	Duck RM 179.1	Duck RM 202.2	Duck RM 243.1	Clinch RM 189.5	Clinch RM 227.4	Copper Cr. RM 1.9	Powell RM 99.2
Lepisosteus osseus	R	R	R		R	R	R	R
Dorosoma cepedianum	R	U	R		U	U	R	R
Campostoma anomalum	U	C	U	SA	U	A	U	C
Notropis amblops	U	U	U		U	R	C	C
Erimystax dissimilis	U	C	C	R	U	U	C	C
*E. insignis**	C	C	U	R		U	U	U
Notropis ariommus	U	U	R		R			U
Luxilus cornutus	U	U	U	U	C	C	C	U
Cyprinella galactura	U	U	R		C	U	U	U
Notropis photogenis	R	R	R		U		U	U
N. rubellus	C	U	R		U	U	U	A
N. sp. cf. N. spectrunculus	C	A	U		U	R		U
Cyprinella spiloptera	C	U		R	C	U	R	U
Notropis telescopus	A	C	C	R	U	C	C	U
Phenacobius uranops	R	U	R	U	U	U	U	C
Pimephales notatus		U	R	R	U		R	U
Hypentelium nigricans	U	U	R	U	U	C	U	U
Moxostoma duquesnei	R	R	U	R	U	R	U	U
M. erythrurum	R	R	U		R	R	U	R
*Ictalurus punctatus***	U	U	R		R			
Noturus eleutherus	C	A			U	U	R	U
Ambloplites rupestris	U	U	U		U	U	U	U
Lepomis megalotis	C	C	U	R	U	U	R	U
Micropterus dolomieu	U	U	R		U	U	R	R
M. punctulatus	U	U	U		U	R		U
Etheostoma blennioides	U	C	U	U	U	A	U	U
E. camurum	U	U	R		U	R		U
E. rufilineatum	C	C	U	R	C	SA	C	SA
E. zonale	A	C	U		U	C	U	U
E. stigmaeum or *jessiae****	R	U	U		R	R	U	U
E. maculatum or *aquali****	U	U	R		R	R	R	R
Percina caprodes	U	U	R	U	R	R	R	U
P. sciera	R	U	R		R	R	R	R
Cottus carolinae	C	U	U	A	R	R		U

*Overlap species for *Q. intermedia* only; **Overlap species for *L. rimosus* only; ***Similarities in systematics and preferred habitat merit considering the two species as a species group.

TABLE 9. (cont.)

Species	Powell RM 117.4	NF Holston RM 6.2	NF Holston RM 85.2	Nolichucky RM 27.8	Paint Rock RM 60.0	Elk RM 91.4	Buffalo RM 79.9
Lepisosteus osseus	R			R	R		
Dorosoma cepedianum	R				R		R
Campostoma anomalum	C	U	C	U	U	C	C
Notropis amblops	C	R		R	U	U	C
*Erimystax dissimilis**	C	U	R		C	U	U
E. insignis	C			C	R		U
Notropis ariommus	U	R				R	U
Luxilus cornutus	U	C	U	C	U	A	C
Cyprinella galactura	U	C	U		C	C	C
Notropis photogenis	U	U	U	R		C	C
N. rubellus	SA	C	U	A		C	R
N. sp. cf. N. spectrunculus	R	A	U		C	C	
Cyprinella spiloptera	U	R	R	A	U	U	U
Notropis telescopus	U	C	A	R	C	U	C
Phenacobius uranops	C	U	R	U		U	U
Pimephales notatus	U				R	R	U
Hypentelium nigricans	U	U	U	C	U	C	U
Moxostoma duquesnei	U	U	R	R	R	U	U
M. erythrurum	R	R	R	U	R	R	U
*Ictalurus punctatus***		R		R	R	R	R
Noturus eleutherus	U	U					
Ambloplites rupestris	U	U	C		R	U	U
Lepomis megalotis	R	R	R		C	R	U
Micropterus dolomieu	R	U	U	U	U		R
M. punctulatus	R	R		R	R		R
Etheostoma blennioides	C	C	U	C	U	C	R
E. camurum	U	C	U	C			
E. rufilineatum	SA	SA	C	R	C	U	R
E. zonale	U	U	R	U	U	U	U
E. stigmaeum or *jessiae****	U			R	U	U	U
E. maculatum or *aquali****	R		U				U
Percina caprodes	U		R		U	U	R
P. sciera	R				R		R
Cottus carolinae	U	U	U	U	U	C	U

*Overlap species for *Q. intermedia* only; **Overlap species for *L. rimosus* only; ***Similarities in systematics and preferred habitat merit considering the two species as a species group.

TABLE 10. Percent of overlap fish species (those collected from each sited containing *Lemiox rimosus* populations) found at standard sampling sites without *L. rimosus* populations.

Location	Percent
Duck River Mile 159.4	97
Powell River Mile 117.4	97
Clinch River Mile 227.4	94
Duck River Mile 202.2	94
Buffalo River Mile 79.9	91
Copper Creek Mile 1.9	85
Paint Rock River Mile 60.0	79
North Fork Holston River Mile 6.2	79
Elk River Mile 91.4	76
North Fork Holston River Mile 85.2	70
Nolichucky River Mile 27.8	67
Duck River Mile 243.1	42

*Sites with *L. rimosus* include: Duck River Mile 179.1, Powell River Mile 99.2, and Clinch River Mile 189.5.

TABLE 11. Percent of overlap fish species (those collected from each site* containing naturally occurring *Quadrula intermedia* populations) found at standard sampling sites without *Q. intermedia* populations.

Location	Percent
Duck River Mile 159.4	97
Clinch River Mile 189.5	97
Clinch River Mile 227.4	94
Duck River Mile 202.2	94
Buffalo River Mile 79.9	91
Copper Creek Mile 1.9	85
Paint Rock River Mile 60.0	79
North Fork Holston River Mile 6.2	79
Elk River Mile 91.4	73
North Fork Holston River Mile 85.2	70
Nolichucky River Mile 27.8	67
Duck River Mile 243.1	46

*Sites with *Q. intermedia* include: Duck River Mile 179.1, Powell River Mile 99.2, and Powell River Mile 117.4.

species were used in the analysis. Overall there was a mean of 19 (S.D. = 3) fish species encompassing 91.6% (S.D. = 3.4) of the total assemblage per reach. Since the fish data were collected during portions of three or four years for most study reaches, they were assumed to be representative of the fish community through time.

After ranking fish in descending order of abundance by study reach, those areas that had populations of Cumberlandian mussels were

TABLE 12. Rankings, weighted by number of samples and relative abundance of twenty-five potential host fish species[1] for Cumberlandian mollusks.

Species		Rank (Sites)		
Scientific Name	Common Name	Overall Rank	With Mollusks	Without Mollusks
Etheostoma rufilineatum	Redline darter	1	1	5
Campostoma anomalum	Central stoneroller	2	2	3
Cyprinella galactura	Whitetail shiner	3	3	8.5
Luxilus cornutus	Common shiner	4	6	1
Cyprinella spiloptera	Spotfin shiner	5	4	13
Notropis rubellus	Rosyface shiner	6	5	14
N. telescopus	Telescope shiner	7.5	12	2
Hypentelium nigricans	Northern hogsucker	7.5	8	7
Cottus carolinae	Banded sculpin	9	7	12
Etheostoma blennioides	Greenside darter	10	10	11
E. zonale	Banded darter	11	11	8.5
Notropis amblops	Bigeye chub	12	9	10
Erimystax dissimilis	Streamline chub	14.5	18	18
Lepomis megalotis	Longear sunfish	14.5	15	24
Notropis (undescribed)	Sawfin shiner	16	14	26
Erimystax insignis	Blotched chub	17	16	20
Phenacobius uranops	Stargazing minnow	18	20	22
Etheostoma simoterum	Tennessee snubnose darter	19	25	6
Pimephales notatus	Bluntnose minnow	20.5	19	39
Noturus eleutherus	Mountain madtom	20.5	17	43
Percina caprodes	Logperch	22	21	28
Moxostoma duquesnei	Black redhorse	23	27	16
Micropterus dolomieu	Smallmouth bass	24	28	19
Etheostoma camurum	Bluebreast darter	25	23	27

[1]The mean number of species that comprised one percent or more of the total fish collected was 19 (S.D. = 3). The twenty-five species listed here include the 19 species plus two standard deviations (2 x S.D. = 6) for a total of 25.

compared with reaches where the group was absent. The 25 most abundant fish species (19 + 2 S.D.) throughout all samples, along with their rank among river systems with (Duck, Powell, and Clinch) and without Cumberlandian mollusks are presented in Table 12.

With the exception of *Etheostoma simoterum* (Tennessee snubnose darter), all of the ranked potential fish host species are included in the overlap species (Table 7). In each case, those fish noted in Table 7 and not included in Table 12 were present only rarely (less than 10 total specimens collected) or were uncommon (less than 100 total specimens) at all sites. The high degree of concordance between *Lemiox* *rimosus* and *Quadrula intermedia,* and fish species listed in Tables 7 and 12, indicate adequate numbers of fish are present at each potential transplant site for mussel reproduction.

DISCUSSION

This study provides information that may be critical to the continued survival of mussels, more particularly the endangered species *Lemiox rimosus* and *Quadrula intermedia,* in several rivers throughout the region. The biotic components of several river reaches that have populations of these endangered species (DRM 179.1, PRM 117.4, PRM 99.2, and CRM 189.5) were examined to determine what biotic attributes were different from those study reaches that did not have these mussels. It was postulated that these comparisons would identify sites to which *L. rimosus* and/or *Q. intermedia* could be transplanted with a high probability that they would survive and reproduce, hence, assuring continuation of the species. Since the two species of interest were part of the Cumberlandian Mollusk Complex (Ortmann, 1924), the presence of other species in this same group was considered to be an important factor for assessing the suitability of recolonization areas outside the Columbia Dam and Reservoir site.

The benthic macroinvertebrate communities throughout the study reaches were quite similar with respect to diversity (median H = 3.47, range; 3.17-4.29). However, the Elk River site (ERM 91.4) and all of the Duck River sites (DRM 159.4, 179.1, 202.2, and 243.1) had significantly fewer bottom fauna species and numbers than did the other study reaches. Jaccard coefficients of similarity between sites ranged from 0.23 (ERM 91.4) to 0.46 (DRM 202.2), indicating considerable variability among the benthic faunas throughout the region. In all cases, the quantity and quality of the benthos would be considered adequate to sustain those consumers, in this case fish, that are necessary to assure continuation of the mussel community.

The 25 potential host fish represent those fish species present in adequate numbers to provide for completion of the life-cycle for Cumberlandian species. With the exception of *Noturus eleutherus* (mountain madtom) and *Pimephales notatus* (bluntnose minnow), the assemblages present in those streams without *Lemiox rimosus* and *Quadrula intermedia* were quite similar to the fishes in the Duck, Powell and Clinch rivers where the endangered mussels are at present surviving.

If fish other than *Etheostoma zonale* (banded darter) are determined to be acceptable hosts for either *Lemiox rimosus* or *Quadrula intermedia* and are a part of the list in Table 12, then there will probably be adequate numbers at each potential transplant site to accomplish reproduction.

Since the molluscan assemblage varies considerably from study reach to study reach (Table 2), there probably exists some factor that either mitigates for or against the presence of mussels in general and Cumberlandian forms in specific. The presence of viable populations of *Lemiox rimosus* and *Quadrula intermedia* in the Duck and Clinch-Powell river systems suggests both species were more widespread than at present. During this study, we have determined that the benthic macrofauna at all sites is adequate, and supports a fish assemblage of considerable diversity and abundance, hence it is probable that adequate fish hosts are available to accommodate a complex mussel fauna.

The two mussel species of concern are part of the Cumberlandian mussel complex which showed considerable variability between reaches (Table 2). The total number of Cumberlandian forms was used to help classify study reaches from most to least acceptable for the species of interest. In those cases where the same number of Cumberlandian forms were present, the total number of mussel species was used to differentiate between reaches. Table 13 shows the classification of the study reaches. Since *Lemiox rimosus* is the species of primary concern, the sites are ranked for this species, hence Lillards Mill (CRM 179.1) is displaced upward in the *Quadrula intermedia* column.

Numerical ranking shows that based on equal weighting for all parameters, the Kyles Ford (CRM 189.5) and Fletcher Ford (PRM 117.4) sites ranked higher than Lillards Mill (DRM 179.1), notwithstanding the fact that Lillards Mill has a much larger population of *Lemiox rimosus.* This suggests that based on these investigations, the Clinch-Powell system would constitute an ideal relocation area. Conversely, the Lillards Mill site would be an acceptable recolonization area for *Quadrula intermedia.* However, in order to evaluate relative success of relocation, the mussels must be introduced into areas with proper habitat requirements, but where they were not presently living.

TABLE 13. A classification of 15 study reaches in descending order, that either have surviving populations of *Lemiox rimosus* and *Quadrula intermedia* or could serve as relocation sites for these mussel species.

		Lemiox rimosus				*Quadrula intermedia*		
Site	River Mile	Rank	Cumberlandian Species in Common	Percentage Overlap	Total Mussel Species (Cumberlandian)	Rank	Cumberlandian Species in Common	Percentage Overlap
Kyles Ford	CRM 189.5	1*	10	100	33(11)	1.5	9	98
Fletcher Ford	PRM 117.4	2	10	97	25(10)	1.5*	9	100
Lillard's Mill	DRM 179.1	4*	7	100	24(8)	6*	5	100
Buchanan Ford	PRM 99.2	4*	7	100	22(9)	3*	8	100
Saltville	NFHRM 85.2	4	7	70	10(8)	4.5	6	70
Copper Creek	CCRM 1.9	6	6	85	10(8)	4.5	6	85
Paint Rock	PRRM 60.0	7	5	79	10(6)	7	4	79
Elk River	ERM 91.4	8.5	4	76	10(4)	8.5	3	73
Click Island	NFHRM 6.2	8.5	4	79	7(4)	8.5	3	79
Ft. Blackmore	CRM 227.4	10	3	94	9(3)	10	2	94
Sowell Ford	DRM 159.4	11	2	97	5(2)	11	1	97
Hall Mill	DRM 202.2	12.5	1	94	3(1)	13.5	0	94
Dement Bridge	DRM 243.1	12.5	1	42	1(1)	13.5	0	46
Nolichucky	NRM 27.8	14.5	0	67	8(0)	13.5	0	67
Buffalo	BFM 79.9	14.5	0	91	1(0)	13.5	0	91

*Endangered species present.

For those sample sites where neither *Lemiox rimosus* nor *Quadrula intermedia* were present, the simultaneous consideration of several biotic parameters produced some apparent incongruities. For example, the relatively low ranking of the Nolichucky River site (tied for last place among 15 sites) in spite of its inclusion in the optimal site group (site complex I, Fig. 2) was due to the absence of Cumberlandian mussel forms and the relatively low percentage of overlap species within the fish assemblage. However, as this information is combined with other attributes of the several potential transplant sites, a hierarchy of preferred sites should develop. It is important to remember that the potential transplant sites were not selected randomly, but were judged the 'best' of several areas in their particular drainages.

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APPENDICES

LEGEND:

---------- = AREAS DRY DURING SAMPLED LOW-FLOW CONDITIONS

a × b = LOCATION OF SAMPLE

× = LOCATION

a = NUMBER OF MUSSELS COLLECTED

b = SURFACE SUBSTRATE TYPE

SUBSTRATE TYPES

F = FINE PARTICLES (SILT AND CLAY)

S = SAND

G = GRAVEL

C = COBBLE

G = ROCK

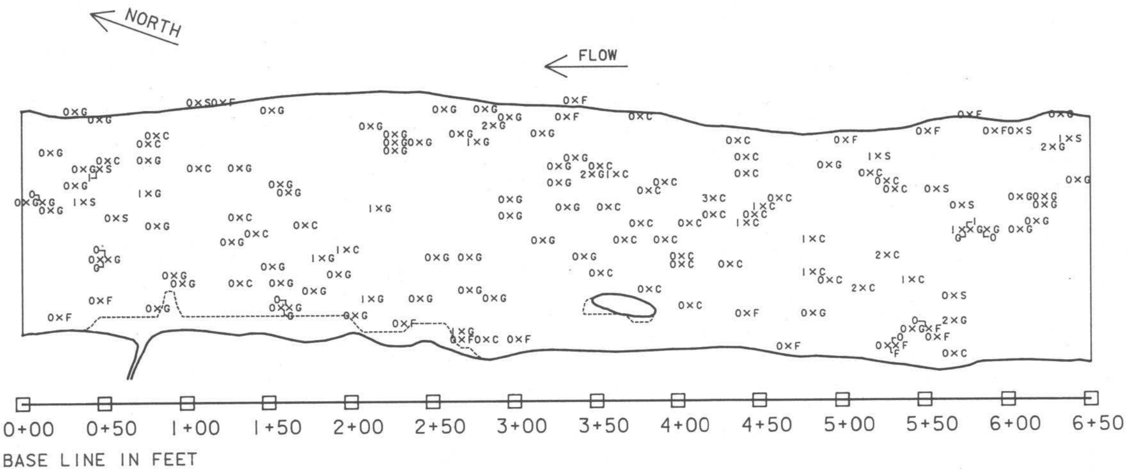


FIG. A-1. Total mussels collected and substrate type (surface) at each sample cell location for study reach ERM 91.4.

LEGEND:

---------- = AREAS DRY DURING SAMPLED LOW-FLOW CONDITIONS

a X b = LOCATION OF SAMPLE

X = LOCATION

a = NUMBER OF MUSSELS COLLECTED

b = SURFACE SUBSTRATE TYPE

SUBSTRATE TYPES

F = FINE PARTICLES (SILT AND CLAY)

S = SAND

G = GRAVEL

C = COBBLE

R = ROCK

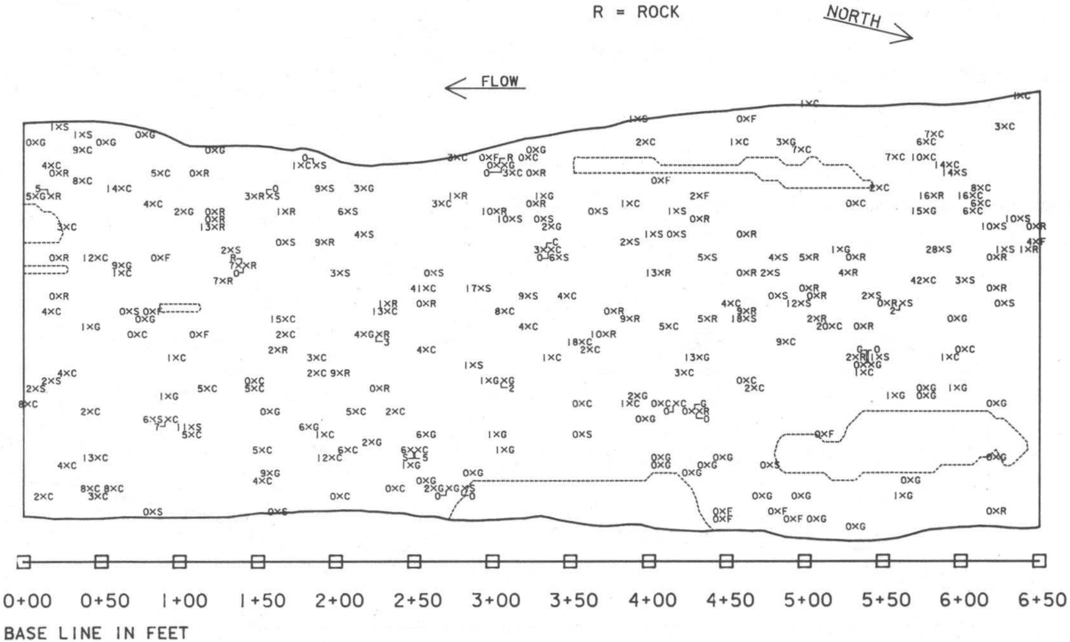


FIG. A-2. Total mussels collected and substrate type (surface) at each sample cell location for study reach CRM 189.5.

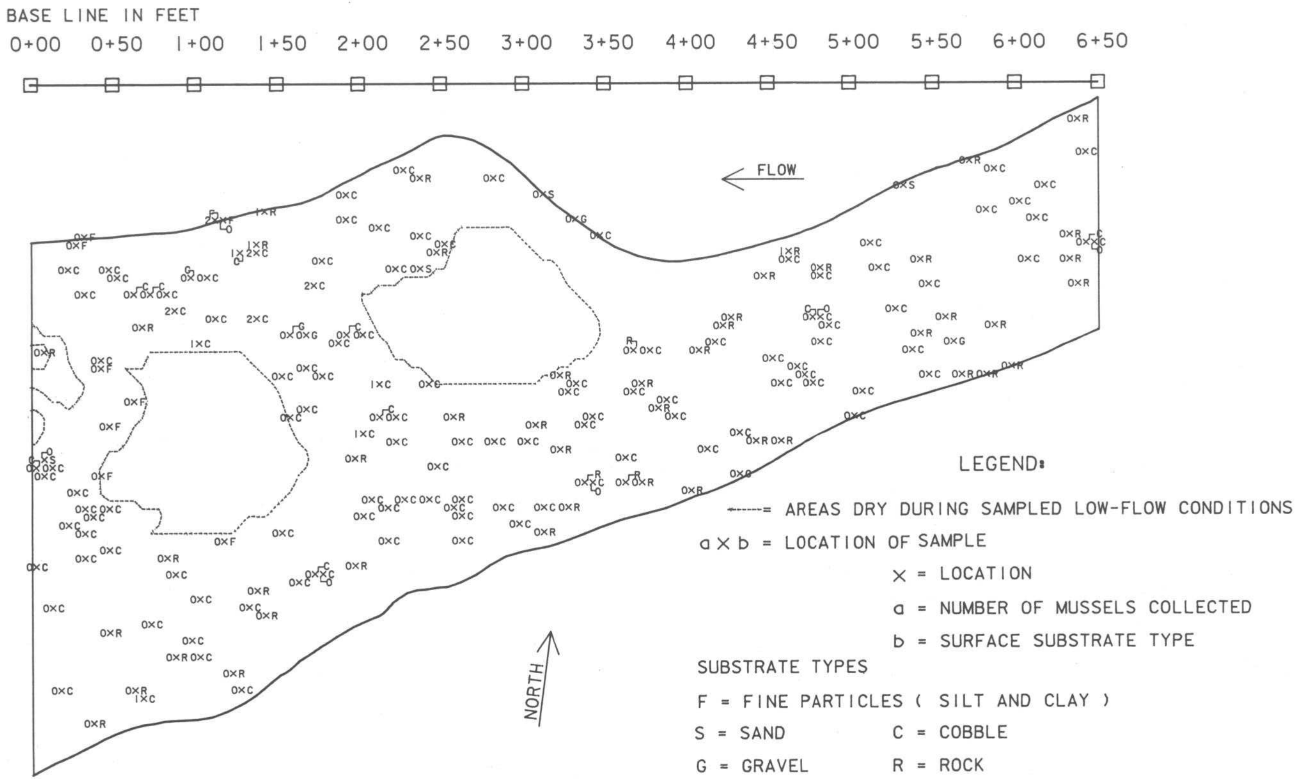


FIG. A-3. Total mussels collected and substrate type (surface) at each sample cell location for study reach CRM 227.4.

LEGEND:

---------- = AREAS DRY DURING SAMPLED LOW-FLOW CONDITIONS

a × b = LOCATION OF SAMPLE

× = LOCATION

a = NUMBER OF MUSSELS COLLECTED

b = SURFACE SUBSTRATE TYPE

SUBSTRATE TYPES

F = FINE PARTICLES (SILT AND CLAY)

S = SAND

G = GRAVEL

C = COBBLE

R = ROCK

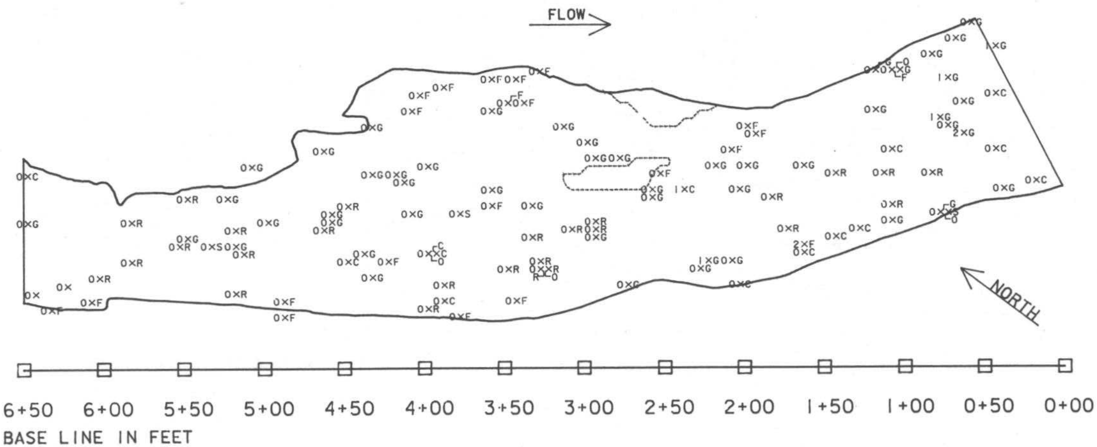


FIG. A-4. Total mussels collected and substrate type (surface) at each sample cell location for study reach DRM 159.4.

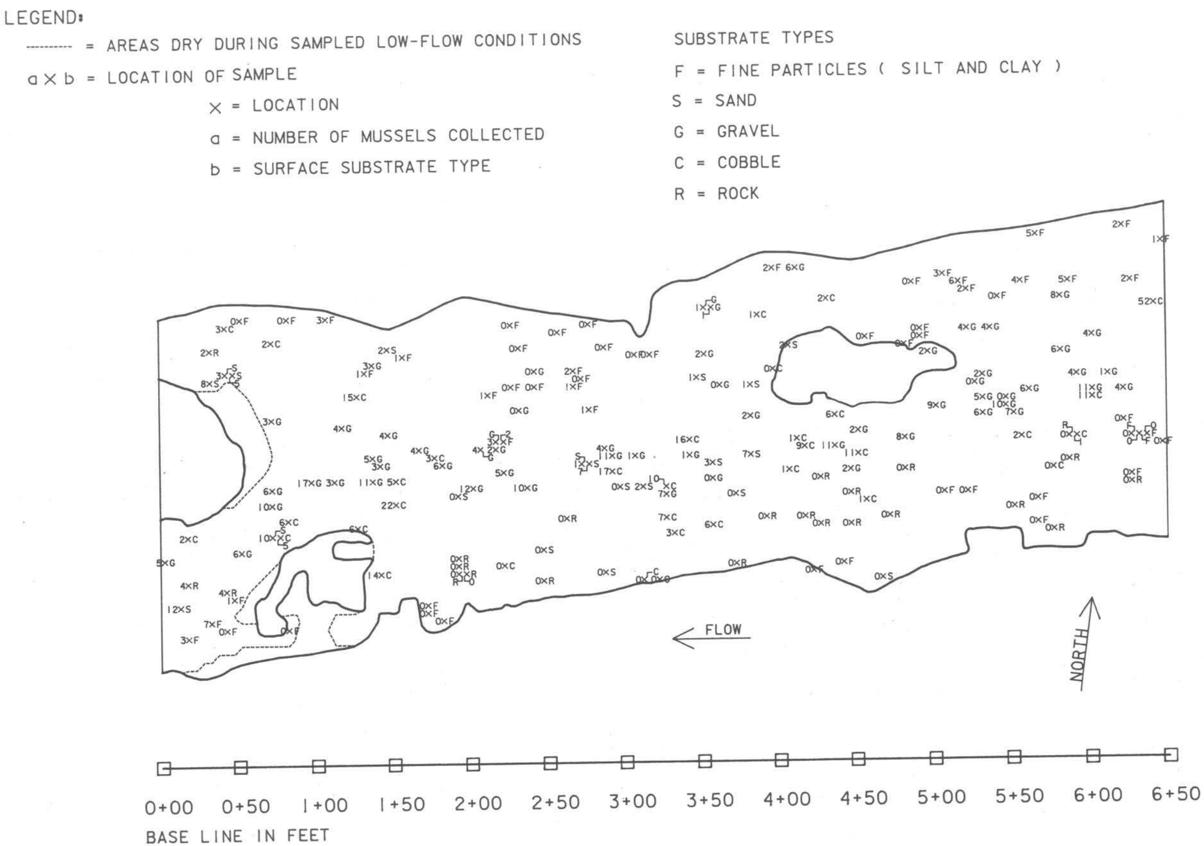


FIG. A-5. Total mussels collected and substrate type (surface) at each sample cell location for study reach DRM 179.1.

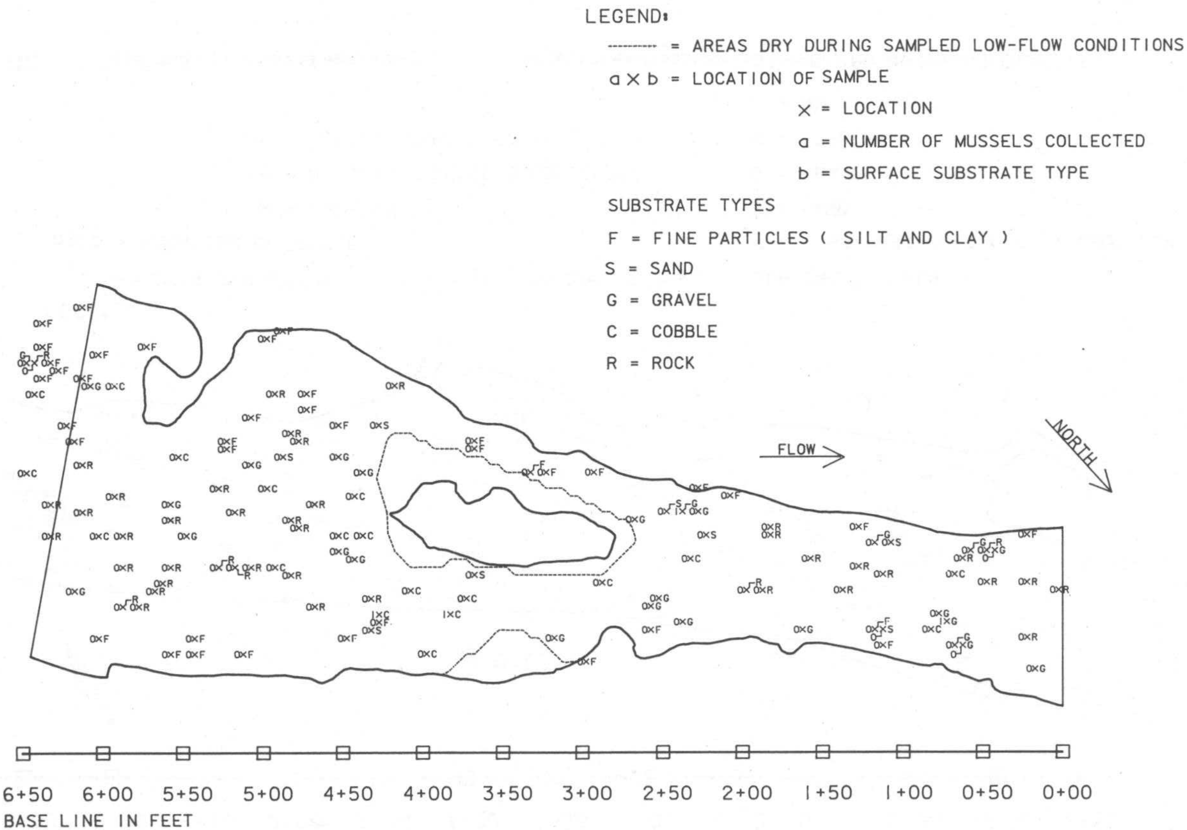
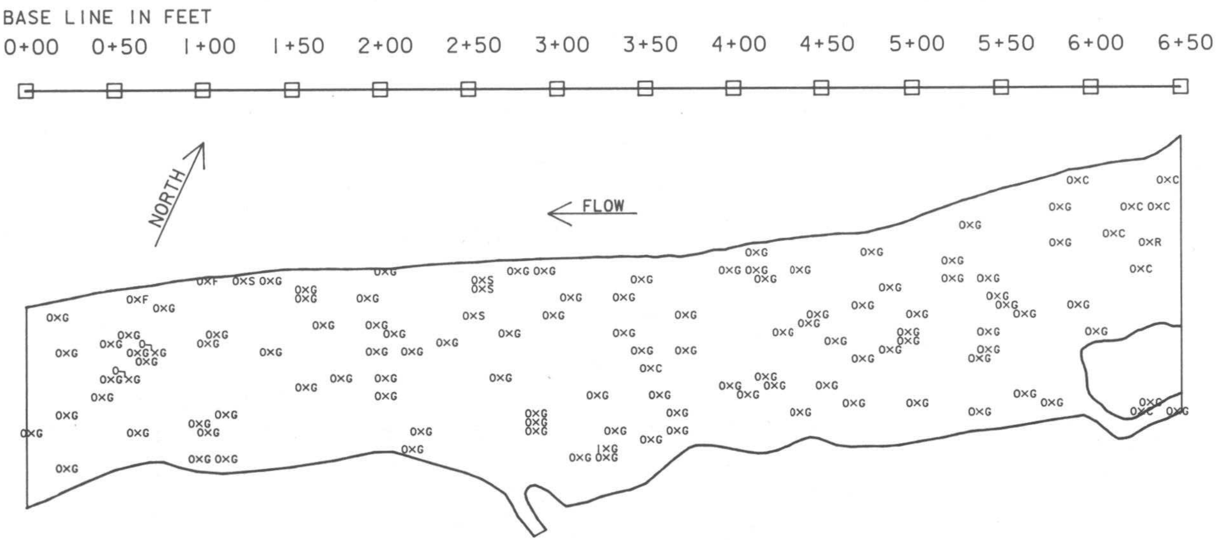


FIG. A-6. Total mussels collected and substrate type (surface) at each sample cell location for study reach DRM 202.2.



LEGEND:

--------- = AREAS DRY DURING SAMPLED LOW-FLOW CONDITIONS

a×b = LOCATION OF SAMPLE

× = LOCATION

a = NUMBER OF MUSSELS COLLECTED

b = SURFACE SUBSTRATE TYPE

SUBSTRATE TYPES

F = FINE PARTICLES (SILT AND CLAY)

S = SAND

G = GRAVEL

C = COBBLE

R = ROCK

FIG. A-7. Total mussels collected and substrate type (surface) at each sample cell location for study reach DRM 243.1.

LEGEND:

- - - - - - = AREAS DRY DURING SAMPLED LOW-FLOW CONDITIONS

a × b = LOCATION OF SAMPLE

× = LOCATION

a = NUMBER OF MUSSELS COLLECTED

b = SURFACE SUBSTRATE TYPE

SUBSTRATE TYPES

F = FINE PARTICLES (SILT AND CLAY)

S = SAND

G = GRAVEL

C = COBBLE

R = ROCK

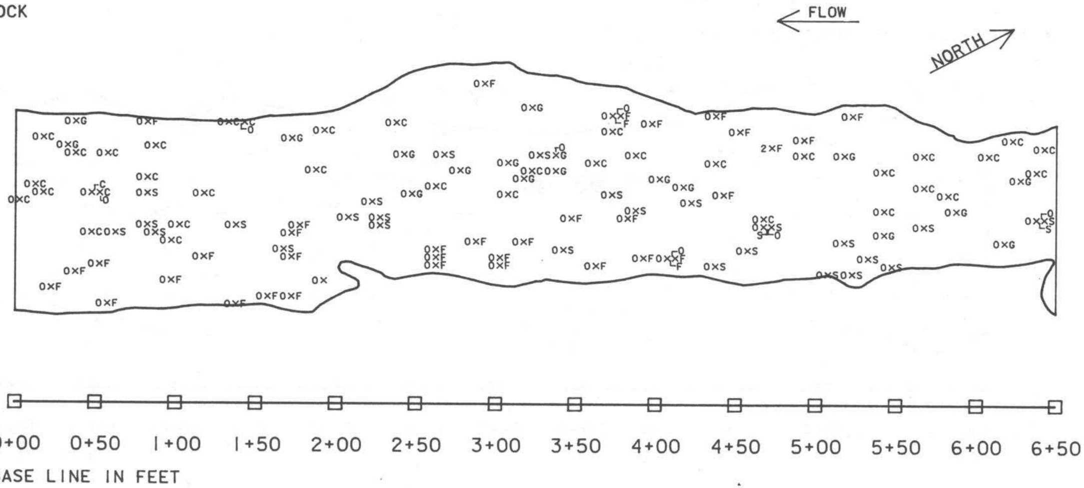


FIG. A-8. Total mussels collected and substrate type (surface) at each sample cell location for study reach BRM 79.9.1.4.

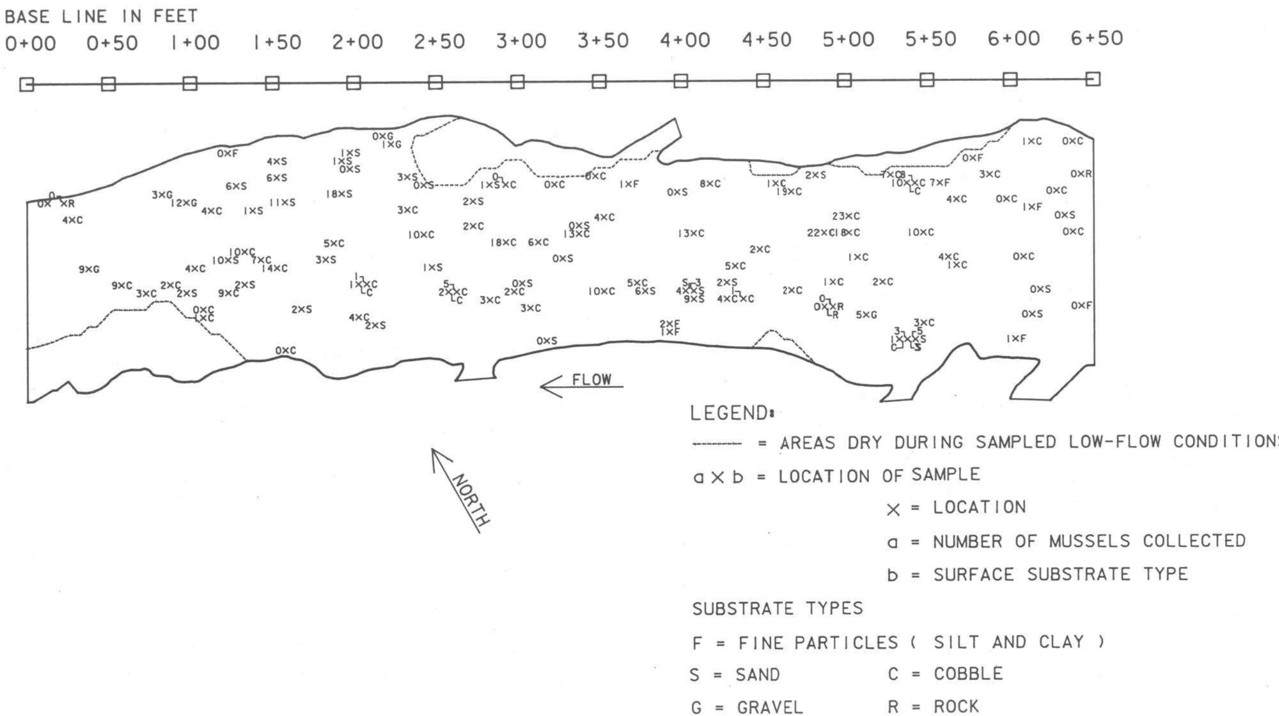


FIG. A-9. Total mussels collected and substrate type (surface) at each sample cell location for study reach PRM 99.2.

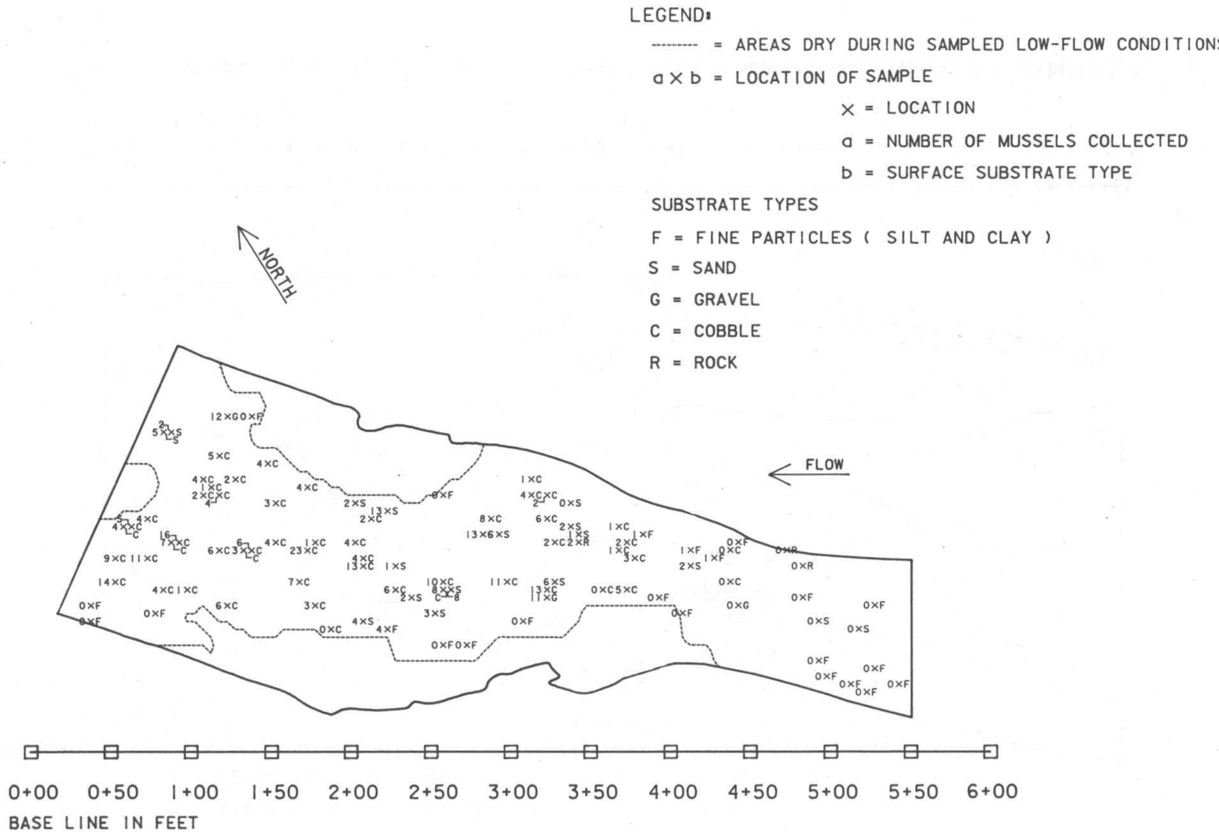


FIG. A-10. Total mussels collected and substrate type (surface) at each sample cell location for study reach PRM 117.4.1.4.

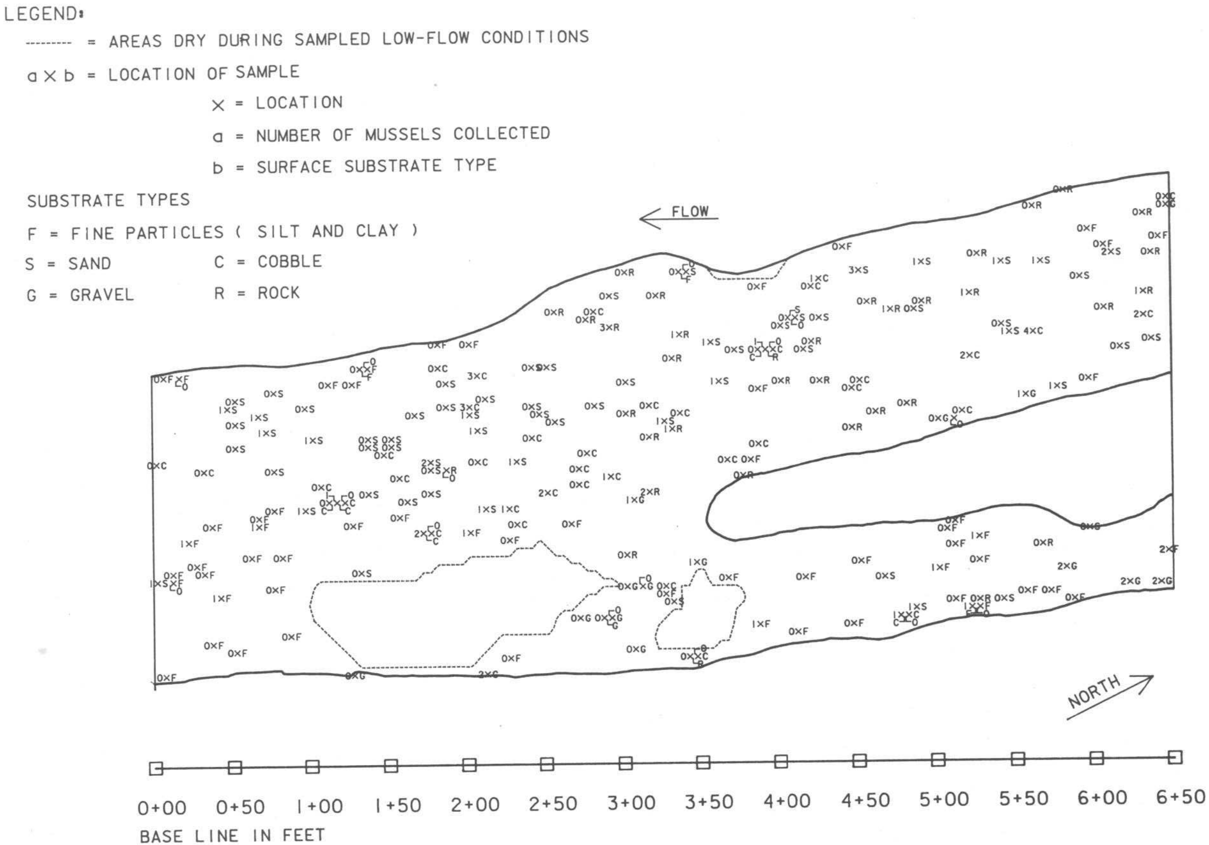


FIG. A-11. Total mussels collected and substrate type (surface) at each sample cell location for study reach NFHRM 6.2.1.4.

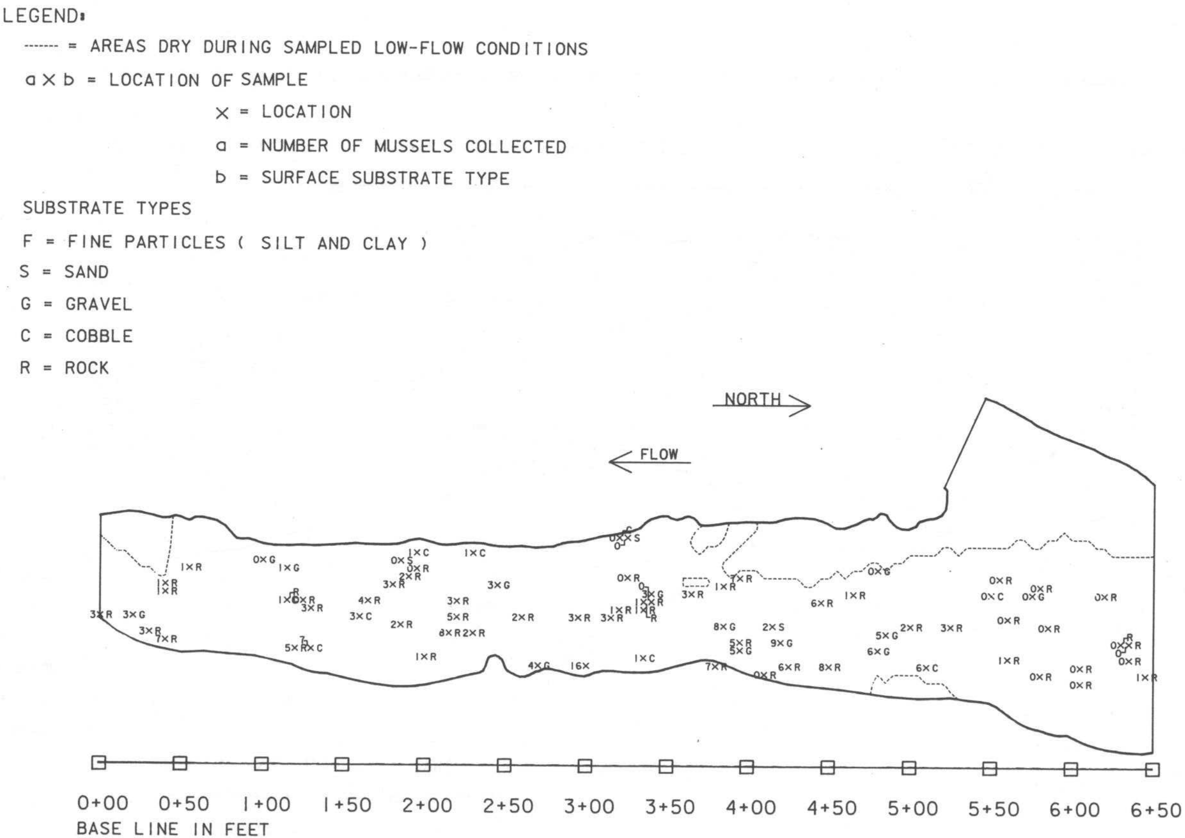


FIG. A-12. Total mussels collected and substrate type (surface) at each sample cell location for study reach NFHRM 85.2.

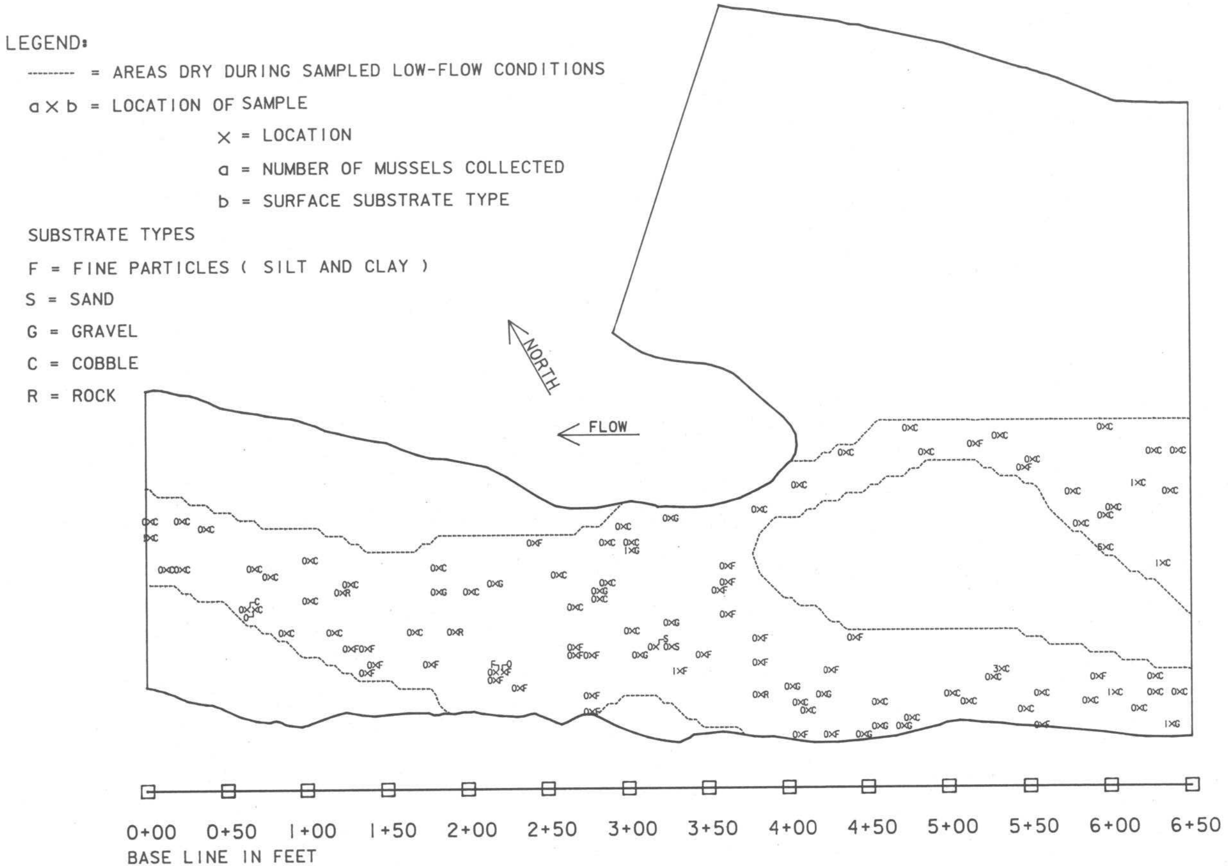


FIG. A-13. Total mussels collected and substrate type (surface) at each sample cell location for study reach NRM 27.8.

LEGEND:

--------- = AREAS DRY DURING SAMPLED LOW-FLOW CONDITIONS

a × b = LOCATION OF SAMPLE

× = LOCATION

a = NUMBER OF MUSSELS COLLECTED

b = SURFACE SUBSTRATE TYPE

SUBSTRATE TYPES

F = FINE PARTICLES (SILT AND CLAY)

S = SAND

G = GRAVEL

C = COBBLE

R = ROCK

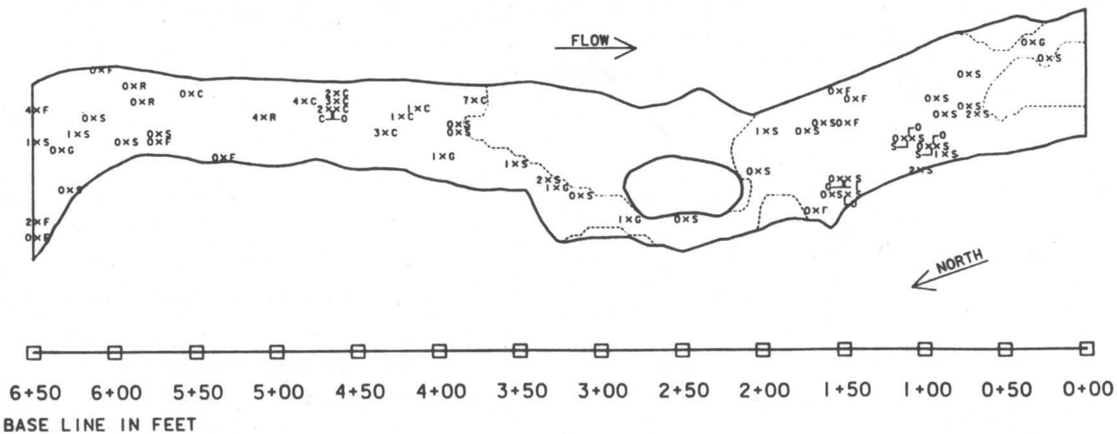


FIG. A-14. Total mussels collected and substrate type (surface) at each sample cell location for study reach PRRM 60.0.

LEGEND:

-------- = AREAS DRY DURING SAMPLED LOW-FLOW CONDITIONS

a × b = LOCATION OF SAMPLE

× = LOCATION

a = NUMBER OF MUSSELS COLLECTED

b = SURFACE SUBSTRATE TYPE

SUBSTRATE TYPES

F = FINE PARTICLES (SILT AND CLAY)

S = SAND

G = GRAVEL

C = COBBLE

R = ROCK

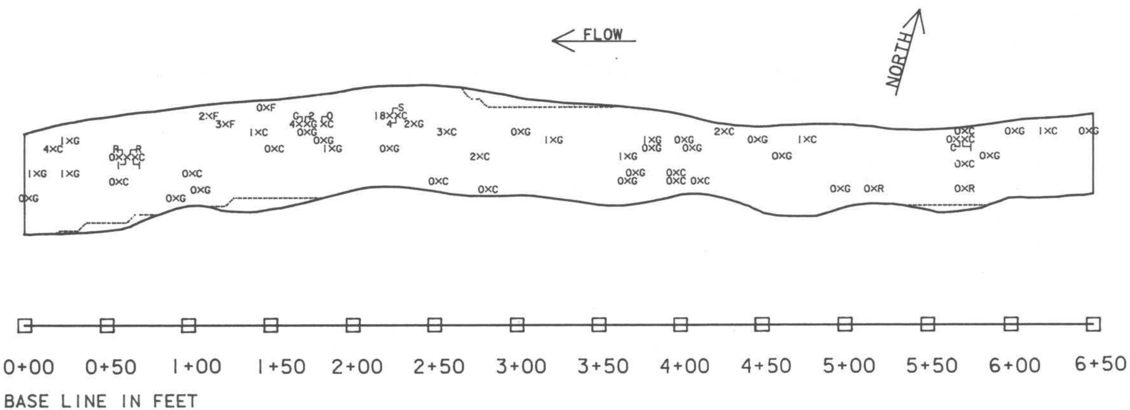


FIG. A-15. Total mussels collected and substrate type (surface) at each sample cell location for study reach CCRM 1.9.

TABLE A-1. Population estimates, with 95 percent confidence intervals, of mussel species occurring at each of the standard sampling sites.

Elk River
ERM 91.4

Species	Estimated no.	95% confidence limits Lower	Upper
Actinonaias pectorosa	1207.85	-1339.14	3754.84
Cyclonaias tuberculata	1158.84	-1241.83	3559.51
Fusconaia barnesiana	348.00	-1060.53	1756.53
Quadrula pustulosa	343.94	-1227.80	1915.68
Hemistena lata	232.00	-1080.39	1544.39
Lexingtonia dolabelloides	228.23	-1063.01	1519.47
Obovaria subrotunda	116.00	-812.00	1044.00
Medionidus conradicus	115.71	-809.97	1041.39
Elliptio dilatata	112.52	-787.64	1012.68
Lampsilis fasciola	112.23	-785.61	1010.07

Clinch River
Kyles Ford – CRM 189.5

Species	Estimated no.	95% confidence limits Lower	Upper
Actinonaias ligamentina	47045.42	35116.72	58973.32
Actinonaias pectorosa	17876.00	10403.44	25348.55
Ptychobranchus subtentum	8716.65	2994.05	14439.24
Medionidus conradicus	7072.30	1943.34	12201.26
Fusconaia subrotunda	3978.36	-75.21	8031.93
Elliptio dilatata	2880.19	-837.99	6598.36
Cyclonaias tuberculata	2676.24	-942.23	6294.71
Fusconaia cuneolus	2542.62	-982.17	6067.41
Lasmigona costata	1813.39	-1325.33	4952.12
Cumberlandia monodonta	1754.87	-1448.84	4958.58
Lampsilis fasciola	1517.73	-1271.00	4306.46
Lampsilis ovata	1498.24	-1389.83	4386.30
Ptychobranchus fasciolaris	1219.02	-1344.25	3782.30
Fusconaia barnesiana	864.35	-1466.44	3195.15
Quadrula cylindrica	790.75	-1475.74	3057.24
Epioblasma capsaeformis	780.72	-1320.73	2882.17
Villosa iris	771.26	-1543.61	3086.14
Amblema plicata	680.91	-1384.06	2745.88
Truncilla truncata	572.21	-1450.77	2595.19
Hemistena lata	562.01	-1414.39	2538.41
Cyprogenia stegaria	543.50	-1376.78	2463.79
Elliptio crassidens	337.48	-1208.47	1883.43
Pleurobema oviforme	336.98	-1221.13	1895.09
Plethobasus cyphyus	223.71	-1005.48	1452.91
Epioblasma triquetra	222.29	-1016.28	1460.87

TABLE A-1. (cont.).

Clinch River
Kyles Ford – CRM 189.5

Species	Estimated no.	95% confidence limits Lower	Upper
Quadrula pustulosa	221.56	-1033.16	1476.28
Ligumia recta	209.79	-919.34	1338.93
Villosa vanuxemensis	116.00	-812.00	1044.00
Epioblasma brevidens	113.10	-791.70	1017.90
Potamilus alatus	109.19	-736.62	955.01
Alasmidonta marginata	105.48	-711.58	922.55
Lemiox rimosus	102.39	-690.72	895.49
Pleurobema cordatum	102.39	-690.72	895.49

Clinch River
Fort Blackmore – CRM 227.4

Species	Estimated no.	95% confidence limits Lower	Upper
Actinonaias ligamentina	550.33	-1172.32	2272.98
Lasmigona costata	427.67	-1136.50	1991.84
Actinonaias pectorosa	328.70	-954.67	1612.08
Amblema plicata	107.08	-665.07	879.22
Cyprogenia stegaria	105.88	-596.43	808.18
Fusconaia barnesiana	101.69	-602.86	806.25
Ligumia recta	101.69	-602.86	806.25
Potamilus alatus	101.69	-602.86	806.25
Villosa vanuxemensis	101.69	-602.86	806.25

Duck River
Sowell Ford – DRM 159.4

Species	Estimated no.	95% confidence limits Lower	Upper
Lampsilis fasciola	566.39	-971.00	2103.78
Actinonaias ligamentina	116.00	-812.00	1044.00
Cyclonaias tuberculata	116.00	-812.00	1044.00
Lexingtonia dolabelloides	116.00	-812.00	1044.00
Medionidus conradicus	116.00	-812.00	1044.00

TABLE A-1. (cont.).

Duck River Lillard Mill – DRM 179.1			
Species		95% confidence limits	
	Estimated no.	Lower	Upper
Cyclonaias tuberculata	22993.98	13726.75	32261.22
Amblema plicata	14580.04	7926.77	21233.31
Quadrula pustulosa	10108.94	4147.20	16070.67
Lemiox rimosus	8272.66	2395.55	14149.77
Elliptio dilatata	3496.24	-235.46	7227.94
Lexingtonia dolabelloides	2685.40	-762.26	6133.06
Lampsilis fasciola	1873.40	-1409.07	5155.87
Tritogonia verrucosa	1513.10	-1373.92	4400.13
Truncilla truncata	1509.39	-1349.79	4368.57
Megalonaias nervosa	1394.55	-1642.59	4431.69
Potamilus alatus	1283.42	-1415.68	3982.52
Lasmigona costata	1165.10	-1572.46	3902.66
Leptodea fragilis	1050.26	-1417.81	3518.34
Fusconaia barnesiana	1046.55	-1510.25	3603.36
Quadrula cylindrica	591.14	-1169.89	2352.16
Villosa vanuxemensis	466.55	-1384.47	2317.57
Villosa iris	235.71	-1076.17	1547.60
Pleurobema cordatum	232.00	-1080.39	1544.39
Pleurobema oviforme	229.68	-844.19	1303.55
Epioblasma capsaeformis	154.67	-916.90	1226.23
Ptychobranchus fasciolaris	119.71	-807.57	1047.00
Actinonaias pectorosa	116.00	-812.00	1044.00
Lampsilis ovata	116.00	-812.00	1044.00
Obovaria subrotunda	114.84	-803.88	1033.56

Duck River Hall Mill – DRM 202.2			
Species		95% confidence limits	
	Estimated no.	Lower	Upper
Lexingtonia dolabelloides	232.00	-852.71	1316.71
Cyclonaias tuberculata	116.00	-812.00	1044.00
Lampsilis fasciola	116.00	-812.00	1044.00

Duck River Dement Bridge – DRM 243.1			
Species		95% confidence limits	
	Estimated no.	Lower	Upper
Lexingtonia dolabelloides	116.00	-812.00	1044.00

TABLE A-1. (cont.).

Buffalo River
BRM 79.9

Species	Estimated no.	95% confidence limits Lower	Upper
Potamilus alatus	232.00	-1080.39	1544.39

Powell River
Buchanan Ford – PRM 99.9

Species	Estimated no.	95% confidence limits Lower	Upper
Actinonaias pectorosa	22358.60	15453.71	29263.49
Actinonaias ligamentina	11367.12	6272.25	16461.98
Medionidus conradicus	9553.10	4160.18	14946.02
Elliptio dilatata	2472.48	-710.10	5655.07
Fusconaia subrotunda	1861.89	-1121.05	4444.84
Amblema plicata	1105.08	-1390.31	3600.47
Epioblasma capsaeformis	898.59	-1348.45	3145.62
Ptychobranchus fasciolaris	893.97	-1285.86	3073.81
Lampsilis ovata	889.34	-1318.53	3097.21
Epioblasma triquetra	781.84	-1213.80	2777.48
Ptychobranchus subtentum	667.97	-1380.26	2716.20
Cyclonaias tuberculata	338.89	-1009.67	1687.44
Leptodea fragilis	338.36	-995.72	1672.44
Ligumia recta	230.84	-1074.99	1536.67
Dromus dromas	229.97	-1070.95	1530.89
Lampsilis fasciola	222.72	-1017.33	1462.77
Lasmigona costata	222.72	-818.60	1264.04
Potamilus alatus	115.42	-807.94	1038.78
Epioblasma brevidens	114.55	-801.85	1030.95
Quadrula intermedia	114.55	-801.85	1030.95
Fusconaia barnesiana	107.30	-751.10	965.70
Pleurobema oviforme	107.30	-751.10	965.70

Powell River
Fletcher Fork – PRM 117.4

Species	Estimated no.	95% confidence limits Lower	Upper
Actinonaias pectorosa	10902.51	6874.36	14930.66
Actinonaias ligamentina	6686.13	3258.28	10113.99
Medionidus conradicus	3593.13	581.86	6604.40
Elliptio dilatata	2658.25	-95.00	5411.50
Epioblasma brevidens	2218.52	-151.56	4588.60

TABLE A-1. (cont.).

Powell River
Fletcher Fork – PRM 117.4

Species	Estimated no.	95% confidence limits Lower	Upper
Fusconaia subrotunda	2032.75	-382.66	4448.15
Lasmigona costata	1283.23	-707.82	3274.29
Epioblasma triquetra	841.07	-1147.17	2829.31
Potamilus alatus	743.57	-1049.30	2536.45
Epioblasma capsaeformis	651.93	-972.39	2276.26
Leptodea fragilis	604.39	-1073.50	2282.28
Cyclonaias tuberculata	563.14	-873.82	2000.10
Lampsilis ovata	536.71	-956.03	2029.45
Fusconaia barnesiana	290.63	-769.54	1350.81
Amblema plicata	278.63	-920.46	1477.72
Ptychobranchus fasciolaris	267.28	-872.51	1407.07
Fusconaia cuneolus	107.34	-724.10	938.78
Plethobasus cyphyus	107.34	-724.10	938.78
Villosa iris	107.34	-724.10	938.78
Dromus dromas	90.33	-609.33	789.98
Quadrula intermedia	90.33	-609.33	789.98
Ligumia recta	83.91	-497.42	665.23
Quadrula cylindrica	83.91	-497.42	665.23
Lampsilis fasciola	81.83	-460.98	624.65
Ptychobranchus subtentum	81.83	-460.98	624.65

North Fork Holston River
Click Island – NFHRM 6.2

Species	Estimated no.	95% confidence limits Lower	Upper
Lampsilis fasciola	4459.25	232.32	8686.18
Lampsilis ovata	2317.84	-887.35	5523.02
Villosa iris	1143.00	-1101.15	3387.14
Pleurobema oviforme	116.00	-812.00	1044.00
Villosa vanuxemensis	116.00	-812.00	1044.00
Amblema plicata	83.52	-584.64	751.68
Fusconaia barnesiana	83.52	-584.64	751.68

North Fork Holston River
Saltville – NFHRM 85.2

Species	Estimated no.	95% confidence limits Lower	Upper
Medionidus conradicus	14842.00	9742.61	19941.40

TABLE A-1. (cont.).

North Fork Holston River
Saltville – NFHRM 85.2

Species	Estimated no.	95% confidence limits Lower	Upper
Villosa iris	4178.46	979.81	7377.11
Fusconaia cor	1019.40	-988.31	3027.11
Lampsilis fasciola	999.74	-1013.53	3013.01
Pleurobema oviforme	961.66	-1280.70	3204.02
Villosa vanuxemensis	624.69	-1197.40	2446.77
Ptychobranchus subtentum	573.43	-1098.70	2245.55
Actinonaias pectorosa	350.23	-908.90	1609.36
Ptychobranchus fasciolaris	283.26	-990.41	1556.93
Fusconaia barnesiana	239.50	-1046.68	1525.67

Nolichucky River
NRM 27.8

Species	Estimated no.	95% confidence limits Lower	Upper
Lampsilis fasciola	300.39	-909.64	1510.41
Cyclonaias tuberculata	285.90	-578.22	1150.01
Elliptio dilatata	223.67	-707.87	1155.21
Potamilus alatus	223.67	-707.87	1155.21
Amblema plicata	190.60	-609.05	990.24
Ptychobranchus fasciolaris	128.37	-500.52	757.27
Lampsilis ovata	115.38	-778.36	1009.12
Actinonaias ligamentina	95.30	-591.91	782.51

Paint Rock River
PRRM 60.0

Species	Estimated no.	95% confidence limits Lower	Upper
Villosa iris	1663.04	-465.59	3791.68
Fusconaia barnesiana	804.04	-732.16	2340.23
Medionidus conradicus	785.52	-911.93	2482.96
Obovaria subrotunda	391.09	-432.34	1214.51
Lampsilis fasciola	302.53	-848.60	1453.65
Villosa vanuxemensis	287.48	-887.43	1462.39
Ptychobranchus fasciolaris	232.00	-852.71	1316.71
Pleurobema oviforme	194.22	-821.90	1210.33
Lampsilis ovata	84.51	-547.93	716.96
Toxolasma lividus	78.22	-335.67	492.10

TABLE A-1. (cont.).

Species	Copper Creek CCRM 1.9		
		95% confidence limits	
	Estimated no.	Lower	Upper
Villosa perpurpurea	1815.40	-824.56	4455.36
Medionidus conradicus	875.74	-1095.77	2847.26
Villosa iris	804.75	-1188.45	2797.95
Elliptio dilatata	699.48	-1014.21	2413.17
Fusconaia barnesiana	508.08	-881.12	1897.28
Fusconaia cuneolus	338.66	-1097.02	1774.34
Epioblasma capsaeformis	318.42	-759.81	1396.65
Lampsilis fasciola	317.55	-1151.18	1786.28
Pleurobema oviforme	218.66	-1018.79	1456.11
Fusconaia cor	197.78	-726.94	1122.50

TABLE A-2. Relative abundance (number/m^2) of mussel species collected at the fifteen standard sampling sites, 1981. C = Cumberlandian species, E = endangered species, T = less than .005.

Species	Status	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Cumberlandia monodonta		—	0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
Amblema plicata		—	0.02	0.01	—	0.66	—	—	—	0.08	0.03	T	—	0.02	—	—
Fusconaia barnesiana	C	0.02	0.03	T	—	0.05	—	—	—	0.01	0.03	T	0.02	—	0.14	0.08
Fusconaia cuneolus	CE	—	0.09	—	—	—	—	—	—	—	0.01	—	—	—	—	0.05
Fusconaia subrotunda		—	0.14	—	—	—	—	—	—	0.12	0.21	—	—	—	—	—
Fusconaia cor	CE	—	—	—	—	—	—	—	—	—	—	—	0.10	—	—	0.03
Quadrula cylindrica		—	0.03	—	—	0.03	—	—	—	—	0.01	—	—	—	—	—
Quadrula intermedia	CE	—	—	—	—	—	—	—	—	0.01	0.01	—	—	—	—	—
Quadrula pustulosa		0.02	0.01	—	—	0.46	—	—	—	—	—	—	—	—	—	—
Tritogonia verrucosa		—	—	—	—	0.07	—	—	—	—	—	—	—	—	—	—
Megalonaias nervosa		—	—	—	—	0.06	—	—	—	—	—	—	—	—	—	—
Cyclonaias tuberculata		0.07	0.09	—	0.01	1.04	0.01	—	—	0.02	0.06	—	—	0.02	—	—
Elliptio crassidens		—	0.01	—	—	—	—	—	—	—	—	—	—	—	—	—
Elliptio dilatata		0.01	0.10	—	—	0.16	—	—	—	0.18	0.27	—	—	0.02	—	0.11
Hemistena lata	E	0.01	0.02	—	—	—	—	—	—	—	—	—	—	—	—	—
Lexingtonia dolabelloides	C	0.01	—	—	0.01	0.12	0.02	0.01	—	—	—	—	—	—	—	—
Plethobasus cyphyus		—	0.01	—	—	—	—	—	—	—	0.01	—	—	—	—	—
Pleurobema cordatum		—	T	—	—	0.01	—	—	—	—	—	—	—	—	—	—
Pleurobema oviforme	C	—	0.02	—	—	0.02	—	—	—	0.01	—	0.01	0.10	—	0.03	0.03
Alasmidonta marginata		—	T	—	—	—	—	—	—	—	—	—	—	—	—	—
Lasmigona costata		—	0.06	0.02	—	0.05	—	—	—	0.02	0.13	—	—	—	—	—
Actinonaias ligamentina		—	1.65	0.03	0.01	—	—	—	—	0.84	0.69	—	—	0.01	—	—
Actinonaias pectorosa	C	0.07	0.63	0.02	—	0.01	—	—	—	1.65	1.12	—	0.04	—	—	—
Toxolasma lividus	C	—	—	—	—	—	—	—	—	—	—	—	—	—	0.01	—
Epioblasma brevidens	C	—	0.01	—	—	—	—	—	—	0.01	0.23	—	—	—	—	—
Epioblasma capsaeformis	C	—	0.03	—	—	0.01	—	—	—	0.07	0.07	—	—	—	—	0.05
Epioblasma triquetra		—	0.01	—	—	—	—	—	—	0.06	0.09	—	—	—	—	—
Lampsilis fasciola		0.01	0.05	—	0.04	0.08	0.01	—	—	0.02	0.01	0.20	0.10	0.03	0.05	0.05
Lampsilis ovata		—	0.05	—	—	0.01	—	—	—	0.07	0.06	0.10	—	0.01	0.01	—
Leptodea fragilis		—	—	—	—	0.05	—	—	—	0.02	0.06	—	—	—	—	—
Ligumia recta		—	0.01	T	—	—	—	—	—	0.02	0.01	—	—	—	—	—
Medionidus conradicus	C	0.01	0.25	—	0.01	—	—	—	—	0.70	0.37	—	1.51	—	0.13	0.14
Obovaria subrotunda		0.01	—	—	—	0.01	—	—	—	—	—	—	—	—	0.07	—
Potamilus alatus		—	T	T	—	0.06	—	—	0.02	0.01	0.08	—	—	0.02	—	—
Truncilla truncata		—	0.02	—	—	0.07	—	—	—	—	—	—	—	—	—	—
Villosa iria	C	—	0.03	—	—	0.02	—	—	—	—	0.01	0.05	0.43	—	0.28	0.13
Villosa vanuxemensis	C	—	0.01	T	—	0.02	—	—	—	—	—	0.01	0.06	—	0.05	—
Villosa perpurpurea	C	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.28
Cyprogenia stegaria	E	—	0.02	0.01	—	—	—	—	—	—	—	—	—	—	—	—
Dromus dromas	CE	—	—	—	—	—	—	—	—	0.02	0.01	—	—	—	—	—
Ptychobranchus fasciolaris		—	0.04	—	—	0.01	—	—	—	0.07	0.03	—	0.03	0.01	0.04	—
Ptychobranchus subtentum	C	—	0.31	—	—	—	—	—	—	0.05	0.01	—	0.06	—	—	—
Lemiox rimosus	CE	—	T	—	—	0.37	—	—	—	—	—	—	—	—	—	—

TABLE A-3. Mean numbers per square-foot of bottom fauna organisms collected at fifteen standard sampling sites. Samples were collected with an unmodified Surber Square-foot Sampler on a quarterly basis from July 1980 through 1981.

Species	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Nematoda	—	0.13	0.31	0.17	—	—	0.06	—	0.13	—	—	—	0.13	0.08	—
Turbellaria															
Tricladida															
Planariidae	—	—	—	—	—	—	—	0.08	—	—	—	—	—	—	—
Dugesia tigrina	—	—	1.56	—	0.88	—	—	—	—	—	—	—	—	—	0.08
Oligochaeta	—	0.25	0.38	—	—	—	—	0.17	—	—	0.25	—	0.63	—	—
Plesiopora															
Tubificidae	1.38	3.94	0.38	1.42	1.31	0.63	0.50	—	0.94	0.19	0.75	0.63	0.44	1.58	0.33
Branchiura sowerbyi	—	0.13	—	0.58	—	0.06	—	—	0.19	—	—	—	—	—	—
Naididae	—	—	—	—	—	—	—	0.17	—	—	—	—	—	—	—
Prosopora															
Branchiobdellidae	—	—	—	—	—	—	—	—	—	—	—	0.06	—	—	—
Lumbriculidae	0.88	0.44	3.25	0.42	—	0.13	0.19	0.08	1.44	0.06	0.63	0.19	0.88	1.42	0.08
Hirudinea	—	—	—	—	—	—	—	—	—	—	—	—	0.06	—	—
Rhynchobdellidae															
Glossiphoniidae	—	—	—	—	0.06	—	—	—	—	—	0.06	—	—	—	—
Clitellata															
Haplotaxida	—	0.19	0.81	—	—	—	0.06	—	—	—	0.38	—	0.56	—	—
Crustacea															
Isopoda															
Lirceus sp.	—	—	—	—	0.06	—	—	0.33	0.06	—	—	—	0.13	—	0.08
Amphipoda															
Gammarus sp.	—	0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
Crangonyx sp.	0.13	—	—	—	0.06	0.06	0.06	—	—	—	—	—	—	—	—
Decapoda	—	—	—	—	—	—	—	—	—	—	—	0.06	—	—	—
Cambarus sp.	—	—	0.06	—	—	—	0.06	—	—	—	—	0.69	—	—	0.25
Orconectes sp.	—	0.13	0.13	—	—	0.31	0.13	—	—	0.13	0.25	0.06	—	0.17	0.08
Insecta															
Plecoptera															
Pteronarcys sp.	—	—	0.06	—	—	—	—	0.08	—	—	—	—	—	—	—
Taeniopteryx sp.	—	8.06	12.63	—	—	—	—	0.75	3.00	0.63	10.75	2.00	28.19	3.25	2.58
Brachyptera sp.	—	5.00	4.81	—	—	—	0.19	—	4.94	2.38	2.19	1.88	13.13	0.50	0.33
Nemoura sp.	0.13	—	—	0.17	0.06	0.31	—	—	—	—	0.31	—	—	—	—
Capniidae	0.13	—	—	0.17	0.06	0.31	—	—	—	—	0.31	—	—	—	—
Allocapnia sp.	—	—	—	—	—	—	—	0.42	—	—	0.06	—	—	—	—
Perlidae	—	0.44	—	1.08	0.25	0.31	—	—	0.13	—	—	—	—	—	—
Acroneuria sp.	—	0.75	0.56	—	—	0.06	—	—	2.00	—	1.00	0.31	—	—	0.42
Neoperla sp.	—	0.13	—	0.42	1.50	1.13	0.50	1.33	—	—	1.00	3.19	—	—	0.25
Phasganophora sp.	—	0.50	2.00	0.83	1.75	0.13	—	0.25	1.25	0.44	1.19	—	—	—	0.25

TABLE A-3. (cont.)

Species	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Phasganophora capitata	—	—	0.88	—	—	0.31	—	—	—	0.06	1.25	—	—	—	—
Perlesta sp.	—	—	—	0.67	0.13	0.50	—	—	—	—	—	—	—	—	—
Perlesta placida	—	0.25	5.88	—	0.38	1.69	—	0.08	0.31	0.63	2.75	—	0.19	0.25	0.83
Isogenus sp.	—	—	0.13	—	—	—	—	—	—	—	—	—	—	—	—
Isogenus bilobatus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.08
Isoperla sp.	—	—	0.06	—	—	—	—	—	0.06	0.13	0.06	—	—	—	0.17
Chloroperlidae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.08
Odonata															
Gomphidae	—	—	—	—	—	—	—	—	—	0.25	—	—	—	—	—
Dromogomphus sp.	—	—	—	—	—	—	—	—	—	0.25	—	—	—	—	—
Gomphus sp.	—	0.06	—	—	—	—	—	—	0.06	0.06	—	—	—	0.08	—
Hagenius brevistylus	—	—	—	—	—	—	—	—	—	—	—	—	—	0.08	—
Lanthus parvulus	—	0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
Stylogomphus albistylus	—	—	—	—	—	0.06	—	—	—	—	—	—	—	—	—
Boyeria sp.	—	—	—	—	—	—	—	—	—	—	0.06	—	—	0.08	—
Hetaerina sp.	—	—	0.19	—	—	—	—	—	—	—	0.13	—	—	—	—
Coenagrionidae	—	0.06	—	—	—	—	—	0.08	—	—	0.25	0.19	0.06	0.08	—
Argia sp.	—	0.75	0.31	0.17	0.06	0.06	—	0.25	—	0.06	0.44	0.06	0.25	0.25	0.08
Ephehemeroptera															
Ephemeridae	—	—	—	—	—	0.06	—	—	—	—	—	—	—	—	—
Ephemera sp.	—	—	—	—	—	—	—	—	—	0.06	—	2.94	—	—	0.25
Ephoron sp.	—	0.38	0.19	—	0.06	—	—	—	0.06	—	0.06	0.44	1.00	—	—
Hexagenia sp.	—	0.75	—	—	—	—	—	—	—	—	—	1.69	0.06	0.08	—
Potamanthus sp.	—	2.00	0.38	7.83	8.25	5.00	—	0.42	—	—	5.00	—	—	0.17	—
Caenis sp.	—	0.63	—	—	—	—	0.44	0.25	0.31	0.06	0.56	0.50	—	0.08	—
Tricorythodes sp.	—	—	0.06	—	—	0.06	—	—	—	0.06	—	—	—	—	—
Ephemerella sp.	0.75	1.63	20.56	2.33	1.38	2.00	0.31	11.08	5.19	5.88	2.06	0.63	29.38	13.42	3.75
Baetisca sp.	—	—	—	—	—	—	—	0.33	—	—	—	—	—	0.17	—
Leptophlebiidae	—	0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
Paraleptophlebia sp.	—	—	—	—	—	—	—	—	—	—	—	3.38	—	0.17	—
Baetidae	—	0.06	—	—	—	—	0.19	—	1.00	—	—	—	—	—	—
Baetis sp.	0.13	0.38	1.19	1.00	0.06	0.69	0.31	—	0.94	0.81	0.13	0.56	2.50	0.92	0.17
Heterocloeon sp.	—	1.81	—	—	—	—	—	—	—	0.06	0.94	—	0.06	—	—
Pseudocloeon sp.	—	0.13	1.38	—	—	—	0.06	0.08	0.25	0.06	1.13	2.69	0.81	0.58	1.75
Isonychia sp.	—	21.44	30.00	0.08	—	—	0.94	0.08	36.63	20.81	1.00	21.81	29.13	0.08	14.25
Heptageniidae	—	—	—	—	—	—	—	—	—	—	—	0.63	—	—	—
Epeorus sp.	—	—	—	—	—	—	—	—	—	—	—	0.56	—	—	0.17
Heptagenia sp.	—	—	—	—	—	—	—	—	—	—	—	1.13	—	—	—
Rhithrogena sp.	—	—	—	0.58	0.38	0.38	—	0.08	—	0.13	—	—	—	—	—
Stenonema sp.	1.25	13.00	14.00	1.75	1.56	1.63	3.44	4.42	8.19	10.19	2.56	31.31	43.31	3.67	16.42

TABLE A-3. (cont.)

Species	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Stenacron sp.	—	2.25	0.06	—	0.50	0.69	0.38	0.33	—	0.19	0.38	8.56	0.25	—	1.00
Cinygmula sp.	—	—	—	—	—	—	—	—	—	—	—	0.50	—	—	—
Trichoptera															
Agapetus sp.	—	—	—	—	0.13	—	—	—	—	—	—	—	—	0.92	—
Glossosoma sp.	—	—	0.06	0.42	0.69	0.63	—	—	—	—	—	0.25	—	0.42	0.92
Rhyacophila sp.	—	—	—	—	—	—	0.06	—	—	0.06	—	—	—	1.50	—
Chimarra sp.	—	—	—	—	—	—	—	—	—	—	0.81	6.44	—	—	14.08
Neureclipsis sp.	—	0.06	—	—	0.06	—	—	0.08	—	—	0.06	—	—	—	—
Polycentropus sp.	—	—	—	—	—	0.06	—	0.08	0.13	—	0.06	—	—	—	0.08
Psychomyia sp.	0.13	—	0.06	0.08	—	0.06	—	1.08	—	—	—	—	—	—	0.08
Hydropsychidae	—	0.19	—	0.08	—	—	0.19	—	—	—	—	—	0.19	—	0.50
Cheumatopsyche sp.	0.25	8.63	31.56	1.58	4.25	0.38	4.63	3.50	14.00	8.63	6.69	5.81	23.19	0.75	20.25
Cheumatopsyche btrona	—	3.00	16.19	0.17	0.88	0.19	—	—	4.88	2.56	1.25	—	0.19	—	0.50
Hydropsyche sp.	—	2.63	27.06	1.25	1.31	0.19	6.38	0.75	4.38	4.88	5.88	6.38	3.31	—	10.58
Macronema zebratum	—	—	0.06	—	—	—	—	—	—	—	—	—	—	—	—
Potamyia flava	—	—	—	—	—	—	—	—	—	—	—	—	0.06	—	—
Hydroptila sp.	0.13	0.19	3.63	0.92	—	—	—	13.33	0.75	—	0.06	—	—	0.33	0.17
Ochrotrichia sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	0.42	—
Pycnopsyche sp.	—	—	—	—	—	0.06	—	—	—	—	—	—	—	0.08	—
Athripsodes sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	0.17	—
Oecetis sp.	—	0.06	—	—	0.13	—	—	—	—	—	—	—	—	—	—
Triaenodes sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	0.08	—
Brachycentrus americanus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.08
Brachycentrus lateralis	—	—	—	—	—	—	—	—	—	—	0.94	—	—	—	—
Micrasema sp.	—	—	—	—	—	—	—	0.33	—	—	—	—	—	2.25	—
Helicopsyche borealis	—	—	—	—	—	—	—	—	—	—	—	0.06	—	—	—
Megaloptera															
Sialis sp.	—	0.19	—	0.08	0.06	—	0.06	0.08	—	0.06	0.13	—	—	—	0.08
Corydalus cornutus	—	3.44	3.19	—	—	—	—	0.33	3.69	0.75	1.88	1.00	5.00	—	0.50
Nigronia sp.	—	0.06	—	0.08	—	—	0.06	—	0.25	0.06	0.06	0.06	0.06	—	0.08
Lepidoptera	—	—	0.13	0.08	0.44	—	—	0.17	0.06	—	0.75	—	—	—	—
Diptera	—	0.13	—	—	—	—	—	—	0.06	—	—	—	—	0.08	—
Simuliidae	—	—	—	0.08	—	—	0.25	—	—	—	—	—	—	—	—
Simulium sp.	—	—	3.75	0.08	—	—	1.25	—	3.69	0.94	113.56	0.44	1.81	3.50	0.08
Blephariceridae	—	0.06	—	—	—	—	—	—	—	—	—	3.19	0.13	—	0.08
Tipulidae	—	0.19	0.06	—	—	0.69	—	0.08	0.06	0.06	0.13	0.19	—	0.08	0.08
Eriocera sp.	—	—	—	—	0.13	—	—	—	—	—	—	—	—	—	—
Tipula sp.	—	—	0.75	—	—	—	—	—	—	—	0.13	0.06	0.88	2.33	0.42
Tipula abdominalis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.08
Antocha sp.	—	0.06	0.06	—	—	—	0.19	2.42	0.06	0.25	—	0.13	0.06	—	—

TABLE A-3. (cont.)

Species	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Protoplasa sp.	—	—	0.06	—	—	—	—	—	—	—	—	—	—	—	—
Ceratopogonidae	—	—	—	—	—	0.06	—	—	—	—	—	—	—	—	—
Chironomidae	4.75	10.19	65.94	4.17	5.06	0.88	7.13	14.25	31.88	65.19	19.69	7.19	66.31	11.33	9.08
Ablabesmyia sp.	—	—	—	—	0.31	—	—	—	—	—	—	—	—	—	—
Chironomus sp.	—	—	—	—	0.13	—	—	—	—	—	—	—	—	—	—
Clinotanypus sp.	—	—	—	—	0.25	—	—	—	—	—	—	—	—	—	—
Coelotanypus sp.	—	—	—	—	0.06	—	—	—	—	—	—	—	—	—	—
Conchapelopis sp.	—	—	—	0.17	—	—	—	—	—	—	—	—	—	—	—
Cricotopus sp.	—	—	—	—	0.06	—	—	—	—	—	—	—	—	—	—
Cryptochironomus sp.	—	—	—	0.25	—	0.06	—	—	—	—	—	—	—	—	—
Dicrotendipes sp.	—	—	—	0.08	—	—	—	—	—	—	—	—	—	—	—
Endochironomus sp.	—	—	—	0.08	—	—	—	—	—	—	—	—	—	—	—
Microtendipes sp.	—	—	—	—	—	0.06	—	0.17	0.06	—	0.44	0.13	0.06	—	—
Polypedilum sp.	—	—	—	1.00	0.25	—	0.13	—	0.06	0.06	0.50	0.06	0.06	0.08	—
Stratiomyiidae	—	—	—	—	—	—	—	—	—	—	—	—	—	0.75	—
Atherix sp.	—	—	—	—	—	—	—	—	0.31	—	—	—	—	—	0.08
Atherix variegata	—	0.38	0.44	—	—	—	0.25	—	0.88	0.69	1.00	2.19	0.06	—	0.17
Empididae	—	0.06	0.69	—	—	—	—	0.17	0.19	0.25	—	—	—	—	0.08
Hemerodromia sp.	—	—	—	—	—	—	—	—	—	0.06	0.06	—	—	—	—
Coleoptera															
Berosus sp.	—	—	0.06	—	—	—	—	—	—	—	0.06	—	—	0.33	—
Helichus sp.	—	—	0.25	—	—	—	—	—	—	—	0.06	—	0.06	0.92	—
Elmidae	—	0.31	—	—	—	—	0.44	—	—	—	0.06	0.06	—	0.33	—
Ancryonyx variegatus	—	0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
Dubiraphia sp.	—	0.13	0.19	—	—	—	—	—	0.13	—	0.69	—	—	0.83	—
Macronychus sp.	—	—	0.25	—	—	—	—	0.08	0.38	0.25	0.13	0.13	0.13	0.17	—
Macronychus glabratus	—	0.06	—	—	—	—	—	—	—	0.06	—	—	—	—	—
Microcylloepus sp.	—	0.06	—	—	—	—	—	—	—	0.06	—	—	—	0.33	—
Microcylloepus pusillus	—	—	0.38	0.08	—	—	—	—	—	—	—	—	—	1.08	—
Optioservus sp.	2.25	—	0.25	—	—	—	—	1.08	0.88	0.81	0.63	0.81	—	0.33	4.17
Optioservus trivittatus	—	0.06	—	—	—	—	—	—	—	—	1.81	0.81	—	—	—
Promoresia sp.	0.13	—	0.06	—	—	—	—	1.33	—	—	—	—	—	—	—
Stenelmis sp.	1.13	11.13	13.25	5.33	10.63	5.00	1.94	0.92	21.44	8.13	14.88	8.13	1.63	3.33	2.00
Oulimnius sp.	—	—	0.88	—	0.06	—	0.06	1.00	0.50	1.31	0.81	3.31	0.56	—	4.92
Ectoparia sp.	—	—	—	—	—	0.06	—	0.08	0.06	—	—	—	—	0.75	—
Psephenus sp.	0.13	2.63	0.50	—	0.44	2.50	0.25	0.58	0.19	0.19	4.25	6.81	0.25	1.08	8.00
Gastropoda															
Mesogastropoda															
Amnicola sp.	—	—	—	—	—	—	—	—	—	—	1.31	—	—	31.17	—

TABLE A-3. (cont.)

Species	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Somatogyrus sp.	—	—	—	0.08	0.13	—	—	—	—	—	—	—	—	—	—
Pleurocera sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	0.50	—
Pleurocera canaliculatum	—	—	—	—	0.63	0.13	—	—	—	—	—	—	—	—	—
Pleurocera unciale	—	1.13	1.31	—	—	—	—	—	1.56	0.88	4.56	1.50	1.63	—	0.75
Elimia sp.	0.25	—	—	—	0.13	1.44	0.19	—	—	0.06	—	—	—	1.75	—
Elimia laqueata	—	—	—	—	0.19	0.25	—	—	—	—	—	—	—	—	—
Lithasia geniculata	—	—	—	0.50	0.44	2.94	0.13	0.17	—	—	—	—	—	—	—
Lithasia verrucosa	3.75	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Leptoxis praerosa	1.88	5.00	14.63	0.75	0.69	1.25	—	—	14.88	10.25	13.63	20.19	0.75	—	15.00
Io fluvialis	—	—	—	—	—	—	—	—	0.13	0.06	—	—	—	—	—
Basommatophora															
Lymnaea sp.	—	0.06	—	—	—	—	—	—	0.44	—	0.63	—	—	1.08	—
Ferrissia sp.	—	0.06	0.25	0.08	—	—	0.06	0.25	—	0.13	1.19	0.31	0.06	0.50	0.50
Gyraulus sp.	—	—	—	—	—	—	—	—	—	—	0.13	—	—	—	—
Physa sp.	—	—	0.19	—	—	—	—	—	0.25	0.06	1.50	—	0.50	—	—
Bivalvia															
Corbiculoidea															
Corbiculidae															
Corbicula fluminea	4.88	7.63	6.56	9.50	7.56	8.88	10.06	1.92	3.63	4.31	3.31	—	31.06	5.92	0.08
Sphaeriidae															
Sphaerium sp.	—	0.13	—	—	—	—	—	—	1.19	0.06	—	0.25	0.13	0.50	—
Psidium sp.	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.25	—
Unionoidea															
Unionidae															
Fusconaia cuneolus	—	0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
Cyclonaias tuberculata	—	—	—	—	0.06	—	—	—	—	—	—	—	—	—	—
Actinonaias ligamentina	—	—	—	0.25	—	—	—	—	—	—	—	—	—	—	—
Actinonaias pectorosa	—	—	—	—	—	—	—	—	0.06	—	—	—	—	—	—
Epioblasma triquetra	—	—	—	—	—	—	—	—	0.06	—	—	—	—	—	—
Lampsilis fasciola	—	—	—	0.08	—	—	—	—	—	—	—	—	—	—	—

TABLE A-4. Benthic macroinvertebrate species occurrence at the fifteen standard sampling sites. Data are based on both qualitative and quantitative samples.

Species	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Nematoda		+	+	+			+		+			+	+	+	
Turbellaria															
Tricladida															
Planariidae									+						
Dugesia tigrina			+		+							+			+
Oligochaeta		+	+				+	+			+		+		
Plesiopora															
Tubificidae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Branchiura sowerbyi		+		+		+		+	+						
Naididae								+							
Prosopora															
Branchiobdellidae												+			
Lumbriculidae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Hirudinea													+		
Rhynchobdellidae															
Glossiphoniidae					+						+	+			
Pharyngobdellida															
Clitellata															
Haplotaxida	+	+	+				+				+		+		
Crustacea															
Isopoda															
Asellus sp.							+								
Lirceus sp.	+				+			+	+				+		+
Amphipoda															
Hyalella azteca				+	+	+						+			
Gammarus sp.		+													
Crangonyx sp.	+				+	+	+								
Decapoda												+			
Cambarus sp.			+	+			+		+		+	+	+		+
Orconectes sp.	+	+	+	+	+	+	+		+	+	+	+	+	+	+
Insecta															
Plecoptera															
Pteronarcys sp.	+	+	+	+	+			+	+	+	+		+		
Taeniopteryx sp.	+	+	+	+	+		+	+	+	+	+	+	+	+	+
Brachyptera sp.		+	+				+		+	+	+	+	+	+	+
Nemoura sp.			+				+	+			+	+	+	+	+
Capniidae	+			+	+	+					+				+
Allocapnia sp.								+			+				
Perlidae		+		+	+	+			+		+				

TABLE A-4. (cont.)

Species	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Acroneuria sp.		+	+			+			+		+	+			+
Neoperla sp.		+		+	+	+	+	+		+	+	+			+
Phasganophora sp.		+	+	+	+	+	+	+	+	+	+		+		+
Phasganophora capitata			+			+				+	+				
Perlesta sp.				+	+	+									
Perlesta placida		+	+		+	+		+	+	+	+		+	+	+
Isogenus sp.			+												
Isogenus bilobatus															+
Isoperla sp.		+	+				+		+	+	+				+
Chloroperlidae		+	+				+		+	+	+				+
Odonata															
Gomphidae						+	+			+					
Orogomphus sp.					+										
Dromogomphus spinosus		+													
Gomphus sp.		+	+	+					+	+				+	
Hagenius brevistylus		+		+		+								+	
Lanthus parvulus		+						+							
Ophiogomphus rupinsulensis					+	+									
Progomphus sp.					+										
Stylogomphus albistylus						+									
Basiaeschna janata			+			+		+		+					
Boyeria sp.		+	+			+		+	+	+	+	+		+	
Boyeria vinosa													+		
Ladona sp.					+										
Macromia sp.		+	+	+	+	+		+			+				
Neurocordulia yamaskanensis						+									
Calopteryx sp.						+		+						+	+
Hetaerina sp.		+	+	+	+	+					+				
Coenagrionidae		+	+	+	+	+		+	+	+	+	+	+	+	
Argia sp.		+	+	+	+	+		+		+	+	+	+	+	+
Enallagma sp.			+	+											
Ischnura sp.					+	+									
Macromiidae						+									
Ephemeroptera															
Ephemeridae			+			+									
Ephemera sp.	+									+		+	+		+
Ephoron sp.		+	+		+				+		+	+	+		
Hexagenia sp.		+										+	+	+	
Potamanthus sp.		+	+	+	+	+		+		+	+	+		+	
Caenis sp.		+	+	+			+	+	+	+	+	+		+	+

TABLE A-4. (cont.)

Species	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Tricorythodes sp.			+			+				+					
Ephemerella sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ephemerella lata														+	
Ephemerella septentrionalis															+
Baetisca sp.						+	+						+		
Leptophlebiidae		+	+				+					+			
Mabrophlebiodes sp.		+													
Leptophlebia sp.			+		+	+		+							
Paraleptophlebia sp.												+		+	
Baetidae		+					+		+						
Baetis sp.	+	+	+	+	+	+	+		+	+	+	+	+	+	+
Heterocloeon sp.		+								+	+		+		
Pseudocloeon sp.		+	+				+	+	+	+	+	+	+	+	+
Siphlonura sp.															+
Isonychia sp.		+	+	+	+	+	+	+	+	+	+	+	+	+	+
Heptageniidae								+				+			
Epeorus sp.												+			+
Heptagenia sp.												+			
Rhithrogena sp.				+	+	+		+		+					
Stenonema sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Stenacron sp.		+	+		+	+	+	+	+	+	+	+	+	+	+
Cinygmula sp.												+			
Siphlonuridae								+							
Hemiptera															
Corixidae					+										
Belostomatidae									+						
Belostoma sp.					+	+									
Rhagovelia sp.					+		+								
Trichoptera															
Agapetus sp.					+									+	
Glossosoma sp.			+	+	+	+						+		+	+
Rhyacophila sp.							+			+				+	
Chimarra sp.											+	+		+	+
Neureclipsis sp.		+			+			+			+				
Polycentropus sp.						+	+	+	+		+	+		+	+
Psychomyia sp.	+		+	+		+		+							+
Hydropsychidae		+		+			+						+		+
Cheumatopsyche sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cheumatopsyche btrona		+	+	+	+	+			+	+	+		+		+
Hydropsyche sp.		+	+	+	+	+	+	+	+	+	+	+	+		+

TABLE A-4. (cont.)

Species	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Macronema zebratum			+												
Potamyia flava													+		
Hydroptila sp.	+	+	+	+				+	+	+	+		+	+	+
Ochrotrichia sp.												+		+	
Ironoquia sp.														+	
Pycnopsyche sp.		+	+		+	+		+						+	
Leptoceridae													+	+	+
Athripsodes sp.									+					+	
Oecetis sp.		+			+			+						+	
Triaenodes sp.														+	
Lepidostoma sp.															+
Brachycentrus sp.											+				
Brachycentrus americanus															+
Brachycentrus lateralis											+				
Micrasema sp.								+						+	
Helicopsyche borealis												+			
Goera sp.														+	
Megaloptera															
Sialis sp.		+	+	+	+		+	+	+	+	+		+	+	+
Corydalus cornutus		+	+	+	+	+	+	+	+	+	+	+	+		+
Nigronia sp.		+		+			+		+	+	+	+	+		+
Lepidoptera			+	+	+			+	+		+				
Diptera		+							+			+		+	
Simuliidae				+			+								
Simulium sp.	+	+	+			+	+	+	+	+	+	+	+	+	
Blephariceridae		+										+	+		+
Tipulidae		+	+	+	+	+	+	+	+	+	+	+		+	+
Eriocera sp.					+										
Tipula sp.		+	+			+				+	+	+	+	+	+
Tipula abdominalis							+								+
Antocha sp.	+	+	+				+	+	+	+		+	+		
Protoplasa sp.			+												
Ceratopogonidae						+									
Chironomidae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ablabesmyia sp.			+		+									+	
Chironomus sp.					+		+								
Clinotanypus sp.					+										
Coelotanypus sp.					+						+				
Conchapelopis sp.				+											
Cricotopus sp.					+										

TABLE A-4. (cont.)

Species	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Cryptochironomus sp.				+		+									
Dicrotendipes sp.				+										+	
Endochironomus sp.				+											
Microtendipes sp.						+		+	+		+	+	+		
Polypedilum sp.		+		+	+	+	+		+	+	+	+	+	+	
Pseudochironomus sp.								+							
Tribelos sp.													+		
Stratiomyiidae															+
Atherix sp.		+	+						+	+	+	+			+
Atherix variegata		+	+				+		+	+	+	+	+		+
Tabanidae							+		+						
Empididae		+	+					+	+	+					+
Hemerodromia sp.										+	+				
Coleoptera															
Peltodytes sp.				+	+									+	
Gyrinidae									+						
Dineutus sp.				+	+	+	+	+		+				+	
Gryrinus sp.								+							
Berosus sp.			+								+			+	
Tropisternus sp.							+								
Helichus sp.		+	+			+		+		+	+		+	+	
Elmidae		+					+				+	+		+	
Ancronyx variegatus		+													
Dubiraphia sp.		+	+						+		+	+	+	+	+
Macronychus sp.			+				+	+	+	+	+	+	+	+	
Macronychus glabratus		+								+				+	
Microcylloepus sp.		+								+				+	
Microcylloepus pusillus			+	+									+	+	
Optioservus sp.	+	+	+				+	+	+	+	+	+		+	+
Optioservus trivittatus		+									+	+			
Promoresia sp.	+		+					+							
Stenelmis sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Oulimnius sp.			+		+		+	+	+	+	+	+	+		+
Ectoparia sp.						+		+	+					+	
Psephenus sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Gastropoda															
Mesogastropoda															
Campeloma sp.						+			+						
Amnicola sp.									+		+			+	

TABLE A-4. (cont.)

Species	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Somatogyrus sp.				+	+										
Pleurocera sp.					+	+							+	+	
Pleurocera canaliculatum				+	+	+	+								
Pleurocera unciale		+	+						+	+	+	+	+		+
Elimia sp.	+				+	+	+		+	+	+			+	
Elimia edgariana							+								
Elimia laqueata	+			+	+	+	+								
Lithasia geniculata				+	+	+	+	+							
Lithasia verrucosa	+														
Leptoxis praerosa	+	+	+	+	+	+			+	+	+	+	+		+
Io fluvialis									+	+					
Basommatophora															
Lymnaea sp.		+		+		+			+		+		+	+	
Ferrissia sp.	+	+	+	+			+	+		+	+	+	+	+	+
Gyraulus sp.					+						+		+		
Physa sp.			+		+				+	+	+		+		
Bivalvia															
Corbiculoidea															
Corbiculidae															
Corbicula fluminea	+	+	+	+	+	+	+	+	+	+	+		+	+	+
Sphaeriidae						+			+					+	
Sphaerium sp.		+					+		+	+		+	+	+	
Psidium sp.		+							+			+	+	+	
Unionoidea															
Unionidae															
Fusconaia cuneolus		+													
Cyclonaias tuberculata					+										
Actinonaias ligamentina				+						+					
Actinonaias pectorosa									+						
Epioblasma triquetra									+						
Lampsilis fasciola				+											
Medionidus conradicus									+						

TABLE A-5. Relative abundance of higher taxa of benthic macroinvertebrates at the 15 standard sampling sites. Values are the percentage of total number of organisms collected at that site which are represented by a particular higher taxon.

Order	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Nematoda	—	0.10	0.11	0.36	—	—	0.15	—	0.07	—	—	—	0.04	0.08	—
Tricladida	—	—	0.53	—	1.62	—	—	0.13	—	—	—	—	—	—	0.08
Oligochaeta	—	0.20	0.13	—	—	—	—	0.25	—	—	0.12	—	0.22	—	—
Plesiopora	5.67	3.28	0.13	4.27	2.43	1.63	1.24	0.25	0.63	0.12	0.31	0.37	0.15	1.52	0.24
Prosopora	3.61	0.35	1.09	0.89	—	0.30	0.45	0.13	0.81	0.04	0.26	0.15	0.30	1.36	0.06
Hirudinea	—	—	—	—	—	—	—	—	—	—	—	—	0.02	—	—
Rhynchobdellida	—	—	—	—	0.12	—	—	—	—	—	0.03	—	—	—	—
Haplotaxida	—	0.15	0.27	—	—	—	0.15	—	—	—	0.16	—	0.19	—	—
Isopoda	—	—	—	—	0.12	—	—	0.51	0.04	—	—	—	0.04	—	0.06
Amphipoda	0.52	0.05	—	—	0.12	0.15	0.15	—	—	—	—	—	—	—	—
Decapoda	—	0.10	0.06	—	—	0.74	0.45	—	—	0.08	0.10	0.48	—	0.16	0.24
Plecoptera	0.52	12.22	9.83	6.76	7.53	10.55	1.66	4.58	6.56	2.75	8.74	4.38	14.30	4.64	3.64
Odonata	—	0.76	0.17	0.36	0.35	0.30	—	0.51	0.04	0.24	0.36	0.15	0.11	0.56	0.06
Ephemeroptera	8.76	35.94	22.83	29.00	22.60	24.96	14.61	26.08	29.50	24.81	5.71	45.88	36.69	18.56	27.50
Trichoptera	2.06	11.91	26.47	9.61	13.79	3.71	27.11	29.26	13.54	10.44	6.51	11.24	9.28	6.56	34.43
Megaloptera	—	2.98	1.07	0.36	0.12	—	0.30	0.64	2.21	0.57	0.85	0.63	1.74	—	0.49
Lepidoptera	—	—	0.04	0.18	0.81	—	—	0.25	0.04	—	0.31	—	—	—	—
Diptera	19.59	8.93	24.15	12.63	11.59	4.16	22.14	26.08	20.90	43.71	56.04	8.05	23.90	17.44	7.41
Coleoptera	14.95	11.66	5.41	11.57	20.63	17.98	6.48	7.76	13.22	7.00	9.67	15.47	0.90	9.12	13.90
Mesogastropoda	24.23	4.95	5.37	2.85	4.06	14.26	0.75	0.25	9.29	7.26	8.06	12.87	0.82	32.08	11.48
Basommatophora	—	0.10	0.15	0.18	—	—	0.15	0.38	0.39	0.12	1.42	0.19	0.19	1.52	0.36
Heterodontida	20.10	6.31	2.21	21.00	14.14	21.25	24.25	2.93	2.77	2.83	1.37	0.15	11.09	6.40	0.06

TABLE A-6. Relative abundance of various higher taxa of benthic macroinvertebrates at the 15 standard sampling sites. Values are the percentage of total number of organisms collected at a site which are represented by a particular higher taxon.

Family	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Nematoda	—	0.10	0.11	0.36	—	—	0.15	—	0.07	—	—	—	0.04	0.08	—
Planariidae	—	—	0.53	—	1.62	—	—	0.13	—	—	—	—	—	—	0.06
Oligochaeta	—	0.20	0.13	—	—	—	—	0.25	—	—	0.10	—	0.22	—	—
Tubificidae	5.67	3.28	0.13	4.27	2.43	1.63	1.20	—	0.63	0.12	0.31	0.37	0.15	1.52	0.24
Naididae	—	—	—	—	—	—	—	0.25	—	—	—	—	—	—	—
Branchiobdellidae	—	—	—	—	—	—	—	—	—	—	—	0.04	—	—	—
Lumbriculidae	3.61	0.36	1.09	0.88	0.30	0.45	0.13	0.81	0.04	0.26	0.11	0.30	1.36	0.06	
Hirudinea	—	—	—	—	—	—	—	—	—	—	—	—	0.02	—	—
Glossiphoniidae	—	—	—	—	0.12	—	—	—	—	—	0.03	—	—	—	—
Haplotaxida	—	0.15	0.27	—	—	—	0.15	—	—	—	0.16	—	0.19	—	—
Asselidae	—	—	—	—	0.12	—	—	0.51	0.04	—	—	—	0.04	—	0.06
Gammaridae	0.52	0.05	—	—	0.12	0.15	0.15	—	—	—	—	—	—	—	—
Decapoda	—	—	—	—	—	—	—	—	—	—	—	0.04	—	—	—
Astacidae	—	0.10	0.06	—	—	0.74	0.45	—	—	0.08	0.10	0.45	—	0.16	0.24
Pteronarcidae	—	—	0.02	—	—	—	—	0.13	—	—	—	—	—	—	—
Taeniopterygidae	—	10.55	5.87	—	—	—	0.45	1.15	4.45	1.94	5.35	2.30	14.23	3.60	2.13
Nemouridae	—	—	0.74	—	—	—	—	0.13	—	—	0.23	—	—	0.80	—
Capniidae	0.52	—	—	0.36	0.12	0.74	—	0.64	—	—	0.16	—	—	—	—
Perlidae	—	1.67	3.13	6.41	7.42	9.81	1.20	2.54	2.07	0.73	2.97	2.08	0.06	0.24	1.28
Perlodidae	—	—	0.06	—	—	—	—	—	0.04	0.08	0.03	—	—	—	0.18
Chloroperlidae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.06
Gomphidae	—	0.10	—	—	0.23	0.15	—	—	0.04	0.20	—	—	—	0.16	—
Aeschnidae	—	—	—	—	—	—	—	—	—	—	0.03	—	—	0.08	—
Calopterygidae	—	—	0.06	—	—	—	—	—	—	—	0.05	—	—	—	—
Coenagrionidae	—	0.66	0.11	0.36	0.12	0.15	—	0.51	—	0.04	0.28	0.15	0.11	0.32	0.06
Ephemeridae	—	2.52	0.19	16.73	15.41	12.04	—	0.64	0.04	0.04	2.09	3.00	0.37	0.24	0.18
Caenidae	—	0.50	0.02	—	—	0.15	1.05	0.38	0.18	0.08	0.23	0.30	—	0.08	—
Ephemerellidae	3.09	1.31	6.92	4.98	2.55	4.75	0.75	16.92	2.91	3.80	0.85	0.37	10.12	12.88	2.73
Baetiscidae	—	—	—	—	—	—	—	0.51	—	—	—	—	—	0.16	—
Leptophlebiidae	—	0.05	—	—	—	—	—	—	—	—	—	2.00	—	0.16	—
Baetidae	0.52	19.23	10.96	2.31	0.12	1.63	3.61	0.25	21.78	14.08	1.32	14.87	11.20	1.52	11.78
Heptageniidae	5.15	12.32	4.73	4.98	4.52	6.39	9.19	7.38	4.59	6.80	1.21	25.33	15.01	3.52	12.81
Rhyacophilidae	—	—	0.02	0.89	1.51	1.49	0.15	—	—	0.04	—	0.15	—	2.72	0.67
Philopotamidae	—	—	—	—	—	—	—	—	—	—	0.34	3.82	—	—	10.26

TABLE A-6. (cont.)

Family	ERM 91.4	CRM 189.5	CRM 227.4	DRM 159.4	DRM 179.1	DRM 202.2	DRM 243.1	BRM 79.9	PRM 99.2	PRM 117.4	NFHRM 6.2	NFHRM 85.2	NRM 27.8	PRRM 60.0	CCRM 1.9
Psychomyiidae	0.52	0.05	0.02	0.18	0.12	0.30	—	1.91	0.07	—	0.05	—	—	—	0.12
Hydropsychidae	1.03	11.66	25.21	6.58	11.94	1.78	26.96	6.49	13.05	10.40	5.71	7.23	9.28	0.72	23.19
Hydroptilidae	0.52	0.15	1.22	1.96	—	—	—	20.36	0.42	—	0.03	—	—	0.72	0.12
Limnephilidae	—	—	—	—	—	0.15	—	—	—	—	—	—	—	0.08	—
Leptoceridae	—	0.05	—	—	0.23	—	—	—	—	—	—	—	—	0.16	—
Brachycentridae	—	—	—	—	—	—	—	0.51	—	—	0.39	—	—	2.16	0.06
Helicopsychidae	—	—	—	—	—	—	—	—	—	—	—	0.04	—	—	—
Sialidae	—	0.15	—	0.18	0.12	—	0.15	0.13	—	0.04	0.05	—	—	—	0.06
Corydalidae	—	2.83	1.07	0.18	—	—	0.15	0.51	2.21	0.53	0.80	0.63	1.74	—	0.43
Lepidoptera	—	—	0.04	0.18	0.81	—	—	0.25	0.04	—	0.31	—	—	—	—
Diptera	—	0.10	—	—	—	—	—	—	0.04	—	—	—	—	0.08	—
Simuliidae	—	—	1.26	0.36	—	—	3.61	—	2.07	0.61	46.96	0.26	0.62	3.36	0.06
Blephariceridae	—	0.05	—	—	—	—	—	—	—	—	—	1.89	0.04	—	0.06
Tipulidae	—	0.20	0.29	—	0.23	1.63	0.45	3.82	0.07	0.20	0.10	0.22	0.32	2.32	0.43
Tanyderidae	—	—	0.02	—	—	—	—	—	—	—	—	—	—	—	—
Ceratopogonidae	—	—	—	—	—	0.15	—	—	—	—	—	—	—	—	—
Chironomidae	19.59	8.23	22.20	12.28	11.36	2.38	17.47	22.01	17.96	42.25	8.53	4.38	22.89	10.96	6.62
Stratiomyiidae	—	—	—	—	—	—	—	—	—	—	—	—	—	0.72	—
Rhagionidae	—	0.30	0.15	—	—	—	0.60	—	0.67	0.45	0.41	1.30	0.02	—	0.18
Empididae	—	0.05	0.23	—	—	—	—	0.25	0.11	0.20	0.03	—	—	—	0.06
Hydrophylidae	—	—	0.02	—	—	—	—	—	—	—	0.03	—	—	0.32	—
Dryopidae	—	—	0.08	—	—	—	—	—	—	—	0.03	—	0.02	0.88	—
Elmidae	14.43	9.54	5.13	11.57	19.81	11.89	5.87	6.74	13.08	6.88	7.86	11.42	0.80	6.16	8.08
Psephenidae	0.52	2.12	0.17	—	0.81	6.09	0.60	1.02	0.14	0.12	1.76	4.04	0.09	1.76	5.83
Bithyniidae	—	—	—	0.18	0.23	—	—	—	—	—	0.54	—	—	29.92	—
Pleuroceridae	24.23	4.95	5.37	2.67	3.82	14.26	0.75	0.25	9.29	7.28	7.52	12.87	0.82	2.16	11.48
Lymnaeidae	—	0.06	—	—	—	—	—	—	0.25	—	0.26	—	—	1.04	
Ancylidae	—	0.05	0.08	0.18	—	—	0.15	0.39	—	0.08	0.49	0.19	0.02	0.48	0.36
Planorbidae	—	—	—	—	—	—	—	—	—	—	0.05	—	—	—	—
Physidae	—	—	0.06	—	—	—	—	—	0.14	0.04	0.62	—	0.17	—	—
Cyrenidae	20.10	6.16	2.21	20.28	14.02	21.10	24.25	2.93	2.03	2.79	1.37	—	10.70	5.68	0.06
Unionidae	—	0.05	—	0.71	0.12	—	—	—	0.07	—	—	—	—	—	—
Sphaeriidae	—	0.10	—	—	—	0.15	—	—	0.67	0.04	—	0.15	0.39	0.72	—

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THE UNIONIDAE OF THE LOWER MUSKINGUM RIVER (RM 34.1 - 0), OHIO, U.S.A.

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ABSTRACT – The lower 55 km (34 miles) of the Muskingum River were surveyed in October 1992 for Unionidae by hand-picking, brailing, and diving. Muskrat middens were examined from October 1992 through October 1993. Forty species and 11,145 individuals were found. Nine of these were encountered only as weathered shells and are presumed extirpated from the study area. Five federally endangered taxa were found, although only *Cyprogenia stegaria* (Rafinesque 1820) was collected alive. Other federally endangered taxa found as weathered shells were: *Lampsilis abrupta* (Say 1831), *Plethobasus cicatricosus* (Say 1829), *Pleurobema clava* (Lamarck 1819), and *Pleurobema plenum* (Lea 1840). Fourteen Ohio endangered species were found (including federally endangered species). Four of these appear to be reproducing and may occur nowhere else in the state: *Ellipsaria lineolata* (Rafinesque 1820); *Plethobasus cyphyus* (Rafinesque 1820); *Pleurobema cordatum* (Rafinesque 1820); and *Quadrula metanevra* (Rafinesque 1820). Mussels are distributed in six beds located downstream of the first five km of each of four locks and dams. Average bed densities ranged from 3.1 to 41.9 individuals/m^2, with a maximum density reaching 124 individuals/m^2. The fauna is dominated by five species, all of which have some commercial value: *Obliquaria reflexa* Rafinesque 1820; *Quadrula pustulosa* (Lea 1831); *Amblema plicata* (Say 1817); *Pleurobema cordatum;* and *Quadrula quadrula* (Rafinesque 1820). The commercially valuable *Megalonaias nervosa* (Rafinesque 1820) is becoming established in the lowest pool with recruitment evident. The State of Ohio is closed to commercial collecting, although poaching pressure for the cultured pearl industry is a serious threat to these beds.

Key Words: Unionidae, Muskingum River, Ohio, zoogeography.

INTRODUCTION

The Muskingum River is the largest river system in Ohio and historically has supported at least 63 unionid species (Bates, 1970; Stansbery & King, 1983; Stansbery *et al.*, 1985). It also has an extensive history of malacological collections, making it one of the best studied rivers for unionids in the country. The most comprehensive survey was that of Stansbery & King (1983). They concluded that large, potentially commercial, beds existed from Dam 4 at Lowell to the mouth at the Ohio River. Although commercial harvesting of mus-sels is now illegal in Ohio, some beds were collected heavily prior to passage of that legislation, and other beds have been harvested illegally since.

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The Muskingum River has been impounded by locks and dams to facilitate navigation between the Ohio River and Zanesville. Many of these structures have fallen into disrepair due to inadequate maintenance funds, and several now are inoperable. Government agencies are now considering the fate of these locks and dams. Options include refurbishing the structures, removing them and returning the river to a free-flowing state, or letting them further deteriorate.

Impoundments have been shown to be deleterious to unionids (Harman, 1974). Most freshwater mussels require free-flowing water to survive. In the Muskingum River mainstream, the only places that remain "free-flowing," are those that are immediately downstream of dams. It is here that the largest remaining mussel beds persist. The construction associated with repairing or removing the dams could have a serious impact on those beds due to the release of sediments contained above the dams.

As of 23 August, 1993, 51 species of freshwater mussels have been placed on the Federally Endangered Species List. At the time of the study of Stansbery & King (1987) five Muskingum River unionids were federally endangered. Eleven Muskingum River species now are federally endangered (U.S. Fish & Wildlife Service, 1991; Table 1). With few exceptions, these are all big river species. That is, they are more likely to reside in the downstream reaches of the river than in the headwaters.

TABLE 1. Federally Endangered species recorded from the Muskingum River (after Stansbery & King, 1987, and US Fish & Wildlife Service, 1991).

Common Name	Scientific Name	Date Listed
Fanshell	*Cyprogenia stegaria*	21 June 1990
White Catspaw	*Epioblasma o. obliquata*	10 July 1990
Tubercled Blossom	*Epioblasma t. torulosa*	14 June 1976
Northern Riffleshell	*Epioblasma t. rangiana*	23 February 1993
Cracking Pearlymussel	*Hemistena lata*	28 September 1989
Pink Mucket	*Lampsilis abrupta*	14 June 1976
Ring Pink	*Obovaria retusa*	29 September 1989
White Wartyback	*Plethobasus cicatricosus*	14 June 1976
Orange-foot Pimpleback	*Plethobasus striatus*	14 June 1976
Clubshell	*Pleurobema clava*	23 February 1993
Rough Pigtoe	*Pleurobema plenum*	14 June 1976

We must document the existence and densities of any species prior to potential human disruption of their habitats. It is critical that this information be gathered for endangered species. Obviously the first step toward preserving and managing these rare organisms is to find where they still exist. Therefore, it was important that the lower reach of the Muskingum River, which potentially supports nine federally endangered species, be surveyed prior to any action taken on the locks and dams. In 1992, Ecological Specialists, Inc., (ESI) of St. Peters, Missouri, was contracted to survey the lower 43 miles of the Muskingum River. Funds were made available for the study through the Ohio Division of Wildlife's "Do Something Wild!" state income tax checkoff. Data for this study are from ESI (1993).

METHODS & MATERIALS

The purpose of this study was to characterize the beds below Dam 5 (Luke Chute) to the mouth (Table 2; Fig. 1). This encompasses the potential range for most big river species. Beds were located by systematically brailing at 0.8 km intervals within the study area from 23 September to 1 October 1992. Three transects were brailed at each interval at equally spaced locations parallel to the shore. Each brail run lasted 10 minutes, and covered 0.3-0.4 km. Brail runs were conducted in a downstream direction and were numbered from right to left descending bank. The existence of a bed was indicated by the presence of mussels caught on several successive brail runs. Once found, a bed was delimited by more intense brailing. This typically consisted of making five brail runs of five minute duration each between the half mile intervals until no mussels were found.

TABLE 2. Study area.

Location	Muskingum River Miles	Length (mi.)	Length (km)
Dam 5 – Dam 4	34.1 – 25.1	9.0	14.4
Dam 4 – Dam 3	25.1 – 14.2	10.9	17.5
Dam 3 – Dam 2	14.2 – 5.8	8.4	13.5
Dam 2 – mouth*	5.8 - 0.0	5.8	7.4

*Dam 1 was submerged when Willow Island Lock & Dam was constructed on the Ohio River.

Within each bed, five weighted 30 m lines were placed randomly parallel to the shore. A diver collected unionids at forty 1/4 meter^2 random quadrat sites. Samples were collected in each bed to estimate the composition and density of each bed. Each quadrat was excavated to a depth of approximately 15-20 cm. The diver also qualitatively collected in each bed for several hours to estimate diversity. The dive survey ran from 23 to 30 October 1992.

Living mussels were identified, measured, weighed, and returned along the same transect line by the diver. Many specimens were either too old or too eroded to give an age estimate. Juveniles under 10 g generally could not be weighed accurately, and very large specimens occasionally exceeded the limits of the scales. Methods were chosen to generate comparable types of data with those of Stansbery & King (1987) and Bates (1970). These surveys provide a baseline description of the area prior to any future changes, manmade or otherwise, that might occur. Methods follow the guidelines of Miller & Payne (1988) for characterizing mussel communities.

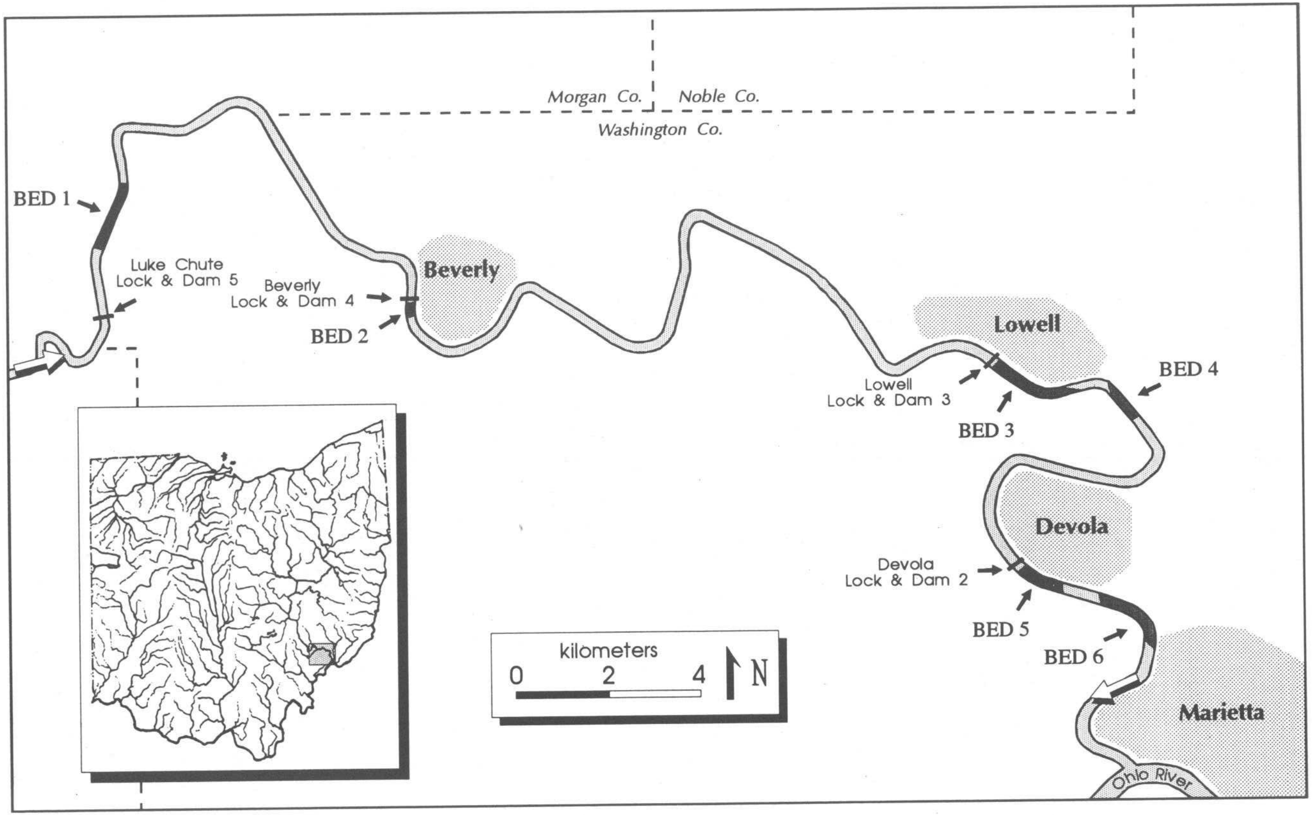

FIG. 1. Study area, lower Muskingum River. Inset – location of study area in Ohio.

After completion of the brailing and diving study, one of us (GTW) continued to sample muskrat middens throughout 1993. Several additional species were recovered, and these are included in the above data.

RESULTS

Six beds were located by brail. Summary statistics for each bed are given in Table 3. Statistics on species age, length, and weight use data from all living specimens in both the quantitative and qualitative surveys. A total of 11,145 specimens was found in the study. Of those, 1,875 were living (17%). Remaining specimens were recovered from muskrat middens and individuals stranded by high water. A few specimens were collected only as weathered shells. All living specimens were returned to the river with the exception of 100 specimens of two common species to be used by other workers for DNA analysis at Ohio University.

TABLE 3. Summary statistics for beds.

Bed	Location	Length (km)	Ave. Density (ind/sq. m)	Diversity (No. spp.)	No. Ohio Endangered	No. Federal Endangered
1	Luke Chute	3.6	3.0	26	6	1
2	Beverly	0.8	30.9	19	2	0
3	Lowell	2.9	17.7	25	7	1
4	Lowell	1.9	9.0	21	7	1
5	Devola	1.6	41.9	34	13	5
6	Devola	1.6	31.0	18	7	1

A total of 40 species was found in the study (Table 4), seven of which were present only as weathered shells. Five species are federally endangered: *Cyprogenia stegaria* (Rafinesque 1820), which was found living or freshdead in three beds, and as a weathered shell in another; and *Lampsilis abrupta* (Say 1831); *Plethobasus cicatricosus* (Say 1829); *Pleurobema clava* (Lamarck 1819); and *Pleurobema plenum* (Lea 1840), which occurred only as weathered or subfossil shells. Fourteen species were Ohio endangered, in addition to the federally endangered species: *Ellipsaria lineolata* (Rafinesque 1820); *Elliptio crassidens* (Lamarck 1819); *Fusconaia maculata* (Rafinesque 1820); *Megalonaias nervosa* (Rafinesque 1820); *Plethobasus cyphyus* (Rafinesque 1820); *Pleurobema cordatum* (Rafinesque 1820); *Pleurobema rubrum* (Rafinesque 1820); *Quadrula cylindrica cylindrica* (Say 1817); and *Quadrula metanevra* (Rafinesque 1820). Age distributions for all species found living in

TABLE 4. Comparison of unionid fauna in Muskingum River beds, 1992-93.

		No. Individuals							%
Endangered	Species	Bed 1	Bed 2	Bed 3	Bed 4	Bed 5	Bed 6	Total	Total
	Actinonaias ligamentina	17	6	4	1*	3	5	36	0.32%
	Alasmidonta marginata					1*		1	0.00%
	Amblema plicata	69	261	353	214	504	105	1506	13.51%
	Anodonta grandis	1	4	4		5		14	0.13%
	Anodonta imbecillis		1	1				2	0.02%
	Cyclonaias tuberculata	6						6	0.05%
F/OH	*Cyprogenia stegaria*	1*			1	6	2	10	0.09%
OH	*Ellipsaria lineolata*	7	1	16	9	150	41	224	2.01%
OH	*Elliptio crassidens*	1*						1	0.00%
	Elliptio dilatata	2						2	0.02%
	Fusconaia flava	2		1*		1		4	0.04%
OH	*Fusconaia maculata*	5		7	3	2	3	20	0.18%
F/OH	*Lampsilis abrupta*					1*		1	0.00%
	Lampsilis radiata luteola	1	1			1		3	0.03%
	Lampsilis ventricosa	7	8	3	1	8	1	28	0.25%
	Lasmigona complanata	7	3	2	1	18		31	0.28%
	Lasmigona costata	2		2	1	1		6	0.05%
	Leptodea fragilis	33	18	46	3	51	8	159	1.43%
	Ligumia recta					1		1	0.00%
OH	*Megalonaias nervosa*			1	4	19	17	41	0.37%
	Obliquaria reflexa	85	325	856	19	1610	179	3074	27.58%
	Obovaria subrotunda	1		8	2	25	12	48	0.43%
F/OH	*Plethobasus cicatricosus*					1*		1	0.00%
OH	*Plethobasus cyphyus*				1	2	3	6	0.05%
F/OH	*Pleurobema clava*					1*		1	0.00%
OH	*Pleurobema cordatum*	22	21	202	146	781	279	1451	13.02%
F/OH	*Pleurobema plenum*			1*		2*		3	0.03%
OH	*Pleurobema rubrum*	1		1*		1		3	0.03%
	Pleurobema sintoxia	2	2	5	3	6	9	27	0.24%
	Potamilus alatus	8	11	16	2	51	5	93	0.83%
	Potamilus ohiensis	3	1	2	1	7		14	0.13%
	Ptychobranchus fasciolaris	1	1					2	0.02%
OH	*Quadrula c. cylindrica*					1*		1	0.00%
OH	*Quadrula metanevra*			1	3	61	31	96	0.86%
	Quadrula pustulosa	156	550	1222	42	695	108	2773	24.88%
	Quadrula quadrula	46	96	52	24	638	390	1246	11.18%
	Simpsonaias ambigua					1*		1	0.00%
	Strophitus undulatus		1	2				3	0.03%
	Truncilla donaciformis	54	15	47	2	71	7	196	1.76%
	Truncilla truncata					10		10	0.09%
	Total No. Species =	26	19	25	21	34	18	40	
	Total No. Individuals =	540	1326	2855	483	4736	1205	11145	
	Densities (no. ind/m^2) =	3.1	31.0	17.8	9.0	41.9	31.2		

*Weathered shells only; F = Federal; OH = Ohio.

both quantitative and qualitative surveys (two or more specimens) are given in Appendix A for all beds combined.

Bed 1 – Luke Chute (Lock & Dam 5). Brailing indicated the presence of a diffuse bed extending from Lock & Dam #5 to approximately 3.6 km downstream. Although this bed had the least average density of any of the beds studied (3 individuals/m^2), it had the second highest diversity. Twenty-six species were found in Bed 1 (Table 5). All but three were present as living or freshdead specimens.

Quadrula pustulosa dominated the fauna, comprising 29% of the individuals found. Of the five commercially valuable taxa in the Muskingum River, as defined by Stansbery & King (1983), four occur in this bed and account for 66% of all specimens: *Quadrula pustulosa* (Lea 1831) (29%); *Obliquaria reflexa* Rafinesque 1820 (16%); *Amblema plicata* (Say 1817) (13%); and *Quadrula quadrula* (Rafinesque 1820) (8.5%). However, the shells are not of high commercial quality (J. Duckworth, Ducktrail Diving Service, personal communication). Thirteen species, nearly half of the diversity of the bed, occur in relative abundances of less than 1% each. Many of the less common species, such as *Elliptio dilatata* (Rafinesque 1820), *Ptychobranchus fasciolaris* (Rafinesque 1820), and *Lampsilis radiata luteola* (Lamarck 1819), typically are found in smaller streams and may be abundant in the Muskingum River tributaries. A living, old individual of *Pleurobema rubrum* (one of the rarest unionid species in Ohio) was found in this bed.

Bed 2 – Beverly (Lock & Dam 4). Brailing indicated the presence of a small, but very dense bed extending from Lock & Dam #4 to approximately 0.8 km downstream. This lower limit marks the mouth of Wolf Creek. Although this bed had the second highest average density of any of the beds studied (31 individuals/m^2), it had the second lowest diversity (Table 6). Only 19 species were found in Bed 2 (Table 6). All were present as living or freshdead specimens. *Quadrula pustulosa* dominated the fauna, comprising 42% of the individuals found. Four of the five commercially valuable taxa occur in this bed and account for nearly 94% of all specimens: *Quadrula pustulosa* (42%); *Obliquaria reflexa* (25%); *Amblema plicata* (20%); *and Quadrula quadrula* (7%). The shells are of high commercial quality (J. Duckworth, personal communication). Twelve species, 2/3 of the diversity of the bed (mostly headwater species), occur in relative abundances of less than 1% each.

Bed 3 – Lowell (Lock & Dam 3). Brailing indicated the presence of a small, but very dense bed extending from Lock & Dam #3 to approximately 2.9 km downstream. The mouth of Bear Creek marks the lower bed limit. This bed had a medium average density (18 individuals/m^2), and a high diversity. Twenty-five species were found in

TABLE 5. Summary of species composition in Bed 1 (Luke Chute) from diving surveys. Species listed in order of abundance.

Species	Best Condition	Endan-gered	No. ind.	% Total	Ave. Age (yr)	Min. Age (yr)	Max. Age (yr)	Ave. Length (mm)	Ave. Wt. (g)
Quadrula pustulosa	L		156	28.89%	14.8	7	20	75.5	192.7
Obliquaria reflexa	L		85	15.74%	10.3	4	18	62.7	109.1
Amblema plicata	L		69	12.78%	12.2	4	20	113.9	345.8
Truncilla donaciformis	L		54	10.00%	5.3	5	6	45.3	21.7
Quadrula quadrula	L		46	8.52%	7.0	7	17	75.0	120.0
Leptodea fragilis	L		33	6.11%	4.9	3	9	96.0	122.3
Pleurobema cordatum	L	OH	22	4.07%	14.5	8	20	97.3	294
Actinonaias ligamentina	D		17	6.11%	16.4	10	22	135.7	560.3
Potamilus alatus	L		8	1.48%	9.7	17	12	163.5	442.5
Ellipsaria lineolata	L	OH	7	1.30%	16.0	11	22	110.0	486.0
Lampsilis ventricosa	L		7	1.30%	15.8	13	19	135.4	617.0
Lasmigona complanata	L		7	1.30%	12.4	9	17	155.6	443.0
Cyclonaias tuberculata	L		6	1.11%	17.2	16	23	98.8	320.0
Fusconaia maculata	L	OH	5	0.93%	17.6	16	19	106.6	339.0
Potamilus ohiensis	D		3	0.56%	NA	NA	NA	NA	NA
Elliptio dilatata	L		2	0.37%	15.0	13	17	115.5	190.0
Fusconaia flava	D		2	0.37%	NA	NA	NA	NA	NA
Lasmigona costata	L		2	0.37%	11.0	11	11	142.0	300.0
Pleurobema sintoxia	L		2	0.37%	15.0	15	15	98.0	237.5
Anodonta grandis	D		1	0.19%	NA	NA	NA	NA	NA
Cyprogenia stegaria	W	F/OH	1	0.19%	NA	NA	NA	NA	NA
Elliptio crassidens	W	OH	1	0.19%	NA	NA	NA	NA	NA
Lampsilis radiata luteola	W		1	0.19%	NA	NA	NA	NA	NA
Obovaria subrotunda	L		1	0.19%	11.0	11	11	69.0	120
Pleurobema rubrum	L	OH	1	0.19%	?	?	?	93.0	370.0
Ptychobranchus fasciolaris	L		1	0.19%	13.0	13	13	115.0	240.0

Total No. Species = 26   No. Ind. = 540   Ave. Density (no. ind/m^2) = 3.1

L =living; D = freshdead; W = weathered; F = federal; OH = Ohio; NA = not applicable (only live individuals measured); ? = could not be measured.

TABLE 6. Summary of species composition in Bed 2 (Beverly) from diving surveys. Species listed in order of abundance.

Species	Best Condition	Endan-gered	No. ind.	% Total	Ave. Age (yr)	Min. Age (yr)	Max. Age (yr)	Ave. Length (mm)	Ave. Wt. (g)
Quadrula pustulosa	L		550	41.48%	12.8	3	21	69.7	148.5
Obliquaria reflexa	L		325	24.51%	11.0	10	63	68.0	125.0
Amblema plicata	L		261	19.68%	0.0	0	0	122.0	375.0
Quadrula quadrula	L		96	7.24%	11.5	4	18	85.4	181.5
Pleurobema cordatum	L	OH	21	1.58%	14.4	6	22	90.4	250.0
Leptodea fragilis	L		18	1.36%	5.3	3	8	101.5	107.5
Truncilla donaciformis	L		15	1.13%	4.0	3	5	34.0	10.0
Potamilus alatus	D		11	0.83%	NA	NA	NA	NA	NA
Lampsilis ventricosa	L		8	0.60%	10.0	10	10	148.0	610.0
Actinonaias ligamentina	L		6	0.45%	15.3	14	16	138.3	370.0
Anodonta grandis	D		4	0.30%	NA	NA	NA	NA	NA
Lasmigona complanata	D		3	0.23%	NA	NA	NA	NA	NA
Pleurobema sintoxia	L		2	0.15%	14.5	13	16	98.5	250.0
Anodonta imbecillis	D		1	0.08%	NA	NA	NA	NA	NA
Ellipsaria lineolata	L	OH	1	0.08%	8.0	8	8	95.0	180.0
Lampsilis radiata luteola	D		1	0.08%	NA	NA	NA	NA	NA
Potamilus ohiensis	L		1	0.08%	5.0	5	5	135.0	230.0
Ptychobranchus fasciolaris	D		1	0.08%	NA	NA	NA	NA	NA
Strophitus undulatus	D		1	0.08%	NA	NA	NA	NA	NA

Total No. Species = 19 No. Ind. = 1326 Ave. Density (no. ind./m^2) = 31.0

L = living; D = freshdead; W = weathered; F = federal; OH = Ohio; NA = not applicable (only live individuals measured).

Bed 3 (Table 7). Three were present only as weathered specimens.

Quadrula pustulosa dominated the fauna, comprising 43% of the individuals found. All five of the commercially valuable taxa listed by Stansbery & King (1983) occur in this bed. They account for nearly 88% of all specimens: *Quadrula pustulosa* (43%); *Obliquaria reflexa* (30%); *Amblema plicata* (12%); *Quadrula quadrula* (2%), and *Megalonaias nervosa* (0.04%). The shells were not of high commercial quality (J. Duckworth, personal communication). Eighteen species, nearly 3/4 of the diversity of the bed, occur in relative abundances of less than 1% each. These include the most upstream occurrences of several big river taxa in this study: *Megalonaias nervosa* and *Quadrula metanevra.* The headwater species found in Beds 1 and 2 have disappeared from the fauna by this point.

Bed 4 – Lowell (between Lock & Dam 2 and 3). Brailing indicated the presence of a small, but diverse bed extending from downstream of Bear Creek to approximately 1.9 km downstream. This bed had a low average density (9 individuals/m^2), but a fairly high diversity. Twenty-one species were found in Bed 4 (Table 8).

Amblema plicata dominated the fauna, comprising 44% of the individuals found. All five of the commercially valuable taxa occur in this bed, accounting for nearly 63% of all specimens: *Amblema plicata* (44%); *Quadrula pustulosa* (9%); *Quadrula quadrula* (5%); *Obliquaria reflexa* (4%); *and Megalonaias nervosa* (0.8%). The shells were not of high commercial quality (J. Duckworth, personal communication). Numbers of both *Quadrula pustulosa* and *Obliquaria reflexa* dramatically decreased between Beds 3 and 4. Fifteen species, nearly 3/4 of the diversity of the bed, occur in relative abundances of less than 1% each. These include several rare big river taxa: *Plethobasus cyphyus,* and the federally endangered *Cyprogenia stegaria,* which was found as a freshdead shell.

Bed 5 – Devola (Lock & Dam 2). Brailing indicated the presence of a large, dense bed extending from Lock & Dam #2 to approximately 1.6 km downstream. This bed had the highest average density (42 individuals/m^2), with a maximum density of 124 individuals/m^2, the highest encountered in the study. This bed also had the greatest diversity. Thirty-four species were found in or adjacent to Bed 5 (Table 9). Seven taxa were found as weathered or subfossil shells only.

Obliquaria reflexa dominated the fauna, comprising 34% of the individuals found. All five of the commercially valuable taxa occur in this bed, accounting for nearly 74% of all specimens: *Obliquaria reflexa*

TABLE 7. Summary of species composition in Bed 3 (Lowell) from diving surveys. Species listed in order of abundance.

Species	Best Condition	Endan-gered	No. ind.	% Total	Ave. Age (yr)	Min. Age (yr)	Max. Age (yr)	Ave. Length (mm)	Ave. Wt. (g)
Quadrula pustulosa	L		1222	42.80%	15.1	6	23	74.5	176.2
Obliquaria reflexa	L		856	29.98%	14.6	4	23	68.1	138.7
Amblema plicata	L		353	12.36%	16.6	5	24	118.8	371.5
Pleurobema cordatum	L	OH	202	7.08%	13.1	7	23	93.4	256.2
Quadrula quadrula	L		52	1.82%	12.3	9	16	95.0	232.2
Truncilla donaciformis	L		47	1.65%	3.0	1	5	35.0	25.0
Leptodea fragilis	L		46	1.61%	7.8	4	10	120.5	188.3
Ellipsaria lineolata	L	OH	16	0.56%	17.4	11	22	108.0	360.5
Potamilus alatus	D		16	0.56%	10.0	7	17	127.3	265.0
Obovaria subrotunda	L		8	0.28%	16.0	16	16	70.0	140.0
Fusconaia maculata	L	OH	7	0.25%	16.3	15	17	104.5	307.5
Pleurobema sintoxia	L		5	0.18%	14.3	9	20	98.0	285.0
Actinonaias ligamentina	L		4	0.14%	13.0	13	13	134.3	566.7
Anodonta grandis	D		4	0.14%	NA	NA	NA	NA	NA
Lampsilis ventricosa	L		3	0.11%	15.0	15	15	146.0	560.0
Lasmigona complanata	D		2	0.07%	7.0	7	7	147.5	85.0
Lasmigona costata	L		2	0.07%	12.0	12	12	142.0	260.0
Potamilus ohiensis	D		2	0.07%	NA	NA	NA	NA	NA
Strophitus undulatus	D		2	0.07%	NA	NA	NA	NA	NA
Anodonta imbecillis	D		1	0.04%	NA	NA	NA	NA	NA
Fusconaia flava	W		1	0.04%	NA	NA	NA	NA	NA
Megalonaias nervosa	L	OH	1	0.04%	32.0	32	32	112.0	?
Pleurobema plenum	W	F/OH	1	0.04%	NA	NA	NA	NA	NA
Pleurobema rubrum	W	OH	1	0.04%	NA	NA	NA	NA	NA
Quadrula metanevra	L	OH	1	0.04%	18.0	18	18	95.0	210.0

Total No. Species = 25   No. Ind. = 2855   Ave. Density (no. ind/m^2) = 17.8

L = living; D = freshdead; W = weathered; F = federal; OH = Ohio; NA = not applicable (only live individuals measured).

TABLE 8. Summary of species composition in Bed 4 (between Lowell and Devola) from diving surveys. Species listed in order of abundance.

Species	Best Condition	Endan-gered	No. ind.	% Total	Ave. Age (yr)	Min. Age (yr)	Max. Age (yr)	Ave. Length (mm)	Ave. Wt. (g)
Amblema plicata	L		214	44.31%	18.3	13	24	117.6	357.9
Pleurobema cordatum	L	OH	146	30.23%	15.2	8	28	90.9	234.2
Quadrula pustulosa	L		42	8.70%	15.6	12	18	71.6	158.1
Quadrula quadrula	L		24	4.97%	16.4	10	15	90.0	206.7
Obliquaria reflexa	L		19	3.93%	17.9	14	23	72.8	153.2
Ellipsaria lineolata	L	OH	9	1.86%	16.7	15	26	109.7	384.3
Megalonaias nervosa	L	OH	4	0.83%	30.7	25	34	214.8	?
Fusconaia maculata	L	OH	3	0.62%	22.5	21	24	107.3	353.3
Leptodea fragilis	L		3	0.62%	4.7	3	7	84.7	60.0
Pleurobema sintoxia	L		3	0.62%	19.5	18	21	110.0	325.0
Quadrula metanevra	L	OH	3	0.62%	17.5	17	18	97.5	320.0
Obovaria subrotunda	L		2	0.41%	19.5	19	20	63.5	115.0
Potamilus alatus	L		2	0.41%	13.0	13	13	168.0	515.0
Truncilla donaciformis	L		2	0.41%	2.5	2	3	29.0	10.0
Actinonaias ligamentina	W		1	0.21%	NA	NA	NA	NA	NA
Cyprogenia stegaria	D	F/OH	1	0.21%	NA	NA	NA	NA	NA
Lampsilis ventricosa	L		1	0.21%	18.0	18	18	126.0	500.0
Lasmigona complanata	D		1	0.21%	?	?	?	178.0	670.0
Lasmigona costata	L		1	0.21%	13.0	13	13	145.0	365.0
Plethobasus cyphyus	L	OH	1	0.21%	14.0	14	14	110.0	305.0
Potamilus ohiensis	L		1	0.21%	4.0	4	4	73.0	30.0

Total No. Species = 21   No. Ind. = 483   Ave. Density (no. ind./m^2) = 9.0

L = living; D = freshdead; W = weathered; F = federal; OH = Ohio; NA = not applicable (only live individuals measured); ? = could not be measured.

TABLE 9. Summary of species composition in Bed 5 (Devola) from diving surveys. Species listed in order of abundance.

Species	Best Condition	Endangered	No. ind.	% Total	Ave. Age (yr)	Min. Age (yr)	Max. Age (yr)	Ave. Length (mm)	Ave. Wt. (g)
Obliquaria reflexa	L		1610	34.04%	14.6	9	21	70.0	113.7
Pleurobema cordatum	L	OH	781	16.51%	13.5	6	22	85.7	214.0
Quadrula pustulosa	L		695	14.69%	13.7	6	19	68.8	148.9
Quadrula quadrula	L		638	13.49%	13.3	5	20	86.9	196.9
Amblema plicata	L		504	10.66%	15.9	2	26	107.8	307.7
Ellipsaria lineolata	L	OH	150	3.17%	11.0	2	24	88.7	213.8
Truncilla donaciformis	L		71	1.50%	2.0	1	3	20.9	?
Quadrula metanevra	L	OH	61	1.29%	14.0	8	18	86.8	223.3
Leptodea fragilis	L		51	1.08%	5.9	3	11	113.6	161.0
Potamilus alatus	L		51	1.08%	9.6	5	15	131.9	235.0
Obovaria subrotunda	L		25	0.53%	18.0	18	18	73.0	180.0
Megalonaias nervosa	L	OH	19	0.40%	23.8	7	33	198.6	?
Lasmigona complanata	L		18	0.38%	9.9	4	17	134.5	353.8
Truncilla truncata	L		10	0.21%	2.5	2	3	23.0	?
Lampsilis ventricosa	L		8	0.17%	16.7	15	20	134.0	609.0
Potamilus ohiensis	D		7	0.15%	NA	NA	NA	NA	NA
Cyprogenia stegaria	L	F/OH	6	0.13%	13.3	9	17	68.0	165.0
Pleurobema sintoxia	L		6	0.13%	14.8	9	18	95.0	260.0
Anodonta grandis	D		5	0.11%	NA	NA	NA	NA	NA

TABLE 9. (cont.)

Species	Best Condition	Endangered	No. ind.	% Total	Ave. Age (yr)	Min. Age (yr)	Max. Age (yr)	Ave. Length (mm)	Ave. Wt. (g)
Actinonaias ligamentina	L		3	0.06%	21.7	21	22	160.7	856.7
Fusconaia maculata	L	OH	2	0.04%	17.0	16	18	115.5	327.5
Plethobasus cyphyus	L	OH	2	0.04%	13.0	13	13	112.0	305.0
Pleurobema plenum	W	F/OH	2	0.04%	NA	NA	NA	NA	NA
Alasmidonta marginata	W		1	0.02%	NA	NA	NA	NA	NA
Fusconaia flava	D		1	0.02%	NA	NA	NA	NA	NA
Lampsilis abrupta *	W	F/OH	1	0.02%	NA	NA	NA	NA	NA
Lampsilis radiata luteola	D		1	0.02%	NA	NA	NA	NA	NA
Lasmigona costata	L		1	0.02%	14.0	14	14	161.0	500.0
Ligumia recta *	D		1	0.02%	NA	NA	NA	NA	NA
Plethobasus cicatricosus *	W	F/OH	1	0.02%	NA	NA	NA	NA	NA
Pleurobema clava *	W	F/OH	1	0.02%	NA	NA	NA	NA	NA
Pleurobema rubrum	L	OH	1	0.02%	17.0	17	17	93.0	290.0
Quadrula c. cylindrica *	W	OH	1	0.02%	NA	NA	NA	NA	NA
Simpsonaias ambigua *	W		1	0.02%	NA	NA	NA	NA	NA

Total No. Species = 34   No. Ind. = 4736   Ave. Density (no. ind./m^2) = 41.9

L = living; D = freshdead; W = weathered; F = federal; OH = Ohio; NA = not applicable (only live individuals measured); ? = could not be measured; * = found in adjacent middens.

(34%); *Quadrula pustulosa* (15%); *Quadrula quadrula* (13.5%); *Amblema plicata* (11%); and *Megalonaias nervosa* (0.4%). The shells were of commercial quality (J. Duckworth, personal communication). The Ohio endangered *Pleurobema cordatum* was the second most abundant species. *Ellipsaria lineolata,* also Ohio endangered, was the sixth most common species. Twenty-four species occurred in relative abundances of less than 1% each. The rare *Pleurobema rubrum* was found living in this bed, and six living or freshdead specimens of the federally endangered *Cyprogenia stegaria* also were found.

Bed 6 – Devola (between Lock & Dam 2 and mouth). Brailing indicated the presence of a large, dense bed extending from approximately 0.8 km below Bed 5 to approximately 1.6 kilometers downstream. This bed had the second highest average density (31 individuals/m^2), but the lowest diversity. Only eighteen species were found in Bed 6 (Table 10). All taxa were found as living individuals.

Quadrula quadrula dominated the fauna, comprising 32% of the individuals found. All five of the commercially valuable taxa occur in this bed, accounting for nearly 66% of all specimens: *Quadrula quadrula* (32%); *Obliquaria reflexa* (15%); *Quadrula pustulosa* (9%); *Amblema plicata* (8.7%); and *Megalonaias nervosa* (1.4%). The shells were of commercial quality (J. Duckworth, personal communication). The Ohio endangered *Pleurobema cordatum* was the second most abundant species. *Ellipsaria lineolata* and *Quadrula metanevra,* both Ohio endangered, were the sixth and seventh most common species, respectively. Ten species, over half of the fauna, occurred in relative abundances of less than 1% each. These were a mixture of headwater and rare big river taxa. Two living specimens of the federally endangered *Cyprogenia stegaria* also were found.

DISCUSSION

Comparison with earlier surveys.

Bates (1970) surveyed much of the Muskingum River between 1967 and 1970. He reported a total of 25 species from the study area of Luke Chute to the mouth (Table 11). That study was followed by the survey of Stansbery & King (1983), which was conducted from 1979 to 1981, and reported 37 species. This study found 40 species. The total diversity reported in all three surveys is 44. Stansbery *et al.* (1985) documented the historical records of six additional taxa not found in the three surveys. Two of these are federally endangered species: *Obovaria retusa* (Lamarck 1819) and *Plethobasus striatus* (Rafinesque

TABLE 10. Summary of species composition in Bed 6 (between Devola and mouth) from diving surveys. Species listed in order of abundance.

Species	Best Condition	Endan-gered	No. ind.	% Total	Ave. Age (yr)	Min. Age (yr)	Max. Age (yr)	Ave. Length (mm)	Ave. Wt. (g)
Quadrula quadrula	L		390	32.37%	12.1	6	18	87.9	209.5
Pleurobema cordatum	L	OH	279	23.15%	12.0	6	20	85.3	215.0
Obliquaria reflexa	L		179	14.85%	10.2	3	15	57.4	93.3
Quadrula pustulosa	L		108	8.96%	12.5	6	17	69.0	147.7
Amblema plicata	L		105	8.71%	11.7	2	23	89.2	295.6
Ellipsaria lineolata	L	OH	41	3.40%	11.3	2	25	87.7	227.0
Quadrula metanevra	L	OH	31	2.57%	12.7	8	17	83.3	207.5
Megalonaias nervosa	L	OH	17	1.41%	14.2	7	24	168.6	701.5
Obovaria subrotunda	L		12	1.00%	14.0	14	14	66.0	112.5
Pleurobema sintoxia	L		9	0.75%	15.4	9	18	103.4	295.0
Leptodea fragilis	L		8	0.66%	3.4	3	4	81.0	75.7
Truncilla donaciformis	L		7	0.58%	2.2	2	3	18.4	?
Actinonaias ligamentina	L		5	0.41%	14.4	4	21	152.6	483.8
Potamilus alatus	L		5	0.41%	5.8	4	10	124.0	252.5
Fusconaia maculata	L	OH	3	0.25%	13.5	7	20	75.5	190.0
Plethobasus cyphyus	L	OH	3	0.25%	10.7	8	14	98.3	226.7
Cyprogenia stegaria	L	F/OH	2	0.17%	10.5	9	11	58.0	102.5
Lampsilis ventricosa	L		1	0.08%	15.0	15	15	138.0	540.0

Total No. Species = 18   No. Ind. = 1205   Ave. Density (no. ind./m^2) = 31.2

L = living; D = freshdead; W = weathered; F = federal; OH = Ohio; NA = not applicable (only live individuals measured); ? = could not be measured.

TABLE 11. Comparison of all unionids in three surveys of the lower Muskingum River.

Endangered	Species	Bates (1970)	Stansbery & King (1983)	This study (1992-3)
	Actinonaias ligamentina	x	x	x
	Alasmidonta marginata		x	w
	Amblema plicata	x	x	x
	Anodonta grandis	x	x	x
	Anodonta imbecillis		x	x
	Cyclonaias tuberculata	x	x	x
F/OH	*Cyprogenia stegaria*	x	x	x
OH	*Ellipsaria lineolata*	x	x	x
OH	*Elliptio crassidens*		w	w
	Elliptio dilatata	x	x	x
F/OH	*Epioblasma t. torulosa*		w	
	Epioblasma triquetra	x		
	Fusconaia flava		x	x
OH	*Fusconaia maculata*	x	x	x
F/OH	*Lampsilis abrupta*		w	w
	Lampsilis radiata luteola	x	x	x
	Lampsilis ventricosa	x	x	x
	Lasmigona complanata	x	x	x
	Lasmigona costata	x	x	x
	Leptodea fragilis		x	x
	Ligumia recta	x	w	x
OH	*Megalonaias nervosa*		x	x
	Obliquaria reflexa	x	x	x
	Obovaria subrotunda	x	x	x
F/OH	*Plethobasus cicatricosus*			w
OH	*Plethobasus cyphyus*	x	x	x
F/OH	*Pleurobema clava*		w	w
OH	*Pleurobema cordatum*	x	x	x
F/OH	*Pleurobema plenum*			x
OH	*Pleurobema rubrum*		x	x
	Pleurobema sintoxia		x	x
	Potamilus alatus	x	x	x
	Potamilus ohiensis		x	x
	Ptychobranchus fasciolaris	x		x
OH	*Quadrula cylindrica cylindrica*			w
OH	*Quadrula metanevra*	x	x	x
	Quadrula pustulosa	x	x	x
	Quadrula quadrula	x	x	x
	Simpsonaias ambigua			w
	Strophitus undulatus	x	x	x
	Toxolasma parvus		x	
	Tritogonia verrucosa		w	
	Truncilla donaciformis	x	x	x
	Truncilla truncata			x
	Total no. Species	25	37	40
Total no. species = 44				

w = weathered or subfossil shell only; F = Federal; OH = Ohio.

1820) *(=cooperianus)*. Both have been extirpated from the state. Another species is Ohio endangered: *Lampsilis teres* (Rafinesque 1820). The remaining three taxa are headwater species known to occur in the Muskingum River system: *Lampsilis fasciola* Rafinesque 1820; *Lampsilis ovata* (Say 1817); and *Lasmigona compressa* (Lea 1829). Including these records, the total number of species reported from the study area is 50. At least 66% of these species still live in the area.

Comparisons of the diversity found by each of the three surveys shows that Bed 1 consistently had the lowest diversity (Fig. 2). Bed 1 also is the smallest of the beds. The diversities per bed were fairly equal for the 1983 and 1992 surveys. The 1970 study reported fewer species in each bed, although they were in the same relative proportions as in 1983 and 1992. It is not known how many man-hours were

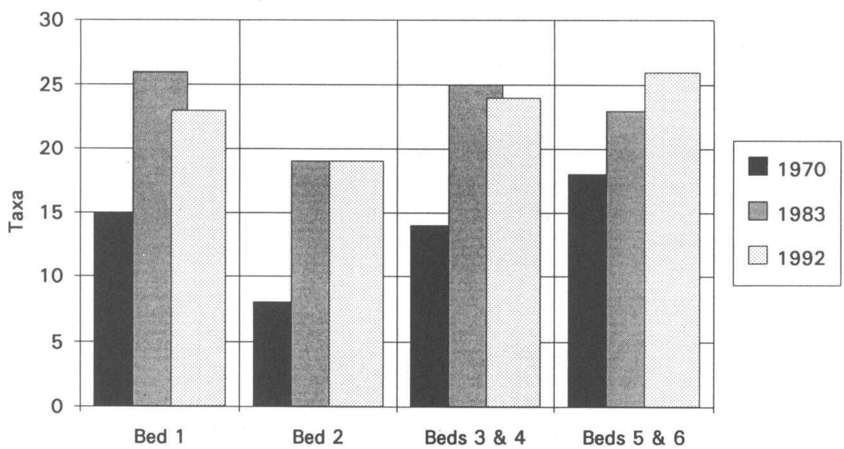

FIG. 2. Comparison of diversity of bed. 1970 – Bates (1970); 1983 – Stansbery & King (1983); 1992 - This study.

spent at each site for either Bates (1970) or Stansbery & King (1983), thus it is impossible to standardize data. We do not know if the low diversities reported by Bates were the result of shorter collecting times, his collecting methods (he did not sample muskrat middens), or if they actually reflect a depressed fauna that now is recovering.

The survey of Stansbery & King (1983) and this study reported densities for Beds 1 to 5. Stansbery and King did not recognize the presence of a sixth bed separate from Bed 5, if it existed at that time. They apparently included it with Bed 5. Fig. 3 compares the densities of these beds between 1983 and 1992. Both surveys found low densi-

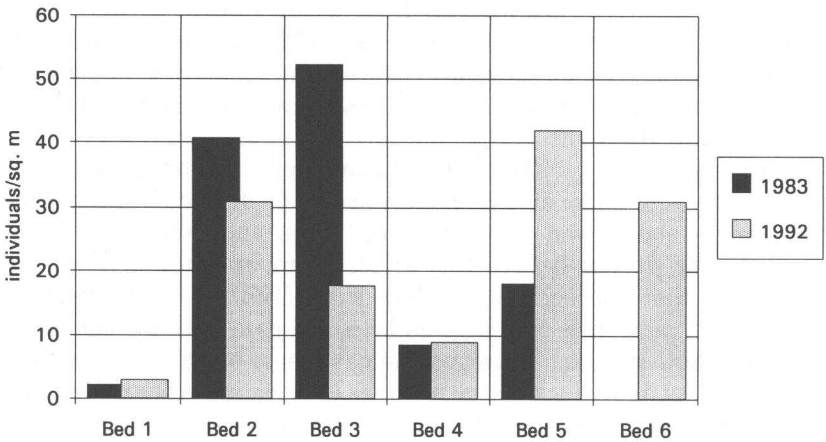

FIG. 3. Comparison of density by bed. 1983 – Stansbery & King (1983); 1992 – This study.

ties in Beds 1 and 4. However, Bed 3, below Lowell Lock & Dam, now has less than half of the density found in 1983. At that time it was the densest of all beds in the study area, whereas now it is the fourth densest. This may be due to several causes. The closure of the Beverly Lock & Dam upstream for repair, as well as the severe droughts of 1986-1989, exposed much of this shallow bed, killing untold numbers of mussels. During this study, the diver reported numerous dead shells that had begun to weather, suggesting that these were killed some years prior to 1992. The diver also found some areas devoid of mussels (live or dead) that previously had contained high densities, possibly attributable to poaching activities. A petroleum spill of 7 June 1992 just above the dam does not appear to have been responsible for this decline in density, but the bed should be monitored for any future effects.

The data presented in Fig. 3 suggest that, with the loss of density in Beds 3 and 4 below Lowell, the emphasis has shifted to Beds 5 and 6 below Devola. These beds are twice as dense now as they were in 1983, and support a higher diversity (Fig. 2). This may be due to their unobstructed connection to the Ohio River. There is some evidence that unionid and fish diversity as well as numbers are recovering in that river (W. Tolin, USFWS, personal communication; Pearson & Pearson, 1989).

For Lowell (Beds 3 & 4) and Devola (Beds 5 & 6), the beds closest to the dams had the highest densities and diversities. Stansbery & King also found this to be the case for Beds 3 and 4 below Lowell (they recognized only one bed below Devola). This may be due to faster currents in these areas, preventing silt accumulation over substrates and mussels, higher DO levels during low flow, and fish host congregations below the dams.

Stansbery & King (1983) presented combined data for age and size classes of all commercial taxa in each bed (their figures 4 & 5). This data mixes short lived and long lived taxa, and large and small species. We do not believe this a valid comparison and have not duplicated that approach here. Both Bates (1970) and Stansbery & King (1983) published age, size, and density data only for commercially valuable species. However, the patchiness of unionid distributions does not allow for quadrat samples to be extended to individual species densities. We have preferred to rank species by relative abundance for those comparisons. Densities were determined here only for all species within a bed. Comparisons on a species by species basis are given in the next section.

Bed 1 – Luke Chute. Bates (1970) recognized three beds below the Luke Chute Lock & Dam. Neither Stansbery & King (1983) nor this study found evidence of more than one diffuse bed.

Thirty-four species have been found in this bed in the three surveys, including four federally endangered species: *Cyprogenia stegari; Epioblasma torulosa torulosa* (Rafinesque 1820); *Lampsilis abrupta;* and *Pleurobema clava.* Twenty-six taxa were found in this study (Table 5). However, no federally endangered species were found as living or freshdead shells. Ten Ohio endangered species also have been recorded from the surveys. Four of these were found living in 1992: *Fusconaia maculata; Ellipsaria lineolata; Pleurobema cordatum;* and *Pleurobema rubrum.*

The same five species are dominant in both the Stansbery and King study and this study. Several of these differ from those reported in Bates' study. *Obliquaria reflexa,* a dominant species in 1992, was only seventh in 1970. *Truncilla donaciformis* (Lea 1827) now fourth, was 12th in 1970. Conversely, the rare, Ohio endangered *Fusconaia maculata* was the second most abundant species in 1970, but 16th and 14th in 1983 and 1992, respectively. Bates reported 93 individuals of this species in this pool, compared to four by Stansbery and King and five here. Unless his specimens were misidentified, this species has been greatly reduced in numbers since 1970. Other species common in 1970 or 1983 also have become rare: *Obovaria subrotunda* (Rafinesque 1820) and *Ptychobranchus fasciolaris.* Several have become more common since 1970 or 1983, including the Ohio endangered *Ellipsaria lineolata.*

Bed 2 – Beverly. The bed below Beverly Lock & Dam is the smallest of the beds studied. Its downstream limit coincides with the mouth of Wolf Creek, suggesting that this creek is releasing some agent into the Muskingum River that is detrimental to unionids. This may be sediment load during flood stage, agricultural runoff, or a combination of factors. Wolf Creek should be investigated for these potential problems.

Twenty-eight species have been found in this bed in the three surveys, including the federally endangered species *Lampsilis abrupta,* which was found by Stansbery and King only as a weathered shell. Nineteen taxa were found in this study (Table 6). Six Ohio endangered species also have been recorded from the surveys, two of which were found living in 1992.

The same four species were dominant in all studies: *Amblema plicata; Obliquaria reflexa; Quadrula pustulosa;* and *Quadrula quadrula.* The fifth most common species in 1992 was *Pleurobema cordatum,* an Ohio endangered species, and Bates found this species to be the sixth most common. Stansbery and King however ranked this taxon as 14th. Clearly, this species is much more common now than it was in 1983, and it apparently was common in 1970. This species also is more common now in the other beds than it was in 1983. Such fluctuations in a population of a long-lived species can only be detected by long term monitoring. The causes of these changes, whether they are due to limits on the mussel or on the host, and whether they are periodic, are unknown. Several other species appear more common today than in 1983: *Actinonaias ligamentina carinata* (Barnes 1823) and *Lampsilis ventricosa* (Barnes 1823). Several common headwater taxa found in 1983 were not encountered in 1992.

Beds 3 & 4 – Lowell. Bates did not recognize two beds below the Lowell Lock & Dam. Although Stansbery and King did find two beds, they combined the data to be comparable to those of Bates. Data from this study for Beds 3 and 4 also have been combined when necessary for comparison with earlier surveys. These beds are separated by the mouth of Bear Creek. As with Wolf Creek and Bed 2, this creek may be influencing beds in the Muskingum River by releasing sediment or other pollutants.

Twenty-five taxa were found in this study in Bed 3, and 21 were found in Bed 4 (Tables 7 and 8). Twenty-seven species were found in the combined beds. Thirty-two species were found in these beds in the three surveys, including the federally endangered species *Cyprogenia stegaria* (living and freshdead) and *Lampsilis abrupta* (as a weathered shell). A third federally endangered taxa, *Pleurobema plenum,* was found in 1992 as a weathered shell. Ten Ohio endangered species also have been recorded from the surveys, seven of which were found living in 1992.

The same six species were dominant in 1992 and 1983, and five of these were dominant in 1970. *Quadrula pustulosa* was the dominant species in 1983 and 1992. The sixth most common species in 1992, and fifth in 1983, was not found in 1970: *Leptodea fragilis* (Rafinesque 1820). Both *Ellipsaria lineolata* and *Truncilla donaciformis* were more common in 1992 than in previous studies. Several species have become less common, such as *Anodonta grandis* Say 1829, *Lampsilis ventricosa,* and *Potamilus ohiensis* (Rafinesque 1820). This may reflect a different emphasis on collecting techniques between 1983 and 1992 than on any biological cause. Those species often are found in slackwater outside the main stem. In 1992 collecting was most intensive in the main stem beds and species in slackwater may not be well represented in the data.

Beds 5 & 6 – Devola. Neither Bates nor Stansbery and King recognized two beds below the Devola Lock & Dam. This study found two beds and data from Beds 5 and 6 have been combined when necessary for comparison with earlier surveys.

Thirty-four taxa were found in this study in Bed 5, and 18 were found in Bed 6 (Tables 9 and 10). Thirty-four species were found in the combined beds. The three surveys combined yielded 39 species in these beds, including the federally endangered species *Cyprogenia stegaria* (living and freshdead), and *Lampsilis abrupta, Plethobasus cicatricosus, Pleurobema clava, Pleurobema plenum,* were found in 1992 as weathered shells. Fourteen Ohio endangered species also have been recorded from the surveys, eight of which were found living in 1992, including *Pleurobema rubrum.*

Four of the five most dominant species in 1992 were also the most dominant in previous surveys. *Obliquaria reflexa* was the most abundant species in 1992, although it had been ranked third and fourth in 1970 and 1983, respectively. *Pleurobema cordatum,* an Ohio endangered species, was the second most abundant taxa in 1992, moving up from sixth in 1983 and 1970. *Ellipsaria lineolata* and *Quadrula metanevra,* both Ohio endangered, also were more common in 1992. The commercially valuable *Amblema plicata* was only the fifth most common species in 1992, falling from first and second places in 1970 and 1983.

Commercially valuable species accounts.

Stansbery & King (1983) listed five species as being the most commercially valuable of the Muskingum River mussels: *Amblema plicata; Megalonaias nervosa; Obliquaria reflexa; Quadrula pustulosa;* and *Quadrula quadrula*. These species currently account for 77.5% of the individuals found in the study area. Four of them are the four most common species in the study. Only *Megalonaias nervosa* is uncommon in this area.

Bates (1970) reported on the commercial harvest of the Luke Chute and Beverly beds in 1967. From Beverly, 6.8 tons of shells were removed, while from Luke Chute, approximately 30.6 tons were taken. Bates described the Luke Chute bed: "the greatest percentage of the total catch of the season came from this area" (1970: 96). Originally described as three rich beds, this is now the least dense area of those studied, having an average density of only $3/m^2$. Only one diffuse bed could be located in 1983 and 1992. Between 1967 and 1970, approximately 1,258 tons of shells commercially were removed from the Muskingum River, much of it from the study beds. It is likely that the low densities found today in the Luke Chute bed (and probably other sites as well) are at least partially attributable to overharvesting.

Amblema plicata (Say 1817). Although this species is less common now than in 1970 and 1983 in most of the study area, still it comprises 13.5% of the total fauna, and there is ample evidence that it is reproducing, particularly in the Devola beds. A comparison of age classes between the three studies (all beds combined) shows strong recruitment in 1970 and 1992, but a single peak of 10-12 year olds in 1983 (Fig. 4; see also Appendix A). A bed by bed comparison of 1992 data shows good recruitment in Beds 5 and 6. Less recruitment was observed in Beds 1 and 2, and little or no recruitment was found in Beds 3 and 4. The average age in Bed 4 is 18.3 years, but only 11.7 years in Bed 6. In addition, large numbers of 1 to 3 year olds were present in beds 5 and 6.

Megalonaias nervosa (Rafinesque 1820). Neither Bates nor Stansbery and King found sufficient numbers of this Ohio endangered species to warrant age comparisons. In 1992, ages ranged from seven to 34 years old, indicative of a constant recruitment (Appendix A). Most of this recruitment occurs in Beds 5 and 6. These beds are open to the

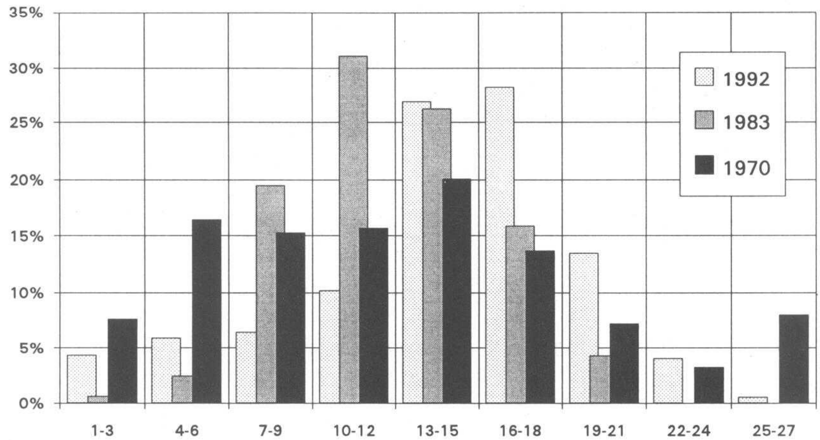

FIG. 4. Age distribution for *Amblema plicata* from three surveys. 1970 – Bates (1970); 1983 – Stansbery & King (1983); 1992 – This study.

Ohio River where this species is common. This species appears to be increasing in numbers in the study area, but currently makes up only 0.4% of the total fauna.

Obliquaria reflexa Rafinesque 1820. Within the study area, this species has increased its numbers in the past decade and is reproducing in most areas. It is most common in beds immediately below the dams, and currently comprises 27.6% of the total fauna – the most common species in the study area. A comparison of age classes found in the three studies for all beds combined shows recruitment in all three studies (Fig. 5; see also Appendix A). A much younger size group was found in 1992 than in other study years. A bed by bed comparison of 1992 data shows recruitment prevalent in Beds 1, 3, and 6, but less prevalent in Beds 2, 4, and 5. Young individuals are preyed upon heavily by muskrats.

Quadrula pustulosa (Lea 1831). Like *Obliquaria reflexa, Quadrula pustulosa* is thriving in the Muskingum River. A comparison of age classes between studies (all beds combined) shows recruitment in all three studies (Fig. 6; see also Appendix A). A bed by bed comparison of 1992 data shows recruitment in all beds except for Bed 4. Except for the Devola beds, it is the second most common species in the study area, comprising 24.9% of the total fauna, and has remained abundant for the past two decades. It is reproducing in most areas and is most common in beds immediately below the dams.

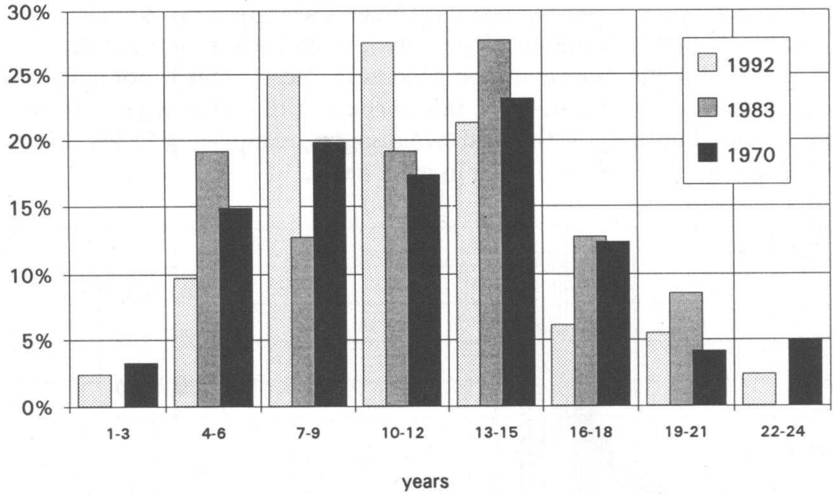

FIG. 5. Age distribution for *Obliquaria reflexa* from three surveys. 1970 – Bates (1970). 1983 – Stansbery & King (1983). 1992 – This study.

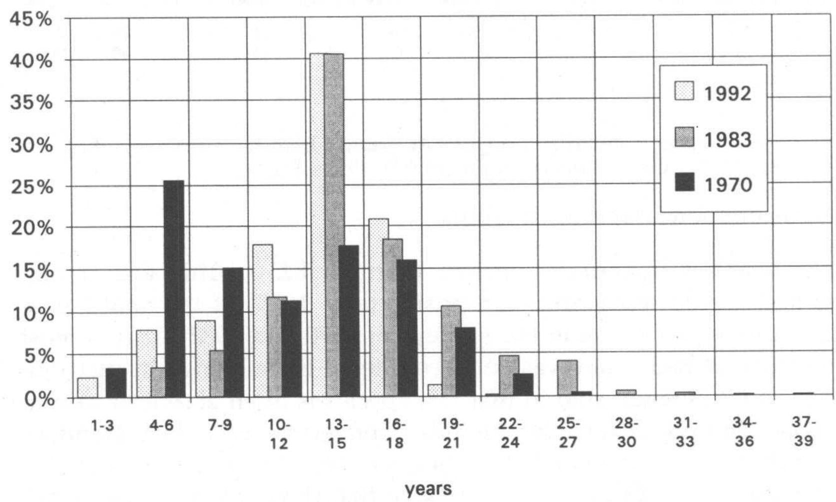

FIG. 6. Age distribution for *Quadrula pustulosa* from three surveys. 1970 – Bates (1970). 1983 – Stansbery & King (1983). 1992 – This study.

Quadrula quadrula (Rafinesque 1820). Although this species has declined in abundance, recruitment has remained fairly constant. A comparison of age classes between studies (all beds combined) shows recruitment in all three studies (Fig. 7; see also Appendix A). Data for 1992 show that recruitment is prevalent in all beds except for Beds 1, 3, and 4. It is the most common species in Bed 6. This is not surprising given the commonness of this species in the Ohio River. It has remained abundant for the past two decades, comprising 11.2% of the total fauna, and is reproducing in most areas.

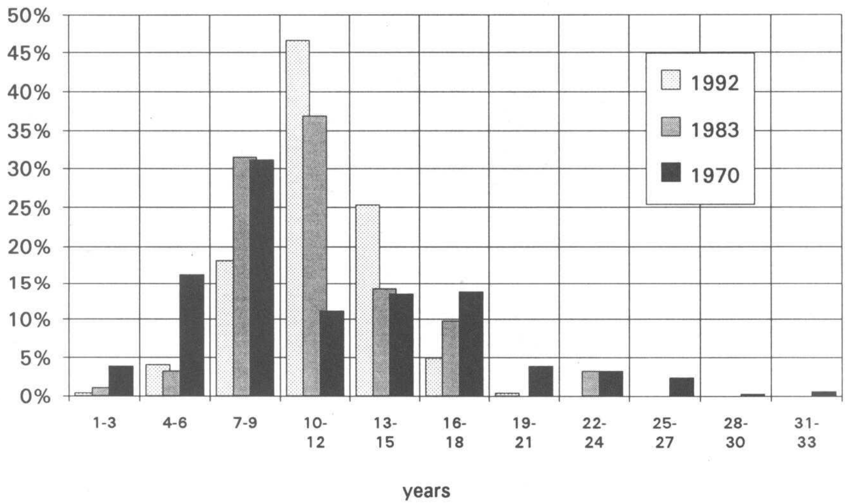

FIG. 7. Age distribution for *Quadrula quadrula* from three surveys. 1970 – Bates (1970). 1983 – Stansbery & King (1983). 1992 – This study.

Non-commercial species accounts

Actinonaias ligamentina carinata (Barnes 1823). This was a rare species in the study area, comprising only 0.32% of the total fauna, and was equally rare in the surveys of 1970 and 1983 . It was most common in Bed 1, but was not encountered there living. Its distribution in Ohio is unusual in that this species is often absent or rare in areas otherwise diverse in unionids. Conversely, it is often abundant at other sites. Although common in the Ohio River, it was not common in the Devola beds closest to that river. However, the only evidence of recruitment was found in Bed 6.

Alasmidonta marginata Say 1818. Only a single weathered shell at Bed 5 was found in this study. Similarly, Stansbery and King found only a single individual in the Lowell beds in 1983. This species typically is found in clear, fast water in large creeks, conditions that are not met in the study area.

Anodonta grandis Say 1829. *Anodonta grandis* was a rare species in this study, comprising only 0.13% of the total fauna, although Stansbery and King found more examples than did this survey. This species is common in backwater areas of rivers and impoundments. This study may not have addressed those areas as thoroughly as did the study of Stansbery and King.

Anodonta imbecillis Say 1829. Like *Anodonta grandis,* this species is most often found in backwaters and impoundments. It was not well represented in this study, although it is often locally common in the proper habitat. Only two individuals were found in this survey.

Cyclonaias tuberculata (Rafinesque 1820). This species was found only in Bed 1 in 1983 and 1992 and does not appear to be reproducing. Six individuals were found in 1992, all 15 years or older. It is a species of sandy substrates in large creeks or rivers.

Cyprogenia stegaria (Rafinesque 1820). This federally endangered species was found living in Beds 5 and 6, and freshdead in Beds 4 and 5. Two of these dead specimens were found in muskrat middens along Bed 5. A weathered shell was found in Bed 1. All living individuals were found among other species in packed sand and gravel. This species comprised 0.09% of the fauna; 19 other species were rarer, or as rare as, *Cyprogenia stegaria*. Bates found a single individual below Devola, and Stansbery and King found two below Lowell and one below Devola. Ages of the 1992 specimens ranged from nine to 17 years, although one freshdead individual was seven years old. Thus there was no evidence that this species was reproducing in the study area. However, this does not preclude the possibility that undetected juveniles exist, or that the adults found will not reproduce in the future. This species is not known to live anywhere else in the state, and now occurs in less than half of a dozen sites in the world.

Ellipsaria lineolata (Rafinesque 1820). This Ohio endangered species was found living or freshdead in every bed in the study area. A total of 224 individuals was found, comprising 2% of the total population, making it the sixth most common species in the study. It was most abundant in Bed 5, where it represented 3.2% of the fauna, and is reproducing below Devola in Beds 5 and 6. In all beds it is now as common, or more common, than in either 1983 or 1970. The only known population of this species in Ohio is in the lower Muskingum River.

Elliptio crassidens (Lamarck 1819). Only a single weathered shell was found within the study beds, at Bed 1. Another weathered shell was found downstream of Bed 2. Bates did not find this species, and

Stansbery and King found only weathered shells. This Ohio endangered species occurs only sporadically within the state's waters, although locally abundant in the Ohio River. Its absence in the lower beds of the Muskingum River is a mystery.

Elliptio dilatata (Rafinesque 1820). Only two living specimens were collected in this study, both in Bed 1. This species typically inhabits smaller rivers and creeks where it may be abundant. It occurs in this bed along with a few other smaller river species that were either absent or very rare in other beds. These specimens may have been introduced from neighboring tributaries. It also was very rare in previous surveys.

Fusconaia flava (Rafinesque 1820). Like *Elliptio dilatata,* this species is common in smaller creeks in the state, but was very rare in the study area. Only four specimens were found in the study, two of these were from Bed 1. Bates did not find this species, and it was rare in the study of Stansbery and King.

Fusconaia maculata maculata (Rafinesque 1820). This Ohio endangered species was found in all beds except Bed 2. However, a single specimen was found living some miles below that bed. It comprises 0.18% of the total fauna of the study area. This also was a rare species in 1983, but Bates reported 93 specimens in 1970 from Bed 1 where it was the second most abundant species. By contrast, it was 16th in 1983 and 14th in the present study. This species has some commercial value, and if Bates' figures are correct, this species may have been over-harvested in that bed. Most specimens found in 1992 were old individuals, the youngest being a seven year old specimen in Bed 6. This is a rare species in the Ohio River, and the Muskingum River population may be the only remaining one within the state boundary. This taxon also may be listed as *Fusconaia subrotunda* (Lea 1831).

Lampsilis abrupta (Say 1831). This federally endangered species was found in 1983 and 1992 only as weathered shells. There is no evidence that is still living in the study area, although recent records from the Ohio River are known.

Lampsilis radiata luteola (Lamarck 1819). This species is the most common unionid in Ohio, but is rare in big rivers. The Muskingum River is no exception and only three specimens were found in the study. Bates found only a single specimen, and Stansbery and King, only five. This species also may be listed as *Lampsilis siliquoidea* (Barnes, 1823).

Lampsilis ventricosa (Barnes 1823). This species comprised 0.25% of the total fauna and was found in all beds. It was most common in

Bed 1, where it may be reproducing. This taxon is more common in smaller rivers and creeks. It was equally uncommon in previous studies. This species also may be listed as *Lampsilis cardium* (Rafinesque 1820).

Lasmigona complanata (Barnes 1823). This species was found in all beds except Bed 6, although most specimens came from Bed 5, where it probably is reproducing. It comprised 0.28% of the total fauna. It was much rarer in 1970, but about equal numbers were found in 1983 and 1992. Its habitat ranges from creeks to large rivers, but it is only locally common.

Lasmigona costata (Rafinesque 1820). This is a creek or small river species that is rare in the Ohio and Muskingum Rivers. Only five specimens were found in this study, and it was equally rare in 1970 and 1983. All specimens in 1992 were old individuals.

Leptodea fragilis (Rafinesque 1820). This species was uncommon, although found in all beds. It comprised 1.43% of the total fauna, and was the eighth most common species. Although Bates did not find this species in 1970, it was present in 1983 in the same numbers as today. It appears to be reproducing in all beds, and the histograms for age (Appendix A) show two recruitment events centered about 3-4 and 7-8 years ago. These pulses may be linked to fish migration.

Ligumia recta (Lamarck 1819). This otherwise common species is surprisingly rare from the Muskingum River. Bates (1970) found a single specimen, and Stansbery & King (1983) recorded only subfossil fragments. In this study, a single freshdead juvenile was found in a midden adjacent to Bed 5.

Obovaria subrotunda (Rafinesque 1820). This species rarely is common in Ohio, although it occurs from creeks to rivers. In the study area it accounted for only 0.43% of the total fauna. Although much more common in 1970, comparison of it's relative abundance between studies shows that it has steadily declined in abundance since then. All specimens in 1992 were old individuals, and there was no indication that this species is reproducing in the study area.

Plethobasus cicatricosus (Say 1829). This very rare, federally endangered mussel was found as a weathered shell fragment adjacent to Bed 5. This represents the first authenticated record of this species for the Muskingum River. The Ohio State University Museum of Zoology (OSUMZ) record of Hildreth in 1830 probably is based on an erroneous locality record (D.H. Stansbery, OSUMZ, personal communication). There is no evidence that it still lives in the study area.

Plethobasus cyphyus (Rafinesque 1820). Only six specimens of this

Ohio endangered species were found in the study area, where it comprised only 0.05% of the total fauna. It was absent from Beds 1, 2, and 3, but became more common with proximity to the Ohio River. It also was rare in 1970 and 1983. It probably is not found anywhere else in the state.

Pleurobema clava (Lamarck 1819). This federally endangered species was found adjacent to Bed 5 as a weathered shell. There is no evidence that it still lives in the study area, although it was once common in several Muskingum River tributaries.

Pleurobema cordatum (Rafinesque 1820). This Ohio endangered species was locally abundant in the study area. It accounted for 13% of the total fauna, and was the fourth most common species. It is more common today than in 1970 and 1983, particularly in Beds 5 and 6, where it now is the second most common species. Bates found 101 individuals in the study area; Stansbery & King (1983) found 153. This study found 1,406 specimens. Although no living individuals were found under six years of age, this species probably is reproducing in the study area. In Ohio, this species may occur only in the lower Muskingum River. Although not considered by Stansbery and King as commercially valuable, poachers have been apprehended in recent years with hundreds of specimens.

Pleurobema plenum (Lea 1840). Three weathered shells were found that may be referable to this federally endangered species. There is no indication that it still lives in Ohio. Although it has not been reported from this system, it is known from historical records in other northern tributaries of the Ohio River.

Pleurobema rubrum (Rafinesque 1820). Two living, and one weathered, individuals were found of this rare, Ohio endangered species. One living specimen was found in Bed 1, where Stansbery & King (1983) had also found a specimen. A second live specimen was found in Bed 5. Although Bates did not find this species in 1970, judging from a weathered shell at Bed 3 in 1992, this species has been a resident in the Muskingum River for many years. Both living specimens were very old, and there is no evidence of reproduction. This species is a relict in this river system, but does not occur anywhere else in the state. It also is listed as *Pleurobema pyramidatum* (Lea 1840).

Pleurobema sintoxia (Rafinesque 1820). Although much more common in smaller rivers and creeks, this is an uncommon species in the study area, where it accounted for 0.24% of the total fauna. Bates did not find (or recognize as distinct) this species. In most beds, it is more common today than in 1983, but there was no evidence in 1992 of recruitment. It also is listed as *Pleurobema coccineum* (Conrad 1834).

Potamilus alatus (Say 1817). This usually common species represented only 0.83% of the total fauna. Although it was found in all beds, it was never common. It is less common now than in 1983, but this may reflect differences in collecting emphasis. This species is more common in backwaters, which was not the main focus of this study. Juveniles were found in the Devola beds.

Potamilus ohiensis (Rafinesque 1820). As with *Potamilus alatus*, this species was less common in 1992 than in 1983, but probably as a result of collecting emphasis. Bates did not find this species.

Ptychobranchus fasciolaris (Rafinesque 1820). This species may be abundant in smaller rivers and creeks, but is rare in many rivers. In the study area only two individuals were found. These came from Bed 1, which had several headwater species that are rare or absent in other beds. Bates also found two specimens in Bed 1 and nowhere else, and Stansbery and King did not find this species in the study area.

Quadrula cylindrica cylindrica (Say 1817). A single subfossil valve was found adjacent to Bed 5. This is the first record of this Ohio endangered species from the study area.

Quadrula metanevra (Rafinesque 1820). This Ohio endangered species was found in all beds except 1 and 2. It was very rare below Lowell, but much more common in the Devola beds. It accounted for 0.86% of the total fauna. Stansbery & King (1983) also found this species only below Lowell and Devola, where it was rare. Bates (1970) found only five specimens of this species only below Devola. It appears to be as rare today as it was in 1970 and 1983. Juveniles were found below Devola, where it probably is reproducing. Its greater relative abundance in Beds 5 and 6 is undoubtedly due to their proximity to the Ohio River, where this species is uncommon. This species does not occur anywhere else in the state.

Simpsonaias ambigua (Say 1825). This uncommon species is recorded from the study area for the first time from a large (52 mm in length) weathered pair of shells. It was found adjacent to Bed 5.

Strophitus undulatus (Say 1817). Although common in creeks, this is not a big river species. Only two freshdead individuals were found in the study area, in middens along Beds 2 and 3. Bates also found this species to be very rare here. Although Stansbery & King (1983) found more specimens than did this study, it nevertheless was rare in 1983 as well. These specimens may represent stray occurrences from tributaries.

Truncilla donaciformis (Lea 1827). This was the seventh most common species in the study, comprising 1.76% of the total fauna. Most specimens were found in muskrat middens. This is a fairly short-lived species, and most evidence of reproduction was found in the beds below Lowell and Devola. Many juveniles were found attached by byssal threads to other unionids. Bates found only two specimens in 1970, but the species had become more common by 1983. It is now more abundant than in either previous study.

Truncilla truncata Rafinesque 1820. In some rivers this species may be present in large numbers, but it is rare in the Muskingum River and adjacent portions of the Ohio River. Specimens were found only in Bed 5, and it comprised only 0.1% of the total fauna. Neither Bates nor Stansbery and King found this species in the study area. However, the two live examples found were two and three years old, suggesting that this species may be reestablishing itself in the study area.

SUMMARY

This study found 11,145 specimens of 40 unionid species, including living specimens of the federally endangered *Cyprogenia stegaria.* Eight species were present only as weathered shells, including the federally endangered *Lampsilis abrupta, Plethobasus cicatricosus, Pleurobema clava,* and *Pleurobema plenum.* Fourteen Ohio endangered species were found (including federally endangered species): *Ellipsaria lineolata; Elliptio crassidens* (only as weathered shells); *Fusconaia maculata; Megalonaias nervosa; Plethobasus cyphyus; Pleurobema cordatum; Pleurobema rubrum; Quadrula cylindrica;* and *Quadrula metanevra.*

The fauna is dominated by five species, which account for 90.2% of the total fauna: *Obliquaria reflexa* (27.6%), *Quadrula pustulosa* (24.9%), *Amblema* plicata (13.5%), *Pleurobema cordatum* (Ohio endangered, 13%), and *Quadrula quadrula* (11.2%). With the exception of *Pleurobema cordatum,* these are all commercially valuable species. *Megalonaias nervosa,* also commercially important, is present in much lower numbers. All of these species appear to be reproducing.

Twenty-one species or 53% of the total fauna occur in relative abundances of 0.1% or less. Eighty percent of the fauna is present in relative abundances under 1%. Clearly, most of the fauna in the study area must be considered rare. This includes the federally endangered *Cyprogenia stegaria,* and the Ohio endangered *Fusconaia maculata, Ellipsaria lineolata, Plethobasus cyphyus, Pleurobema cordatum, Pleurobema rubrum,* and *Quadrula metanevra,* all of which probably do not occur anywhere else in the state.

Approximately 3/5th of the species found live are reproducing, including many of the Ohio endangered taxa. Most recruitment was found in Beds 5 and 6. These beds are open to the Ohio River and probably derive their fish hosts from there. The concentration of big river unionids in these beds suggests that their hosts rarely migrate through the locks to more upstream pools. Bed 4 showed the least recruitment.

While a few species appear to be declining in numbers since 1970, such as *Amblema plicata, Fusconaia maculata,* and *Obovaria subrotunda,* most species are either more common today or have not changed in rarity. Species that have increased in abundance are *Ellipsaria lineolata* (Ohio endangered), *Megalonaias nervosa* (Ohio endangered), *Obliquaria reflexa, Pleurobema cordatum* (Ohio endangered), *Pleurobema sintoxia, Truncilla donaciformis,* and *Truncilla truncata.*

Few specimens were found outside of the beds. The majority of the study area consists of long depauperate reaches between beds. This especially is true below Dams 5 and 4. However, there is ample evidence to suggest that prior to construction of the dams, the unionid fauna was widely distributed in this area. A subfossil deposit below Dam 4 at river mile 22 at Dana Island (no longer an island) reveals that this fauna consisted of species that are now rare or extirpated.

Average densities within the beds ranged from 3 to 42 individuals $/m^2$. The most diffuse bed was Bed 1. Bates (1970) reported that this was the most dense commercially harvested bed on the Muskingum River. In 1967 alone, 30.6 tons of shells were taken from that bed. It may be no coincidence that this bed now is the least dense of those studied. The densest bed was Bed 5 below Devola Lock & Dam, where one quadrat contained 124 individuals$/m^2$. Ohio legislation banned commercial harvesting of mussels before clammers began harvesting from this bed. It is interesting that the beds found by Stansbery and King in 1983 still exist in approximately the same locations, and cover the same amount of river. Clearly, if left alone, beds may persist for decades or longer, and become self-maintaining.

Although these Muskingum River beds represent the largest mussel beds in Ohio, their survival is precarious. The beds are located in a 34 mile stretch of a single river, and contain rare and endangered species that do not occur anywhere else in the state. It is foreseeable that a single major environmental accident upstream, such as an oil or pesticide spill, could irreparably damage or even eliminate this fauna. One such spill, although apparently minor and well contained, occurred in 1992. All agencies should be especially vigilant in maintaining the health of this river.

For these same reasons any work on the existing Lock and Dam system must be undertaken with caution. Sediment samples revealed that silt and detritus have accumulated against the upstream side of the dams. The release of this material would be disastrous to the beds below. Since most of the beds are immediately below the dams, and most of the mussel populations are in these beds, any construction would jeopardize them. Removal of the dams such as these must be accompanied by prior removal of the sediment. Similarly, dredging activities must be closely monitored. No dredging on existing beds should be permitted unless the mussels are relocated. Dredging above beds should be done so as to minimize sediment release.

There is little doubt that harvesting pressure has long term effects on animals that have a low turnover rate. Recruitment in mussels is sporadic and mortality is high. Survival rates for a glochidium to metamorphosis range from 0.000001% (Young & Williams, 1984) to 0.0001% (Jansen & Hanson, 1991), not including predation after metamorphosis. Successful recruitment may depend on a critical number of individuals in proximity, plus the proper host. Any efforts that kill or remove large numbers of individuals from a bed reduce the chance of successful reproduction. The Muskingum River may be the only Ohio river containing beds with sufficient density to be commercially important in Ohio. These beds contain numerous endangered species, hence commercial harvesting should remain closed in Ohio. These beds, occurring in such a small area, are the last of their kind in Ohio and cannot endure the removal of tons of living individuals. Ultimately, the study section should be made into a mussel sanctuary similar to sanctuaries in other states, such as the Clinch River in Tennessee.

ACKNOWLEDGMENTS

We would like to thank Mr. Dave Ross, Division of Wildlife, Ohio Department of Natural Resources, for his time and efforts in making this survey a reality, and a special thanks to our willing and able diver and crew, Jim and Teresa Duckworth, of Ducktrail Diving, Lebanon, Tennessee.

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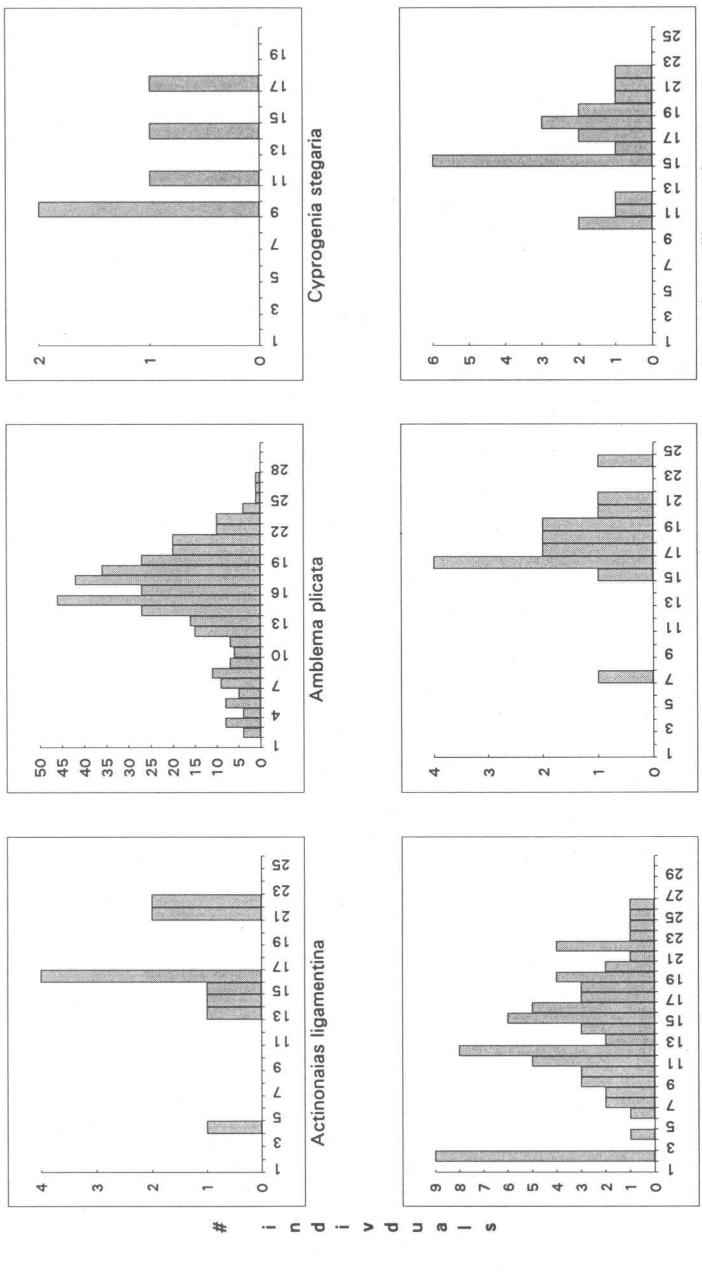
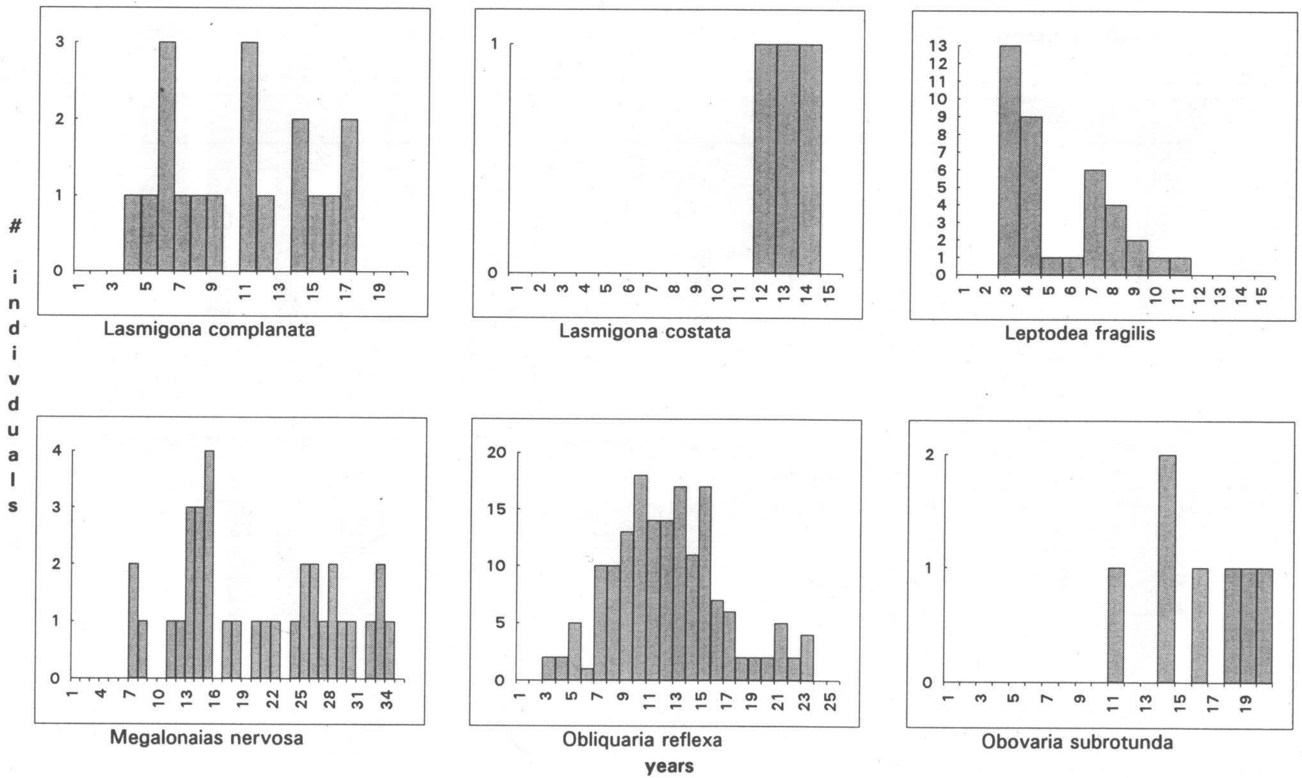
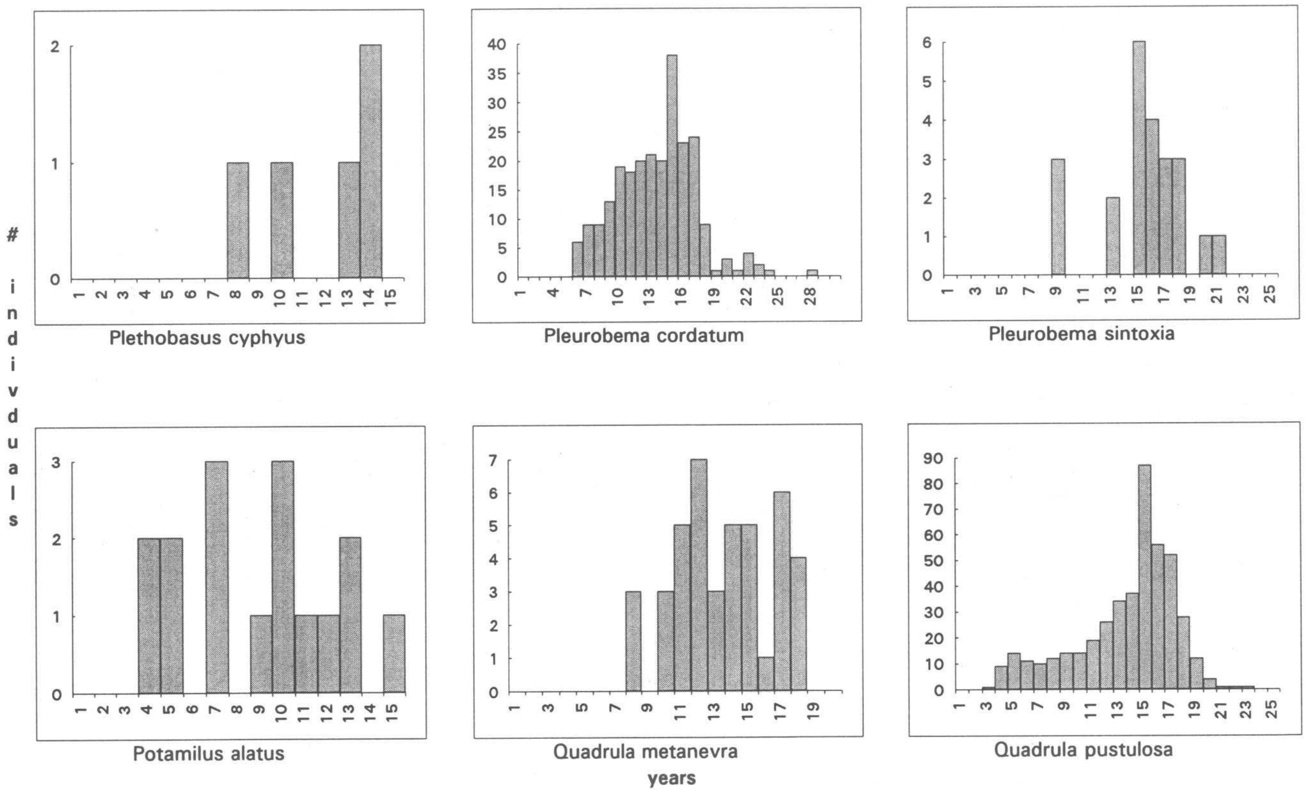
APPENDIX A.

Age distributions for species found in two or more beds. All beds combined.

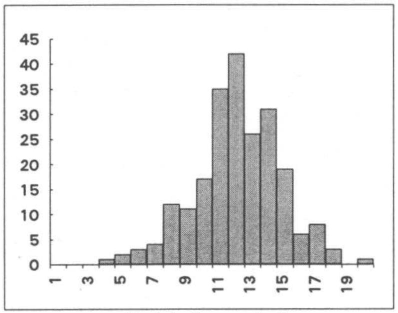




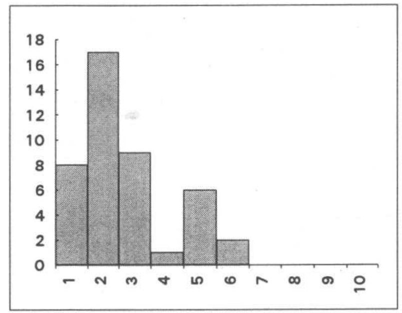
individuals
Lasmigona complanata
Lasmigona costata
Leptodea fragilis
Megalonaias nervosa
Obliquaria reflexa
Obovaria subrotunda
years



individuals
Plethobasus cyphyus
Pleurobema cordatum
Pleurobema sintoxia
Potamilus alatus
Quadrula metanevra
Quadrula pustulosa
years



Quadrula quadrula



Truncilla donaciformis

years

Walkerana, 1993, 7(17/18): 265-273

ANODONTA HEARDI, A NEW SPECIES OF FRESHWATER MUSSEL (BIVALVIA: UNIONIDAE) FROM THE APALACHICOLA RIVER SYSTEM OF THE SOUTHEASTERN UNITED STATES

Mark E. Gordon[1] and Walter R. Hoeh[2]

ABSTRACT – ***Anodonta heardi*** n. sp., is described from the Apalachicola River. Previously considered to be a disjunct population of *A. couperiana* Lea 1840, it is specifically distinct on the basis of morphological and allozymic comparisons with other regional species. Its closest faunal affinities appear to be with *A. couperiana* and *A. suborbiculata* Say 1831.

Key words: *Anodonta heardi*, Unionidae, Apalachicola River system.

INTRODUCTION

Distributions of anodontine species within coastal drainages of the southeastern United States have been surveyed by Clench & Turner (1956), Johnson (1965, 1969, 1970, 1972), and Heard (1979). Heard (1975) examined the reproductive biology of several of these species. In particular, he noted that a disjunct population of *Anodonta couperiana* Lea 1840[3], from the Apalachicola River (see Johnson, 1969) contained only females and hermaphrodites, whereas, a population from peninsular Florida was found to be gonochoric. This difference in visceral sex together with subsequent morphological comparisons and allozyme analyses (Hoeh, 1990) indicate that *Anodonta "couperiana"* in the Apalachicola River represents a distinct, previously undescribed species.

Family Unionidae, Subfamily Anodontinae, Tribe Anodontini
Genus *Anodonta* Lamarck 1799

Anodonta heardi n. sp.

Figs. 1, 6.

Anodonta gibbosa Say, Clench & Turner 1956, p. 186, in part; Tanvat Pond, 3 miles north of Sneads, Jackson Co., Florida.

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[3]The publication date for *Anodonta couperiana* generally has been given as Lea (1842) (*e.g.*, Johnson, 1970, 1972; Burch, 1975). However, Clench & Turner (1956) and Haas (1969) noted that this species originally was described by Lea (1840) as *A. cowperiana*. This mussel was named for J.H. Couper and the incorrect original spelling was corrected to *A. couperiana* in Lea (1842). In accordance with the International Code of Zoological Nomenclature (Ride *et al.*, 1985: Articles 19a, 32c-d), the correct citation for this species should be *A. couperiana* Lea 1840, as referenced by Frierson (1927) and Turgeon *et al.*, (1988).

Anodonta couperiana Lea, Johnson, 1969, p. 34, in part; Apalachicola River at Ocheesee Landing, 6 miles North of Blountstown, Calhoun Co., Florida.
Anodonta couperiana Lea, Heard, 1975, p. 84, in part; Apalachicola River at Ocheesee Landing, about 6 miles north of Blountstown, Calhoun Co., Florida.
Anodonta "couperiana," Hoeh, 1990, p. 65, fig. 1b; Apalachicola River, Chattahoochee, Gadsden Co., Florida.

Diagnosis: *Anodonta heardi* has a relatively heavier shell, a more ovate lateral aspect, and a lesser tendency towards periostracal raying than *A. couperiana* (*cf.* Figs. 1, 2 and 6). The posterior slope of *A. couperiana* also is relatively more compressed, exhibiting a greater degree of wing development. Contrasted to *A. suborbiculata* Say 1831, *A. heardi* does not grow as large or as circular in shape, although their periostraca and shell thickness can be similar (*cf.* Figs. 1, 3 and 6). *Anodonta heardi* has a relatively heavier shell and develops a greater degree of ventral convexity than does *Utterbackia imbecillis* (Say 1829) or *U. peggyae* (Johnson 1965) and lacks the oblique orientation of the ventral convexity exhibited by the latter species (*cf.* Figs. 1, 4, 5 and 6).

Holotype: University of Michigan Museum of Zoology (UMMZ) no.253324, collected 4 August 1968 by W.H. Heard and R.H. Guckert. Paratypes: three specimens from UMMZ no. 250516 and three specimens from UMMZ no. 250517, collected 2 August, 1968, at type locality by C.C. Swift and J.C. Wolfe.

Type locality: Apalachicola River, Florida, Calhoun County, approximately 9.7 km north of Blountstown at Ocheesee Landing.

Etymology: This species is named for Dr. William H. Heard, Department of Biological Science, Florida State University, in recognition of his significant contributions to malacology.

Description: Shell medium-sized (see Table 1), broadly elliptical, sub-ovate, thin and translucent but relatively solid for *Anodonta,* quite inflated; anterior margin rounded and merging evenly into the slightly convex dorsal and deeply convex ventral margins, posterior margin bluntly pointed, posterio-dorsal junction distinctly angular; posterior ridge broadly rounded, concave, somewhat double; posterior slope flattened but with a slight longitudinal furrow; ligament low and relatively long, extending from the posterio-dorsal angle to the umbo; umbo positioned at 0.36 of shell length from anterior margin; umbonal region swollen but dorsally flattened, only slightly elevated above dorsal margin; umbonal sculpture of three double-looped and several subsequent concentric ridges; periostracum shiny, grayish-green, lightening to yellowish-green peripherally, obscurely rayed

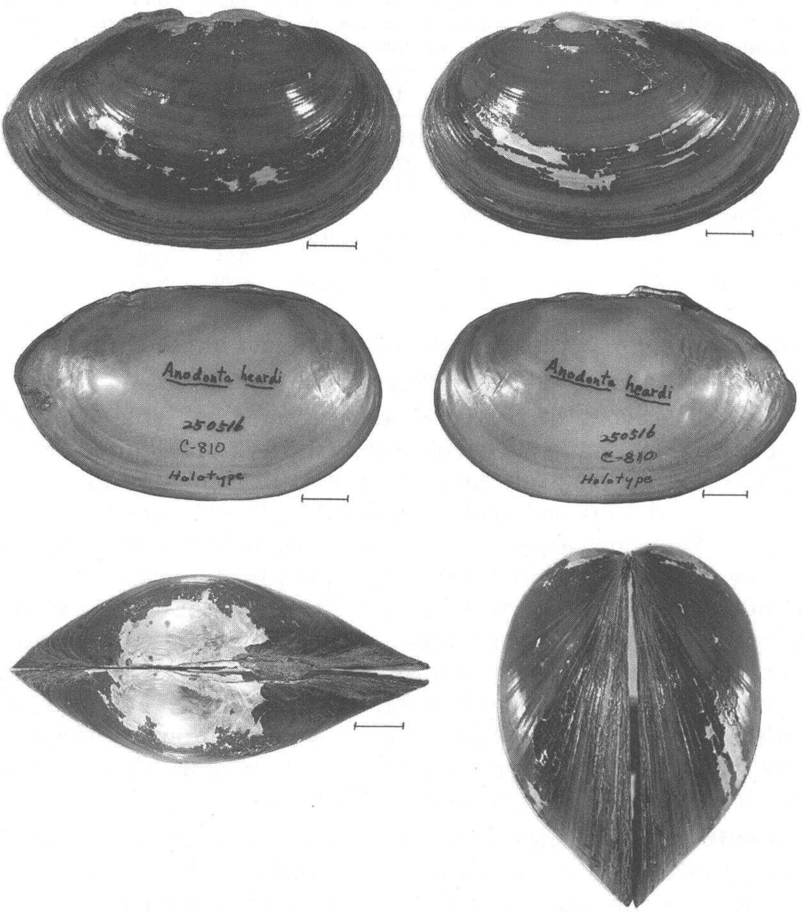


FIG. 1. Holotype of *Anodonta heardi* n.sp., UMMZ 253324: external (top row) and internal (middle row) views of right and left valves, and top and anterior end views (bottom row). Scale lines = 1 cm.

with dark-green capillary-like lines, prevalence for such raying on the posterior slope.

Hinge edentulous, not thickened, with a notch at the posterior terminus of the ligament; anterior muscle scars confluent, posterior muscle scars confluent; dorsal muscle scars small, irregular, positioned anterior to umbo and subparallel to dorsal margin; pallial line lightly impressed; umbonal cavity present but very shallow; nacre

TABLE 1. Shell dimensions of type specimens of *Anodonta heardi* new species (measurements in mm; L = length, H = height, W = width, U = distance of umbo from anterior margin parallel to the longitudinal axis).

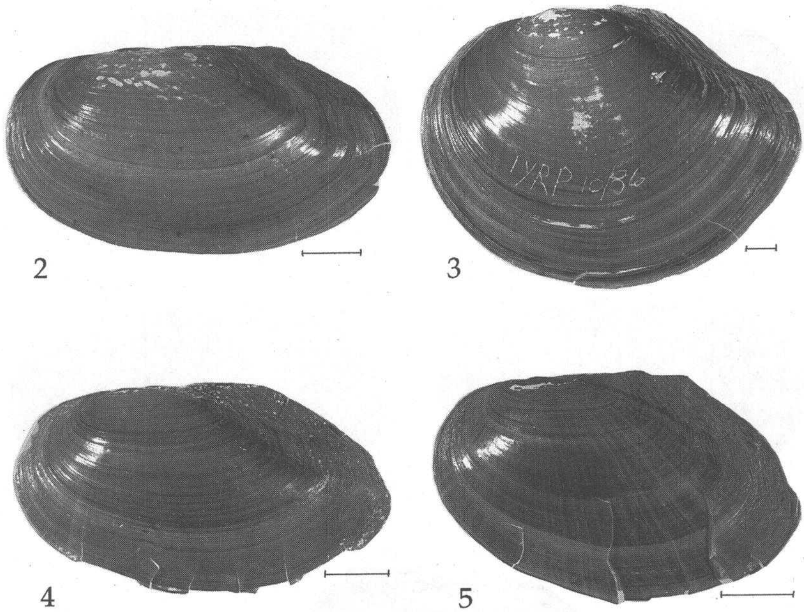
Specimen	L	H	W	U	H/L	W/H	U/L	UMMZ cat. no.
Holotype	81.4	47.9	35.9	29.3	0.59	0.75	0.36	253324
Paratype	95.0	54.6	45.5	32.2	0.58	0.83	0.34	250516
Paratype	82.5	47.2	36.2	28.7	0.57	0.77	0.35	250516
Paratype	71.7	40.8	31.4	22.6	0.57	0.77	0.32	250516
Paratype	88.5	52.0	43.4	31.8	0.59	0.83	0.36	250517
Paratype	84.0	48.5	39.5	31.4	0.58	0.81	0.37	250517
Paratype	80.2	47.6	37.7	27.9	0.59	0.79	0.35	250517

white, iridescent, appears somewhat bluish and blotched due to external erosion and staining showing through the thin shell.

Shell dimensions of paratypes are presented in Table 1. With respect to shell length, the lateral aspect (H/L) and position of umbos (U/L) remained relatively constant. However, there may be a slight trend toward increased shell inflation (W/H) with increased shell length. With increasing size, the convexity of the ventral margin becomes quite pronounced and the posterior margin may vary from bluntly pointed to rounded (Fig. 6). Therefore, the outline of the ventral region may appear somewhat subcircular. In smaller specimens, the umbo essentially is flush with the dorsal margin but may be swollen slightly above this margin in larger shells. Periostracum varies from grayish or yellowish-green to dark brown. Although faint narrow rays may be present on any portion of the shell exterior, they tend to occur most frequently on the posterior slope.

Distribution: Presently known only from the lower Apalachicola River system. This species appears to be quite rare. In addition to the type material, one specimen of *Anodonta heardi* (UMMZ no. 250708) was collected 17 July 1986 from the Apalachicola River at Chattahoochee, Gadsen County, Florida (Hoeh, 1990; electrophoretic specimen). An additional specimen of *A. heardi* was located in the Florida State Museum (no. 1915: labeled as *A. gibbosa* Say 1824) from Tanvat Pond, 4.8 km north of Sneads, Jackson County, Florida (evidently a voucher specimen from Clench & Turner, 1956: p. 186). This last record indicates that *A. heardi* historically was distributed in the Apalachicola River basin above Chattahoochee, Florida. However, the extent of its current upstream distribution and the effects of inundation by Seminole Reservoir on former habitats are not known.

Habitat: At the type locality, *Anodonta heardi* was found in a back-



FIGS. 2-5. Left valves of other species of pertinent Anodontinae. FIG. 2. *Anodonta couperiana* Lea 1840, St. Johns River, Florida Hwy 192 bridge, Brevard County, Florida (UMMZ 250706); FIG. 3. *Anodonta suborbiculata* Say 1831, ponds off the Yazoo River, Yazoo County, Mississippi (UMMZ 250703); FIG. 4. *Utterbackia imbecillis* (Say 1829), Coe's Landing, Lake Talquin, Leon County, Florida (UMMZ 250702); FIG. 5. *Utterbackia peggyae* (Johnson 1965), Coe's Landing, Lake Talquin, Leon County, Florida (UMMZ 250705). Scale lines = 1 cm.

water area with a substrate composed of muddy, medium packed sand. Although collected during a period of very low water levels (0.55 m at Bristol-Blountstown gaging station, 4 August, 1968), depths at that site may exceed 6 m. *Anodonta heardi* may typically occur in relatively deep water. The type specimens were found associated with *Glebula rotundata* (Lamarck 1819).

Discussion: Species of eastern North American mussels that have been classified as *Anodonta* express two general shell morphologies distinguished primarily by umbonal development. The umbo may be well-developed and distinctly elevated above the dorsal margin (*Pyganodon* Crosse & Fischer 1894) or, alternatively, the umbo may be essentially flush with the dorsum (*Anodonta* Lamarck 1799 [except for *A. implicata* Say 1829], and *Utterbackia* Baker 1927; see Hoeh [1990] for revised generic classifications). Within the Apalachicola River sys-

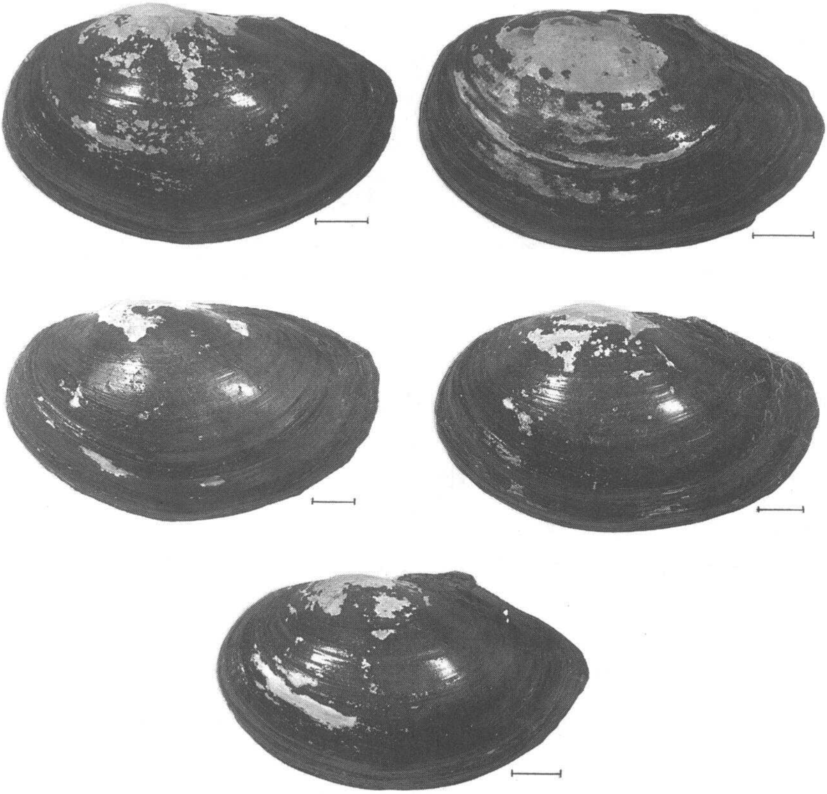


FIG. 6. Left valves of five paratypes of *Anodonta heardi*, n.sp, UMMZ 250516 and UMMZ 250517. Scale lines = 1 cm.

tem, three species exhibit the latter characteristic: *U. imbecillis*[4] (Fig. 4); *U. peggyae* (Fig. 5); and *A. heardi* (Figs. 1 & 6). Phylogenetic analyses (Hoeh, 1990) suggest that the former two species are members of a distinct clade and that *A. heardi* is not related closely to either (*e.g.*, Nei's [1978] genetic distance estimate between *U. peggyae* and *A. heardi* is 1.21, the distance estimate between *U. imbecillis* and *A. heardi* is 0.96; based on 24 loci [Hoeh 1990]). The phylogenetic hypothesis

[4]In recent publications, this species variously has been spelled *imbecilis* (*e.g.*, Johnson, 1970; Burch, 1975; Hoeh, 1990) or *imbecillis* (*e.g.*, Parmalee, 1967; Davis & Fuller, 1981; Turgeon *et al.*, 1988). The use of *imbecilis* appears to have resulted from a typographical error in the reprint of Say's (1829) description in Binney (1858: p. 140), although it subsequently was spelled *imbecillis* in the reprint of Say (1831) (Binney, 1858: p. 235). Say's (1829: p. 355) original spelling is *imbecillis*, thus validating the use of a double "l."

presented by Hoeh (1990, Fig. 4) suggests that the umbonal similarities shared by *U. peggyae, U. imbecillis,* and *A. heardi* are plesiomorphic in nature and, therefore, not indicative of a relatively close evolutionary relationship. It also suggests that *Anodonta heardi* is most closely related to *A. couperiana* (as which it previously had been classified by Johnson, 1969) and *A. suborbiculata* Say. Based on allozymes, the conclusion is that *A. heardi* is as distant from *A. couperiana* as the latter species is from *A. suborbiculata* (Nei's D = 0.136, 24 loci; Hoeh, 1990). This level of differentiation suggests a relatively recent origin for these three species.

In terms of overall shell morphology, *Anodonta heardi* can be viewed as intermediate between *A. couperiana* and *A. suborbiculata.* The geographic distributions of these three species exhibit a similar relationship. *Anodonta suborbiculata* generally occurs within the Interior Basin but also inhabits Gulf drainages from the Brazos River, Texas, to the Escambia River system of Florida and Alabama (Johnson, 1969, 1980; Neck, 1982; Gordon, 1984). *Anodonta couperiana* is found in drainages of the southern Atlantic slope and peninsular Florida (and possibly the Florida panhandle; Johnson, 1965, 1970, 1972)[5]. With its distribution apparently restricted to the Apalachicola River system, *A. heardi* inhabits the region between the ranges of its two closest relatives. The highly variable shell morphology (*e.g., cf.* figures in Clench & Turner, 1956; Johnson, 1970, 1972; Burch, 1975; Hoeh, 1990) and relatively large geographic range of *A. couperiana* are consistent with the hypothesis that it remains a species complex despite the specific-level recognition of *A. heardi.* The same may be true for *A. suborbiculata* (P.D. Hartfield, personal communication). Only a thorough examination of the *A. couperiana – A. heardi – A. suborbiculata* clade, based on comprehensive geographic sampling and the evaluation of conchological, anatomical and molecular characteristics, will enable a test of this hypothesis.

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[5]Johnson's (1969) record for *Anodonta couperiana* and at least one of the records for *Pyganodon gibbosa* in Clench & Turner (1956: Tanvat Pond, see above) from the Apalachicola River were specimens of *A. heardi.*

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UTTERBACKIA PENINSULARIS, A NEWLY RECOGNIZED FRESHWATER MUSSEL (BIVALVIA: UNIONIDAE: ANODONTINAE) FROM PENINSULAR FLORIDA, U.S.A.

Arthur E. Bogan[1,2] and Walter R. Hoeh[3]

ABSTRACT – An eastern Gulf Slope freshwater mussel species, *Utterbackia peggyae* (Johnson 1965), was found to contain a cryptic species, ***Utterbackia peninsularis, nova species***, rendering a total of three currently recognized species in this anodontine genus. Diagnosis of the new species was effected by comparisons of allozymes and stomach anatomy. The *U. penisularis-U. peggyae* species pair spans the hypothesized Suwannee Straits area of northern Peninsular Florida, therefore providing further evidence consistent with the submergence of this area during the Late Cenozoic. Repeated cycles of marine incursions and regressions in the Suwannee Straits area have likely had a profound effect on faunal diversification in the region.

Keywords: biodiversity, cryptic species, allozymes, stomach anatomy, southeastern United States, biogeography, Unionidae, *Utterbackia.*

INTRODUCTION

It has been hypothesized that portions of Peninsular Florida have been isolated from the southeastern United States mainland as a result of multiple marine incursions during the Late Cenozoic. These marine incursions may have played a major role in the diversification of the freshwater and terrestrial biota of the region (*e.g.*, see Dall, 1903; Hubbell, 1932; Carr, 1940; Cooke, 1945; Olson *et al.*, 1954; Clench & Turner, 1956; Neill, 1957; Johnson, 1970, 1972; Burgess & Franz, 1978; Riggs, 1984; Bert, 1986; Bermingham & Avise, 1986; Swift *et al.*, 1986; Gilbert, 1987; Dillon & Popenoe, 1988; Moler & Kezer, 1993). Freshwater mollusk distributional patterns have been used to both support and discount the hypothesis that an isolated Peninsular Florida was a significant factor in the genesis of the current freshwater molluscan fauna of the area (*e.g.*, see Dall, 1903; Clench & Turner, 1956; Thompson, 1968; Johnson, 1972, 1973).

Utterbackia peggyae (Johnson 1965) (Bivalvia: Unionidae: Anodontinae) is a freshwater mussel species that occurs in many of the Eastern Gulf Slope drainages flowing through the Florida Panhan-

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dle and northern Peninsular Florida region (*e.g.*, see Johnson, 1965; Heard, 1979; Butler, 1989). The type locality, located in the Florida Panhandle region (*sequens* Butler, 1989), is the southeastern shore of Lake Talquin (an impoundment of the Ochlockonee River), Leon County, Florida (Johnson, 1965). However, phylogenetic analyses of allozyme variation (Hoeh, 1991; Hoeh *et al.*, 1995) suggest that the populations of *U. peggyae* from the Peninsular Florida drainages (herein inclusive of the drainages from the Suwannee River to the Hillsborough River) form a monophyletic group distinct from populations in the panhandle drainages. This inference is corroborated by a preliminary analysis of mitochondrial DNA restriction fragments (estimated sequence divergence of 12% between panhandle and peninsula populations; Hoeh, unpublished data). The estimated average level of allozyme divergence (Nei's D, 1978; based on 25 presumptive genetic loci) between panhandle and peninsular populations was 0.354 (Hoeh *et al.*, 1995). Furthermore, the analyses suggest that the peninsular populations of *U. peggyae* are more closely related to *U. imbecillis* (Say 1829) than to the panhandle populations of *U. peggyae*. A subsequent examination of soft-tissue anatomy supported the distinction of the peninsular drainage populations from those of the panhandle drainages. In summary, the allozymic, anatomical, and geographic cohesion evinced by the populations of *U. peggyae* from the peninsular drainages is evidence consistent with species-level recognition for these populations.

MATERIALS AND METHODS

Type materials of *Utterbackia peninsularis* are deposited in the following institutions: University of Michigan Museum of Zoology (UMMZ), Florida Museum of Natural History (UF), Academy of Natural Sciences, Philadelphia (ANSP), Carnegie Museum of Natural History (CMNH).

The specimens used herein for anatomical comparisons were chosen from among those that had been previously analyzed for allozyme variation (Hoeh, 1991; Hoeh *et al.*, 1995) (see Table 1). Stomachs of two or more specimens from each locality were examined whenever possible. In this way, evaluations of the degree of congruence between the anatomical observations and those of the allozyme analyses were facilitated.

Soon after specimen collection, gill and mantle tissues were excised (from only one side of the animal, if possible, in order to maximize the utility of the specimen for subsequent anatomical comparisons) and cleaned of macroscopic parasites and debris, frozen in liquid nitrogen, and subsequently stored at -70°C. The remainder of each animal (*i.e.*, shell, visceral mass, and remaining gill/mantle) was fixed in 10% sodium phosphate buffered (pH 7.0) formalin, rinsed with multiple washes of tap water, and preserved in 70% ethanol. Gill tissues were homogenized with a glass pestle in conical-bottomed 1.5 ml microcentrifuge tubes. The gill tissues contained sufficient water to eliminate the need for homogenization buffer. The resultant homogenate was centrifuged at 13,605 x g for 10 minutes at 4°C.

Horizontal starch gel electrophoresis (12% starch gels; 51 g Connaught starch in 425 ml of gel buffer) was used to detect electromorphs at 25 putative genetic loci using five buffer systems (see Hoeh, 1990, 1991).

Stomach floor observations were enabled by an anterior-dorsal incision that opened, initially, the mouth/esophagus region and, subsequently, the stomach proper. This dorsal entry into the stomach minimized mechanical disruption of the stomach floor. The nomenclature used for areas and landmarks on the stomach floor closely followed Kat (1983). However, we have chosen not to follow Kat's numbering scheme for the sorting areas (Kat, 1983; Graham, 1949). At this time, there is insufficient evidence to rigorously assess the potential homology of these sorting areas among different orders of bivalves. The voucher specimen of *Utterbackia peggyae* used for the stomach anatomy illustration (Fig. 3b) has been deposited at the University of Michigan, Museum of Zoology, Malacology Collections (UMMZ 253585).

TABLE 1. Locality information and abbreviations for electrophoretic specimens used and number of specimens (Hoeh, 1991, p. 41).

1. ACH – Attapulgus Creek, at Florida County Route 159, Gadsden County, Florida. (N = 16) [*Utterbackia peggyae*]
2. CSL – Chumuckla Springs Lake, Santa Rosa County, Florida (N = 15) [*U. peggyae*]
3. ERF – Escambia River, at FL County Route 4, Escambia County, Florida (N = 1) [*U. peninsularis*]
4. GCP – Gator Creek, at Florida County Route 471, Polk County, Florida (N = 14) [*U. peggyae*]
5. HCC – Holmes Creek, at US Route 90, Holmes County, Florida (N = 8) [*U. peggyae*]
6. HRH – Hillsborough River, at Florida County Route 579, Hillsborough County, Florida (N = 13) [*U. peninsularis*]
7. HRP – Hillsborough River, at Florida Route 39, Pasco County, Florida (N = 5) [*U. peninsularis*]
8. LRG – Little River, at Florida Route 12, Gadsden County, Florida (N = 16) [*U. peggyae*]
9. LTC – Ochlockonee River, Lake Talquin, Coe's Landing, Leon County, Florida (N = 15) Topotypes [*U. peggyae*]
10. NRB – New River, at Florida County Route 231, Bradford County, Florida (N = 5) [*U. peninsularis*]
11. ORT – Ochlockonee River, at US Route 84, Thomas County, Georgia (N = 1) [*U. peggyae*]
12. RCA – Rocky Creek, at FL County Route 235, Alachua County, Florida (N = 20) [*U. peninsularis*]
13. SHF – sink hole, at Florida Caverns State Park, Jackson County, Florida (N = 19) [*U. peggyae*]
14. SR – canal off of the Suwannee River, at Dilger's Campground, Dixie County, Florida (N = 20) Type locality [*U. peninsularis*]
15. YRC – Yellow River, at US Route 90, Okaloosa County, Florida (N = 10) [*U. peggyae*]

SPECIES ACCOUNT

Utterbackia peninsularis Bogan & Hoeh, new species

Common name: peninsular floater

(Figs. 1; 3a)

Synonymy: *Anodonta imbecillis* Say 1829
Clench & Turner, 1956:187-189 (*partim*)

Anodonta peggyae Johnson 1965
Johnson, 1965, pp. 1-7 (*partim*)
Johnson, 1970, pp. 272, 362, 364, 366 (*partim*)
Johnson, 1972, pp. 228-230, fig. 3B (*partim*)
Burch, 1973, pp. 17 (*partim*)
Burch, 1975, pp. 15 (*partim*)
Heard, 1979, pp. 28 (*partim*)
Kat, 1983, (*partim*)
Butler, 1989, pp. 244 (*partim*)

Diagnosis: This species is included in *Utterbackia* based on a phylogenetic analysis of allozyme data (Hoeh, 1991; Hoeh *et al.*, 1995). Species in the genus *Utterbackia* can be differentiated from those in *Pyganodon* (a closely related genus in the subfamily Anodontinae) by the position of the umbo in relation to the hinge line; in *Utterbackia* the umbos are not raised above the hinge line as they are in *Pyganodon*. *Anodonta couperiana* Lea 1840 and *Anodonta suborbiculata* Say 1831 can be distinguished from *Utterbackia* based on the raying patterns on the shell and degree of ventral shell margin curvature. The raying pattern in *Utterbackia* typically covers the majority of the shell disc while rays are typically restricted to the posterior half of the disc in *A. couperiana* and *A. suborbiculata*. Within *Utterbackia*, *U. imbecillis* can be distinguished from *U. peggyae* and *U. peninsularis* based on the shape of the ventral margin of the shell: typically, *U. imbecillis* has a relatively straight ventral margin which is parallel with the hinge line while those of *U. peggyae* and *U. peninsularis* are somewhat rounded.

Utterbackia peninsularis can be distinguished from *U. peggyae* by the presence of five diagnostic electromorphs at four genetic loci: Aconitase Hydratase (ACOH1-b), Aspartate Aminotransferase (AAT-b), Fumarate Hydratase (FUMH-d), Glucose-6-phosphate Isomerase (GPI-b, GPI-e). Electromorph designations are those presented in Hoeh (1991) and Hoeh *et al.* (1995). *U. peninsularis* can also be diagnosed from *U. peggyae* based on the shape of the right lateral sorting area of the stomach: *U. peninsularis* has a narrow

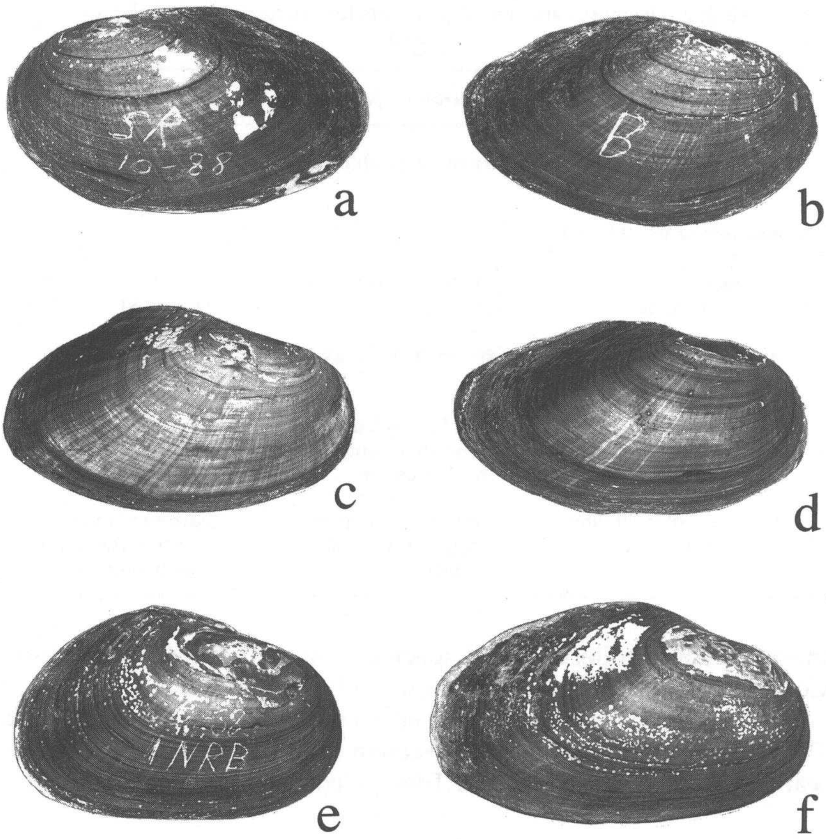

FIG. 1. Photographs of representative shells of *Utterbackia peninsularis* Bogan and Hoeh, new species. (For locality information see Table 1). **a**, Holotype, left valve, SR (B) 10-88, length: 55.8 mm; height, 32.2 mm; width: 22.0 mm. **b**, Holotype, right valve. **c**, HRH (3) 6-88, length: 54.5 mm. **d**, RCA (6) 6-88, length: 75.1 mm. **e**, NRB (1) 6-88, length: 50.8 mm. **f**, GCP (2) 6-88, length: 58.3 mm.

row sorting area which is extended laterally contrasting with the same area in *U. peggyae* which is markedly expanded anteriorly (Fig. 3a,b; Table 2).

Holotype: UMMZ 253583; Collectors: W.R. Hoeh and R.S. Butler; 17 October 1988.

Paratypes: UMMZ 253584 (two specimens); ANSP A18104 (two specimens); CMNH 47384 (two specimens); UF 211099 (two speci-

TABLE 2. Diagnostic anatomical characters for *Utterbackia penisularis* and *U. peggyae.*

Characters	*Utterbackia peggyae*	*Utterbackia peninsularis*
1. General body color:	usually orangish-brown	usually yellowish-cream color
Characters of the stomach		
2. Shape of major typhlosole:	usually more elongate to oval	more or less evenly rounded
3. Shape of conical mound depression:	depression is elongate	depression evenly rounded
4. Mound on left lateral wall of stomach (shape):	mound is obvious and somewhat elongate like the depression	mound is usually less obvious and rounded
5. Shape of right lateral sorting area:	elongate anterio-posteriorly, narrow medio-laterally	narrower anterio-posteriorly, wider medio-laterally

mens); authors collections; all specimens are from the type locality. Collectors: W.R. Hoeh and R.S. Butler; 17 October 1988.

Type Locality: Unnamed canal adjacent to the Suwannee River at Dilger's Campground, near intersection of U.S. Highway 19 and Suwannee River, southeast of Old Town, Dixie County, Florida.

Description

Shell (Fig. 1): The shell is elongate oval in outline and the maximum observed shell length is 76 mm, shell valves are moderately inflated but thin, the anterior end of the shell is evenly rounded, the posterior end of the shell is squared off to a rounded point, ventral margin in some animals is straight like *Utterbackia imbecillis* but varying to a broadly curved ventral margin, the shell dorsal margin is straight like in *U. peggyae* (Fig. 2) and *U. imbecillis,* the posterior ridge is round and not very distinct, the umbos are low, not extending above the hingeline, the beak sculpture is broad undulations varying to double looped, the periostracum is smooth and shining, becoming roughened on the posterior slope. The periostracum is covered with fine green rays over the entire shell, with broad green rays on the posterior slope; some individuals have a greenish background with yellowish rays. Periostracum color varies from light yellowish to green or brown. There is no hinge plate and the shell lacks any indication of teeth or vestigial swellings. Nacre color is bluish-white to iridescent.

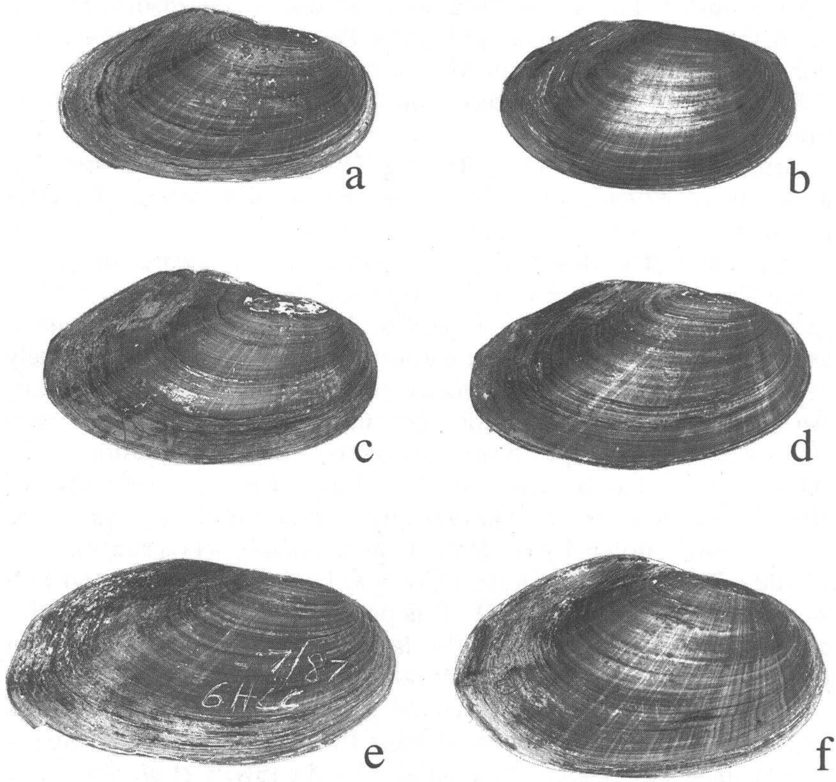

FIG. 2. Photographs of representative shells of *Utterbackia peggyae* (Johnson 1965). (For locality information see Table 1). **a**, YRC (8) 7-87, length: 70.8 mm. **b**, LTC (1) 2-88, length: 66.2 mm. **c**, CSL (1) 7-87, length: 54.6 mm. **d**, SHF (6) 10-88., length: 75.7 mm. **e**, HCC (6) 7-87, length: 86.6 mm. **f**, ORT (13) 10-88, length: 60.9 mm.

Stomach Anatomy: The stomach floor of the holotype is illustrated in Fig. 3a. The most striking feature of the stomach floor of *Utterbackia peninsularis* is the shape of the right lateral sorting area (Fig. 3a). This rather narrow sorting area is extended laterally and is in marked contrast to the anterior extension of the same area in *U. peggyae* (Fig. 3b; Table 2).

Allozyme Analysis: Allozymically distinct from *Utterbackia peggyae* (see above and Hoeh, 1991, table 4, pp. 44-46).

Habitat: Sand and/or muddy substrates in canals, creeks, and rivers with slight to moderate current.

Distribution: Fig. 4. Northwestern portion of Peninsular Florida from the lower Suwannee and Sante Fe rivers south to the Hillsborough River, including the Withlacoochee River.

Etymology: The name is based on the Peninsular Florida distribution of the new species.

Comments: Kat's (1983, p. 368, fig. 5) illustration of the stomach anatomy of *Anodonta peggyae* is, in fact, an illustration of *Utterbackia peninsularis*.

Discussion: The description of *Utterbackia peninsularis* brings to three the total number of currently recognized species within the genus *Utterbackia* (*i.e., U. imbecillis, U. peggyae* and *U. peninsularis*). However, this small number of recognized species is not likely representative of the actual biodiversity extant within the genus. An allozymically distinct entity, conchologically similar to *U. imbecillis,* exists in multiple drainages of the Southern Atlantic Slope (Hoeh, 1991; Hoeh *et al.,* 1995). Furthermore, specimens of *Utterbackia* that are conchologically similar to *U. peggyae* have been recently noted by us from 1) near Alamo, Veracruz, Mexico (UMMZ 248931) and 2) Drake's Creek at Lookout Road, Vernon Parish, Louisiana (Vidrine, 1993). It is probable, given their geographically disjunct locations, that the latter two populations represent genetically distinct taxa. This hypothesis should be evaluated.

The occurrence of closely related and parapatrically distributed freshwater taxa (often abutting near the hypothesized Suwannee Straits area of northen Peninsular Florida [Swift *et al.,* 1986]) in eastern Gulf of Mexico drainages has been documented in fish (Burgess & Franz, 1978; Bermingham & Avise, 1986; Gilbert, 1987; Gilbert *et al.,* 1992) salamanders (Moler & Kezer, 1993), pleurocerid gastropods (Genus *Elimia;* our reinterpretation of data presented in Chambers, 1980, 1982) and viviparid gastropods (Katoh & Foltz, 1994. The relative importance of historical marine incursions on the evolution and present distribution of freshwater mollusks of this region has been discussed by Dall (1903), Clench & Turner (1956, pp.

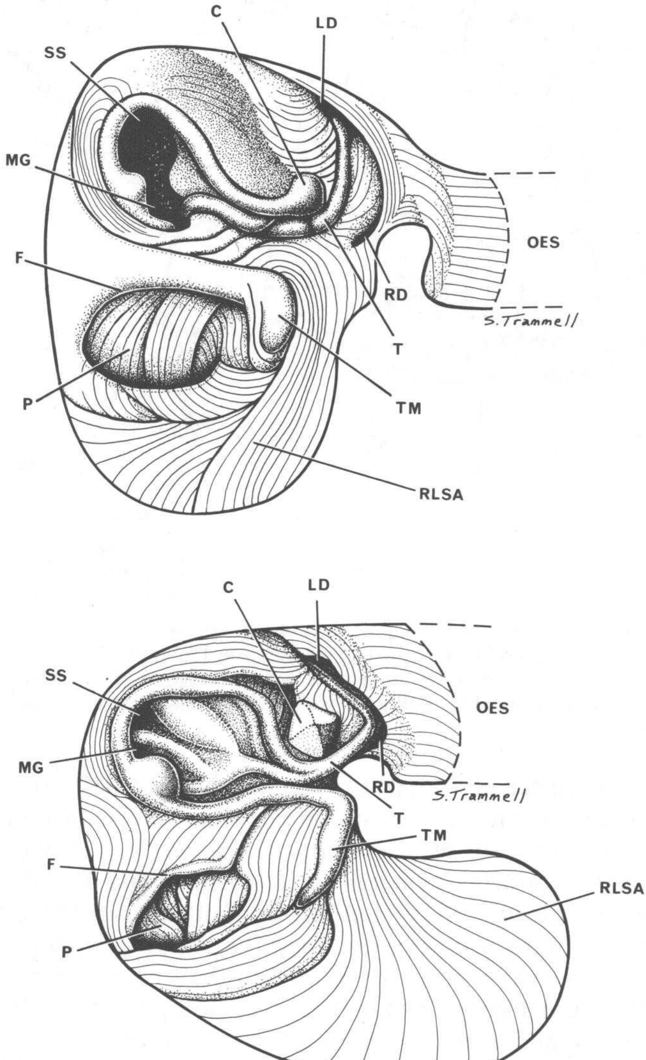

FIG. 3. Stomach Anatomy. **a**, Stomach anatomy of *Utterbackia peninsularis* Bogan and Hoeh, New Species. SR (B) 10-88, Holotype UMMZ, canal off of Suwannee River, Dixie County, Florida. **b**, Stomach anatomy of *Utterbackia peggyae* (Johnson 1965). ORT (13) 10-88, Ochlockonee River, Thomas County, Florida. Abbreviations: C-conical mound, F-fold, LD-left digestive diverticula, MG-midgut, OES-oesophagus, P-pouch, RD-right digestive diverticula, RLSA-right lateral sorting area, SS-style sack, T-major typhlosole, TM-minor typhlosole.

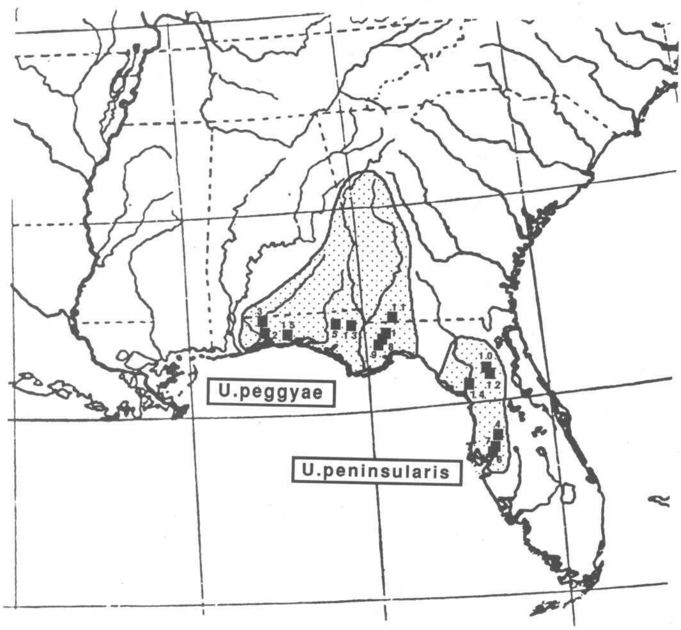

FIG. 4. Distribution of the populations of *Utterbackia peninsularis* Bogan and Hoeh, new species and *Utterbackia peggyae* (Johnson 1965) used in these analyses. The northern extension of the range of *U. peggyae* is based upon recent records from J. Brim-Box and J.D. Williams, National Biological Survey, Gainesville, Florida.

104-108), Thompson (1968, pp. 14-16) and Johnson (1972, pp. 183, 185-186). Impediments to a consensus on this issue can be attributed to 1) the likely existence of multiple cryptic species of freshwater mollusks in the region (as evinced by *Utterbackia* and *Elimia),* 2) the lack of well corroborated phylogenetic hypotheses for the groups in question, and 3) the problems of dating the coastal plain terraces (see Johnson, 1970). Hoeh *et al.* (1995) argued that the Suwannee Straits area of northern Florida was submerged multiple times during the Late Cenozoic and that these vicariant events were likely responsible for early differentiation within the *Utterbackia* clade. The geographic placement of the distributional discontinuity between *U. peggyae* (Florida Panhandle distribution; Escambia River to the Ochlockonee River) and *U. peninsularis* (Peninsular Florida distribution; Suwannee River to Hillsborough River) is consistent with the hypothesis of an insularized peninsula of Florida during the Late Cenozoic.

Other nominal unionid species with distributions that span the Suwannee Straits area of northern Florida need to be carefully examined for potential anatomical and/or molecular discontinuities that, if present, may be causally related to the hypothesized insularization. The elucidation of the actual freshwater mollusk biodiversity of the region is a necessary prelude to phylogenetic analyses of the pertinent higher taxa. Furthermore, the availability of well corroborated phylogenetic hypotheses for the freshwater biota of the southeastern United States is fundamental to any explication of the sequence of Late Cenozoic marine insularization events in the Peninsular Florida region.

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Latin names of genera and species should be underlined or italicized, and all Latin specific names of all organisms must be followed by the authority when the name is first mentioned in the text or table. Generic names should be written out when first used in a paragraph or at the beginning of a sentence; thereafter in the paragraph generic names are abbreviated when used with a specific name.

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Voucher specimens of all species used in research papers published in *Walkerana* must be lodged in a recognized repository, *i.e.*, sample specimens must be sent to a museum and, preferably, the registered numbers and full data of these specimens published. This insures that future workers will have easy access to this material and that species determinations can be checked.

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Correspondence should be directed to the Editor, P. O. Box 2701, Ann Arbor, Michigan 48106, U.S.A.

(continued from front cover)

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