

Effects of Impoundments on Freshwater Mussels
(Mollusca: Bivalvia: Unionidae)
in the Main Channel of the Black Warrior
and Tombigbee Rivers in Western Alabama

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ABSTRACT: Williams, J. D., S. L. H. Fuller, and R. Grace. Effects of impoundments on freshwater mussels (Mollusca: Bivalvia: Unionidae) in the main channel of the Black Warrior and Tombigbee rivers in western Alabama. *Bulletin Alabama Museum of Natural History*, Number 13:1-10, 3 tables, 1 figure. Freshwater mussels were sampled at six stations in the unimpounded upper Tombigbee River and at 14 stations in impounded segments of the Black Warrior and Tombigbee rivers. Specimens were collected by hand in shallow areas and by SCUBA diving in deep water. The mussel fauna of the unimpounded segment of the Tombigbee was 30 species compared with 19 species in the impounded segments of the Black Warrior and Tombigbee. Twenty-nine species of mussels were collected at a single station in the unimpounded Tombigbee River. The five most common species collected in the unimpounded segment of the Tombigbee were *Fusconaia ebena*, *Quadrula asperata*, *Ellipsaria lineolata*, *Obliquaria reflexa*, and *Pleurobema marshalli*. The most productive stations in the impounded segments of the Black Warrior and Tombigbee yielded 13 and 8 species, respectively. *Medionidus macglameriae*, known only from the type specimens collected from the Tombigbee River at Epes, Alabama, was not collected during this study. The Asian clam, *Corbicula fluminea*, was present in small numbers at 12 of the 20 stations in the study area. This exotic competitor for space and energy entered the Mobile River basin at least a quarter-century ago, but no damage to native mussels was detected in the study area. All of the 1930s' mussel species remained in the unimpounded Tombigbee in the 1970s'. Habitat destruction associated with impoundments has severely depleted mussels of the main channels of the Tombigbee and Black Warrior rivers. Based on published records and museum collections, 54 mussel species are known from these two rivers, 50 in the upper Tombigbee, 48 in the Black Warrior and 44 shared by both. Eleven (20.4%) of the mussel species in these two rivers are currently listed or are under review for listing as endangered by the U. S. Fish and Wildlife Service.

Introduction

The first collections of freshwater mussels from the Black Warrior and Tombigbee rivers, like other rivers of the Mobile River basin, were taken during the early 1800s and reported by naturalists Timothy A. Conrad and Issac Lea. Lewis (1876), who compiled the first list of freshwater and land shells of Alabama, reported 24 species of unionid mollusks from the Black Warrior River system. Hinkley (1904) reported collecting 29 species from the Black Warrior River and the Mulberry River, a headwater tributary of the Black Warrior. Forty-one species of mussels were reported from the Tombigbee River system in Alabama and Mississippi by Hinkley (1906). Van der Schalie (1939a) reported 50 species (approximately 40 of these currently are recognized as valid) in four collections from the Tombigbee River in the vicinity of Epes, Alabama, and Columbus, Mississippi. Additional distribution records of unionids from the Tombigbee and Black Warrior rivers were reported by van der Schalie (1981a, 1981b). Williams (1982) and Hartfield and Jones (1989a, 1989b, 1990) reported on the status of endangered mussels in the Tombigbee River in Alabama and Mississippi. Other reports on mussels from these rivers have been limited to a few species included in taxonomic revisions and unpublished faunal studies.

Beginning in the early 1900s, a series of low navigation locks and dams was constructed along the Black Warrior and Tombigbee rivers. These low structures were replaced by larger dams to produce hydropower and increase the navigation channel depth to nine feet from the vicinity of Birmingham, Alabama, on the Black Warrior River downstream to Mobile, Alabama. These impoundments have drastically altered the main channels of the rivers and the lower portions of their tributaries. Both river systems have also been subjected to the widespread problem of siltation from agricultural and mining activities (sand and gravel in Coastal Plain areas and coal in the upper Warrior basin). Pollution from industries along these rivers has caused localized problems. However, impoundments are the most important factor in restructuring the riverine ecosystem of the Mobile basin.

The purpose of this report is to examine the effects of impoundments on the species composition of the mussel fauna of an unimpounded segment of the Tombigbee River with the faunas of sections of the impounded segments of the Black Warrior and Tombigbee rivers. The mussels reported from the unimpounded segment of the Tombigbee River (stations T1–T6 of those described below) also represent base line data for the area that was impounded in 1976 as part of the Tennessee Tombigbee Waterway. We also provide a comprehensive list (Table 1) of mussels known to occur in the upper Tombigbee and Black Warrior rivers based on published reports and museum collections.

Study Area

The Black Warrior and Tombigbee rivers, draining portions of western Alabama and eastern Mississippi, are the westernmost rivers in the Mobile basin. The headwater tributaries of the Black Warrior River basin downstream to Tuscaloosa, Alabama, are developed on Paleozoic formations of the Cumberland Plateau. Streams draining this area are characterized by moderate to steep gradient and by rocky shoals and riffles. The Fall Line (inland boundary between the Coastal Plain and other physiographic provinces) extends across the Warrior watershed from the northwest to the southeast in Tuscaloosa County. About seventy five percent of the basin is above the Fall Line; twenty five percent, below.

The Black Warrior River downstream from Tuscaloosa, Alabama (the reaches below the Fall Line), and the Tombigbee River are developed on Cretaceous formations of the upper Coastal Plain. This terrain is characterized by low, gently rolling hills where elevations range from 150 to 300 feet above sea level. Rivers draining the upper Coastal Plain are typified by a low gradient (approximately one foot per mile) with sand, gravel, and mud substrates. The study area is shown in Figure 1 and is totally within the upper Coastal Plain physiographic province.

In the study area there are two locks and dams on the Black Warrior River, Warrior Lock and Dam and William Bacon Oliver Lock and Dam, and two on the Tombigbee River, Demopolis Lock and Dam and Gainesville Lock and Dam. The Demopolis Lock and Dam on the Tombigbee River also impounds the lowermost portion of the Black Warrior River. A tabulation of pertinent data about each navigation lock and dam is provided in Table 2.

The Warrior Lock and Dam site is an atypical navigation structure in having the dam on the river channel and the lock located apart in an excavated canal. The bendway below the dam is almost undisturbed in comparison to the area downstream from the lock canal and the area upstream from the dam. However, a major adverse impact in this bendway is the regulated (irregular) discharge from the dam.

Precipitation in the study area is rather evenly distributed throughout the year, with slightly higher accumulation in the winter and spring. The average precipitation is 52 inches annually. Temperatures for the area are moderate: the average daytime high in the summer is about 30°C; the average nighttime low, 20°C. Severe winter weather is rare, and temperatures below freezing usually persist less than 48 hours. The winter high-low range of temperatures is 5°C–15°C, and collective frost-free periods range from 200 to 250 days per year (Hays, 1973).

Table 1. List of unionid mollusks known to have occurred in the upper Tombigbee and Black Warrior rivers. An "X" in the habitat column indicates the presence of a record of that species in that size stream. Species are arranged alphabetically.

SCIENTIFIC NAME	UPPER TOMBIGBEE	BLACK WARRIOR		HABITAT			
		Below Fall Line	Above Fall Line	Large River	Small River	Large Creek	Small Creek
<i>Ambelma plicata perplicata</i> (Conrad, 1841)	X	X	X	X	X	X	
<i>Anodonta grandis</i> Say, 1829	X			X	X		
<i>Anodonta imbecillis</i> Say, 1829	X	X	X	X	X	X	
<i>Anodonta suborbiculata</i> Say, 1831	X			X			
<i>Anodontoides radiatus</i> (Conrad, 1834)	X	X	X			X	X
<i>Arcidens confragosus</i> (Say, 1829)	X	X		X			
<i>Ellipsaria lineolata</i> (Rafinesque, 1820)	X	X	X	X	X	X	
<i>Elliptio arca</i> (Conrad, 1834)	X	X	X	X	X		
<i>Elliptio arctata</i> (Conrad, 1834)	X	X	X	X	X	X	X
<i>Elliptio crassidens</i> (Lamarck, 1819)	X	X	X	X	X	X	
<i>Epioblasma metastrata</i> (Conrad, 1840)			X	X	X	X	
<i>Epioblasma penita</i> (Conrad, 1834)	X	X		X	X		
<i>Fusconaia cerina</i> (Conrad, 1838)	X	X	X	X	X	X	
<i>Fusconaia ebena</i> (I. Lea, 1831)	X	X	X	X	X		
<i>Lampsilis altilis</i> (Conrad, 1834)	X	X	X		X	X	X
<i>Lampsilis ornata</i> (Conrad, 1835)	X	X	X	X	X	X	
<i>Lampsilis perovalis</i> (Conrad, 1834)	X		X	X	X	X	
<i>Lampsilis straminea claibornensis</i> (I. Lea, 1838)	X	X	X	X	X	X	X
<i>Lampsilis teres</i> (Rafinesque, 1820)	X	X	X	X	X	X	
<i>Lasmigona complanata alabamensis</i> Clarke, 1985	X	X	X	X	X	X	
<i>Leptodea fragilis</i> (Rafinesque, 1820)	X	X	X	X	X	X	
<i>Ligumia recta</i> (Lamarck, 1819)	X	X	X	X	X		
<i>Ligumia subrostrata</i> (Say, 1831)	X					X	X
<i>Medionidus acutissimus</i> (I. Lea, 1831)	X	X	X	X	X	X	
<i>Medionidus maglameriae</i> van der Schalie, 1939	X			X			
<i>Megaloniais nervosa</i> (Rafinesque, 1820)	X	X	X	X	X	X	
<i>Obliquaria reflexa</i> Rafinesque, 1820	X	X	X	X	X		
<i>Obovaria jacksoniana</i> (Frierson, 1912)	X	X		X	X	X	
<i>Obovaria unicolor</i> (I. Lea, 1838)	X	X		X	X	X	
<i>Plectomerus dombeyanus</i> (Valenciennes, 1827)	X	X		X	X		
<i>Pleurobema curtum</i> (I. Lea, 1859)	X			X			
<i>Pleurobema decisum</i> (I. Lea, 1831)	X		X	X	X		
<i>Pleurobema furvum</i> (Conrad, 1834)			X	X	X		
<i>Pleurobema marshalli</i> Frierson, 1927	X			X			
<i>Pleurobema perovatium</i> (Conrad, 1834)	X	X	X	X	X	X	
<i>Pleurobema rubellum</i> (Conrad, 1834)			X	X	X		
<i>Pleurobema taitianum</i> (I. Lea, 1834)	X	X		X	X		
<i>Potamilius inflatus</i> (I. Lea, 1831)	X	X		X			
<i>Potamilius purpuratus</i> (Lamarck, 1819)	X	X	X	X	X	X	
<i>Ptychobranchus greeni</i> (Conrad, 1834)			X	X	X	X	
<i>Quadrula apiculata</i> (Say, 1829)	X	X	X	X	X	X	
<i>Quadrula asperata</i> (I. Lea, 1861)	X	X	X	X	X	X	
<i>Quadrula metanevra</i> (Rafinesque, 1820)	X	X		X	X		
<i>Quadrula rumphiana</i> (I. Lea, 1852)	X	X	X	X	X	X	
<i>Quadrula stapes</i> (I. Lea, 1831)	X	X		X			
<i>Strophitus connasaugaensis</i> (I. Lea, 1857)	X	X	X		X	X	X
<i>Strophitus subvexus</i> (Conrad, 1834)	X	X	X	X	X	X	X
<i>Toxolasma parvus</i> (Barnes, 1823)	X	X	X	X	X	X	X
<i>Tritogonia verrucosa</i> (Rafinesque, 1820)	X	X	X	X	X	X	X
<i>Truncilla donaciformis</i> (I. Lea, 1828)	X	X	X	X	X	X	
<i>Uniomereus tetralasmus</i> (Say, 1831)	X	X	X		X	X	X
<i>Villosa lienosa</i> (Conrad, 1834)	X	X	X		X	X	X
<i>Villosa nebulosa</i> (Conrad, 1834)	X	X	X	X	X	X	X
<i>Villosa vibex</i> (Conrad, 1834)	X	X	X	X	X	X	X

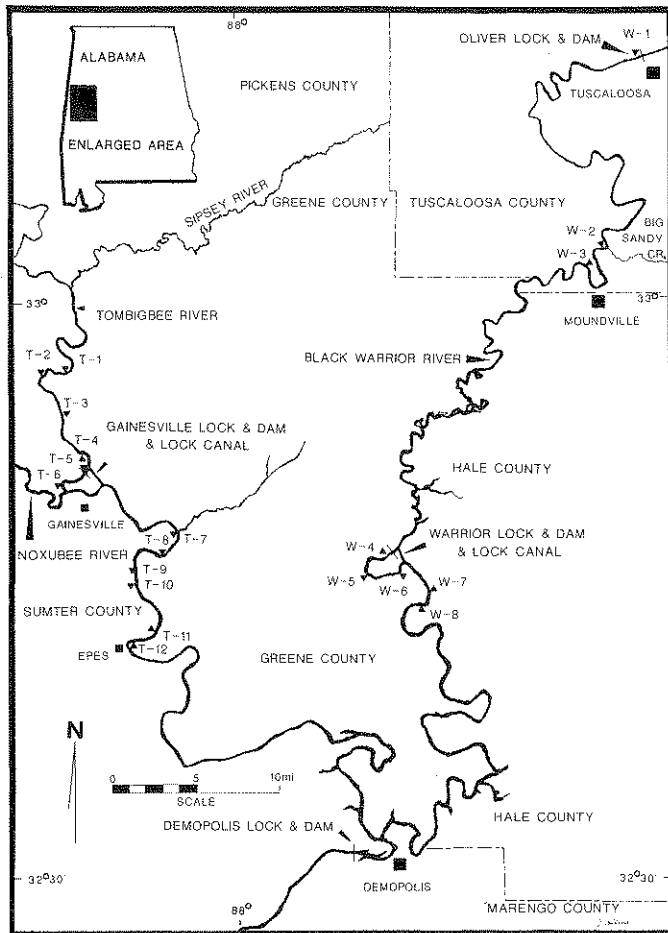


Figure 1. Sample sites on the Black Warrior and Tombigbee Rivers in western Alabama. Stations T1–T6 on the Tombigbee River were sampled prior to construction of the Gainesville Lock and Dam. The remaining stations on the Tombigbee River (T7–T12) and Black Warrior River (W1–W8) were sampled in impounded areas.

Methods

Two methods of collecting mussels were employed during the field sampling phase of this study. Hand collecting was used in the shallow areas (up to 3 feet of depth) throughout the study area. Most specimens collected using this method were taken along the banks and from islands and sand and gravel bars associated with shoal areas. In the unimpounded segment of the Tombigbee River large middens created by riverine mammals, usually in shoal areas, were sampled extensively. The second collecting method, SCUBA diving, was used in deeper, impounded segments of the study area. Preimpoundment topographic maps were used to locate impounded shoal areas that had potential as productive sites. Most specimens collected were freshly empty (hinge intact), but live individuals of some species were found. Field sampling occurred during the years 1972–1975.

For each collection we made notes describing the physi-

Table 2. Date of completion, height and reservoir area of the four major impoundments located in the study area.

LOCK AND DAM	YEAR COMPLETED	HEIGHT OF DAM (FT)	ACRES OF RESERVOIR
Demopolis	1954	58	10,000
Warrior	1957	71	7,800
Wm. B. Oliver	1939	49	**
Gainesville	1976	71	6,400

(United States Army Corps of Engineers, 1979)

** reservoir primarily within original river banks

cal characters of the site, e.g., depth, substrate, and current. The location and a brief description of each station is presented in Appendix I. After collection the specimens were cleaned, identified, and shipped to the Museum of Zoology at The Ohio State University. There the collections received final cleaning, and each specimen was cataloged and deposited in the permanent museum collection. Badly eroded or broken specimens were recorded on the field data sheets and subsequently discarded.

Twelve localities in the upper Tombigbee River (Tombigbee above its confluence with the Black Warrior River) and eight localities in the Black Warrior were sampled (Fig. 1). In the Tombigbee River six stations (T1–T6) were located in the main channel of the river in unimpounded waters between Gainesville and 0.2 mi upstream from Warsaw, Alabama. Six stations (T7–T12) were in the impounded river channel between Epes and Gainesville. In the Black Warrior River, one station (W1) was just below Oliver Dam; two stations (W2–W3), in the impounded river channel behind Warrior Dam; three (W4–W6), in the river bendway below Warrior Dam; and two (W7–W8), in the impounded river channel below Warrior Lock cutoff. The locality, date, and description of each collecting station are presented in Appendix I.

The list of mussels occurring in the Tombigbee and Black Warrior rivers was compiled from published records and museum collections in the Academy of Natural Sciences of Philadelphia, the Florida Museum of Natural History, and the National Museum of Natural History. In many cases it was not possible to determine the identity of some species reported in the pre-1900 literature; this was especially true in situations where there was a list of species without illustrations or descriptions. We use the common and scientific names presented by Turgeon et al. (1988).

Unionid Fauna of the Upper Tombigbee and the Black Warrior Rivers

The diverse unionid fauna of this region was the subject of considerable interest during the 1800s and early 1900s, but has received very little attention in the past seventy years. In recent decades systematic revisions have produced numerous taxonomic changes among the mussels recognized as valid species. In the course of identifying

material collected during this study we compiled a list of unionids known to occur in the upper Tombigbee and the Black Warrior rivers that is based on our own collections, museum records, and published reports (Table 1). Relative stream size (large vs small and river vs creek) data, also, are given for all species known to occur in the upper Tombigbee and the Black Warrior rivers (Table 1); these data are far from complete, but do reflect the information available from collections of unionids throughout the Mobile basin.

Of the 54 unionid species known to occur in the upper Tombigbee or the Black Warrior rivers 44 are shared by both. There are 50 species that are known to have occurred in the upper Tombigbee and 48 in the Black Warrior. Ten of the 54 species are known to occur in only one of the two basins. Twenty-one of the 54 species are endemic to the Mobile Basin. Distribution patterns and habitat requirements in other Mobile basin drainages suggest that 3 of these 10 species (*Anodonta grandis*, *A. suborbiculata*, and *Ligumia subrostrata*) probably occurred below the Fall Line in the Black Warrior. Each of the remaining seven species that are found in only one of the two river systems is localized in its geographic distribution and/or has habitat requirements that preclude its occurrence outside the system where it is found.

Six species (*Epioblasma penita*, *Pleurobema curtum*, *P. marshalli*, *P. taitianum*, *Potamilius inflatus*, and *Quadrula stapes*) of unionids from the Tombigbee and Black Warrior basins are listed as endangered species (U. S. Fish and Wildlife Service, 1991). An additional 5 species (*E. metastriata*, *Lampsilis altilis*, *L. perovalis*, *Pleurobema decisum*, and *P. rubellum*) are under consideration for listing as endangered or threatened species pending completion of field surveys. One species, *Medionidus macglameriae*, is known only from two specimens (found at Epes, Alabama), on which van der Schalie (1939a) based the original description; this species is presumed extinct (Turgeon et al. 1988). The 11 species that are listed as endangered or are under review for conservation status represent 20.4% of the total unionid fauna of the upper Tombigbee and Black Warrior basin recognized here. Much, immediate attention will be required to protect and recover these freshwater mussels.

Results and Discussion

The study area (Fig. 1) was divided into three segments defined by flow conditions and locations: (1) the unimpounded Tombigbee River (stations T1–T6), (2) the impounded Tombigbee River (T7–T12), and (3) the impounded Black Warrior River (W1–W8). Most samples from the free-flowing (unimpounded) segment of the Tombigbee River (T1–T6) were taken from shallow gravel shoals and riffle areas with moderate to swift current. This type of habitat contrasts sharply with the deeper, reservoir habitat present in the impounded segments of the

Tombigbee (T7–T12) and Black Warrior (W1–W8). A list of mussels collected at each station is presented in Table 3.

The unionid fauna at stations in the unimpounded segment of the upper Tombigbee ranged from a low of 14 species (at T2) to a high of 29 species (at T5). The five most common species collected in the unimpounded segment were *Ellipsaria lineolata*, *Fusconaia ebena*, *Obliquaria reflexa*, *Pleurobema marshalli*, and *Quadrula asperata*. Each of four species (*Elliptio arca*, *Strophitus subvexus*, *Truncilla donaciformis*, and *Villosa vibex*) was taken at only one station and was represented by one or two individuals. The total mussel fauna for all stations in the unimpounded segment was 30 species, of which twelve (*Ellipsaria lineolata*, *Elliptio arca*, *Epioblasma penita*, *Lampsilis ornata*, *P. decisum*, *P. marshalli*, *P. taitianum*, *Q. metanevra*, *Q. stapes*, *S. subvexus*, *T. donaciformis*, and *V. vibex*) were not collected in the impounded segments of the Tombigbee and Black Warrior rivers.

The six stations (T7–T12) in the impounded portion of the Tombigbee River yielded very few mussels. At three of the six stations (T7, T8, and T12) *Corbicula fluminea* was present, but no unionids were found. Two species of mussels were collected at stations T9 and T11; eight, at station T10. A total of 10 species of mussels was collected in the impounded portion of the Tombigbee River. All of these 10 species were present in the unimpounded segment of the Tombigbee. One species, *Amblema plicata*, present in the impounded upper Tombigbee, was not found in the impounded Black Warrior.

Eighteen species of mussels were collected from the impounded portion of the Black Warrior River. The mussel fauna ranged from one species (at stations W7 and W8) to a high of 13 species (W6). At two stations (W1 and W4) no mussels were found, but *Corbicula fluminea* was present. At station W6 the most abundant of the 13 species present was *Elliptio crassidens*, followed by *Fusconaia ebena*, *Megaloniaias nervosa*, *Plectomerus dombeyanus*, and *Quadrula asperata*. The shells of the larger individuals from station W6 were very badly eroded. This may have been caused by increased movement of sediments associated with the periodic releases from upstream reservoirs.

Although there are no comprehensive preimpoundment mussel studies of the Black Warrior River within the study area, a few species not encountered in this study have been reported. Conrad (1835–1838) reported *Medionidus acutissimus* from the Black Warrior River at Erie, Greene County, Alabama. Archaeological exploration of Indian middens located on the Black Warrior River southwest of Tuscaloosa revealed the remains of 16 species of mussels (R. W. Hanley, personal communication). Six of these (*Tritogonia verrucosa*, *Quadrula stapes*, *Amblema plicata*, *Pleurobema taitianum*, *Pleurobema* sp., and *Lampsilis ornata*) were not found at any of the eight Black Warrior River stations that we examined. The age of the Indian middens was estimated to be 400 years.

A total of 19 species of mussels was found in the im-

Table 3. Species of unionids and *Corbicula fluminea* taken in the upper Tombigbee and Black Warrior rivers study area (Fig. 1) and species reported from the Tombigbee River at Epes, Alabama, by van der Schalie (1939a) based on preimpoundment collections made in 1933 and 1935. The specimens collected from impoundment station T-12 at Epes, Alabama, are from the same locality as the preimpoundment collection reported by van der Schalie (1939a). Tombigbee River station numbers are preceded by a "T" and those of the Black Warrior by a "W". An "X" indicates the presence of a species, but number of individuals was not reported.

	Preimpoundment						Impoundment						Preimpoundment van der Schalie	Impoundment								
	T-1	T-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T-10	T-11	T-12	(1939a)	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	
<i>Amblema plicata perplicata</i>	2	1		2	16	5			1				16									
<i>Arcidens confragosus</i>																1						
<i>Ellipsaria lineolata</i>	42	13	71	1	161	9							26									
<i>Elliptio arca</i>					2								19									
<i>Elliptio arctata</i>													4									
<i>Elliptio crassidens</i>	4	1	1	1	6	6							10							138		
<i>Epioblasma penita</i>	3	8	4	1	62	1							4									
<i>Fusconaia cerina</i>	3	2	9	14	3	1							93								5	
<i>Fusconaia ebena</i>	86	70	97	5	498	24			2				91		2			2		85		
<i>Lampsilis ornata</i>	7		1	6	28	4							25									
<i>Lampsilis straminea</i>																						
<i> claibornensis</i>	3				8	4									1	4						
<i>Lampsilis teres</i>	5	1	1	1	13	5			1				52		2	3				2		
<i>Leptodea fragilis</i>	2		2	1	13	5			1	1			1			1						1
<i>Ligumia recta</i>					2	2							1							1		
<i>Medionidus macglameriae</i>													2									
<i>Megaloniais nervosa</i>	1			1	1	2							66		1						49	
<i>Obliquaria reflexa</i>	30	6	28	5	148	25		1		1			12			2		5	3			
<i>Obovaria jacksoniana</i>													X									
<i>Obovaria unicolor</i>	18	6	3	1	13	1							7							1		
<i>Plectomerus dombeyanus</i>	1		1		7	3				1			1							1	28	
<i>Pleurobema decisum</i>	1		1		1																	
<i>Pleurobema marshalli</i>	14	24	21	1	102	7							2									
<i>Pleurobema taitianum</i>	13	7	49		30	3							4									
<i>Potamilus inflatus</i>													1								1	1
<i>Potamilus purpuratus</i>	4		2	1	8	7			1				8			1		1				
<i>Quadrula apiculata</i>	4		1		6	14							18		1	3					4	
<i>Quadrula asperata</i>	86	74	72	5	261	21			1				89							15	25	
<i>Quadrula metanevra</i>	14	3	6	1	88								17									
<i>Quadrula rumphiana</i>						5							2								1	
<i>Quadrula stapes</i>	2	2	3		24																	
<i>Strophitus subvexus</i>					1										2							
<i>Tritogonia verrucosa</i>	1				9	2							44									
<i>Truncilla donaciformis</i>					1								1									
<i>Villosa lienosa</i>	1				1	3			1				10			3						
<i>Villosa vibex</i>					1																	
<i>Corbicula fluminea</i> (Müller, 1774)					3	2	X	X				X		X	4	2	X	2	9			
TOTAL NUMBER OF SPECIES	25	14	19	15	30	24	1	1	2	8	2	1	31	1	5	9	1	7	14	1	1	

pounded portions of the Tombigbee and Black Warrior rivers. In the Tombigbee segment only 10 species were collected; 18, in the Black Warrior segment. The reduced number of species and individuals in the impounded segment of the Tombigbee appears to be habitat-related. Habitat in the Tombigbee segment was characterized by slow to non-existent current over a bottom of sand, mud, or bedrock (chalk and marl). In the Black Warrior segment there was a more diverse habitat with varying substrate and flow conditions. The Black Warrior station supporting the most diverse mussel fauna (13 species) was W6, located approximately four miles below Warrior Dam in the old river channel at Hall Shoals. Of the eight stations sampled in the impounded Black Warrior, W5 and W6 were the least altered. The presence of more diverse mussel populations below dams in comparison to impounded areas above dams was discussed by Fuller (1974).

Of the 19 species of mussels collected from the 14 stations in the impounded segments of the study area, 11 species (57.9%) occurred at only one or two stations. The most widespread species in the impounded segments was *Obliquaria reflexa*, present at five of the 14 stations. This species has been reported from streams and impounded waters, where it was associated with a variety of substrates (Buchanan, 1980; Hurd, 1974). The facultative nature of the parasitic stage of *O. reflexa* (Fuller, 1974) probably contributes to survival of the species' juveniles. Three species (*Fusconaia ebena*, *Leptodea fragilis*, and *Lampsilis teres*) were taken at four of the 14 impoundment stations, and four species (*Plectomerus dombeyanus*, *Quadrula apiculata*, *Q. asperata*, and *Potamilus purpuratus*) were taken at three impoundment stations.

Hartfield and Jones (1989b) found 25 species of unionids alive along 46 transects in the Gainesville bendway (just above and below station T6 of this study). Quantified as the number of juveniles, recruitment was very low and was observed in only nine of the 25 species reported. Two of these nine, *Ellipsaria lineolata* and *Lasmigona complanata*, were not found in the impoundment stations sampled in this study. The remaining seven species with recruitment were present in our impoundment samples, also.

The preimpoundment mussel fauna of the Tombigbee River at Epes, Sumter County, Alabama, and Columbus, Lowndes County, Mississippi, was reported by van der Schalie (1939a). The Epes material was collected from gravel bars and shoals in 1933 and 1935. From the Epes locality van der Schalie reported 34 species of mussels, of which 31 are presently recognized. The impoundment of this area by Demopolis Dam in the mid-1950s drastically altered the riverine habitat. The most obvious changes are the increased depth, decreased current, and loss of gravel substrate due to sedimentation. The Epes area was sampled (station T12) by diving during this study, but no mussels were found. Assuming that the 10 species of mus-

sels present at other stations in the impounded segment of the Tombigbee are present in the Epes area, one still would find a loss of 67.7% of the preimpoundment fauna.

We sampled a preimpoundment midden of undetermined age located on the west bank of the impounded upper Tombigbee River approximately 1.5 miles above the interstate route 59 bridge (station T10). Badly eroded remains of seven species (*Quadrula asperata*, *Q. stapes*, *Fusconaia cerina*, *F. ebena*, *Pleurobema* sp., *P. decisum*, and *P. taitianum*) were collected. Three of the seven species (*Q. asperata*, *F. cerina*, and *F. ebena*) were present in the dive sample at this locality. The shells in the midden were embedded in the bank a few feet above and below normal pool level. The four species taken only from the midden are omitted from Table 3 because they appear to be part of the preimpoundment mussel fauna.

The mussel fauna reported from Epes by van der Schalie (1939a) and that of the unimpounded segment of the Tombigbee River (stations T1–T6) are very similar. Of the 30 species present in the Tombigbee (T1–T6) only three (*Pleurobema decisum*, *Villosa vibex*, and *Lampsilis straminea claibornensis*) were not reported from Epes by van der Schalie (1939a). These three species, which are more abundant in small rivers, were present in limited numbers at stations T1–T6. Of the 31 species reported from Epes by van der Schalie (1939a) four species (*Elliptio arctata*, *Obovaria jacksoniana*, *Potamilus inflatus*, and *Medionidus macglameriae*) were not encountered in the unimpounded Tombigbee segment during this study. We have taken two of these, *E. arctata* and *O. jacksoniana*, at several localities upstream of the study area and one, *Potamilus inflatus*, has been collected in the Gainesville bendway in recent years (Hartfield and Jones, 1989b). The remaining species, *M. macglameriae*, has not been collected from the Tombigbee River system since 1935 and is considered to be extinct (Turgeon et al., 1988). In a monograph on the genus *Medionidus* Johnson (1977) recognized *M. macglameriae* as a valid taxon and commented on its relationship to other species in the genus, but offered no new data beyond those presented in the original description by van der Schalie (1939a).

The absence of *Potamilus inflatus* in most Tombigbee River mussel collections during the past twenty years is somewhat surprising. It was collected from the Tombigbee River in Alabama and Mississippi on several occasions during the late 1800s and early 1900s. The increased silt loads (van der Schalie, 1939a) resulting from poor agricultural practices may have brought about the reduced abundance of this species in the upper Tombigbee River. Our collection of *P. inflatus* from two stations (W6 and W7) in the Black Warrior River suggests that it is tolerant of some impoundment conditions. We note that one of these two stations (W6) was located just below Warrior Dam and usually had some current. This station was one of the least altered of the eight areas sampled in the Black Warrior.

Recent collections of *P. inflatus* from the Tombigbee in the upper portion of the Demopolis Pool and the Gainesville bendway (Hartfield and Jones, 1989b) appear to be from an area similar to the stations where we encountered the species in the Black Warrior.

The impact of reservoirs and impoundments on mussel populations is known to be generally detrimental. Ortmann (1909) pointed out the adverse effects of pollution and dams on the freshwater fauna, particularly mollusks and crustaceans, in western Pennsylvania. The adverse impacts of Tennessee Valley Authority (TVA) impoundments on the mussels in the Muscle (Mussel) Shoals area of the Tennessee River in northern Alabama are perhaps the best-documented case. Ortmann (1924) was the first to express concern about the reduction of the Muscle Shoals mussel fauna, the most diverse (approximately 70 species in 31 genera) in North America. Subsequent studies of this fauna (van der Schalie, 1939b; Stansbery, 1964; Isom, 1969) have shown a drastic reduction (approximately 50 percent) in the number of species present. This reduction is attributed almost entirely to the habitat alterations associated with impoundment. Fuller (1974) reviewed the impacts of dams on bivalve mollusks. A broader assessment of the impacts of dams and impoundments on the aquatic environment is discussed in Baxter (1977) and Baxter and Glaude (1980).

In reviewing the adverse effects of impoundments (dams) on mussels, Fuller (1974) singled out the disruption of the reproductive process as the most significant impact. The habitat alterations associated with impoundments bring about profound changes in the fish fauna and thus displace or eliminate glochidial (larval) hosts. If the host fish is present and glochidial infections are successful, the water quality and substrate conditions in impoundments may not be suitable for juvenile mussels. Scruggs (1960) found that silt deposits on the bottoms of Wheeler and Chickamauga impoundments were detrimental to young, as well as adult mussels. Ellis (1936) reported adult mussel mortality of approximately 90% for several species when one-fourth of an inch to one inch of silt covered the substrate in laboratory experiments. Scruggs (1960) found that the most productive substrates for mussels in Wheeler Reservoir were a mixture of rubble, gravel, and sand. Substrate conditions at the most productive impoundment station (W6 with 14 species) were rocky with patches of sand and gravel. The substrates at impoundment stations that were least productive consisted of clean, tightly packed sand or mixtures of sand and mud.

The Asian clam, *Corbicula fluminea*, was present throughout the study area, but was not abundant at any of the stations sampled. The exact date when this exotic species was introduced into the Mobile basin is not known, but appears to have been during the late 1950s. Hubricht (1963) reported it as abundant in the Mobile River in the spring of 1962 and (Hubricht, 1966) reported finding adults abundant below Demopolis Dam, Sumter County,

Alabama, in the fall of 1965. The low densities of the Asian clam encountered during this survey suggest that it was not adversely impacting the mussel fauna in the impounded or unimpounded river segments within the study area.

Appendix I: Collecting Stations.

Brief descriptions of the collecting stations and sampling methods used are presented. River miles given in the station descriptions are taken from the U.S. Army Corps of Engineers River Navigation Charts. Initials of individuals participating in collection of specimens are given for each station: Herbert Boschung (HB), Glenn Clemmer (GC), Robert Esher (RE), Patricia Grace (PG), Randall Grace (RG), John Hall (JH), Philip Mundy (PM), Vicki Pearson (VP), David Stansbery (DS), Royal Suttikus (RS), James Williams (JW). Current or flow conditions for the Black Warrior stations were not described because of their variability depending on release from upstream reservoirs. Species of mussels taken at each station are presented in Table 3. Stations T1-T6 were not impounded when sampled. Stations T7-T12 and W1-W8 were impounded.

Tombigbee River System

T-1. Tombigbee River about 0.2 mi above (upstream) Warsaw, about 7.8 mi NNW of Gainesville, Sumter County (T23N; R2W; Sec.33-34), Alabama. 8 June 1972 and 21 August 1974. Collected by HB, RG, PM, and JW. Specimens were collected by hand in the shallows (to a depth of 3 ft.) of a large island. The substrate was predominately gravel mixed with some sand. The current was moderate to swift. Aquatic vegetation (*Justicia* sp.) was present along the channel on the east side of the island.

T-2. Tombigbee River about 0.2 mi below (downstream) Warsaw, about 7.6 mi NNW of Gainesville, Sumter County (T23N; R2W; Sec.33), Alabama. 8 June 1972. Collected by HB, PM, and JW. Specimens were collected by hand from a midden along the east bank. A gravel shoal along the west bank created a swift current across the entire river channel.

T-3. Tombigbee River approximately 5 mi NNW of Gainesville, Sumter County (T22N; R2W; Sec.15), Alabama. 8 June 1972 and 21 August 1974. Collected by HB, GC, RG, PM, and JW. The sample was taken by hand from middens along the east and west banks. The current was moderate. The substrate consisted of mixtures of sandy clay and gravel.

T-4. Tombigbee River approximately 3 mi N of Gainesville, Sumter County (T22N; R2W; Sec.26), Alabama. 26 October 1973. Collected by GC, RE, RS, and JW. Specimens were collected by hand in the shallows around a low island (1 to 2 ft. above the water). The substrate was gravel with some sand and mud. The current was moderate.

T-5. Tombigbee River approximately 2 mi N of Gainesville, Sumter County (T22N; R2W; Sec.25), Alabama. 24 June 1972, 14 September 1973, 26 October 1973, and 21 August 1974. Collected by GC, RG, JH, VP, DS, and JW. Specimens were collected by hand from shallows around an island and from middens along the east bank. The island and channels along the island were predominately gravel with some sand. The banks were a mixture of sand and clay. Current around the island was moderate to swift.

T-6. Tombigbee River approximately 0.2 mi above mouth of Noxubee River NW of Gainesville, Sumter County (T21N; R2W; Sec.3), Alabama. 24 June 1972 and 26 October 1973. Collected by GC, RE, VP, DS, RS, and JW. The samples were taken by hand from the gravel bar and shallow areas along the east bank. The west bank is a steep chalk bluff. Substrate was primarily gravel with some sand and clay at each end of the bar. The current was moderate to swift. This is the first shoal area above the backwaters of Demopolis Reservoir.

T-7. Tombigbee River at the mouth of Brush Creek, approximately 3.3 mi NW of Boligee, Greene County (T21N; R1W; Sec.14), Alabama. 26 July 1975. Collected by PG, RG, and JW. The shallows at the mouth of the creek were sampled by hand. The substrate was mud and mud mixed with sand. The current in and around the mouth of the creek was slow.

T-8. Tombigbee River at mouth of unnamed tributary on the east bank 3 mi WNW of Boligee, Greene County (T21N; R1W; Sec.26), Alabama. 26 July 1975. Collected by PG, RG, and JW. The sample was taken from shallows around the mouth of the creek and sand banks on the west side of the river. There was very little current. Bottom material was a mixture of sand and mud.

T-9. Tombigbee River about 2 mi above I-59 bridge crossing approximately 5 mi NNE of Epes, Sumter County (T21N; R1W; Sec.32), Alabama. 26 July 1975. Collected by PG, RG, and JW. The sample was collected by hand from shallows along the west bank. The substrate was predominately mud with the exception of one gravel area where a small intermittent stream entered the reservoir. Current in the area was slow.

T-10. Tombigbee River approximately 1.5 mi above I-59 bridge, about 4.5 mi NNE of Epes, Sumter County (T21N; R1W; Sec.32), Alabama. 26 July 1975. Collected by PG, RG, and JW. This area was sampled for 45 minutes by diving in the channel (10 to 15 ft. deep) and by hand for 30 min in the shallows along the east bank. Current in the channel was slow. An old preimpoundment midden on the west bank, was also sampled. The substrate in the channel was firm sand with small patches of gravel. Substrate along the east bank was mud mixed with sand.

T-11. Tombigbee River approximately 0.5 mi below the public access boat ramp at Miller, Greene County (T20N; R1W; Sec.16), Alabama. 26 July 1975. Collected by RG. The sample was taken by diving for 45 minutes in the

channel where depths ranged from 18 to 20 ft. The bottom was rocky (eroded chalk) towards the east bank and clean coarse sand along the west bank. The current was slow.

T-12. Tombigbee River just above railroad bridge at Epes, Sumter County (T20N; R1W; Sec.20), Alabama. 26 July 1975. Collected by RG. The area was sampled by diving for 30 minutes in water approximately 18 ft. deep with little or no current. The bottom was primarily sand with a mixture of mud and sand in some areas.

Black Warrior River System

W-1. Warrior River below Oliver Lock and Dam at Tuscaloosa (River Mile 338.2) Tuscaloosa County (T21S; R5E; Sec.21), Alabama. 3 August 1975. Collected by JW. The sample was taken by hand in shallows (depth to 2 ft.) on the west bank. The substrate consisted of sand mixed with some gravel and clay. The shallow area is below a rock outcrop and is accessible only during periods of low discharge from upstream reservoirs.

W-2. Warrior River opposite the mouth of Big Sandy Creek (River Mile 307), Tuscaloosa County (T24N; R4E; Sec.24), Alabama. 2 August 1975. Collected by PG, RG, and JW. The shallow along the sand bar on the west banks were sampled by hand. The bottom was a mixture of sand and loose gravel. A dive sample was attempted, but discontinued after 30 minutes because the water was too swift.

W-3. Warrior River at Mud Bar (River Mile 302.3) about 1.5 mi N of Moundville, Tuscaloosa County (T24N; R4E; Sec.26), Alabama. 2 August 1975. Collected by PG, RG, and JW. The sample was taken in shallows along Mud Bar on the west bank. The substrate was a mixture of sand and gravel.

W-4. Warrior River just below Warrior Dam about 4 miles SSE of Eutaw, Greene-Hale County line (T21N; R2E; Sec.24), Alabama. 30 July 1975. Collected by PG, RG, and JW. Shallow areas on the east and west banks were sampled by hand. The substrate on the east bank was clay with some sand and gravel. The west bank was predominately sand and gravel.

W-5. Warrior River, about 3 mi below Warrior Dam, about 5 air miles SSE of Eutaw, Greene-Hale County line (T21N; R2E; Sec.27), Alabama. 29 July 1975. Collected by RG. The sample was taken by diving for 1 hour near midstream at a depth of approximately 15-18 ft. Substrate in the sample area was sand and gravel with small patches of gravel mixed with sand.

W-6. Warrior River, at Hall Shoals, about 0.2 mi above junction of Warrior Lock Channel, Greene-Hale County line (T21N; R2E; Sec.25), Alabama. 28 July 1975 and 30 July 1975. Collected by RG. The samples were taken by diving for approximately 1 hour each day in midstream at depths of 15 to 20 ft. The substrate was rocky (large pieces of chalk) with patches of sand and sand mixed with gravel.

W-7. Warrior River at River Mile 259.5, about 6.5 air miles SE of Eutaw, Greene-Hale County line (T21N; R3E;

Sec.31), Alabama. 29 July 1975. Collected by RG. The sample was collected by diving for about 30 minutes from near the east bank to midstream. The bottom was tightly packed sand (4–6 in. deep) gravel. Water depths ranged from 15 to 18 ft. in the sample area.

W-8. Warrior River at River Mile 257 about 8.3 air miles SSE of Eutaw, Greene–Hale County line (T20N; R3E; Sec.6), Alabama. 29 July 1975. Collected by RG. The sample was taken by diving for approximately 30 minutes in 15 to 18 ft. of water along the east side of the channel. The substrate was tightly packed sand (about 6 in. deep) over gravel. There were some stumps that protruded through the sand.

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