Hartfield 2002

MUSSELS OF THE CAHABA RIVER
SPECIES ASSESSMENT AND SOURCES OF INFORMATION

U.S. Fish and Wildlife Service

Much of the Cahaba River that lies above the Fall Line (north of Centreville, Bibb Co., AL) has been placed on Alabama's 303d list for not maintaining its designated use as "Fish and Wildlife." The Environmental Protection Agency (EPA) has identified the biological impairment in the Cahaba as the decline and loss of endangered and threatened mussel species, and the causes of the biological impairment (loss of species) as sediments and nutrients. EPA has used information from U.S. Fish and Wildlife Service (Service) regulations listing species under the Act as the basis for their determination. The purpose of this report is to summarize information on status of mussels in the upper Cahaba River.

The Service has identified pollution as a primary cause of extirpation or decline of endangered and threatened fishes (3 species), mussels (11 species), and snails (3 species) within the Cahaba River. The Service has been especially concerned with sediment and nutrient impacts to listed species in this system.

COLLECTION RECORD

Published site-specific records of the Cahaba River are few. Henry van der Schalie collected the river in 1933 and 1935 and published his observations in 1938. Baldwin (1973) covered much of the same ground, as well as additional sites during 1972-73, and compared his findings to van der Schalie. Pierson's (1991) searches for rare mussels were concentrated in the middle river below the confluence of the Little Cahaba. The Geological Survey of Alabama (GSA) made several surveys in the early to mid-90's that concentrated on different portions of the River. GSA reports include Sheppard *et al.* (1994) which covered a portion of the upper river, while lower river collections are documented by McGregor *et al.* (in press). Table 1 summarizes published mussel records from the Cahaba River.

The Service is aware of various other site collections for mussels and snails made by individual collectors during the past decade, including Dr. Art Bogan (North Carolina Museum of

Natural History), Dr. Randall Haddock (Cahaba River Society), and Malcolm Pierson (Calera, Alabama). These collections are recorded in private field notes.

Dr. Jim Williams (U.S. Geological Survey) has compiled Mobile River Basin mussel records from major museum collections around the country. During this process, he examined over 1,000 individual species collection lots from the Cahaba River drainage, dating from the early 1900's to 1998. The museum collections illustrate the collection history of the Cahaba River. Of the over 1000 individual species collection lots from the Cahaba, only 63 species lots were collected in the 1970's or later from the reaches that are above the Fall Line, and these represent only 17 site collections.

MUSSEL LIFE HISTORY

Details of mussel life history, including host fish interactions, are poorly known for most species. Watters (1994) provides an annotated bibliography of mussel reproduction. Age of sexual maturity is variable, usually requiring 3-9 years. Sexes in unionid mussels are usually separate. Males release sperm into the water column, which enter the incurrent siphons of females through normal respiratory and feeding activities. Eggs are held in the females gills where they may come into contact with the sperm. Fertilized eggs develop into larva called glochidia. Glochidial parasitism is the primary means of dispersal for unionid mussels. The glochidia of most mussels must undergo a parasitic stage on a fish prior to metamorphosis into a juvenile mussel. Some species release mature glochidia into the water column where they must find and attach to the gills or fins of a suitable host fish species. Glochidia may be released separately, or in masses termed conglutinates. Other species have evolved mechanisms to attract fish, and hold their glochidia until a fish provides a stimulus to release. Some mussels may only parasitize a single species of fish, while other mussels may attach to several species. After attaching to a fish host, the glochidia eventually metamorphose to a juvenile mussel. The duration of the parasitic stage varies with water temperature, mussel species, and perhaps host fish species. After metamorphosis, the juvenile mussels release from the host. To survive, they must drop onto a suitable substrate and habitat. Within stable habitats, most mussel species are long-lived surviving 20-50+ years in the wild.

WHAT ARE THE SPECIES OF CONCERN THAT ARE RESPONSIBLE FOR THE REQUIRED HABITAT AND NUTRIENT TMDL TARGETS?

The Cahaba River between U.S. Highway 280 and Centreville was placed on the AL 1998 303(d) list for nutrients and sediments, due to habitat impacts on federally listed mussel species. Table 2 summarizes historic and recent mussel collection records from this reach. Six species of federally listed mussel species were reported from this reach of the Cahaba River. Only two of these, *Lampsilis altilis* and *Ptychobranchus greeni* have been recently collected. There has been no evidence of recruitment of these two species.

Species extirpated since 1975

In order to be considered an "existing use", aquatic species should have been extant in the Cahaba River in 1975 or later. The Service has been unable to locate any 1975 collection records from the Cahaba above Centreville. Apart from Baldwin's 1973 records, the Service is aware of only two mid-1970's site collections of single species (1976) that were taken between U.S. Highway 280 and Centreville. Therefore, Baldwin (1973) represents the best record of Cahaba River mussel fauna in the mid-1970's. There are several site specific collection records from this reach during the the late 1980's, and a more extensive survey of several sites by Sheppard *et al.* in 1994 (see Table 2).

Listed species collected alive or freshly dead by Baldwin (1972-1973) between U.S. Hwy 280 and Centreville include:

Alabama moccasinshell *(Medionidus accutissimus* - T),

southern clubshell *(Pleurobema decisum* - E),

upland combshell *(Epioblasma metatstiata - E*),

triangular kidneyshell (*Ptychobranchus greeni* - E),

fine-lined pocketbook (*Lampsilis altilis* - T).

More recent collections (e.g., Sheppard *et al.* 1994) indicate that the first three of these, Alabama moccasinshell, southern clubshell, and upland combshell are now extirpated from the Cahaba River drainage.

Other species that appear to have declined or become extirpated from the Cahaba River above Centreville since 1973 (Table 2) are:

southern mapleleaf (*Quadrula apiculata*)

ridged mapleleaf (*Quadrula rumphiana*)

butterfly (*Ellipsaria lineolata*)

pistolgrip (*Tritogosa verrucosa*)

delicate spike *Elliptio arctata*

fragile papershell (*Leptodea fragilis)*

Alabama heelsplitter (*Lasmigona complanata alabamensis*)

black sandshell (*Ligumia recta*)

hickorynut (*Obovaria* sp.)

Southern creekmussel (*Strophitus subvexus*)

little spectaclecase (*Villosa lienosa*)

southern rainbow (*Villosa vibex*)

Is the assumption that mussels reported in 1973 were alive after 1975 valid?

Unionid mussels are long-lived, surviving 20-50+ years in the wild. Adult mussels are fairly hardy, able to survive pollution events or even droughts by shutting their valves tightly and "clamming up." Barring some significant change in habitat or water quality, or some unknown catastrophic pollution or geomorphic event, there is little doubt that mussel species found alive in 1973 are likely to have persisted to 1975 and later. We have no information that such an event occurred in the Cahaba during this time period. The affects of sedimentation, nutrification, or other forms of pollution on mussels are insidious, causing loss of reproduction or recruitment, or disrupting host fish relationships. These are manifested by a gradual decline in abundance, and eventual disappearance over a period of years.

Is there evidence of past or current nutrient (algal) problems or shifts?

The Service has little information on this. During the early 90's, the Service funded water-quality and biomonitoring studies in the upper Cahaba River by GSA. Shepard *et al.* (1996)

identified nutrification as a "complex problem" in their section 3, due to two major waste water treatment plant outfalls as well as runoff from golf courses, turf farms, and thousands of managed lawns. They rated biological condition in this reach as poor. Downstream of Buck Creek, they noted eutrophic conditions demonstrated primarily by heavy growth of filamentous algae on the river bottom. In 2000 and 2001, Dr. Randall Haddock, Cahaba River Society (*in litt.*), photographed heavy algal mats in the Cahaba River below I-20, I-459, and Piper bridges.

What defines the habitat loss of the species that caused the listing?

All of the species of concern in the Cahaba River inhabit stable riffles, shoals, and runs of large streams and rivers. The primary cause of habitat loss of listed mussels in the Mobile River Basin has been attributed to impoundment. The primary threats identified for endangered and threatened mussel populations surviving in the Cahaba River are associated with pollution and deteriorating habitat quality.

What do we measure that will make a difference to listed mussels?

In regard to mussels, excessive sedimentation may directly harm mussels by burial of adults and juveniles, or by interrupting respiration or feeding activities (Brim Box and Mossa 1999). Suspended sediments and sediment deposits may also displace host fish within the riverine habitat (Watters 1995), or disrupt host fish/mussel interactions leading to decline or loss of recruitment of some species.

High levels of nutrients promote excessive filamentous algal growth. Dense filamentous algal growth covers gravel, cobble, or bedrock interstices, affecting feeding and respiration in adult and juvenile mussels. These interstices are important habitat for recently excised juvenile mussels, and algal growth may exclude them. Algal mats may also provide cover for invertebrate predators of juvenile mussels (e.g., flatworms, hydra, chironomids, etc.), and increase the vulnerability of juvenile mussels to these predators. Filamentous algae may also displace certain species of fish, affecting fish/mussel interactions essential to successful recruitment.

In a review of the effects of eutrophication on mussels, Patzner and Muller (2001) noted that stenoecious (narrowly tolerant) species disappear as waters become more eutrophic. They

reviewed studies that closely associated increased levels of nitrate with the decline and absence of juvenile mussels. Augspurger *et al. (in prep.)* reviewed unpublished data on effects of ammonia on nine species of mussels and concluded that mussels are more sensitive to ammonia relative to other invertebrates and fishes. Other studies have suggested that early life stages of mussels are sensitive to inorganic chemicals such as chlorine, metals, and ammonia (Keller and Zam 1991, Goudreau et al. 1993, Jacobson et al. 1993).

Although the physical effects of nutrification and algal growth on mussels has not been directly addressed in the literature, field observations by Service biologists (e.g., Hartfield, *pers. obsv.*) indicate a direct relationship between dense filamentous algal growth and lack of mussel recruitment in streams and the loss of mussel species. Recent studies on early mussel life history indicate that heavy filamentous algal growth promoted by nutrification may physically disrupt mussel/fish interactions (e.g., Hartfield and Hartfield 1993), and/or juvenile mussel survival. In hatcheries, filamentous algae reduces mussel juvenile survival by reducing flow, increasing sedimentation, and by deleterious affects on the unicellular algal community on which the mussels feed (Neves *pers. com.* 2002).

Listed mussels still inhabiting the Cahaba River above the Fall Line:

Fine-lined pocketbook (*Lampsilis altilis*) - Threatened

The fine-lined pocketbook (*Lampsilis altilis* (Conrad 1834)) is a medium-sized mussel, suboval in shape, and rarely exceeds 100 mm (4 in.) in length. The ventral margin of the shell is angled posteriorly in females, resulting in a pointed posterior margin. The periostracum is yellow-brown to blackish and has fine rays on the posterior half. The nacre is white, becoming iridescent posteriorly. Life history is poorly known. Gravid females have been observed March through June. Fine-lined pocketbooks have also been observed releasing glochidia in a single, large conglutinate (Haag et al. 1999), termed a superconglutinate (Haag et al. 1995). The success of the superconglutinate to attact host fish may be limited by turbidity. Redeye bass, spotted bass, largemouth bass, and green sunfish have been identified as suitable hosts (Haag et al. 1999). The fine-lined pocketbook was historically reported from the Tombigbee, Black Warrior, Cahaba,

Alabama, Tallapoosa, and Coosa Rivers and many of their tributaries in Alabama, Georgia, Mississippi, and Tennessee. Populations continue to survive in the upper Cahaba River and the Little Cahaba River, (Jefferson, Bibb Counties, Alabama); Coosa River (Cherokee County, Alabama) and its tributaries, Conasauga River (Murray/Whitfield County, Georgia, Polk County, Tennessee) and Holly Creek (Murray County, Georgia), Terrapin Creek and South Fork Terrapin Creek (Cleburne County, Alabama), Big Canoe Creek (St. Clair County, Alabama), Cheaha Creek (Talladega/Clay County, Alabama), Yellowleaf Creek and its tributary Muddy Prong (Shelby County, Alabama), Kelly Creek and its tributary Shoal Creek (Shelby/St. Clair County, Alabama), Shoal Creek (Cleburne County, Alabama), and Tallasahatchee Creek (Talladega County, Alabama); and the Tallapoosa River and tributaries, Uphapee Creek (Macon County, Alabama), Choctafaula Creek (Macon/Lee County, Alabama), Chewacla Creek (Macon/Lee County, Alabama), Opintlocco Creek (Macon County, Alabama), Cane and Little Cane Creeks (Cleburne County, Alabama), Muscadine Creek (Cleburne County, Alabama), Big Creek (Haralson County, GA), McClendon Creek (Paulding County, Georgia). Populations are small and localized within these streams (Gangloff in litt. 2000, E. Irwin, U.S. Geological Survey, in litt. 2000; Johnson and Evans 2000; L. McDougal, U.S. Forest Service, in litt. 1994; McGregor 1993, Pierson 1991, Pierson 1993, Shepard et al. 1994, Williams and Hughes 1998).

Triangular kidneyshell (*Ptychobranchus greeni*) - Endangered

The triangular kidneyshell (Ptychobranchus greeni (Conrad 1834)) is oval to elliptical in outline, and may approach 100 mm (4.0 in.) in length. The shell is generally compressed, and may be flattened ventral to the umbos. The posterior ridge is broadly rounded and terminates in a broad round point post-ventrally. The pseudocardinal teeth are heavy, and the laterals are heavy, gently curved and short. The periostracum is straw-yellow in young specimens, but becomes yellow-brown in older ones. It may have fine and wavy, or wide and broken, green rays anterior to the posterior ridge. Gravid triangular kidneyshell females were observed in March 1994. Glochidia are packaged into conglutinates that mimic dipteran larvae (Hartfield and Hartfield 1996) or fish eggs (Haag and Warren 1997). Suitable fish hosts have been identified as Warrior darter, tuskaloosa darter, blackbanded darter and logperch.

The historic range of the triangular kidneyshell included the Black Warrior, Cahaba, Alabama, and Coosa Rivers and tributaries in Alabama, Georgia, and Tennessee. The species is currently known from the Sipsey Fork and tributaries (Winston/Lawrence County, Alabama), Locust Fork (Blount County, Alabama), Cahaba River (Bibb County, Alabama), Kelly Creek (Shelby County, Alabama), Terrapin Creek (Cherokee County, Alabama), Conasauga River (Murray/Whitfield County, Georgia, Bradley County, Tennessee), Holly Creek (Murray County, Georgia), Coosawattee River (Gordon County, Georgia), and Oostanaula River (Floyd/Gordon County, Georgia). Populations are small and localized (Gangloff in litt. 2000, Johnson and Evans 2000, McGregor 1992, Shepard et al. 1998, Shepard et al. 1994, Warren and Haag 1994, Williams and Hughes 1998).

Listed snail species in the Cahaba also affected by sedimentation and eutrophication:

Cylindrical lioplax (*Lioplax cyclostomaformis*) - Endangered

The cylindrical lioplax (*Lioplax cyclostomaformis* (Lea 1841)) is a gill-breathing snail in the family Viviparidae. The shell is elongate, reaching about 28 millimeters (mm) (1.1 inches (in)) in length. Shell color is light to dark olivaceous-green externally, and bluish inside of the aperture (shell opening). The cylindrical lioplax is distinguished from other viviparid (eggs hatch internally and the young are born as juveniles) snails in the Basin by the number of whorls, and differences in size, sculpture, microsculpture, and spire angle. No other species of lioplax snails are known to occur in the Mobile Basin (see Clench and Turner 1955 for a more detailed description).

Habitat for the cylindrical lioplax is unusual for the genus, as well as for other genera of viviparid snails. It lives in mud under large rocks in rapid currents over stream and river shoals. Other lioplax species are usually found in exposed situations or in mud or muddy sand along the margins of rivers. Little is known of the biology or life history of the cylindrical lioplax. It is believed to brood its young and filter-feed, as do other members of the Viviparidae. Life spans have been reported from 3 to 11 years in various species of Viviparidae.

Collection records for the cylindrical lioplax exist from the Alabama River (Dallas County, Alabama), Black Warrior River (Jefferson County, Alabama) and tributaries (Prairie Creek,

Marengo County, Alabama; Valley Creek, Jefferson County, Alabama), Coosa River (Shelby, Elmore counties, Alabama) and tributaries (Oothcalooga Creek, Bartow County, Georgia; Coahulla Creek, Whitfield County, Georgia; Armuchee Creek, Floyd County, Georgia; Little Wills Creek, Etowah County, Alabama; Choccolocco Creek, Talladega County, Alabama; Yellowleaf Creek, Shelby County, Alabama), and the Cahaba River (Bibb, Shelby counties, Alabama) and its tributary, Little Cahaba River (Jefferson County, Alabama) (Clench and Turner 1955). A single collection of this species has also been reported from the Tensas River, Madison Parish, Louisiana (Clench 1962), however, there are no previous or subsequent records outside of the Alabama-Coosa system, and searches of the Tensas River in Louisiana by Service biologists (1995) and others (Vidrine 1996) have found no evidence of the species or its typical habitat.

The cylindrical lioplax is currently known only from approximately 24 kilometers (km) (15 miles (mi)) of the Cahaba River above the Fall Line in Shelby and Bibb counties, Alabama. Recent survey efforts have failed to relocate the species at historic localities in the Alabama, Black Warrior, Little Cahaba, and Coosa rivers and their tributaries.

Flat pebblesnail (*Lepyrium showalteri*)- E

The flat pebblesnail (*Lepyrium showalteri* (Lea 1861)) is a small snail in the family Hydrobiidae; however, the species has a large and distinct shell, relative to other hydrobiid species. This snail's shell is also distinguished by its depressed spire and expanded, flattened body whorl. The shells are ovate in outline, flattened, and grow to 3.5 to 4.4 mm (0.1-0.2 in) high and 4 to 5 mm (0.2 in) wide. The umbilical area is imperforate (no opening), and there are 2 to 3 whorls which rapidly expand. The anatomy of this species has been described in detail by Thompson (1984). The flat pebblesnail is found attached to clean, smooth stones in rapid currents of river shoals. Eggs are laid singly in capsules on hard surfaces. Little else is known of the natural history of this species.

The flat pebblesnail was historically known from the mainstem Coosa River in Shelby and Talladega counties, the Cahaba River in Bibb and Dallas counties, and Little Cahaba River in Bibb County, Alabama. The flat pebblesnail has not been found in the Coosa River portion of its range since the construction of Lay and Logan Martin Dams, and recent survey efforts have failed to

locate any surviving populations outside of the Cahaba River drainage. The flat pebblesnail is currently known only from Booth Ford on the Cahaba River, Shelby County, Alabama. Recent attempts to locate the species on the Little Cahaba have been unsuccessful.

Round rocksnail (*Leptoxis ampla*) - Threatened

The round rocksnail (*Leptoxis ampla* (Anthony 1855)) grows to about 20 mm (0.8 in) in length. The shell is subglobose, with an ovately rounded aperture. The body whorl is shouldered at the suture, and may be ornamented with folds or plicae. Color may be yellow, dark brown, or olive green, usually with four entire or broken bands. Round rocksnails inhabit riffles and shoals over gravel, cobble, or other rocky substrates.

Rocksnails are gill breathing snails found attached to cobble, gravel, or other hard substrates in the strong currents of riffles (a shallow area in a streambed that causes ripples in the water) and shoals. Adult rocksnails move very little, and females probably glue their eggs to stones in the same habitat. Heller (1990) reported a short life span (less than 2 years) in a Tennessee River rocksnail. Longevity in the round rocksnail is unknown. Specimens of the plicate rocksnail (Black Warrior drainage) have survived up to 3 years in captivity.

The round rocksnail was historically found in the Cahaba River, and its tributary, Little Cahaba River, Bibb County, Alabama; and the Coosa River, Elmore County, and tributaries--Canoe Creek and Kelly's Creek, St. Clair County; Ohatchee Creek, Calhoun County; Yellowleaf Creek, Shelby County; and Waxahatchee Creek, Shelby/Chilton counties, Alabama.

The round rocksnail is currently known from a shoal series in the Cahaba River, Bibb and Shelby counties, Alabama, and from the lower reach of the Little Cahaba River, and the lower reaches of Shade and Six-mile creeks in Bibb County, Alabama.

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TABLE 1: MUSSELS OF THE CAHABA RIVER

Comparison of various surveys of Cahaba River mussel fauna.

(Adapted from McGregor *et al., in press*)

Species	v d S 1938	Baldwin '73	Pierson '91	GSA '94
Amblema plicata (Say, 1817)	X	X	X	X
Ellipsaria lineolata (Rafinesque, 1820)	X	X	X	X
Elliptio arca (Conrad, 1834)	X			
Elliptio arctata (Conrad)	X	X		
Elliptio crassidens (Lamarck, 1819)	X	X	X	X
Epioblasma metastriata (Conrad, 1838)	X	X		
Epioblasma penita (Conrad, 1834)				
Fusconaia cerina (Conrad, 1838)	X	X	X	X
Fusconaia ebena (I. Lea, 1831)	X	X	X	X
Lampsilis altilis (Conrad, 1834)	X	X		
Lampsilis ornata (Conrad, 1835)	X	X	X	X
L. straminea claibornensis (I. Lea, 1838)	X	X	X	X
Lampsilis teres (Rafinesque, 1820)	X	X	X	X
Lasmigona complanata alabamensis Clarke, 1985	X	X	X	X
Lasmigona holstonia (I. Lea, 1838)	X			
Leptodea fragilis (Rafinesque, 1820)	X	X	X	X
Ligumia recta (Lamarck, 1819)	X	X		X
Medionidus acutissimus (I. Lea, 1831)	X	X		
Medionidus parvulus (I. Lea, 1860)	X			
Megalonaias nervosa (Rafinesque, 1820)	X			X
Obliquaria reflexa Rafinesque, 1820	X	X	X	X
Obovaria jacksoniana (Frierson, 1912)	X	X	X	
Obovaria unicolor (I. Lea, 1845)	X	X	X	X
Plecotmerus dombeyana (Valenciennes, 1827)				X
Pleurobema decisum (I. Lea, 1831)	X	X	X	X
Pleurobema perovatum (Conrad, 1834)	X			
Pleurobema rubellum (Conrad, 1834)	X			
Pleurobema taitianum (I. Lea, 1834)	X			
Potamilus purpuratus (Lamarck, 1819)	X	X	X	X
Ptychobranchus greenii (Conrad, 1834)	X	X		X
Pyganodon grandis (Say, 1829)			X	
Quadrula apiculata (Say, 1829)	X	X	X	X
Quadrula asperata (I. Lea, 1861)	X	X	X	X
Quadrula metanevra (Rafinesque, 1820)	X	X	X	X
Quadrula rumphiana (I. Lea, 1852)	X	X	X	X
Toxolasma ref. corvunculus (I. Lea, 1868)	X			X
Tritogonia verrucosa (Rafinesque, 1820)	X	X	X	X
Truncilla donaciformis (I. Lea, 1828)	X		X	X
Uniomerus tetralasmus (Say, 1831)	X	X		
Utterbackia imbecillis (Say, 1829)	X	X		
Villosa lienosa (Conrad, 1834)	X	X	X	X
Villosa nebulosa (Conrad, 1834)	X	X		
Villosa vanuxemensis umbrans (I. Lea, 1857)	X			

Villosa vibex (Conrad, 1834)	X	X		
Corbicula fluminea (Müller, 1774)		X	X	X

TABLE 2: MUSSELS RECORDS FROM THE CAHABA RIVER, BETWEEN U.S. HIGHWAY 280 AND CENTREVILLE, BIBB COUNTY

Species	v d S 1938	Baldwin 1973	Sheppard 1994	Status
Amblema plicata	X	X	FD, R	
Ellipsaria lineolata		X		Extirpated after 1973.
Epioblasma metastriata - E	X	X		Extirpated after 1973.
E. othcaloogensis - E	X			Extirpated after 1938
Elliptio arctata	X	X		Extirpated after 1973
E. crassidens	X	X	A, FD, R	
E. arca	X			Extirpated after 1938
Fusconaia cerina	X	X	A, FD, R	
Lampsilis teres anodontoides	X	X	A, R	
Lampsilis altilis - T	X	X	FD	No recruitment
Lampsilis ornata	X	X	FD, R	
Lampsilis straminea claibornensis	X	X	A, FD	
Lasmigona alabamensis	X	X		Extirpated after 1973.
Leptodea fragilis	X	X		Extirpated after 1973.
Ligumia recta	X	X	R	Extirpated after 1973.
Medionidus acutissimus - T	X	X		Extirpated after 1973.
M. parvulus	X			Extirpated after 1938
Megalonaias gigantea			FD	
Obliquaria reflexa		X	A	
Obovaria sp.		X		Extirpated after 1973.
Pleurobema decisum - E	X	X	R	Extirpated after 1973.
P. perovatum	X			Extirpated after 1938
Potamilus purpuratus	X	X	A, FD	
Ptychobranchus greeni - E	X	X	FD	No recruitment
Quadrula asperata	X	X	A, FD, R	
Q. apiculata	X	X		Extirpated after 1973.
Q. rumphiana	X	X	R	Extirpated after 1973.
Strophitus subvexus	X	X		Extirpated after 1973.
Toxolasma corvunculus	X			Extirpated after 1938
Tritogonia verrucosa	X	X	R	Extirpated after 1973.
Truncilla donaciformis	X			Extirpated after 1938
Villosa lienosa	X	X	R	Extirpated after 1973.
Villosa nebulosa		X	A	
V. umbrans	X			Extirpated after 1938
V. vibex	X	X		Extirpated after 1973.
Corbicula fluminea		X	A, FD, R	

Total	30	28	19	

A = alive
FD = fresh dead
R = relic

REFERENCES

Augspurger, T., A.E. Keller, M.C. Black, W. G. Cope, and F. J. Dwyer. In preparation. Evaluation of water quality criteria for protection of freshwater mussels (Unionidae) from acute ammonia exposure. U.S. Fish and Wildlife Service, Raleigh, NC.

Baldwin, C.S. 1973. Changes in the freshwater mussel fauna in the Cahaba River over the past forty years. M.S. Thesis. Tuskegee Institute, Tuskegee, Alabama. 45 pp.

Clench, W.J. 1962. New records of the genus Lioplax. Occasional Papers on Mollusks. 2(27):288.

Clench, W.J. and R.D. Turner. 1955. The North American genus Lioplax in the Family Viviparidae. Occasional Papers on Mollusks. 2(19):1-20.

Goudreau, S., R. J. Neves, and R. J. Sheehan. 1993. Effects of wastewater treatment plant effluents on freshwater mollusks in the upper Clinch River, Virginia, U.S.A. Hydrobiologia 252(3):211-230.

Haag, W.R., R.S. Butler, and P.D. Hartfield. 1995. An extraordinary reproductive strategy in freshwater bivalves: prey mimicry to facilitate larval dispersal. Freshwater Biology 34:471-476.

Haag, W. R., and M.L. Warren, Jr. 1997. Fish hosts and reproductive aspects of six freshwater mussel species from the Mobile Basin, USA. Journal of the North American Benthological Society 16:576-585.

Haag, W.R., M.L. Warren, Jr., and M. Shillingsford. 1999. Host fishes and host-attracting behavior of Lampsilis altilis and Villosa vibex (Bivalvia: Unionidae). Am. Midl. Nat. 141:149-157.

Hartfield, P. and R. Bowker. 1992. Mussel survey of Luxapalila Creek, Steens, Mississippi to the Tombigbee River, May 11-12, 1992. Report to U.S. Army Engineer District, Mobile, AL. U.S. Fish and Wildlife Service, Jackson, MS.

Hartfield, P. and R. Butler. 1997. Observations on the release of superconglutinates by *Lampsilis perovalis* (Conrad 1834). Pp. 11-14. *In*: K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo (eds.). Conservation and management of freshwater mussels II: initiatives for the future. Proceedings of a UMRCC symposium. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Hartfield P. and E. Hartfield. 1996. Observations on the conglutinates of *Ptychobranchus greeni* (Conrad, 1834) (Mollusca: Bivalvia: Unionoidea). American Midland Naturalist 135:370-375.

Hartfield, P. and R. Jones. 1989. The status of Epioblasma penita, Pleurobema curtum, and P. taitianum in the East Fork Tombigbee River - 1988. Mississippi Mus. Nat. Sci. Tech. Rpt. No. 8:44 pp.

Hartfield, P. and R. Jones. 1990. Population status of endangered mussels in the Buttahatchee River, Mississippi and Alabama - Segment 1, 1989. Mississippi Mus. Nat. Sci. Tech. Rpt. No. 9. 35 pp.

Hartfield P. and E. Hartfield. 1996. Observations on the conglutinates of *Ptychobranchus greeni* (Conrad, 1834) (Mollusca: Bivalvia: Unionoidea). American Midland Naturalist 135:370-375.

Heller, J. 1990. Longevity in molluscs. Malacologia 31(2):259-295.

Irwin, E., G. Kowalski, and D. Buckmeir. 1998. Distribution of endemic and threatened aquatic fauna in the upper Tallapoosa River. Alabama Cooperative Fish and Wildlife Research Unit, Auburn, Alabama. 38 pp.

Jacobson, P. J., J. L. Farris, D. S. Cherry, and R. J. Neves. 1993. Juvenile freshwater mussel (Bivalvia: Unionidae) responses to acute toxicity testing with copper. Environmental Toxicology and Chemistry 12:879-883.

Johnson, P.D. and R.R. Evans. 2000. A contemporary and historical database of freshwater mollusks in the Conasauga River Basin. U.S. Geological Survey Contract #98HQAG-2154. 291 pp.

Jones, R.L. 1991. Population status of endangered mussels in the Buttahatchee River, Mississippi and Alabama, Segment 2 1990. Mississippi Mus. Nat. Sci. Tech. Rpt. No. 14. 36 pp.

Jones, R.L. and T.C. Majure. 1999. Endangered mussels of Tombigbee River tributaries: Bull Mountain Creek. Mississippi Mus. Nat. Sci. Tech. Rpt. No. 65. 10 pp.

Kat, P.W. 1984. Parasitism and the Unionacea (Bivalvia). Biol. Rev. 59:189-207.

Keller, A. E., and S. G. Zam. 1991. The acute toxicity of selected metals to the freshwater mussel *Anodonta imbecilis* [sic]. Environmental Toxicology and Chemistry 10:539-546.

McGregor, M. 1993. A qualitative assessment of the unionid fauna found in streams in and near the Tuskeggee National Forest. Report to USDA Forest Service, Montgomery, AL.

McGregor, S. 1992. A mussel survey of the streams draining Bankhead National Forest and the Oakmulgee Division of Talladega National Forest, Alabama 1992. Geological Survey of Alabama, Tuscaloosa, Alabama. 29 pp.

McGregor, S.W., T.E. Shepard, T.D. Richardson, and J.F. Fitzpatrick, Jr. 1996. A survey of the primary tributaries of the Alabama and lower Tombigbee Rivers for listed and candidate species of freshwater mussels, snails and crayfish, 1994-1996. Geological Survey of Alabama, Tuscaloosa, Alabama. 34 pp.

McGregor, S.W. 1999. A mussel survey of the upper Tombigbee River system of Alabama and Mississippi, 1994-99. Geological Survey of Alabama, Tuscaloosa, Alabama. 19 pp.

McGregor, S.W., J.M. Pierson, and P.E. O'Neil. In press. Status of the freshwater mussel fauna in the Cahaba River system, Alabama. Walkeriana.

Miller, D. 1998. An analysis of freshwater mussels (Unionidae) along Luxapalila Creek, Mississippi. US COE Waterways Experiment Station, Vicksburg, MS. 14 pp.

Patzner, R.A., and D. Muller. 2001. Effects of eutrophication on Uniodids. Pp. 327-335. *In*: G. Bauer and K. Wachtler (Eds.), Ecology and evolution of the freshwater mussels Unionoida. Springer.

Pierson, J.M. 1991. Status survey of the southern clubshell, *Pleurobema decisum* (Lea, 1831). Mississippi Mus. Nat. Sci. Tech. Rpt. Jackson, Mississippi. 50 pp.

Pierson, J.M. 1993. A survey of mollusks in Cheaha and Salt Creeks, Talladega County, Alabama. Florence and Hutcheson, Inc. Athens, GA. 7 pp.

Shepard, T.E., P.E. O'Neil, S.W. McGregor, and S.C. Harris. 1994. Water-quality and biomonitoring studies in the upper Cahaba River drainage of Alabama. Geological Survey of Alabama. Bulletin 160. 118 pp.

Shepard, T.E., P.E. O'Neil, S.W. McGregor, and M.F. Mettee. 1998. Biomonitoring in the Locust Fork watershed, 1997-98. Geological Survey of Alabama, Tuscaloosa, AL. p. 60.

U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants: endangered status for eight freshwater mussels and threatened status for three freshwater mussels in the Mobile River Drainage. Federal Register 58:14330-14340.

Thompson, F.G. 1984. North American freshwater snail general of the hydrobiid subfamily Lithoglyphinae. Malacologia 25(1):109-141.

van der Schalie, H. 1938. The naiades (fresh-water mussels) of the Cahaba River in northern Alabama. Occ. Papers Mus. Zool., University of Michigan, Ann Arbor, Michigan. 29 pp.

Vidrine, M.F. 1996. River survey of freshwater mollusks of Tensas River system in northeastern Louisiana. Report to Natural Heritage Program, Louisiana Department of Wildlife and Fisheries, Baton Rouge, LA. 135 pp.

Williams, J. and M. Hughes. 1998. Freshwater mussels (Unionidae) of selected reaches of the main channel rivers in the Coosa Drainage of Georgia. Biological Resources Division, U.S. Geological Survey, Gainesville, Florida. Final report to the U.S. Fish and Wildlife Service. 13 pp.