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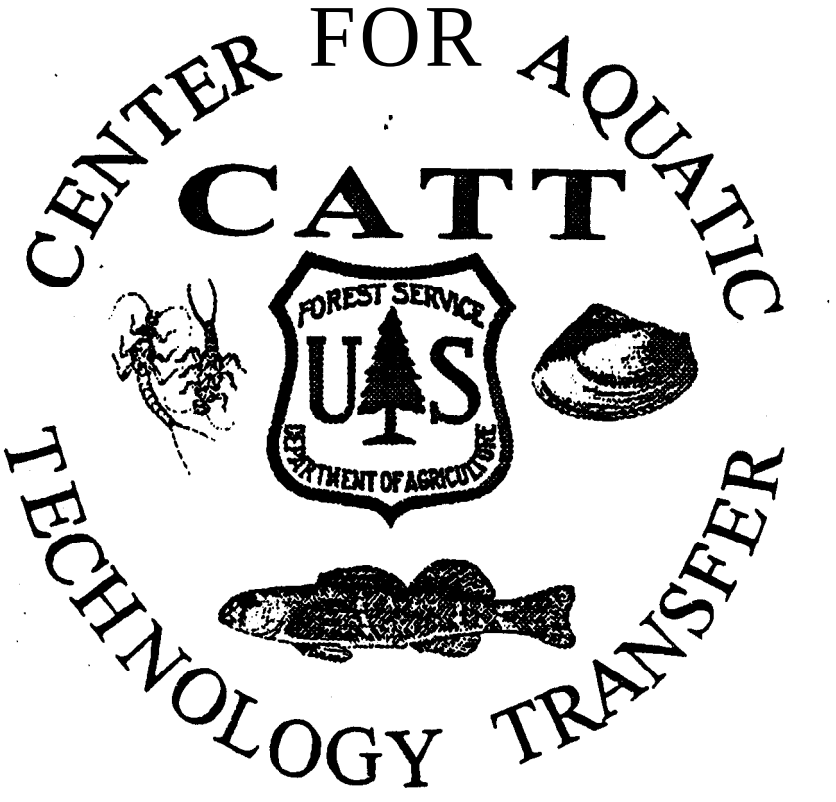
Freshwater Mussels of the Delta National Forest, Mississippi



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Final Report

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Summary

Twenty-three species of freshwater mussels were collected during a survey of aquatic habitats in the Delta National Forest, Mississippi. An additional 6 species not encountered in this survey were reported by an earlier study in the Big Sunflower River near the northern proclamation boundary of the Forest. These species are included here, bringing the total species list for the Forest to 29 species. These species are distributed unequally among aquatic habitats in the Forest. Twenty-four species occurred only in large river habitats represented by the Big and Little Sunflower Rivers. Three other habitat types, bayous and small permanent streams, intermittent streams and ditches, and palustrine wetlands, had mussel faunas that were similar to each other but differed from the large river fauna. Two species occurred only in these habitats and not in large rivers. An additional three species were widely distributed among all habitat types.

Most species found in large river habitats showed little or no evidence of recent recruitment; most individuals were greater than 10 years old. Five species unique to large stream sites were found only as relict shells, indicating that these species are now rare or extirpated from these sites. In contrast, all species found in bayous and small permanent streams, intermittent streams and ditches, and palustrine wetlands showed evidence of recent recruitment.

The continued existence of the diverse and distinctive large stream mussel fauna in the Forest is contingent on: 1) maintaining the habitat integrity of the Little Sunflower and the Big Sunflower rivers; 2) determining factors that are limiting recruitment and eliminating species; and 3) identifying management alternatives that may mitigate these factors. The current conditions for freshwater mussels in the Little Sunflower and Big Sunflower rivers of the Forest are inexorably influenced by upstream watershed conditions. From that perspective, the continued existence of the diverse mussel fauna of the Delta National Forest is also contingent on the cooperation and coordination of 'state and federal management and regulatory activities in the Big and Little Sunflower rivers.

Introduction

Freshwater mussels of the family Unionidae are an important part of stream, lake, and wetland ecosystems in the southeastern United States, In many areas, mussels account for a large proportion of the biomass in streams (Negus 1966, others) and serve as an important food resource for fish and other animals (Neves and Odum 1988, Daiber 1952). Dense populations of mussels also contribute to the functioning of aquatic ecosystems by filtering large volumes of water (McMahon 1991). Different aquatic habitats support different mussel species assemblages and stream communities are usually different than communities found in lentic habitats such as lakes and wetlands (Parmalee and Bogan 1998).

Many large streams in the Mississippi River Embayment support diverse, abundant mussel communities. Species composition of these communities is distinctive from other large streams in the southeast, as well as from other aquatic habitats within the Mississippi River Embayment. Examples in this region include the Big Black River, MS, with 31 species (Hartfield and Rummel 1985), the Hatchie River, TN, with 33 species (Manning 1989), the St. Francis River, AK, with 35 species (Ahlstedt and Jenkinson 1991, Jenkinson and Ahlstedt 1994), and the Cache River, AK, with 19 species (Jenkinson and Ahlstedt 1994). Mussel assemblages of these rivers are.characterized by a predominance of long-lived, heavy-shelled species including a mixture of

southern species such as the Round pearshell (*Glebula rotundata),* Bankclimber (*Plectomerus dombeyanus*), Bleufer (*Potamilus purpuratus),* Southern mapleleaf *(Quadrula apiculata*), Texas lilliput (*Toxolasma* texasensis), and the Tapered pondhorn *(Uniomerus declivus),* and more widespread Interior Basin species such as the Three-ridge (*Amblema plicata),* Wabash pigtoe *(Fusconaia flava),* Washboard *(Megalonaias nervosa),* Three-horned wartyback (*Obliquaria reflexa),* Pimpleback *(Quadrula pustulosa),* and at least 15 other species.

Lentic habitats such as lakes and wetlands support less diverse but similarly distinctive mussel communities. These assemblages are characterized by a predominance of short-lived, thin-shelled species such as the Flat floater *(Anodonta suborbiculata),* Pondmussel (*Ligumia* subrostrata), Giant floater *(Pyganodon grandis),* Pondhorn (Uniomerus *tetralasmus*), and the Paper pondshell *(Utterbackia imbecillis).* These species are widespread in lentic habitats of the southern and central United States.

Mussel populations in the United States have declined precipitously in the last 50 years due to a variety of human-induced modifications to aquatic habitats such as channelization, impoundment, and water pollution. Currently, 72 percent of the freshwater mussel fauna of North America is considered threatened, endangered, or of special concern (Williams et al. 1993). National Forests contain some of the highest quality

aquatic habitat remaining in the southeast and represent important refugia for remnants of the southern mussel fauna.

The Delta National Forest (NF) contains a wide variety of aquatic habitats including large rivers, small lowland streams and bayous, and wetlands. The proclamation boundary of the Forest encompasses 47,885 ha in the Yazoo Delta physiographic region in west-central Mississippi. The Delta NF is drained entirely by the Sunflower River system of the Yazoo drainage. Information on mussel distributions within the Delta NF was limited to one site, on the Big Sunflower River immediately upstream from the Delta NF (Miller et al. 1992). No information on mussel occurrences was available for other sections of this river or for other aquatic habitats in the Forest (Haag and Warren 1995).

The goal of this study is to fully document the mussel fauna of the Delta National Forest. We present a comprehensive species list for the Forest and document species assemblages occurring in different aquatic habitats. We also provide information on mussel densities and length-frequencies that can be used as baseline information for future monitoring of mussel resources in the Delta National Forest.

Methods

We surveyed freshwater mussel populations in waters of the Delta National Forest during low-water conditions in August 1997

and November 1998. Water bodies were located by examining USGS 7.5 minute topographic maps and the USFS 15 minute Delta NF district map. We made an attempt to visit representatives of all major aquatic habitat types occurring on the Forest. Only sites with standing water or evidence of recent standing water were surveyed. Sites that appeared to be dry for most of the year were not sampled. At all sites with water, live mussels were located by feeling along the bottom and sifting through the substrate. We augmented our survey results with information from previously published studies on mussel distributions in the Delta NF to provide a complete list of mussel species in the area.

In addition to searching for live mussels, at all sites shorelines were searched for empty shells which were bagged and returned to the laboratory for identification. All shells encountered were classified as freshly dead, weathered dead, or relict shells. Freshly dead shells were defined as those which had traces of soft tissue remaining in the shell or had a lustrous nacre (mother-of-pearl layer) inside the shell; these traits indicate that the animal died recently and the species probably continues to exist at the site. Weathered dead shells were defined as those without traces of soft tissue and with a non-lustrous nacre, but for which the periostracum (the outer, proteinaceous layer of the shell) and prismatic layer (the calcium-based structural element of the shell) were not decomposed and were structurally sound; these traits indicate that the animal died within approximately the last five years and

the species may continue to exist at the site. Relict shells were defined as those for which the periostracum and prismatic layers were partially decomposed, resulting in a chalky, easily broken shell; these traits indicate that the animal likely died greater than 5 years ago. Representation of a species only by relict shells at a site indicates that the species may no longer occur at that site. Relict shells may persist for many years and when present, they provide a record of the historical fauna of the site.

At sites surveyed during 1998, we made quantitative estimates of mussel abundance at most sites by conducting a series of timed searches. At each site, two different observers each made from one to five 5-10 minute searches and mussel abundances were expressed as mean number of mussels encountered/hour.

We made observations on ages and lengths of most live mussels encountered to assess the extent of recent recruitment. At intermittent stream and ditch sites and palustrine wetland sites, we made age observations on freshly dead shells because of the rarity of live mussels at these sites. Mussels deposit annual growth rings in the shells similar to those found in trees, and ages can be estimated by counting these rings. However, in older individuals, shell erosion or mineral deposits obscure growth rings, making accurate estimation of age difficult. Therefore, we estimated ages of mussels by counting growth rings where possible and each individual was classified

into one of two age groups: 1) less than 10 years old or 2) greater than 10 years old. In this way, we were able to evaluate the extent to which recruitment has occurred 'in the past 10 years.

We also measured the length of all live individuals encountered at quantitatively sampled sites. Because mussels have indeterminate growth, length can be used as a surrogate measure to estimate age. In order to estimate age, length measurements must be calibrated against individuals of known ages. This information is lacking for this region. However, our measurements serve as baseline information for future comparisons of size distributions of mussels.

We described the habitat of all sites sampled for mussels according to the guidelines set forth by the U.S. Fish and Wildlife Service (Cowardin et al. 1979). We analyzed mussel occurrence in each habitat type in order to identify fauna1 assemblages characteristic of these habitats.,

Results

We sampled thirty-two sites for mussels during this study (Figure 1). We visited 38 sites but three appeared to be dry for much of the year and were not sampled. Two sites visited on the Big Sunflower River and one site on Six-mile Cutoff were too deep for sampling using our methodology. Twenty-one (66%) of the sampled sites had at least one species of mussel. Two sites had

only *Corbicula fluminea,* a small bivalve introduced from Asia, or fingernail clams (family Sphaeriidae).

We classified sites in Delta NF with permanent water into 4 major aquatic habitat types: large rivers, bayous and small permanent streams, intermittent streams and ditches, and palustrine wetlands (Table 2). Nine large river sites, 1 bayou and small permanent stream site, 14 intermittent stream and ditch sites, and 8 palustrine wetland sites were sampled. Mussels occurred in all habitat types, but species composition and abundance varied among habitats (Table 1).

Mussel communities of large river sites were distinctive from all other habitat types and had the highest species diversity (27 species)(Table 1) and mean mussel abundance (74 mussels/hour, standard error (SE) = 29). Twenty-four species were found only in large river habitats. These communities were dominated by the Three-ridge (*Amblema plicata*)(28 individuals/hour, SE = 17), Bankclimber (*Plectomerus dombeyanus)* (18 individuals/hour, SE = 8), and Pimpleback *Quadrula pustulosa* (5 individuals/hour, SE = 3). Three species (Flat floater, *Anodonta suborbiculata;* Giant floater, *Pyganodon grandis;* and Texas lilliput, *Toxolasma texasensis)* found at large river sites also were widely distributed among other habitat types.

Bayous and small permanent streams, intermittent small streams, and palustrine wetlands were similar in species diversity (2-5 species), species composition, and mussel

abundance. Two species, the pondhorn (*Uniomerus tetralasmus*) and the paper pondshell, (*Utterbackia imbecillis*) were found only in these habitat types and were not found at large river sites. Mussel density was low in bayous, intermittent streams, and palustrine wetlands (less than 1 mussel/hour).

Large excavated drainage canals represent an additional habitat type present in the Forest, but we did not sample these habitats. This habitat type is represented in Delta NF by Holly Bluff Cutoff and Six-mile Cutoff.

Age structure of mussel populations varied among habitat types. At large-river sites, age structure of most species was biased strongly toward older individuals (>10 years old), and there was little evidence of recent recruitment (Tables 3 and 4). Of 16 species found alive in large river habitats, individuals less than 10 years old were found for only 7 species. For 6 of these seven species, young individuals comprised less than 27% of the total. The dominant species in this habitat all showed extremely low levels of recent recruitment (*Amblema plicata,* 5% of total individuals were less than 10 years old; Plectomerus *dombeyanus* and *Quadrula pustulosa,* no individuals were less than 10 years old). In bayous and small permanent streams, intermittent streams and ditches, and palustrine wetlands, age structure of all species was biased towards individuals less than 10 years old. With the exception of one species, all individuals encountered were less than 10 years old.

Discussion

The Delta National Forest supports a diverse mussel fauna of at least 29 species (Table 1). We collected *23* species during this survey. Eighteen species were collected alive and *5* species were collected only as relict shells. Mussels were widely distributed throughout the waters of the Forest and were found in a wide variety of aquatic habitats. At several sites, diverse and abundant communities were present. Six species previously reported from the Delta NF (Miller et al. 1992) were not encountered in the present study (Table 1). Mussels are widely distributed throughout a variety of aquatic habitat types in the Forest. Most species are found only in large stream habitats and this habitat type supports the most diverse species assemblages *(27* species). Small permanent streams, intermittent streams, and wetlands support a less diverse, but distinctive fauna of 5 species.

The mussel fauna of the Delta NF supports several species considered imperiled and that have conservation status at some level. Two species, the rock pocketbook *(Arcidens confragosus)* and the pyramid pigtoe (*Pleurobema pyramidatum*) appear on the National Forests in Mississippi Sensitive Species List. Three species, the butterfly (*Ellipsaria lineolata*), wartyback *(Quadrula nodulata),* and the tapered pondhorn (*Uniomerus declivus*) appear on the Mississippi Natural Heritage Program's Locally Rare Species List. One species, the deertoe (*Truncilla*

truncata), not encountered in our survey but reported by an earlier study (Miller et al. 1992) appears on the Mississippi Natural Heritage Program Locally Rare Species List. *Pleurobema pyramidatum* and *Ellipsaria lineolata* are considered threatened, and of special concern, respectively, by the American Fisheries Society (Williams et al. 1993). All of these species occur only in large river habitats in the Delta NF.

Most species of large river habitats depend on stable habitat conditions. These species are usually long-lived, and reproduction can be infrequent (Payne and Miller 1989). However, we observed an almost complete lack of reproduction for most species in this habitat. Low recruitment has been observed throughout the lower Sunflower River' (Miller et al. 1995). Furthermore, the presence of 5 species as relict shells only suggests that some species may have been lost from the fauna in recent years. At least two of these species, the ebonyshell *(Fusconaia ebena)* and the pyramid pigtoe *(Pleurobema pyramidatum*), appear to once have been common, judging by the abundant valves of both species found at several sites. Cut-offs and other recently dredged water bodies may provide poor habitat for many large river species due to the unstable nature of the substrate (Ahlstedt and Jenkinson 1991).

In contrast to large river mussel species, wetland species are adapted to ephemeral, dynamic habitats. Most species common in these habitats are relatively short-lived and reproduce at an early age. Further, some species, notably the pondhorn

(Uniomerus tetralasmus), are thought to able to survive periods of drought by burying in the mud (Cummings and Mayer 1992, Parmalee and Bogan 1998). Other species such as the flat floater (*Anodonta suborbiculata),* Giant floater *(Pygandon grandis),* and the Paper pondshell *(Utterbackia imbecillis*) are host-generalists that can use a'wide variety of fishes as hosts (Watters 1994). Some evidence suggests that the Paper pondshell may be able to reproduce without a fish host (Watters 1994). These traits allow these species to rapidly colonize new habitats. Thus, most areas of newly-created aquatic habitat in the Delta NF that hold water for extended periods, such as beaver ponds, may be colonized by one or all of these species in a relatively short time period.

Our survey indicates a diverse and viable freshwater mussel fauna in the Delta National Forest. At least 18 species are currently living in the Forest out of a historical fauna of 29 species. Species found in wetland habitats all showed some evidence of recent recruitment and are adapted to the extremes in the hydrological regime of these Forest habitats. In contrast, many species restricted to large river habitats are not reproducing or recruitment is occurring at an extremely low level, and formerly common species are now rare or extirpated from the Forest. Low recruitment and species extirpations portend further declines in the large river mussel fauna. The causes for low recruitment and species extirpations have not been identified.

The continued existence of the diverse and distinctive large

stream mussel fauna in the Forest is contingent on: 1) maintaining the habitat integrity of the Little Sunflower and the Big Sunflower rivers; 2) determining factors that are limiting recruitment and'eliminating species; and 3) identifying management alternatives that may mitigate these factors. The current conditions for freshwater mussels in the Little Sunflower and Big Sunflower rivers of the Forest are inexorably influenced by upstream watershed conditions. From that perspective, the continued existence of the diverse mussel fauna of the Delta National Forest is also contingent on the cooperation and coordination of state and federal management and regulatory activities in the Big and Little Sunflower rivers.

Acknowledgments

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Figure 1. Map of Delta National Forest, Mississippi showing location of sites sampled for freshwater mussels, 1997-1998.

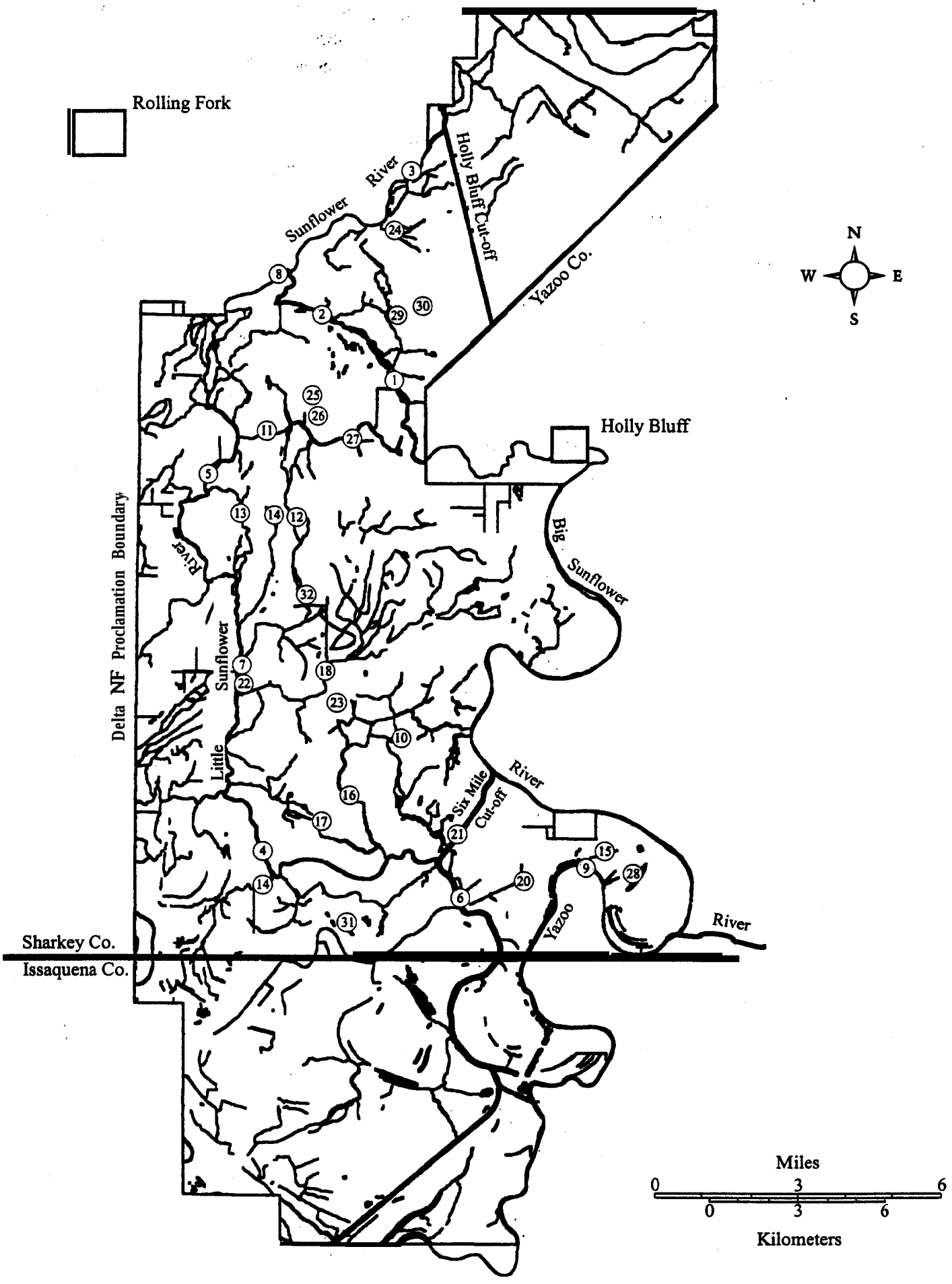
Rolling Fork
Holly Bluff Cut-off
Sunflower River
Yazoo Co.
N
W
E
S
Holly Bluff
Big Sunflower River
Delta NF Proclamation Boundary
Little Sunflower River
Six Mile Cut-off
Yazoo River
Sharkey Co.
Issaquena Co.
Miles
0 3 6
0 3 6
Kilometers

Table 1. Mussel fauna of Delta National Forest, Mississippi. Habitat types are: 1) large rivers; 2) bayous and small permanent streams; 3) intermittent streams and ditches; 4) palustrine wetlands. "X" denotes that the species has been found in a particular habitat-type, "-" denotes that the species has not been found in that habitat type.

Species	Common name	Habitat type			
		1	2	3	4
Actinonaias ligamentina	Mucket	X[1]	-		
Amblema plicata	Three-ridge	X	-		
Andodonta suborbiculata	Flat floater	X	-	X	X
*Arcidens confragosus**	Rock pocketbook	X	-		
Ellipsaria lineolata+#	Butterfly	X[2]	-		
Elliptio crassidens	Elephant-ear	X[1]	-		
Fusconaia ebena	Ebonyshell	X[2]	-		
F. flava	Wabash pigtoe	X	-		
Glebula rotundata	Round pearlshell	X[1]	-		
Lampsilis siliquoidea	Fatmucket	X[2]	-		
L. teres	Yellow sandshell	X	-		
Leptodea fragilis	Fragile papershell	X	-		
Megalonaias nervosa	Washboard	X	-		
Obliquaria reflexa	Three-horned wartyback	X	-		
Plectomerus dombeyanus	Bankclimber	X	-		
Pleurobema pyramidatum'°	Pyramid pigtoe	X[2]	-		
Potamilus ohiensis	Pink papershell	X[1]	-		
P. purpuratus	Bleufer	X	-		
Pyganodon grandis	Giant floater	X	-	X	X
Quadrula nodulata'	Wartyback	X	-	-	
Q. pustulosa	Pimpleback	X	-	-	
Q. quadrula	Mapleleaf	X	-	-	
Toxolasma texasensis	Texas lilliput	X	X	X	X
Tritogonia verrucosa	Pistolgrip	X[2]	-	-	
Truncilla donaciformis	Fawnsfoot	X[1]	-	-	
T. truncata+	Deertoe	X[1]	-	-	
Unionmerus declivus'	Tapered pondhorn	X	-	-	
U. tetralasmus	Pondhorn	-	-	X	X
Utterbackia imbecillis	Paper pondshell	-	X	X	X

[1] Species was reported in an earlier study from this habitat type, but was not encountered in the present study
[2] Species was found only as relict shells
* National Forests in Mississippi Sensitive Species
+ Mississippi Natural Heritage Program Locally Rare Species
# Considered of Special Concern by the American Fisheries Society
° Considered Threatened by the American Fisheries Society

Table 2. Classification of aquatic habitats for mussels in the Delta National Forest, Mississippi (Based on Cowardin et al. 1979) .

1. Large Rivers. System: Riverine, subsystem: lower perennial, class: unconsolidated, subclass: mud, also some sand in places. Water regime: permanent, flow all year.

2. Bayous and small permanent streams. System: Riverine, subsystem: lower perennial, class: unconsolidated, subclass: mud. Water regime: permanent, but may not flow in summer.

3. Intermittent small streams and ditches. System: riverine, subsystem: intermittent, class: streambed, subclass: mud, vegetated. Water regime: intermittently to semipermanently flooded.

4. Palustrine wetlands. system: Palustrine, class: unconsolidated bottom, subclass mud, organic; class: aquatic bed, subclass: floating vascular; class: unconsolidated shore, subclass: mud, vegetated, broad-leaved scrub-shrub wetland, broad-leaved and needle-leaved deciduous forested wetland. Water regime: permanently to intermittently flooded.

Table 3. Proportion of live or freshly dead mussels that were estimated to be less than 10 years old in four habitat types in Delta National Forest, Mississippi. Proportions for large rivers and bayous are based on live individuals. Proportions for intermittent stream and wetland habitats are based on both live individuals and freshly dead shells.

	Habitat type			
Species	Large Rivers	Bayous	Inter-mittent	Wetlands
Amblema plicata	0.05	-	-	-
Anodonta suborbiculata	1.00	-	1.00	-
Arcidens confragosus	0	-	-	-
Fusconaia flava	0	-	-	-
Lampsilis teres	0	-	-	-
Leptodea fragilis	0.25*	-	-	-
Megalonaias nervosa	0	-	-	-
Obliquaria reflexa	0	-	-	-
Plectomerus dombeyanus	0	-	-	-
Potamilus purpuratus	0*	-	-	-
Pyganodon grandis	0.06	-	1.00	1.00
Quadrula nodulata	0	-	-	-
Q. pustulosa	0	-	-	-
Q. quadrula	0.27	-	-	-
Toxolasma texasensis	0	0.60	1.00	1.00
Uniomerus declivus	0	-	-	-
U. tetralasmus	-	-	1.00	1.00
Utterbackia imbecillis	-	*1.00*	*1.00*	*1.00*

* Although few or no young individuals of these species were found alive, freshly dead shells of individuals less than 10 years old were found.

Table 4. Minimum (Min.), maximum (Max.), mean, and standard errors (SE) for lengths of live mussels collected from large river habitats in Delta National Forest, MS, 1998. All measurements are in millimeters.

Species	N	Min.	Max.	Mean	SE
Amblema plicata	86	27	116	97	1
Arcidens confragosus	7	98	119	111	2
Fusconaia flava	8	42	78	65	4
Lampsilis teres	4	95	106	102	2
Leptodea fragilis	3	40	122	93	22
Megalonaias nervosa	8	120	158	140	4
Obliquaria reflexa	5	43	56	51	2
Plectomerus dombeyanus	59	95	118	109	1
Potamilus purpuratus	3	100	132	113	8
Pyganodon grandis	9	95	145	132	5
Quadrula nodulata	8	40	59	50	2
Q. pustulosa	16	52	66	57	1
Q. quadrula	11	35	75	59	

Appendix 1. List of sites by habitat type and mussel species present in Delta National Forest, Mississippi. 'Table entries in parentheses represent the number of individuals that were estimated to be less than 10 years old. For entries with no values in parentheses, all individuals were estimated to be greater than 10 years old.

Large Rivers

Site 1, Big Sunflower River at the boat launch on MS highway 16. 7.5 mi. SE of Rolling Fork, 4.0 mi. WNW of Holly Bluff. T12N, R6W, Sec. 36. Sharkey Co., MS. 4 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Quantitative site: six 5-minute searches

Species	Number of live mussels							
	Search							
	1	2	3	4	5	6	Totals	No./hour
Amblema plicata	3	0	0	1	5	2	11(1)	22
*Arcidens confragosus**	0	2	0	0	0	0	2	4
Lampsilis teres'	0	0	0	0	0	0	0	0
Leptodea fragilis[2]	0	0	0	0	0	0	0	0
Megalonaias nervosa	0	0	0	0	0	1	1	2
Obliquaria reflexa	1	0	0	0	0	0	1	2
Plectomerus dombeyanus	7	1	0	4	4	0	16	32
Potamilus purpuratus[2]	0	0	0	0	0	0	0	0
Pyganodon grandis	0	1	0	1	1	0	3	6
Quadrula nodulata'	2	1	0	0	0	0	3	6
Q. pustulosa	3	2	0	1	1	0	7	14
Q. quadrula	1	2	0	0	2	0	5(2)	10
Toxolasma texasensis	0	0	0	0	1	0	1	2
Totals								100

[1] Freshly dead shells only
[2] Weathered shells only
* National Forests in Mississippi Sensitive Species
\+ Mississippi Natural Heritage Program Locally Rare Species

Site 2, Big Sunflower River 0.5 mi. NW of the junction of MS Highway 16 and FS road 715, 5.75 mi. SE of Rolling Fork, and 5.75 mi. NW of Holly Bluff. T12N, R6W, Sec. 27. Sharkey Co., MS. 2 Nov 1998. W.R. Haag and J.G. McWhirter.

Quantitative site: nine lo-minute searches

Species	Number of live mussels: Search 1	2	3	4	5	6	7	8	9	Totals	No./hour
Amblema plicata	0	2	3	7	3	1	7	2	0	25(1)	17
Arcidens *confragosus**	0	0	2	0	1	0	0	0	0	3	2
Fusconaia ebena[3]	0	0	0	0	0	0	0	0	0	0	0
F. flava	1	0	0	1	0	0	0	0	0	2	1
Lampsilis teres	0	0	1	1	0	0	0	0	0	2	1
Leptodea fragilis[1]	0	0	0	0	0	0	0	0	0	0	0
Megalonaias nervosa	0	0	0	1	0	1	3	0	0	5	3
Obliquaria reflexa .	0	0	1	1	0	0	1	0	0	3	2
Pl ectomerus *dombeyanus*	2	10	0	5	1	1	3	1	1	24	16
*Pleurobema pyramidatum**[3]	0	0	0	0	0	0	0	0	0	0	0
Potamilus purpuratus'	0	0	2	0	0	0	0	0	0	2	1
Pyganodon grandis	0	0	1	1	0	0	0	1	0	3	2
Quadrula nodulata'	0	0	0	1	2	0	1	0	0	4	3
Q. pustulosa	0	0	3	2	0	0	0	0	0	5	3
Q. *quadrula*	0	1	0	2	0	0	0	0	0	3(1)	2
Toxolasma texasensis'	0	0	0	0	0	0	0	0	0	0	0
Totals	3	13	13	22	7	3	15	4	1	81	53

[1] Freshly dead shells only
[3] *Relict* shells only
• National Forests in Mississippi Sensitive Species
+ Mississippi Natural Heritage Program Locally Rare Species

Site 3. Big Sunflower River at the end of FS road 717-A, N of Green Ash Greentree Reservoir. 6.0 mi. E of Rolling Fork, 6.25 mi. NW of Holly Bluff. T12N, R6W, Sec. 12. Sharkey Co., MS. 4 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Quantitative site: Six 5-minute searches

Species	Number of live mussels							
	Search							
	1	2	3	4	5	6	Totals	No./hour
Amblema plicata	3	5	8	1	17	12	46(1)	92
Ellipsaria lineolata[3]	0	0	0	0	0	0	0	0
Fusconaia ebena[1]	0	0	0	0	0	0	0	0
F. *flava*	0	0	0	0	5	0	5	10
Lampsilis siliquoidea[3]	0	0	0	0	0	0	0	0
L. teres	0	0	0	0	0	2	2	4
Leptodea fragilis	0	0	0	1	0	0	1	2
Megalonaias nervosa	0	0	0	0	2	0	2	4
Obliquaria reflexa	0	0	1	0	0	0	1	2
Plectomerus dombeyanus	0	0	0	0	9	9	18	36
Pleurobema pyramidatum[*3]	0	0	0	0	0	0	0	0
Potamilus purpuratus[1]	0	0	0	0[4]	0	0	0	0
Pyganodon grandis	0	0	0	1	0	0	1	2
Quadrula nodulata[*3]	0	0	0	0	0	0	0	0
Q. pustulosa	0	0	0	0	3	1	4	8
Q. quadrula	0	0	0	0	1	1	2	4
Tritogonia verrucosa[3]	0	0	0	0	0	0	0	0
Uniomerus declivus[+]	0	0	0	0	0	0	0	0
Totals	3	6	8	3	37	25	82	164

[1] Freshly dead shells only
[3] Relict shells only
[4] One live individual found outside of timed searches
[*] National Forests in Mississippi Sensitive Species
[+] Mississippi Natural Heritage Program Locally Rare Species

Site 4. Little Sunflower River at Dummy Line road bridge, 4.5 mi NE Valley Park, 10.5 mi SW Holly Bluff. T10N, R6W, sec. 21. Sharkey Cc., MS. 27 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site (ages not estimated at this site)

Amblema plicata	1 Live
Quadula quadrula	3 Live
Pyganodon grandis	4 Live
Toxolasma texasensis	3 Live

Site 5. Little Sunflower River at end of FS ATV trail 703-F, at end of FS road 703-W, 3.5 mi W Delta NF Work Center, 7.5 mi SSE Rolling Fork, 7.7 mi. WSW of Holly Bluff. T11N, R6W, sec. 17. Sharkey Co., MS. 26 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

Amblema plicata	*2* live (1 < 10 yr old)
Anodonta suborbiculata	*2* live (2 < 10 yr old)
Lampsilis siliquoidea	1 relict shell
Lampsilis teres	1 freshly dead shell
Leptodea fragidis	1 weathered shell
Pyganodon grandis	*6* live (1 < 10 yr old)
Quadrula quadrula	1 weathered shell
Toxolasma texasensis	*4* live
Uniomerus declivis	*2* live

Site 6, Little Sunflower River at South Greentree reservoir pump station, about 1 mile downstream of the confluence of the Little Sunflower River and Six-Mile Cutoff. *17.3* mi. SE of Rolling Fork, and 10.2 mi. SSW of Holly Bluff. T10N, R5W, Sec. 30. Sharkey Co. MS.
3 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Non-quantitative site (ages not estimated at this site)

Amblema plicata	1 freshly dead shell
Lampsilis teres	2 weathered shells
Leptodea fragilis	2 freshly dead shells
Plectomerus dombeyanus	1 freshly dead shell
Potamilus purpuratus	1 weathered shell
Pyganodon grandis	1 freshly dead shell
Toxolasma texasensis	*2* live

Site 7. Little Sunflower River at the end of FS road 707-H. 11.5 mi. SSE of Rolling Fork, 8.8 mi. SE of Holly Bluff. T10N, R6W, Sec. 4. Sharkey Co., MS. 3 Nov. 1998. W.R. Haag, D. Thurmond, J.G. McWhirter. . .

Quantitative site: eight S-minute searches

Species	Number of live mussels: Search 1	2	3	4	5	6	7	8	Totals	NO. /hour
Pyganodon grandis	0	0	0	0	0	0	1	0	1	2
Totals	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**2**

Site 8. Little Sunflower River at MS highway 16 bridge. 2.5 mi SE of Rolling Fork, 7.0 mi NW of Holly Bluff. T12N, R6W, Sec. 21. Sharkey Co., MS. 4 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Quantitative site: Six S-minute searches

Species	Number of live mussels: Search 1	2	3	4	5	6	Totals	No. /hour
Amblema plicata	1	1	0	0	1	**1**	4	8
Arcidens confragosus*	1	0	**1**	0	0	0	2	4
Fusconaia *ebena'*	0	0	0	0	0	0	0	0
F. flava	0	1	0	0	0	0	1	2
Lampsilis teres'	0	0	0	0	0	0	0	0
Leptodea fragilis	0	1	0	1	0	0	**2(1)**	4
Megalonaias ***nervosa***[3]	0	0	0	0	0	0	0	0
Plec tomerus *dombeyanus*	0	0	1	0	0	0	1	2
Pleurobema ***pyramidatum****[3]	0	0	0	0	0	0	0	0
Potamilus *purpuratus*	1	0	0	0	0	0	1	2
Pyganodon ***grandis***	0	1	0	0	0	1	2	4
Quadrula nodulata'	0	1	0	0	0	0	1	2
Q. pustulosa'	0	0	0	0	0	0	0	0
Q. ***quadrula***	0	1	0	0	0	0	1	2
Toxolasma tesasensis'	0	0	0	0	0	0	0	0
Totals	**3**	**6**	**2**	**1**	**1**	**2**	**15**	**30**

[1] Freshly dead shells only
[3] Relict shells only
[4] One live individual found outside of timed searches
* National Forests in Mississippi Sensitive Species
\+ Mississippi Natural Heritage Program Locally Rare Species

Site 9.8 Yazoo River at the end of FS Road 715-A. E of Rolling Fork, 9.25 mi. S of Holly Bluff. T10N, R5W, Sec. 27. Sharkey Co., MS. 3 Nov. 1998. W.R. Haag, D. Thurmond, J.G. McWhirter. . .

Non-quantitative site

Lampsilis teres	21 freshly dead shells (17 < 10 yr old)
Leptodea fragilis	1 weathered shell
Corbicula fluminea	present

Permanent bayous and small streams.

Site 10. Cypress Bayou at Dummy Line road bridge, 6.5 mi SW Holly Bluff, 13.75 mi. SSE of Rolling Fork. T10N, R6W, sec. 12. Sharkey Co., MS. 27 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

Toxolasma texasensis	5 Live (3 < 10 yr old)
Utterbackia imbecillis	3 Live (all < 10 yr old)

Intermittent streams and ditches

Site 11, Howlett Bayou at FS road 715 bridge. 7.0 mi SE Rolling Fork, 6.0 mi. W of Holly Bluff. T11N, R6W, junction of sections 3,4,9,10. Sharkey Co., MS. 26 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

No mussels found

Site 12, unnamed slough at FS road 703-W bridge, 0.7 mi W junction of FS roads 703 and 707, first culvert W of junction, 9.0 mi SSE Rolling Fork, 6.0 mi. WSW of Holly Bluff. T11N, R6W, sec. 15/22. Sharkey Co., MS. 26 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

No mussels found
Sphaeriidae present

Site 13. unnamed slough at FS road 703-W bridge, 1.65 mi W junction of FS roads 703 and 707, 8.0 mi SSE Rolling Fork, 7.0 mi. WSW of Holly Bluff. T11N, R6W, sec. 16. Sharkey Co., MS. 26 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

Uniomerus tetralasmus 1 Live (< 10 yr old)
Sphaeriidae

Site 14. unnamed slough at FS road 703-W bridge, 1.1 mi W junction of FS roads 703 and 707, 0.1 mi W of junction of sections 15, 16, 21, 22, 8.0 mi SSE Rolling Fork, 6.5 mi. WSW of Holly Bluff. T11N, R6W, sec. 16/21. Sharkey Co., MS. 26 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

No mussels found

Site 15. unnamed tributary to Yazoo River at FS road 710 crossing, 1.0 mi WNW Clark Lake, 8.5 mi. S of Holly Bluff. T10N, R5W, sec. 22. Sharkey Co., MS. 27 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

No mussels found
Corbicula fluminea present

Site 6. Six-mile Bayou at *Dummy* Line road bridge, 6.5 mi NE Valley Park, 9.0 mi SW Holly Bluff. T10N, R6W, sec. 14. Sharkey co., MS. 27 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

No mussels found

Site 17, unnamed tributary to Six-mile Bayou and roadside drainage ditch at Dummy Line road bridge, 6.0 mi NE Valley Park, 10.0 Mi SW Holly Bluff. T10N, R6W, sec. 22. Sharkey Co., MS. 27 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

Toxolasma texasensis 1 freshly dead shell (< 10 yr old)
Utterbackia imbecillis 2 freshly dead shells (all < 10 yr old)
Sphaeriidae present

Site 18. unnamed bayou at the SE corner of Long Bayou Greentree Reservoir on FS road 707-H. *12.0* mi. SSE of Rolling Fork, and *7.0* mi. SW of Holly Bluff. T11N, R6W, Sec. 34. Sharkey Co., MS. *2* Nov *1998.* W.R. Haag and J.G. McWhirter.

Non-quantitative site

Uniomerus tetralasmus	1 freshly dead shell (< 10 yr old)
Toxolasma texasensis	1 freshly dead shell (< 10 yr old)
Sphaeriidae	present

Site 19. unnamed slough at the crossing of FS road 720, about 0.25 mi. upstream of the confluence with the Little Sunflower River. 16.0 mi. SSE of Rolling Fork, and 11.2 mi. SE of Holly Bluff. T10N, R6W, Sec. 28. Sharkey Co., MS. *2* Nov. 1998. W.R. Haag and J.G. McWhirter.

Quantitative site: two S-minute searches

No mussels found.

Site20. roadside ditch along FS road 710-B, at the entrance to South Greentree Reservoir. *17.5* mi. SE of Rolling Fork, and 9.5 mi. SSW of Holly Bluff. T10N, R5W, Sec. 28&29. Sharkey Co., MS. *3* Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Quantitative site: four S-minute searches

No live mussels found

Anodonta suborbiculata	27 freshly dead shells (all < 10 yr old)
Pyganodon grandis	10 freshly dead shells (all < 10 yr old)
Uniomerus tetralasmus	13 freshly dead shells (all < 10 yr old)

Site ... roadside ditch along FS road 710-B, between Six-Mile Cutoff and FS 710-B. 16.3 mi. SE of Rolling Fork, and 8.75 mi. SSW of Holly Bluff. T10N, R5W, Sec. 19. Sharkey Co., MS. 3 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Non-quantitative site

Pyganodon grandis	1 weathered shell (< 10 yr old)

Site 22. ditch along FS road 707-H, near the SW corner of Long Bayou Greentree Reservoir. 11.7 mi. SSE of Rolling Fork, 8.9 mi. SE of Holly Bluff. T10N, R6W, Sec. 4. Sharkey Co., MS. 3 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Non-quantitative site

No mussels found

Site 23. roadside ditch along FS road 707, about 0.75 mi. S of the SE corner of Long Bayou Greentree Reservoir. 12.5 mi. SSE of Rolling Fork, 7.5 mi. SE of Holly Bluff. T10N, R6W, Sec. 2&3. Sharkey Co., MS. 3 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Non-quantitative site

No mussels found

Site 24. unnamed slough/drainage ditch along FS road 717-A, S of Green Ash Greentree Reservoir. 6.4 mi. ESE of Rolling Fork, 5.2 mi. NW of Holly Bluff. T12N, R6W, Sec. 13. Sharkey Co., MS. 4 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Quantitative site: four S-minute searches

No live mussels found

Pyganodon grandis 1 weathered shell (< 10 yr old)

Palustrine wetlands

Site 25. Blue Lake at boat ramp and campground, 7.5 mi SE Rolling Fork, 5.5 mi. W of Holly Bluff. T11N, R6W, sec. 10. Sharkey Co., MS. 26 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

Toxolasma texasensis 1 freshly dead shell (< 10 yr old)
Sphaeriidae present

Site 26. Lost Lake at end of FS road 715-C. 8.0 mi SE Rolling Fork, 5.5 mi. W of Holly Bluff. T11N, R6W, sec. 10. Sharkey Co., MS. 26 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

Anodonta suborbiculata	1 weathered shell
Pyganodon grandis	1 weathered shell
Toxolasma texasensis	1 live (< 10 yr old)
Utterbackia *imbecillis*	1 live (< 10 yr old)

Site 27, Fish Lake at end of FS road 703-A: 8.0 mi SE Rolling Fork, 4.4 mi. W of Holly Bluff. T11N, R6W, sec. 11. Sharkey Co., MS. 26'August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

Toxolasma texasensis	1 freshly dead shell (< 10 yr old)
Sphaeriidae	present

Site 28. Clark Lake at end of FS ATV trail 710-A, 1.5 mi NW confluence of Big Sunflower and Yazoo Rivers, 10.0 mi S Holly Bluff, 11.0 mi. ENE of Valley Park. T10N, R5W, sec. 26. Sharkey co., MS. 27 August 1997. W.R. Haag and D. Thurmond.

Non-quantitative site

No mussels found

Site 29, unnamed slough just downstream of series of small lakes, 3.25 mi NNW Jct SR 16 and FS 703, 2.25 mi ESE point where Big and Little Sunflower Rivers split, approximately 6.75 mi SE Rolling Fork. T12N, R6W, Sec. 25. Sharkey Co., MS. 1998. D. Thurmond

Non-quantitative site

Uniomerus *tetralasmus*	1 weathered shell

Site 30. unnamed lake along the E side of FS road 717. 7.3 mi. SE of Rolling Fork, 4.0 mi. NW of Holly Bluff. T12N, R6W, Sec. 25. Sharkey Co., MS. 4 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Non-quantitative site

Uniomerus *tetralasmus*	2 freshly dead shells (all < 10 yr old)

Site 31. unnamed lake S of FS road 720. 17.2 mi. SSE of Rolling Fork, 11.5 mi. SE of Holly Bluff. T10N, R6W, Sec. 35, NW1/4. Sharkey Co., MS. 3 Nov 1998. W.R. Haag, J.G. McWhirter.

Quantitative site:" two 5-minute searches

No mussels found

Site 32. unnamed cypress slough on North Boundary of Long Bayou Greentree Reservoir on FS Road 707-C. 9.5 mi. SE of Rolling Fork, and 6.5 mi. SW of Holly Bluff. T11N, R6W, Sec. 27. Sharkey Co., MS. 2 Nov 1998. W.R. Haag and J.G. McWhirter.

Quantitative site: four 5-minute searches

No mussels found

Appendix 2. Lengths (mm) of individual mussels encountered in quantitative sampling in the Delta National Forest, MS.

Site. 1, Big Sunflower River at the boat launch on MS highway 16. 7.5 mi. SE of Rolling Fork, 4.0 mi. WNW of Holly Bluff. T12N, R6W, Sec. 36. Sharkey Co., MS. 4 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Search 1.

Species	Lengths (mm)
Amblema plicata	110, 92, 94
Obliquaria reflexa	49
Plectomerus dombeyanus	109, 106, 103, 95, 112, 114, 106
Quadrula nodulata	46, 53
Q. pustulosa	56, 53, 66
Q. quadrula	56

Search 2.

Species	Lengths (mm)
Arcidens confragosus	113, 118
Plectomerus dombeyanus	113
Pyganodon grandis	145
Quadrula nodulata	59
Q. pustulosa	59, 56
Q. quadrula	48*, 38*

*estimated less than 10 years old based on growth rings

Search 3. No mussels.

Search 4.

Species	Lengths (mm)
Amblema plicata	103
Plectomerus dombeyanus	110, 96, 118, 99
Pyganodon grandis	138
Q. pustulosa	54

Search 5.

Species	Lengths (mm)
Amblema plicata	100, 102, 109, 113, 72*
Plectomerus dombeyanus	102, 117, 118, 112
Pyganodon grandis	132
Q. pustulosa	58
Q. quadrula	71, 75
Toxolasma texasensis	51

*estimated less than 10 years old based on growth rings

Search 6.

Species	Lengths (mm)
Amblema plicata	109, 107
Megalonaias nervosa	120

Appendix 2, cont. Lengths (mm) of individual mussels encountered in quantitative sampling in the Delta National Forest, MS.

Site 2. Big Sunflower River 0.5 mi. NW of the junction of MS Highway 16 and FS road 715, 5.75 mi. SE of Rolling Fork, and 5.75 mi. NW of Holly Bluff. T12N, R6W, Sec. 27. Sharkey Co., MS.
2 Nov 1998. W.R. Haag and J.G. McWhirter.

Search 1.

Species	Lengths (mm)
Fusconaia flava	59
Plectomerus dombeyanus	108, 117

Search 2.

Species	Lengths (mm)
Amblema plicata	82, 86
Plectomerus dombeyanus	98, 104, 109, 103, 106, 107, 117, 114, 113, 117
Q. quadrula	65

Search 3.

Species	Lengths (mm)
Amblema plicata	94, 103, 97
Arcidens confragosus	109, 119
Lampsilis teres	106
Obliquaria reflexa	56
Potamilus purpuratus	100, 132
Pyganodon grandis	130
Q. pustulosa	55, 52, 56

Search 4.

Species	Lengths (mm)
Amblema plicata	85, 88, 98, 107, 90, 97, 95
Fusconaia flava	59
Lampsilis teres	95
Megalonaias nervosa	150
Obliquaria reflexa	43
Plectomerus dombeyanus	111, 106, 103, 113, 108
Quadrula nodulata	41
Q. pustulosa	52, 58
Q. quadrula	35*, 63

*estimated less than 10 years old based on growth rings

Search 5.

Species	Lengths (mm)
Amblema plicata	94, 91, 103
Arcidens confragosus	98
Plectomerus *dombeyanus*	110
Quadrula *nodulata*	52, 52

Appendix 2, cont. 'Lengths (mm) of individual mussels encountered in quantitative sampling in the Delta National Forest, MS.

Site 2, cont.

Search 6.

Species	Lengths (mm)
Amblema plicata	85
Megalonaias nervosa	158
Plectomerus dombeyanus	118

Search 7.

Species	Lengths (mm)
Amblema plicata	90, 99, 98, 98, 114, 102, 109
Megalonaias nervosa	153, 125, 126
Obliquaria reflexa	54
Plectomerus dombeyanus	107, 110, 117
Quadrula nodulata	58

Search 8.

Species	Lengths (mm)
Amblema plicata	90, 27*
Plectomerus dombeyanus	111
Pyganodon grandis	133

*estimated less than 10 years old based on growth rings

Search 9.

Species	Lengths (mm)
Plectomerus dombeyanus	111

Appendix 2, cont. Lengths (mm) of individual mussels encountered in quantitative sampling in the Delta National Forest, MS.

Site 3. Big Sunflower River at the end of FS road 717-A, N of Green Ash Greentree Reservoir. 6.0 mi. E of Rolling Fork, 6.25 mi. NW of Holly Bluff. T12N, R6W, Sec. 12. Sharkey Co., MS.
4 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Search 1.

Species	Lengths (mm)
Amblema plicata	98, 98, 92

Search 2.

Species	Lengths (mm)
Ainblema plicata	90, 93, 98, 95, 101
Obliquaria reflexa	51

Search 3.

Species	Lengths (mm)
Amblema plicata	96, 96, 89, 79, 102, 107, 95, 95

Search 4.

Species	Lengths (mm)
Amblema plicata	*99*
Leptodea fragilis	122
Pyganodon grandis	95

Search 5.

Species	Lengths (mm)
Amblema plicata	93, 97, 107, 101, 112, 108, 104, 113, 116, 100, 99, 100, 97, 108, 96, 97, 102
Fusconaia flava	*69, 78, 73, 68, 42"*
Megalonaias nervosa	140, 131
Plectomerus dombeyanus	105, 112, 111, 111, 107, 109, 98, 113, 106
Q. pustulosa	62, 58, 56
Q. quadrula	70

*estimated less than 10 years old based on growth rings

Search 6.

Species	Lengths (mm)
Amblema plicata	90, 107, 104, 95, 98, 97, 100, 99, 100, 98, 93, 39"
Lampsilis teres	103, 102
Plectomerus dombeyanus	108, 100, 107, 117, 113, 109, 97, 113, 107
Q. pustulosa	55
Q. quadrula	73

*estimated less than 10 years old based on growth rings

Appendix 2, cont. Lengths (mm) of individual mussels encountered in quantitative sampling in the Delta National Forest, MS.

Site 7. Little Sunflower River at the end of FS road 707-H. 11.5 mi. SSE of Rolling Fork, 8.8 mi. SE of Holly Bluff. T10N, R6W, Sec. 4. Sharkey Co., MS. 3 Nov. 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Searches 1-6,8. No mussels.

Search 7.

Species	Lengths (mm)
Pyganodon grandis	160

Site 8. Little Sunflower River at MS highway 16 bridge. 4.25 mi. SE of Rolling Fork, 7.0 mi NW of Holly Bluff. T12N, R6W, Sec. 21. Sharkey Co., MS. 4 Nov 1998. W.R. Haag, D. Thurmond, J.G. McWhirter.

Search 1.

Species	Lengths (mm)
Amblema plicata	98
Arcidens confragosus	110
Potamilus purpuratus	106

Search 2.

Species	Lengths (mm)
Amblema plicata	99
Fusconaia flava	68
Leptodea fragilis	117
Pyganodon grandis	137
Quadrula nodulata	40
Q. quadrula	58

Search 3.

Species	Lengths (mm)
Arcidens confragosus	111
Plectomerus dombeyanus	100

Search 4.

Species	Lengths (mm)
Leptodea fragilis	40*

*estimated less than 10 years old based on growth rings

Search 5.

Species	Lengths (mm)
Amblema plicata	95

Appendix a, cont. Lengths' (mm) of individual mussels encountered in quantitative, sampling in the Delta **National** Forest, **MS.**

Site 8, cont.

Search 6.

Species	Lengths (mm)
Amblema plicata	93
Pyganodon grandis	139