

# Workbook and Key



to the



## Freshwater Bivalves of South Carolina



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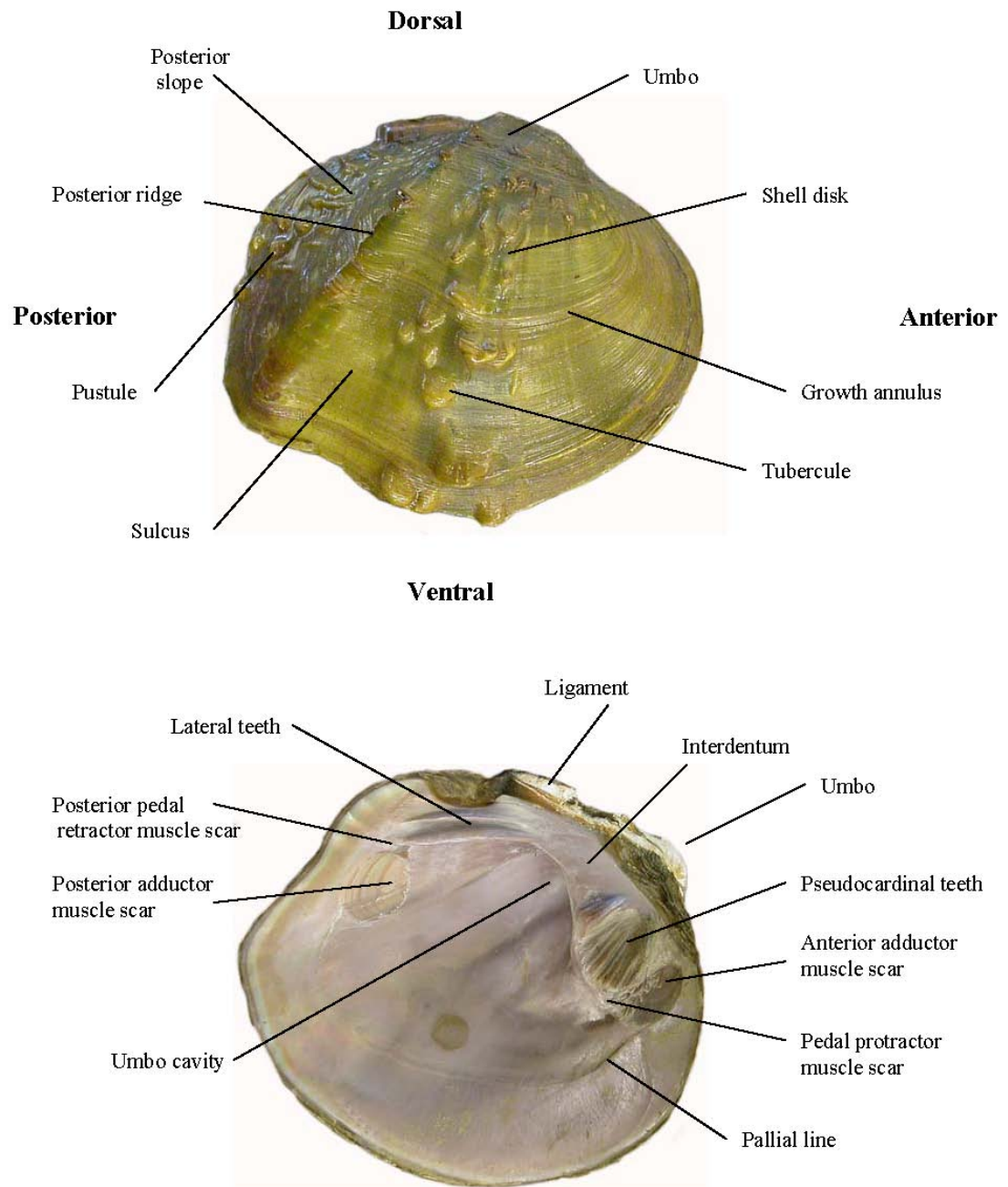


Figure 1. Morphology of a freshwater unionid shell, illustrating structures and terminology. Top figure: exterior of right valve; Bottom figure: interior of left valve.

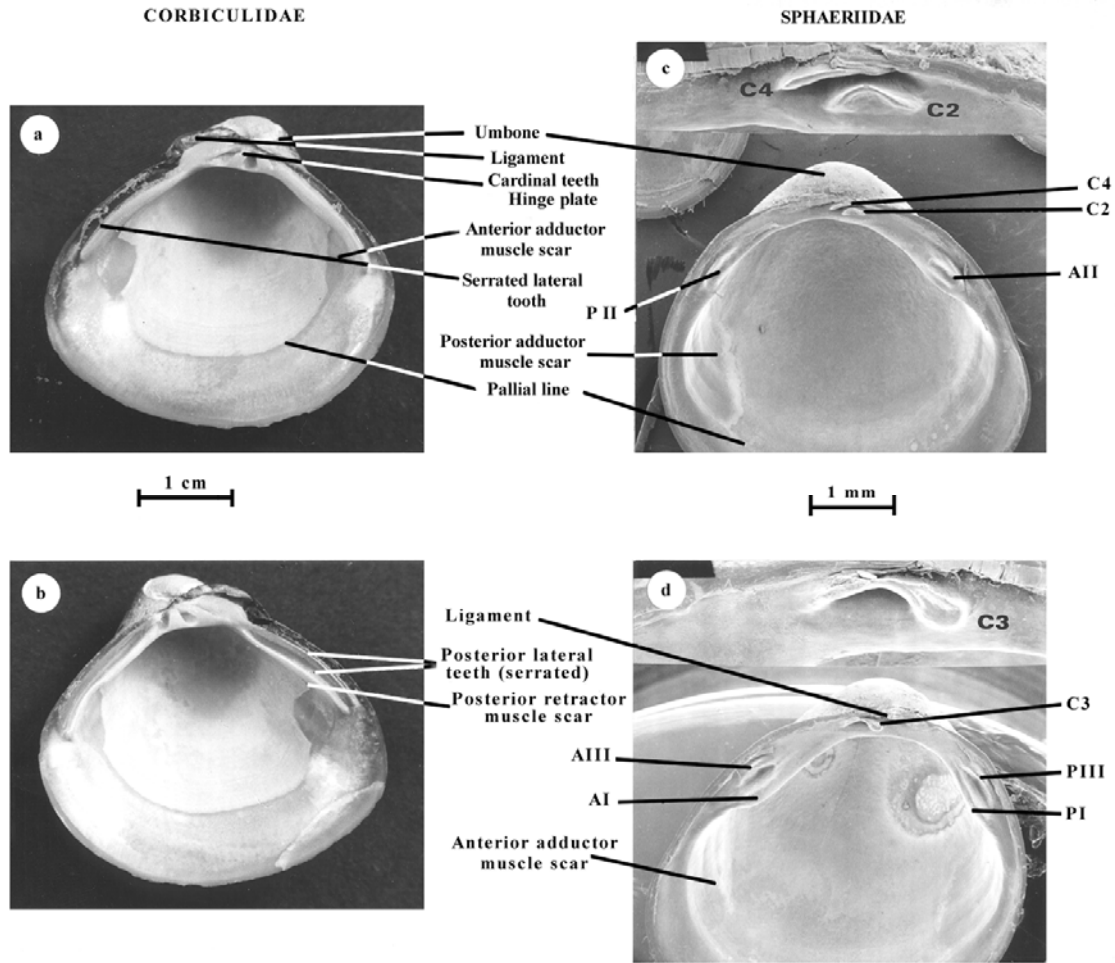


Figure 2. Internal shell features of left (a) and right (b) valves of *Corbicula fluminea* and of left (c) and right (d) valves of *Pisidium variabile*, representing the Sphaeriidae. C2, C3, C4 are the cardinal teeth; AI, AII, AIII are the anterior lateral teeth; PI, PII, PIII are the posterior lateral teeth. Reprinted from Mackie (2001) with the author's permission.

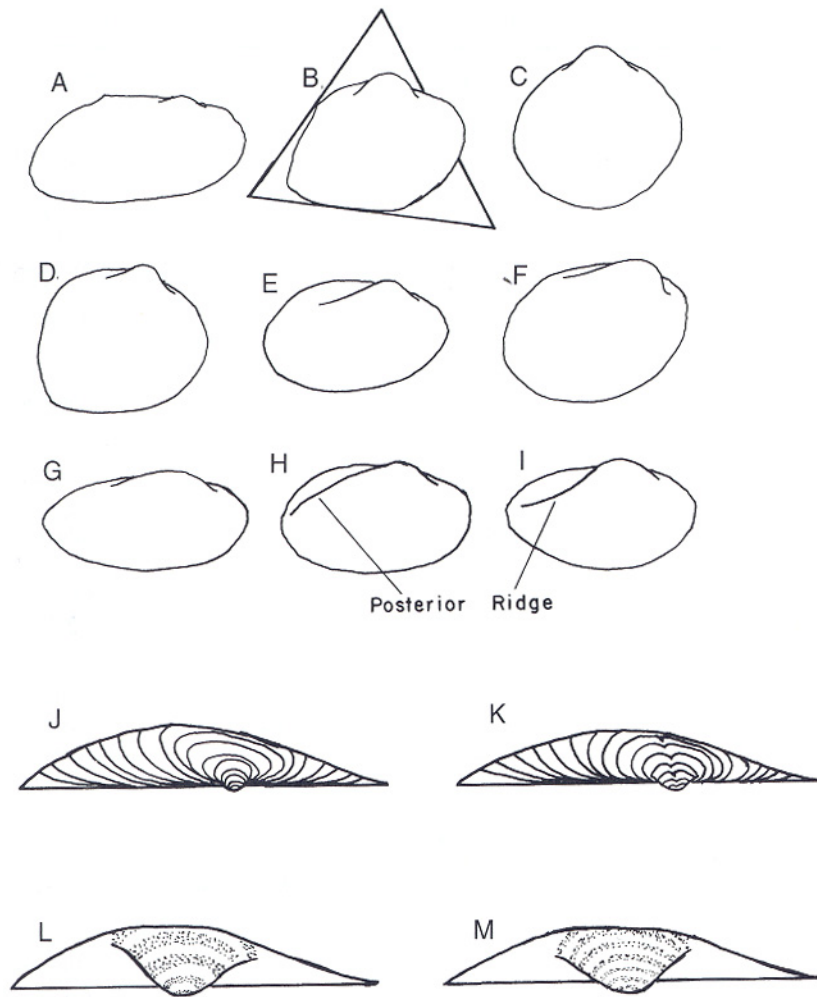


Figure 3. Illustrations of shell shape and beak sculpture. Shell shape descriptions: (A) rhomboidal; (B) triangular or trigonal; (C) round; (D) quadrate; (E and F) oval or ovoid; and (G) elliptical. Posterior shell-ridge morphology: (H) posterior ridge convex; and (I) posterior ridge concave. Concentric ridge structures of umbos: (J) single-looped concentric ridges; (K) double-looped concentric ridges; (L) coarse concentric ridges; and (M) fine concentric ridges. (Reproduced from McMahon and Bogan 2001).

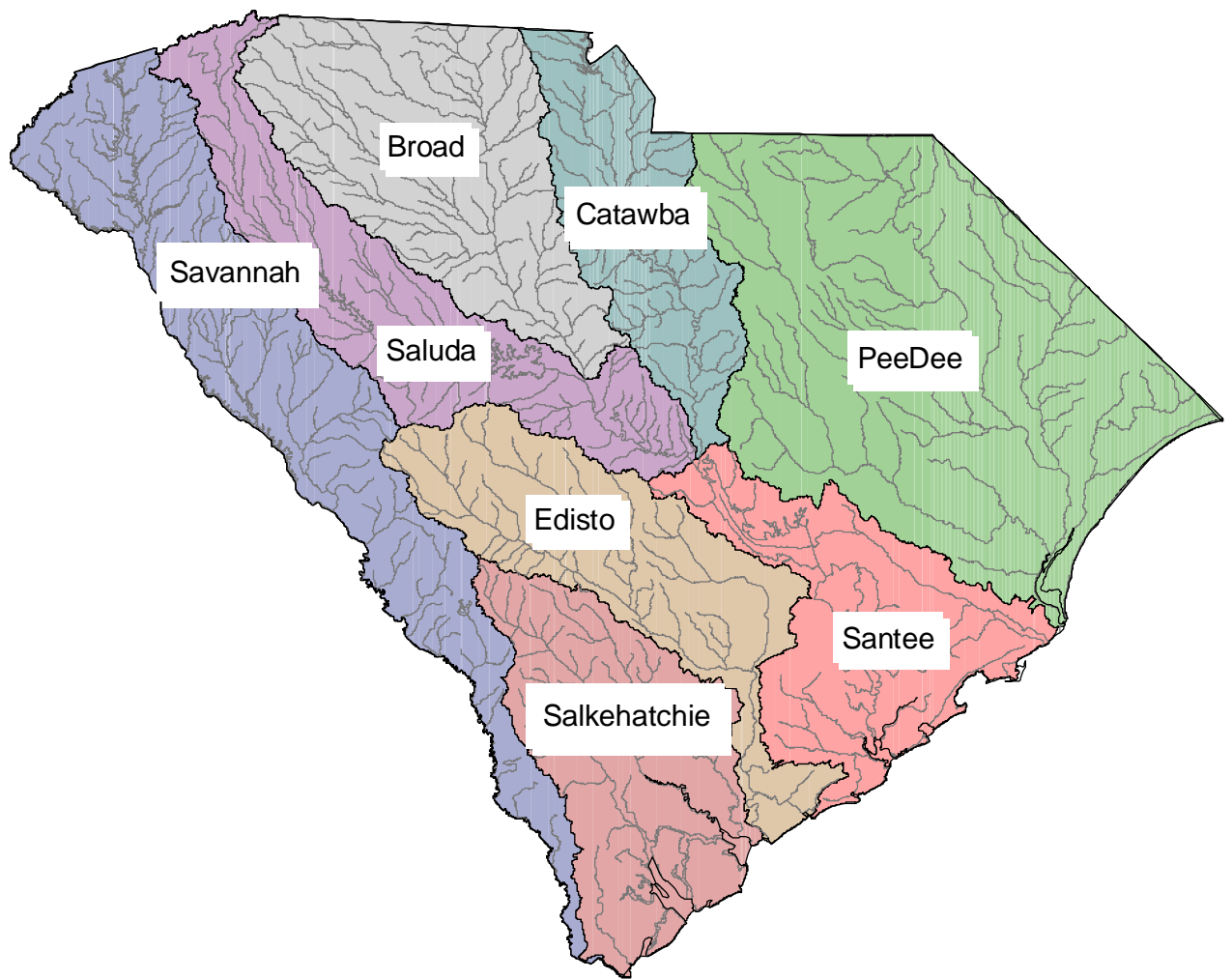


Figure 4. Map of the Major River Basins of South Carolina.

## Key to the freshwater bivalves of South Carolina

- 1
  - a. animal with byssal threads or evidence of thread attaching adult animals to solid substrate, isolated valves may lack any evidence of byssal threads, shaped like a marine mussel, *Mytilus*, generally less than 30 millimeters .....2
  - b. animal without byssal threads attaching adult animal to substrate, with or without teeth but not with above shape .....3
- 2 (1a)
  - a. shell without a sharp posterior ridge, shell elongate anterior-posterior, identified by apophysis under anterior adductor plate (pl. 5, fig. 32) .....*Mytilopsis leucophaeta*
  - b. shell with a very sharp posterior ridge, (pl. 5, fig. 31) [Not known from SC at this time] .....*Dreissena polymorpha*
- 3 (1b)
  - a. valves with cardinal teeth and two sets of lateral teeth (pl. 5, fig. 30) .....4
  - b. valves with one set of lateral teeth and pseudocardinal teeth **or** without teeth **or** with some or all teeth vestigial (Unionidae).....**Unionidae 5**
- 4 (3a)
  - a. valves with serrated lateral teeth (Fig. 2; pl. 5, fig. 30).....*Corbicula fluminea*
  - b. valves with smooth lateral teeth (Fig. 2) [See Burch 1975b]..... **Sphaeriidae**
- 5 (3b)
  - a. shell with hinge teeth absent or greatly reduced..... 6
  - b. shell with pseudocardinal teeth present, with or without lateral teeth ..... 10
- 6 (5a)
  - a. umbo not projecting or slightly projecting above the hinge-line..... 7
  - b. umbo clearly projecting above the hinge-line ..... 8
- 7 (6a)
  - a. umbo not projecting above the hinge line, ventral margin slightly concave to straight (pl. 5, fig. 25) .....*Utterbackia imbecillis*
  - b. umbo slightly projecting above the hinge line, ventral margin rounded (pl. 1, fig. 3).....*Anodonta couperiana*
- 8 (6b)
  - a. beak sculpture double looped, shell uniformly thin (pl. 4, fig. 21) .....*Pyganodon cataracta*
  - b. beak sculpture consists of concentric bars..... 9



- 9 (8b)** a. nacre usually iridescent with some orange in the beak cavity, pseudocardinal tooth area represented by a thickening near the umbo in right valve and pseudocardinal tooth vestigial in left valve, lateral teeth only swellings, ventral shell margin uniform thickness, dorsal margin steps down before umbo on anterior end of shell, periostracum often “chocolate brown” in adults (pl. 4, fig. 22) ..... *Strophitus undulatus*
- b. nacre bluish or white, hinge plate uniformly thin, teeth or swellings absent, ventral margin with a prominent thickened area along the anterior ventral margin below the pallial line (pl. 1, fig. 4)..... *Anodonta implicata*
- 10 (5b)** a. shell not truncated posteriorly, shell with lateral teeth absent or reduced, neither functional nor interlocking ..... **11**
- b. shell truncated, with well-developed lateral teeth ..... **12**
- 11 (10a)** a. shell elongate to elongate oval, inflated, uniformly thin shell, periostracum greenish to brownish with prominent to obscured rays in adults, wrinkles usually present on posterior slope (pl. 1, fig. 2) ..... *Alasmidonta varicosa*
- b. shell outline triangular, inflated but thin to thick shell, anterior half of shell usually thickened, beak sculpture consists of large bars extending down onto the disk of the shell in juveniles, green rays usually present in juveniles, absent in adults, adult periostracum usually dark gray (pl. 1, fig. 1) ..... *Alasmidonta undulata*
- 12 (10b)** a. hinge plate in left valve usually with an additional small to large interdental or accessory tooth, giving the appearance of three lamellate pseudocardinal teeth, shell more or less compressed, shell shape rhomboid, juvenile periostracum dark green with numerous green rays, beak sculpture consists of prominent bars, shell thick and maximum size 114 mm, maximum height 68 mm, restricted to the Savannah, Wateree-Santee and Pee Dee River drainages (pl. 3, fig. 18)..... *Lasmigona decorata*
- b. left valve without extra interdental tooth..... **13**
- 13 (12b)** a. shell shape rectangular to broadly triangular shell, beak cavity shallow, interdentum broad and flat in left valve, relatively short, thick ligament, periostracum tends to be parchment like, anterior half of shell usually thickened with nacre salmon colored, species is from an area extending from the James River basin south to the headwaters of the Ogeechee River basin (pl. 3, fig. 14)..... *Fusconaia masoni*
- b. shell shape elongate, rhomboid, oval, or round ..... **14**
- 14 (13b)** a. shell shape elongate, rhomboid or grading toward rectangular ..... **15**

- b. shell shape oval or round..... **19**
- 15 (14a)** a. shell usually more than twice as long as high..... **16**
- b. shell usually less than twice as long as high..... **18**
- 16 (15a)** a. periostracum usually with many narrow rays, posterior end tapered to a point in middle of posterior margin, periostracum not mat, sexual dimorphism present, posterior-ventral margin inflated in females (pl. 4, fig. 20)..*Ligumia nasuta*
- b. no sexual dimorphism seen in shell ..... **17**
- 17 (16b)** a. usually only slightly more than twice as long as high, usually reddish brown periostracum, often extremely large and thick shelled – greater than 140 mm in length, usually restricted to areas below last dam on major rivers (pl.2, fig. 12)..... *Elliptio roanokensis*
- b. from two to more than three times as long as high, shell usually not heavy and thick, may exceed 130 mm in length..... the *Elliptio lanceolata* complex [including *angustata*, *folliculata*, *producta*] (pl. 1, fig 5; pl. 2, figs 8, 11)
- 18 (15b)** a. periostracum unrayed, dorsal margin with slight step down before umbo on anterior end of shell, umbos relatively close to anterior end compared with typical “elliptios,” teeth relatively small compared with “elliptios” from same habitat, periostracum mat or fuzzy, rectangular in shell shape (pl. 4, fig. 24) .....*Unio merus carolinianus*
- b. great variation in shell characteristics, often confused with many other taxa .....the *Elliptio complanata* complex [including *complanata*, *congregata*, *fraterna*, *roanokensis*, *waccamawensis*]; those shells with short shell length, not too tall and inflated **AND** the *Elliptio icterina* complex] [See Table 5 for species groups and figures for each species of *Elliptio*]. [NOTE: The *Elliptio* taxa recognized by Davis and Mulvey (1993) and Turgeon et al. (1998) are not addressed here pending a revision of the genus. We do not address the possibility that some taxa presumed to be endemic to the Altamaha River basin, Georgia, may extend into the Savannah River basin.]
- 19 (14b)** a. adult shell typically <40 mm in length, with a fuzzy or mat textured dark brown to black periostracum (pl. 4, fig. 23).....*Toxolasma pullus*
- b. adult shell >40 mm in length, lacking the pronounced fuzzy periostracum..... **20**
- 20 (19b)** a. shell shape oval to elongate oval, interdentum relatively wide and clearly evident, periostracum very shiny to mat with rays..... **21**
- b. shell shape oval, periostracum dull yellow, usually with fine rays all over the shell, interdentum very narrow, found in or near tidewater, nacre often a salmon color (pl. 4, fig. 19) .....*Leptodea ochracea*

- 21** (20a) a. periostracum shiny, waxy yellow, green rays, when present, usually restricted to the posterior slope, usually with waxy yellow periostracum (pl. 3, fig. 15) ..... *Lampsilis cariosa*  
.....
- b. periostracum mat to smooth ..... **22**
- 22** (21b) a. relatively large mussels, often more than 80 mm in length ..... **23**
- b. relatively small mussels, usually less than 50 mm in length ..... **24**
- 23** (22a) a. posterior ridge inflated and prominent, umbos inflated, (pl.3, fig. 17)  
..... *Lampsilis splendida*
- b. posterior ridge well rounded, umbos not inflated, maximum size >130 mm, shell broad and inflated, widespread, (pl. 3, fig. 16)..... *Lampsilis radiata*
- 24** (22b) a. periostracum greenish to yellow, often with numerous green rays, shell relatively thin, oval to elongate oval, blade-like pseudocardinal teeth ..... **25**
- b. periostracum dark to black in adults, shell relatively thick, no green rays seen except in juveniles which may have yellowish to greenish periostracum, chunky pseudocardinal teeth, shell shape oval to round (pl. 5, fig. 26)  
..... *Villosa constricta*
- 25** (22a) a. shell outline elliptical, numerous broad green rays, bluish-white to pink or purple nacre (pl. 5, fig. 28) ..... *Villosa modioliformis*
- b. shell outline elongate oval, nacre bluish white or iridescent..... **26**
- 26** (25b) a. entire surface covered with narrow to wide green rays usually interrupted by growth lines (pl. 5, fig. 27) ..... *Villosa delumbis*
- b. usually with numerous continuous dark narrow green rays over most of the shell (pl. 5, fig. 29) ..... *Villosa vaughaniana*

**Table 1.** List of Native Freshwater Unionid Bivalves of South Carolina

*Alasmidonta undulata* (Say, 1817); Triangle Floater  
*Alasmidonta varicosa* (Lamarck, 1819); Brook floater  
*Anodonta couperiana* (Lea, 1840); Barrel Floater  
*Anodonta implicata* (Say, 1829); Alewife Floater  
*Elliptio angustata* (Lea, 1831); Carolina Lance  
*Elliptio complanata* (Lightfoot, 1786); Eastern Elliptio  
*Elliptio congrarea* (Lea, 1831); Carolina Elephantear  
*Elliptio folliculata* (Lea, 1838); Pod Lance  
*Elliptio fraterna* (Lea, 1852); Brother Spike  
*Elliptio icterina* (Conrad, 1834); Variable Spike  
*Elliptio producta* (Conrad, 1836); Atlantic Spike  
*Elliptio roanokensis* (Lea, 1838); Roanoke Slabshell  
*Elliptio waccamawensis* (Lea, 1863); Waccamaw Spike  
*Fusconaia masoni* (Conrad, 1834); Atlantic Pigtoe  
*Lampsilis cariosa* (Say, 1817); Yellow Lampmussel  
*Lampsilis radiata* (Gmelin, 1791); Eastern Lampmussel  
*Lampsilis splendida* (Lea, 1838); Rayed Pink Fatmucket  
*Lasmigona decorata* (Lea, 1852); Carolina Heelsplitter  
*Leptodea ochracea* (Say, 1817); Tidewater Mucket  
*Ligumia nasuta* (Say, 1817); Eastern Pondmussel  
*Pyganodon cataracta* (Say, 1817); Eastern Floater  
*Strophitus undulatus* (Say, 1817); Creeper  
*Toxolasma pullus* (Conrad, 1838); Savannah Lilliput  
*Unio merus carolinianus* (Bosc, 1801); Eastern Pondhorn  
*Utterbackia imbecillis* (Say, 1829); Paper Pondshell  
*Villosa constricta* (Conrad, 1838); Notched Rainbow  
*Villosa delumbis* (Conrad, 1834); Eastern Creekshell  
*Villosa modioliformis* (Lea, 1834); Eastern Rainbow  
*Villosa vughaniana* (Lea, 1838); Carolina Creekshell

**Table 2.** Major River Basins of South Carolina:

**Savannah River Basin:** this includes all streams tributary to the main channel of the Savannah River in South Carolina including the Colleton and New Rivers.

**Salkehatchee-Combahee River Basin:** this includes all streams tributary to both the Salkehatchee and Combahee rivers in South Carolina.

**Edisto River Basin:** this includes the North and South Forks of the Edisto River and the Four Hole Swamp.

**Cooper-Santee River Basin:** this includes all streams of the Cooper, Wando, and Santee River drainages. The headwaters of the Cooper-Santee Basin include the drainages of the Saluda, Broad, Congaree, Catawba, and Wateree rivers in South Carolina.

**Pee Dee River Basin:** This includes all streams of the Sampit, Black, Waccamaw, Lumber and Little Pee Dee rivers as well as the headwaters of the Pee Dee River, including the Lynches River drainage.

**Table 3.** Distribution of Unionidae in South Carolina's Atlantic Slope River basins (within river basin: X = Extant; H = Historic; N = just into N. Carolina; G = just into Georgia)

Species	Savannah	Salkehatchee - Combahee	Edisto	Cooper-Santee	Pee Dee	Pee Dee (Waccamaw)
<i>Alasmidonta undulata</i>	X			H	N	
<i>Alasmidonta varicosa</i>	X			H, N	X	
<i>Anodonta couperiana</i>	X	X	X	H?	X	
<i>Anodonta implicata</i>					N	
<i>Elliptio angustata</i>	X	X	X	X	X	X
<i>Elliptio complanata</i>	X	X	X	X	X	X
<i>Elliptio congaraea</i>	X		X	X	X	
<i>Elliptio folliculata</i>	X	X	X	X	X	X
<i>Elliptio fraterna</i>	X					
<i>Elliptio icterina</i>	X	X	X	X	X	X
<i>Elliptio producta</i>	X	X	X	X	X	X
<i>Elliptio roanokensis</i>	X			X	X	
<i>Elliptio waccamawensis</i>						X
<i>Fusconaia masoni</i>	H				N	
<i>Lampsilis cariosa</i>	X			X	X	H?
<i>Lampsilis radiata</i>				X	N	X
<i>Lampsilis splendida</i>	X			X		X
<i>Lasmigona decorata</i>	X			X	X	
<i>Leptodea ochracea</i>	X			X	N	X
<i>Ligumia nasuta</i>	H, G			X	N	
<i>Pyganodon cataracta</i>	X			X	X	X
<i>Strophitus undulatus</i>	X			X	X	
<i>Toxolasma pullus</i>	X			X	N	X
<i>Unio merus carolinianus</i>	X	X	X	X	X	X
<i>Utterbackia imbecillis</i>	X	X	H?	X	N	X
<i>Villosa constricta</i>				N	X	
<i>Villosa delumbis</i>	X	X	X	X	X	X
<i>Villosa modioliformis</i>	X	X	H	H	H	H
<i>Villosa vaughaniana</i>				X	N	
Total Taxa	24	10	11	24	26	16

Prepared by J. Alderman, E. Keferl, J.D. Williams, and A.E. Bogan; revised Jan. 2008

**Table 4.** Proposed Status List of South Carolina freshwater bivalves.\*

**FEDERAL AND STATE  
ENDANGERED**

*Lasmigona decorata*

**STATE ENDANGERED**

*Alasmodonta undulata*

*Alasmodonta varicosa*

*Anodonta couperiana*

*Elliptio fraterna*

*Elliptio waccamawensis*

*Fusconaia masoni*

*Lampsilis cariosa*

*Ligumia nasuta*

*Strophitus undulatus*

*Toxolasma pullus*

*Villosa constricta*

*Villosa modioliformis*

*Villosa vauhaniana*

**STATE THREATENED**

*Anodonta implicata*

*Elliptio roanokensis*

*Lampsilis radiata*

*Leptodea ochracea*

**STATE SPECIAL CONCERN**

*Elliptio angustata*

*Elliptio producta*

*Elliptio folliculata*

*Lampsilis splendida*

*Villosa delumbis*

\* Proposed status based on fieldwork and consideration of species status in North Carolina and Georgia.

**Table 5.** A Working List of the *Elliptio* of South Carolina.  
A preliminary idea of the relationships of South Carolina *Elliptio*

**ELLIPTIO COMPLANATA GROUP**

*Elliptio complanata* (Lightfoot, 1786) Eastern *Elliptio* [pl. 1, fig. 6]  
*Elliptio congaraea* (Lea, 1831) Carolina Elephantear [pl. 2, fig. 7]  
*Elliptio errans* (Lea, 1856) Oval *Elliptio*\*  
*Elliptio fraterna* (Lea, 1852) Brother Spike [pl. 2, fig. 9]  
*Elliptio roanokensis* (Lea, 1838) Roanoke Slabshell [pl. 2, fig. 12]  
*Elliptio waccamawensis* (Lea, 1863) Waccamaw Spike [pl. 3, fig. 13]

**ELLIPTIO ICTERINA GROUP**

*Elliptio icterina* (Conrad, 1834) Variable Spike [pl. 2, fig. 10]  
*Elliptio hepatica* (Lea, 1859) Brown *Elliptio*\*  
*Elliptio raveneli* (Conrad, 1834) Carolina Spike\*

**ELLIPTIO LANCEOLATA GROUP**

*Elliptio angustata* (Lea, 1831) Carolina Lance [pl. 1, fig. 5]  
*Elliptio folliculata* (Lea, 1838) Pod Lance [pl. 2, fig. 8]  
*Elliptio producta* (Conrad, 1836); Atlantic Spike [pl. 2, fig. 11]

\*These taxa are not treated here, but you will encounter them in the literature on *Elliptio* from South Carolina.



**CORBICULIDAE*****Corbicula fluminea* (Müller, 1776) INTRODUCED****Asian Clam**

Plate 5, Figure 30

**General Distribution:** The Asian Clam appears to have been introduced into North America sometime during or before the 1920s (Counts, 1986). It was first collected in the United States along the banks of the Columbia River in Pacific County, Washington, in 1938 (Burch, 1944), and since then it has invaded nearly every major river system in the country.

**South Carolina Distribution:** This introduced species is widespread in all rivers, most reservoirs, and many lakes.

**Description:** The shell is fairly small, seldom exceeding 50 mm in length, very solid, ovate when young, and triangular in outline when mature. Beaks are high, full, directed inward, elevated well above the hinge line, and centrally located. Thin, prominent concentric rings indicate growth periods. There are three cardinal teeth directly below the beaks in each valve, with two straight to slightly curved lateral teeth on each side in the right valve and one on each side in the left valve. The lateral teeth are serrated, a character distinguishing *Corbicula* from the Sphaeriidae. The beak cavity is deep. The periostracum is a light yellowish olive to cream-colored in immature clams, changing with age to tan, olive, and finally, dark brown to black in old individuals. Very young individuals possess a characteristic dark stripe or band on the anterior slope of the valves. The nacre is white to a shiny light purple, darkest along the lateral teeth and in the beak cavity. The entire inner surface of adults is a very light purple and white, appearing highly polished outside the pallial line.

**Life History and Ecology:** Unlike our native freshwater mussels, the juvenile or larva (called a veliger) of the Asian Clam is free swimming and does not require a host for partial development. Oesch (1984) noted that in Missouri the spawning time of *Corbicula* generally is between May and September. The period of growth of the free-swimming veliger lasts about 7–10 days (McMahon and Bogan, 2001).

The Asian Clam reaches its greatest population densities in a substrate of almost pure sand or one of mixed sand, silt, and mud. Although it thrives in rivers with slow to moderate current, typically at depths of less than three feet, *C. fluminea* may become abundant and grow to a large size in the quiet waters of small ponds. This small clam is highly resistant to desiccation and can survive for weeks in damp sand or mud.

**Status:** INTRODUCED

**UNIONIDAE*****Alasmidonta undulata* (Say, 1817)****Triangle Floater**

Plate 1, Figure 1

**Synonymy:***Monodonta undulata* Say, 1817; Say, 1817: no pagination, pl. 3, fig. 3**Type Locality:** Delaware and Schuylkill rivers [near Philadelphia, Philadelphia County, Pennsylvania].**General Distribution:** extending from the Bosquet River of the lower St. Lawrence River Basin south to the Ogeechee River Basin (Clarke, 1981).**South Carolina Distribution:** This species is found in the Savannah River Basin in South Carolina and the Pee Dee River Basin in North Carolina (Alderman 2002, Johnson, 1970; Clarke, 1981b; Table 3).**Description:** Shell shape is subtriangular to ovate, solid, thicker anteriorly than in the posterior, shell is subinflated to inflated with maximum inflation at the middle of the shell, maximum shell length about 75 mm. Anterior shell margin rounded, ventral margin broadly rounded, posterior margin roundly pointed below the midline. Sexual dimorphism is not apparent. Posterior ridge present and usually quite distinct in populations south of Virginia, the posterior slope somewhat compressed. Beaks are more or less full inflated and somewhat elevated above the hinge line, beak sculpture is extremely heavy, strong ridges that run parallel with the growth lines and composed of five prominent, single-looped, curved ridges that extend out onto the shell surface in young individuals (Clarke, 1981b). These ridges are usually not evident in large adults. Posterior slope sometimes marked by

oblique ridges or corrugations.

Periostracum is smooth and shiny.

Left valve with a single short, stumpy, sculptured pseudocardinal teeth. There is usually a well-developed interdental projection present. Right valve has two short stumpy often-sculptured pseudocardinal teeth. The interdental area is broad and flat, with the lateral teeth either short and vestigial or absent. The beak cavity is triangular, compressed and rather deep.

Periostracum is yellowish, greenish, with broad, green or blackish rays of variable width in juvenile specimens, becoming black with age. Growth lines are rather indistinct. Nacre color is typically white anteriorly, but including salmon, pink or red, becoming iridescent posteriorly.

**Life History and Ecology:** Ortmann (1919) lists the Triangle Floater as being gravid from July to September and April to June, while Clarke (1981b) lists gravid females from 28 August to 24 October. Ortmann (1919) reported this species as common in smaller rivers and streams, going well into the headwaters, found mainly in quiet waters with some current, avoiding the riffles, living in coarser gravel and sand. It does not appear to like slack water but can be found in ponds and canals. Lellis (Pers. Comm. 1996) and Art Bogan have observed this species deeply buried during the summer but sitting up on top of the substrate in January and February when water temperatures are at the coldest in northern latitudes. Hostfishes confirmed in the laboratory include the Blacknose Dace (*Rhinichthys atratulus*), Common Shiner (*Luxilus cornutus*), Fallfish (*Semotilus corporalis*), Largemouth Bass (*Micropterus salmoides*), Longnose Dace (*Rhinichthys cataractae*), Pumpkinseed (*Lepomis gibbosus*), Slimy Sculpin (*Cottus*

*cognatus*), and White Sucker (*Catostomus commersoni*), (Watters et al., 1999; from Nedeau et al., 2000:67).  
**Status:** Special Concern (Williams et al., 1993:10). This species is proposed as State Endangered in South Carolina (Table 4).

***Alasmidonta varicosa*  
(Lamarck, 1819)**

**Brook Floater**

Plate 1, Figure 2

**Synonymy:**

*Unio varicosa* Lamarck, 1819; Lamarck, 1819:78

**Type Locality:** La rivière Schuylkill [Schuylkill] près de Philadelphie [Philadelphia Co. Pennsylvania] ... aussi dans le lac Champlain.

**General Distribution:** Lower St. Lawrence River Basin south in streams and rivers draining into the Atlantic to the Savannah River Basin in South Carolina (Clarke, 1981).

**South Carolina Distribution:** The Brook Floater is found in the Savannah and historically in the Cooper-Santee and Pee Dee River basins (Clarke, 1981b; Table 3).

**Description:** Shell shape is oblong, long rhomboid, thin-shelled, slightly inflated with the maximum inflation at the posterior ridge, maximum length is about 70 mm. Anterior shell margin is abruptly curved, the ventral margin is long, and centrally gently concave, the posterior margin roundly biangulate below and obliquely flattened or flatly curved above. Female shells may be slightly more swollen in the area of the posterior ridge, but in many cases the sex cannot be determined based on shell characters. Posterior ridge is broad, rounded, and inflated. Posterior slope is flattened, slightly concave, and covered with numerous, low corrugations or ridges. Beaks are narrow and bluntly pointed, located about 1/3 the distance from the anterior end and project only slightly above the hinge line. Beak sculpture is coarse, variable and composed of a few single-looped or occasionally double-looped ridges, mostly seen in juvenile specimens.

Growth ridges are marked by concentric ridges, the periostracum is generally smooth except on the posterior slope. Left valve with a single small rounded variously developed or reduced pseudocardinal tooth, some specimens also have an interdental projection or denticle, lateral teeth are vestigial or entirely absent. Right valve has a single small rounded or rudimentary pseudocardinal tooth. Beak cavity is open and shallow. Periostracum is yellowish but more often greenish and partly or completely covered with dark greenish rays in juveniles, becoming brownish with rays partially obscured to almost black in adult specimens. The periostracal color on the posterior slope is the same as the rest of the shell, not yellowish as in *Alasmidonta marginata*. Nacre color is whitish or bluish-white, often with salmon, pink, or purple shades in the beak cavity (Ortmann, 1919; Clarke, 1981b).

**Life History and Ecology:** Ortmann (1919:191-192) reported gravid females from 9 August to 8 September and 3 May with glochidial discharge in May. Ortmann (1919) reported this species evenly distributed across eastern Pennsylvania except in the larger rivers and more common in smaller rivers and streams. Ortmann (1919:104) described the ecology of the Brook Floater as "It prefers strong currents and gravelly bottoms, thus being most frequently found in and near riffles." Lellis (Pers. Comm. 1996) has observed this species in northern latitudes deeply buried during the summer but sitting up on top of the substrate in January and February when water temperatures are at their coldest. J. M. Alderman has observed this species actively siphoning during the warmer months of the year in South Carolina. The Blacknose Dace

(*Rhinichthys atratulus*), Golden Shiner (*Notemigonus chrysoleucas*), Longnose Dace (*Rhinichthys cataractae*), Margined Madtom (*Schilbeodes marginatus marginatus*) Pumpkinseed (*Lepomis gibbosus*), Slimy Sculpin (*Cottus cognatus*), and the Yellow Perch (*Perca flavescens*) have been identified in the laboratory as potential hostfish for the glochidia of this species (Wicklow and Richardson, 1995; Nedeau et al., 2000). Fishes recently shown to serve as glochidial hosts for *A. varicosa* in laboratory trials include Bluegill (*Lepomis macrochirus*), Redbreast sunfish (*Lepomis auritus*), Fantail darter (*Etheostoma flabellare*), Johnny darter (*Etheostoma nigrum*), Piedmont darter (*Percina crassa*), Roanoke darter (*Percina roanoka*) and White Shiner (*Luxilus albeolus*) (Eads et al., 2007). **Status:** Threatened (Williams et al., 1993:10). This species is proposed as State Endangered in South Carolina (Table 4).

***Anodonta couperiana* Lea, 1840****Barrel Floater**

Plate 1, Figure 3

**Synonymy:**

*Anodonta couperiana* Lea, 1840; Lea, 1840:227, pl. 20, fig. 146

**Type Locality:** McIntosh County, Georgia.

**General Distribution:** The barrel floater is found from Florida's Apalachicola region to the Cape Fear River Basin in North Carolina.

**South Carolina Distribution:** This species is known from the Savannah, Salkehatchee-Combahee, Edisto, Cooper-Santee and Pee Dee River basins (Table 3).

**Description:** The Barrel Floater may reach over 100 mm in length. Like other *Anodonta*, this species also lacks pseudocardinal and lateral teeth. The barrel floater's dorsal margin of the shell is similar to that of *Utterbackia imbecillis*. In *U. imbecillis* the umbos do not extend above the hinge margin; however, in *A. couperiana* the umbos just barely extend above the hinge margin. Additionally, the barrel floater's length to height ratio is around 1.5 compared with 2 for *Utterbackia imbecillis*. The ventral margin of the barrel floater is broadly rounded and there are fine green rays on the periostracum (Adams et al., 1990).

**Life History:** According to Johnson (1970), the Barrel Floater is found in ponds and slow-flowing streams with mud or sand bottoms. The hostfish for this species is unknown.

**Status:** Williams et al. (1993:10) listed as Special Concern. This species is proposed as State Endangered in South Carolina (Table 4).

***Anodonta implicata* Say, 1829****Alewife Floater**

Plate 1, Figure 4

**Synonymy:***Anodonta implicata* Say, 1829; Say, 1829:340

**Type Locality:** Pond in Danvers [Essex Co.] Massachusetts. Changed by Johnson (1946:112, pl. 16, figs. 1, 2) when he selected a neotype to Agawam River (outlet of Halfway Pond), Plymouth [Plymouth Co.] Massachusetts.

**General Distribution:** North Atlantic Slope rivers from New Brunswick, Nova Scotia, and Quebec, Canada south to the Potomac River, Maryland, with a disjunct population in the Chowan River and Pee Dee River, North Carolina (Adams et al., 1990, NCWRC data files 2003).

**South Carolina Distribution:** This species is found in Pee Dee River Basin in North Carolina and would be expected in South Carolina (Shelley, 1983; Adams et al., 1990, NCWRC data files 2003; Table 2).

**Description:** Shell shape is elliptical, oblong to ovate in outline, approaching subcylindrical in cross-section, shell thickness rather solid, with a pronounced thickening of the anterior ventral margin from about the middle of the shell anterior, inflated, shell length reaching about 142 mm. Anterior margin of the shell is narrowly rounded, the ventral margin straight, with a straight dorsal margin, the posterior margin bluntly pointed slightly below the midline. The posterior ridge is rounded and generally double, ending posteriorly in a biangulation slightly below the midline. Beaks are moderately full and slightly raised above the hingeline, beak sculpture consists of 5-7 straight bars running parallel with the hingeline or slightly curved. The shell surface is

marked by irregular growth lines, which may form ridges, surface varies from smooth almost shiny to rough.

This is a typical *Anodonta* completely lacking any indication of pseudocardinal or lateral teeth. The beak cavity is open and relatively shallow. Periostracum is yellowish brown, greenish brown, to reddish brown becoming dark brown to black with age, immature specimens have fine green rays. Nacre color varies from white, salmon or purple and almost always darker in the beak cavity.

**Life History and Ecology:** The Alewife Floater is found living in ponds, overbank pools, streams and rivers in a variety of substrates including silt, sand and gravel. The distribution is closely tied to the distribution of its hostfish.

Nedea et al. (2000) report this species is bradytictic, a long-term brooder, with eggs being fertilized in August and glochidia being released the next spring. The Alewife (*Alosa pseudoharengus*) has been reported as a hostfish for this mussel (Davenport and Warmuth, 1965).

**Status:** Currently Stable (Williams et al., 1993:10). This species is proposed as State Threatened in South Carolina (Table 4).

***Elliptio angustata* (Lea, 1831)****Carolina Lance**

Plate 1, Figure 5

**Synonymy:**

*Unio angustatus* Lea, 1831; Lea, 1831:114, pl. 17, fig. 43

**Type Locality:** Cooper River, South Carolina

**General Distribution:** The Carolina Lance ranges from the Ogeechee River north to the Potomac River Basin in Virginia and Maryland (Johnson, 1970).

**South Carolina Distribution:** This species ranges from the Savannah River Basin north to the Pee Dee River Basin (Table 3).

**Description:** Shell elongate, elliptical to subrhomboid and slightly compressed and rather thin, shell length to 140 mm. Anterior end evenly rounded, posterior margin pointed with the most posterior point below the midline of the shell, ventral margin mostly straight, dorsal margin mostly straight. Beaks only slightly elevated with beak sculpture consisting of strong ridges. Posterior ridge is well developed, often double ending slightly below the middle of the posterior end of the shell. Periostracum olive becoming nearly black in older specimens.

Left valve with two compressed pseudocardinal teeth and two long lateral teeth. Right valve with two compressed pseudocardinal teeth with the dorsal one smaller, with two long lateral teeth.

Nacre is a shade of purple.

**Life History and Ecology:** This species is found in sand and sandy gravel often along the edges of aquatic vegetation.

Hostfish are unknown.

**Status:** Special Concern (Williams et al. 1993: 11). This species is proposed as State Special Concern (Table 4).



***Elliptio complanata***  
**(Lightfoot, 1786)**

**Eastern Elliptio**

Plate 1, Figure 6

**Synonymy:**

*Mya complanata* Lightfoot, 1786; Lightfoot, 1786: 100, No. 2190

Comment: Johnson (1970) lists an extensive synonymy for this species. The taxonomy of this species in the southern end of its range becomes very confusing and many of the shell shapes have names but will not be dealt with here.

**Type Locality:** Maryland. Johnson (1948) restricted the type locality to: Potomac River, Washington, District of Columbia [approximately opposite Fairfax Co. Virginia].

**General Distribution:** Altamaha River Basin of Georgia, north to the St. Lawrence River Basin, west in the Interior Basin west to Lake Superior and parts of the Hudson Bay Basin (Johnson, 1970).

**South Carolina Distribution:** This species is wide spread in the Atlantic Slope rivers in South Carolina from the Savannah River Basin north to the Pee Dee River Basin (Johnson, 1970; Table 3).

**Description:** Shell shape is trapezoidal to rhomboid or subelliptical, compressed to inflated, shell thickness varies from thin to solid, length 120 mm. Anterior margin is rounded, dorsal and ventral margins are roughly parallel, ventral margin is usually straight, posterior margin broadly rounded ending at or near the base in a point or biangulation. Posterior ridge is broad, double, and rounded to angular. The posterior slope is flat. Beaks are low and uninflated, beak sculpture consists of 5-6 ridges, the first two or three curved and subconcentric, the rest run parallel to the growth lines, nearly straight in the middle and curved up at both ends.

Surface with irregular growth lines and varies from smooth to mat.

Left valve has two ragged pseudocardinal teeth and two nearly straight lateral teeth. Right valve has a single pseudocardinal tooth and a single lateral tooth. Interdentum of variable width. Beak cavity is shallow.

Periostracum is yellowish to brown and blackish, young specimens with indistinct greenish rays present. The rays generally disappear in older shells. Nacre varies from white, pink, salmon, to various shades of purple.

**Life History and Ecology:** Ortmann (1919:109) commented that the Eastern Elliptio "apparently has no ecological preferences, being found practically in any permanent body of water; in canals and reservoirs with quiet water and muddy bottom, as well as in large rivers with strong current and heavy gravel and rocks. In the small creeks it goes up very far into the headwaters." *Elliptio complanata* is tachytictic, gravid females have been found from late April through the middle of July. The females expelled their glochidia in conglutinates (Ortmann, 1919). The Banded Killifish (*Fundulus diaphanus*), Green Sunfish (*Lepomis cyanellus*), Largemouth Bass (*Micropterus salmoides*), White Crappie (*Pomoxis annularis*), and Yellow Perch (*Perca flavescens*) have been listed as hostfish for the glochidia for this mussel (Watters, 1994:103).

**Status:** Currently Stable (Williams et al., 1993:11).

***Elliptio congaraea* (Lea, 1831)****Carolina Elephantear**

Plate 2, Figure 7

**Synonymy:***Unio congaraeus* Lea, 1831; Lea, 1831:72, pl. 6, fig. 4**Type Locality:** Congaree River, South Carolina.**General Distribution:** This species is known from the Ogeechee River Basin in Georgia north to the Chowan River Basin in Virginia (Johnson, 1970, J.M. Alderman database 2004; Table 3).**South Carolina Distribution:** *Elliptio congaraea* is known from Savannah, Edisto, Cooper-Santee and Pee Dee River basins in South Carolina (Johnson, 1970; Table 3).**Description:** "Shell rhomboid, subcompressed, rather thin to subsolid, somewhat inequilateral; beaks moderately full and slightly elevated; the sculpture consisting of parallel undulations, posterior ridge high and angled, double below, the greatest diameter of the shell being along its line; in front of it the shell is wedge-shaped; basal line nearly straight; posterior end obliquely truncated above, somewhat biangulate below; surface with irregular growth lines, usually wrinkled on the posterior slope; epidermis dirty greenish yellow or tawny, generally rayed, especially in young shells, scarcely shining; left valve with two ragged, subcompressed pseudocardinals and two delicate laterals; right valve with two pseudocardinals, the upper small, and one lateral; beak cavities not deep; muscle scars superficial; nacre purplish, often lurid in the shell cavities." (Simpson 1914:615).**Life History:** The hostfish for the glochidia of this species is unknown.**Status:** Williams et al. (1993:11) listed as Special Concern.**Remarks:** The common name of this species was listed by Turgeon et al. (1998) as the Carolina Slabshell. However, the shell shape is not similar to other species with a common name of slabshell. We propose to change the name here to the Carolina Elephantear.

***Elliptio folliculata* (Lea, 1838)****Pod Lance**

Plate 2, Figure 8

**Synonymy:***Unio folliculatus* Lea, 1838; Lea, 1838:38, pl. 11, fig. 33**Type Locality:** Savannah River, [Georgia] (Lea, 1838).**General Distribution:** the Pod Lance ranges from the Ogeechee River north to the Waccamaw and Cape Fear River basins in North Carolina (Johnson, 1970; Table 3).**South Carolina Distribution:** This species is found in the Savannah River Basin north to the Waccamaw and Pee Dee River basins (Table 3).**Description:** This is a narrow, uninflated, elongated naiad that in its lake form resembles a straight-edged razor. The umbo is flat and the dorsal and ventral shell margins are parallel to each other. The anterior-dorsal margin is angular in shape. The shell is covered by a rough dark-brown to black periostracum. The shell nacre varies from bluish to pink. The hinge has pyramidal pseudocardinal teeth.

The original description by Lea (1838) is as follows: "Shell narrow-elliptical, very transverse, very inequilateral, subbiangular behind, rounded before, rather compressed, flattened at the side; substance of the shell rather thin; beaks scarcely prominent; ligament long and curved; epidermis very dark brown; cardinal teeth small and lobed; lateral teeth long and somewhat curved; anterior cicatrices distinct; posterior cicatrices confluent; dorsal cicatrices in the center of the cavity of the beaks; cavity of the shell small; cavity of the beak very small; nacre purple and iridescent." (Adams et al., 1990).

**Life History:** As in all *Elliptio* species, the cream colored marsupium of the female extends along the ventral margin

of the entire outer demibranch. Habitat depth ranged between 1.4-3.0 m in the lake. Hostfish for the glochidia of this species is unknown.

Generally the species was found in a sand substrate at greater than one-meter depths in Lake Waccamaw waters (Porter, 1985). Specimens from Big Creek and Waccamaw River were collected in conditions similar to that from Lake Waccamaw except that some downstream Waccamaw River specimens were extracted from a clay bank in a semi-swift flowing river segment. On the other hand, the Orton Pond canal habitat was a muddy high-sided bank with considerable vegetation nearby in sluggishly moving water

This species, like most *Elliptio* sp., is believed to be tachytictic (short-term breeder). Of the few specimens collected in Lake Waccamaw waters during the 1978-1981 sampling period (Porter, 1985), gravid conditions were seen only in June, 1980 and August, 1980. Since then, gravid specimens have been collected in July (1986) from a canal exiting Orton Pond, Brunswick County, North Carolina (Adams et al., 1990).**Status:** Williams et al. (1993:11) listed as Special Concern. This species is proposed as State Special Concern in South Carolina.

***Elliptio fraterna*****(Lea, 1852)****Brother Spike**

Plate 2, Figure 9

**Synonymy:***Unio fraternus* Lea, 1852; Lea, 1852:263, pl. 16, fig. 15**Type Locality:** Abbeville District [Savannah River drainage], South Carolina.**General Distribution:** Restricted to the Savannah River Basin in Georgia and South Carolina (Johnson, 1970).**South Carolina Distribution:**

Restricted to the Savannah River Basin in South Carolina (Johnson, 1970; Table 3).

**Description:** Shell elongate, rather thin, subrhomboid, shell reaching 65 mm in length. Anterior end regularly rounded, posterior end blunt, ventral margin mostly straight. Dorsal margin straight or only slightly curved. Posterior ridge well developed single dorsally becoming double near the posterior margin.

Posterior slope slightly concave and sculptured near the beaks with ridges radiating from the posterior ridge to the posterior dorsal margin. Beaks full but not elevated. Beak sculpture is not reported. Periostracum smooth and shiny, reddish brown to yellowish often with fine green rays becoming obscured with age and darkening periostracum. Left valve with two low stout or rugged pseudocardinal teeth and two long and slightly curved lateral teeth. Right valve with a single roughly sculptured pseudocardinal tooth and a single lateral tooth. Nacre varies from white to pink, salmon, and purple.

**Life History and Ecology:** Johnson (1970) remarked that this species is found living in swift current in sand bars in large rivers as well as smaller

tributaries. No hostfish are known for the glochidia of this species

**Status:** Williams et al. (1993:11) listed as Endangered. This species is proposed as State Endangered in South Carolina (Table 4).

***Elliptio icterina*****(Conrad, 1834)****Variable Spike**

Plate 2, Figure 10

**Synonymy:***Unio icterinus* Conrad, 1834; Conrad, 1834:41, pl. 6, fig. 5**Type Locality:** Muddy shore, Savannah River opposite Augusta [Richmond Co.] Georgia (Johnson, 1970).**General Distribution:** St. Marys River of Florida north to the Chowan River system in Virginia (Johnson, 1970; Table 3).**South Carolina Distribution:** This species is found in from the Savannah River Basin north to the Pee Dee and Waccamaw River basins (Johnson, 1970; Table 3).**Description:** “Shell oblong, subelliptical or subrhomboid, convex, solid, inequilateral; beaks moderately full and elevated, their sculpture a number of strong concentric ridges; posterior ridge prominent, somewhat double, ending behind in a narrow faint biangulation at or below the median line; surface nearly smooth; epidermis greenish yellow to tawny or tawny brown, usually showing dark rest marks, scarcely rayed, shining; pseudocardinals subcompressed to solid, rough; laterals long, curved; muscle scars large, impressed; nacre white often silvery, a little thicker in front.” (Simpson, 1914:665).**Life History:** No hostfish are known for the glochidia of this species.**Status:** Williams et al. (1993:11) listed as Currently Stable.

***Elliptio producta* (Conrad, 1836)****Atlantic Spike**

Plate 2, Figure 11

**Synonymy:**

*Unio productus* Conrad, 1836; Conrad, 1836:31, pl. 14, fig.1

**Type Locality:** Savannah River, Augusta, [Richmond Co.] Georgia.

**General Distribution:** Wide spread on the Atlantic Coast from the Savannah River north to the Potomac River Basin in Maryland and Virginia (Johnson, 1970).

**South Carolina Distribution:** This species is wide spread in South Carolina ranging from the Savannah River Basin north to the Pee Dee, including the Waccamaw River Basin (Johnson, 1970; Table 3).

**Description:** Shell elongate, somewhat compressed, solid, with a maximum length of nearly 140 mm. Anterior margin is rounded, posterior margin roundly pointed with the most posterior point slightly above the midline of the shell, dorsal and ventral margin nearly straight. Posterior ridge low, beaks not elevated and low. Beak sculpture not reported. Periostracum has a fine uneven incremental growth lines, slightly shiny, dark reddish brown or greenish brown without rays.

Left valve with two small short pseudocardinal teeth and two long lateral teeth. Right valve with a single small pseudocardinal tooth and a single lateral tooth. Nacre is a shade of purple.

**Life History:** No hostfish are known for the glochidia of this species.

**Status:** Special Concern (Williams et al. (1993:11). This species is proposed as State Special Concern (Table 4).

***Elliptio roanokensis* (Lea, 1838)****Roanoke Slabshell**

Plate 2, Figure 12

**Synonymy:***Unio roanokensis* Lea, 1838; Lea, 1838:27, pl. 8, fig. 21**Type Locality:** Roanoke River, between Tarboro, North Carolina and Norfolk, Virginia.**General Distribution:** According to Walter (1954) the Roanoke Slabshell ranges from the Connecticut River in Massachusetts to the Savannah River in Georgia.**South Carolina Distribution:** This species is found in the Cooper-Santee and Pee Dee River systems and in the Savannah River Basin (Table 3).**Description:** Individual Roanoke Slabshells grow to greater than 150 mm total length. In North Carolina it is one of our largest freshwater mussel species. Of 13 specimens recently examined from the Tar River, the height to length ratio ranged from .458 to .544, and the width to length ratio ranged from .212 to .283. The posterior ridge varies from being well defined to being uniformly rounded. The periostracum is generally smooth except near the margins of the shell. Growth rests are distinct. Color of the periostracum is usually a yellow reddish brown, which darkens with age. Narrow greenish rays are often present from the anterior end of the shell to the posterior ridge. The rays are less distinct in larger individuals. The nacre is usually purple (Adams et al., 1990).**Life History:** Little is known of the life history and ecology of this species. Gravid individuals have been observed in North Carolina during the early spring months (Alderman, unpubl. data). In the Tar River, the Roanoke Slabshell is usually found associated with the deeper channels near shore in relatively fastflowing water. The substrate consists of coarse to medium sized sands and small gravel (Alderman, unpubl. data) (Adams et al., 1990). Fishes recently shown to serve as glochidial hosts for *E.**roanokensis* in laboratory trials include Blueback herring (*Alosa aestivalis*), Gizzard shad (*Dorosoma cepedianum*) and White perch (*Morone americana*) (C. Eads, Pers. Comm., August 2007).**Status:** Williams et al. (1993:11) listed as Special Concern. This species is proposed as State Threatened in South Carolina (Table 4).**Remarks:** Johnson (1970) considered the Roanoke Slabshell to be one of the many forms of *Elliptio complanata* found throughout the southern Atlantic Slope Region. However, the Roanoke Slabshell has a centrally plicate shell, certain of the incurrent papillae being subdivided into smaller papillae, and irregularly developed branchial septa. These characteristics distinguish the Roanoke Slabshell from *Elliptio complanata*.Although live *E. roanokensis*, *F. masoni*, and *U. carolinianus* are not easily confused with one another in the field, they are often misidentified as other species. As documented by Fuller for *Unio merus* (Britton and Fuller, 1980), Clarke (1992) for *E. judithae* - probable synonym of *E. roanokensis*, and Fuller (1973) for *F. masoni*, each of these species has numerous dendritic papillae on their incurrent apertures. As observed by J.M. Alderman during the past 20 years, these characteristics are consistent among the various populations of these taxa in North Carolina, South Carolina, and Georgia. Observation of papillae is best accomplished through patient observation of siphoning individuals (placed in shallow water or in a small aquarium).

***Elliptio waccamawensis***  
**(Lea, 1863)**

**Waccamaw Spike**

Plate 3, Figure 13

**Synonymy:**

*Unio waccamawensis* Lea, 1863; Lea, 1863:193

**Type Locality:** Lake Waccamaw, North Carolina.

**General Distribution:** This species is restricted to the Waccamaw River Basin in North Carolina and South Carolina (Johnson, 1970; Heard, 1975; Adams et al., 1990).

**South Carolina Distribution:** The Waccamaw Spike is restricted to the Waccamaw Lake and River in North Carolina and the Waccamaw River in South Carolina (Johnson, 1970; Porter and Horn, 1984a; Adams et al., 1990, Table 3).

**Description:** This naiad has a moderately inflated elliptical shell with a prominent angular ridge on its posterior slope. The ventral margin is straight. The umbo has a trapezoidal beak sculpture. Pseudocardinal teeth are present on the hinge and variable in shape. There is a white to bluish nacre on the inner shell surface. A light to dark brown, smooth periostracum covers the outer shell surface.

"Shell smooth, triangular, inflated, flattened at the sides, very inequilateral, subbiangular behind, rounded before; valves thin; beaks prominent; epidermis brownish green or olivaceous, obscurely rayed; cardinal teeth very small, compressed, oblique, double in both valves; lateral teeth long, lamellar and straight; nacre bluish white and iridescent." (Lea, 1863) (Adams et al., 1990).

**Life History:** Glochidia are suboval, hookless and marginally bilaterally asymmetrical in shape. Its hinge varies from straight to slightly concave in

appearance. Dimensions, as reported in Porter and Horn (1980) are: length = 0.210 mm; height = 0.217 mm; hinge length = 0.144 mm; hinge length/length ratio = 0.69; height/length ratio = 1.04; and hinge length/height ratio = 0.66. This is a short-term breeder (tachytictic). Time of its reproductive cycle does vary from season to season. Marsupia have been observed from April into August. Glochidia have been found in May through July. Hostfish for the glochidia are unknown.

The 1978-1981 survey (Porter, 1985) found large numbers of *E.*

*waccamawensis* throughout the lake including in the deepest depths where the substrate is peat. Average density of the species in the lake was 22.79/m<sup>2</sup>. Highest recorded density was 132.3/m<sup>2</sup>. Densities of *E. waccamawensis* were positively correlated with light penetration and pH; densities were negatively correlated with: sediment pheo-pigment and mean sediment size. *Elliptio waccamawensis* densities were lower within beds of the emergent plants Maidencane and Spatterdock than in areas not containing Maidencane and Spatterdock (Adams et al., 1990).

**Status:** Williams et al. (1993:11) listed as Special Concern. This species is proposed as State Endangered in South Carolina (Table 4).



***Fusconaia masoni* (Conrad, 1834)**

**Atlantic Pigtoe**

Plate 3, Figure 14

**Synonymy:**

*Unio masoni* Conrad, 1834; Conrad, 1834:34, pl. 5, fig. 2

**Type Locality:** Savannah River, Augusta, [Richmond Co.] Georgia (Johnson, 1970).

**General Distribution:** The Atlantic Pigtoe ranges from the Ogeechee River Basin, Georgia north to the James Drainage Basin, Virginia. In North Carolina, this species was once found in every Atlantic drainage except the Cooper- Santee and Waccamaw River basins (Johnson 1970).

**South Carolina Distribution:**

Historically, this species is known from the Savannah River Basin. It may exist in the Pee Dee River Basin in South Carolina, since it is found in this river basin in North Carolina (Johnson, 1970; Table 3).

**Description:** Atlantic Pigtoes are sub-rhomboidal except in individuals from headwater areas. Such individuals tend to be more elongate. The posterior ridge is very distinct, and the umbos extend well above the dorsal margin. The periostracum is yellow to dark brown and parchment like. The nacre ranges from an iridescent blue, to salmon, to white, to orange. Pseudocardinal and lateral teeth are well developed except for the anterior pseudocardinal tooth in the right valve, which is vestigial. All four demibranchs serve as marsupia in gravid females. As the glochidia mature, the demibranchs and adductor muscles develop a bright orange-red to red color. Additional species descriptions can be found in Johnson (1970) and Fuller (1973).

**Life History:** The preferred habitat for the Atlantic Pigtoe is a yielding substrate

composed of coarse sands and gravel at the downstream edge of riffle areas. In such habitats, which are becoming increasingly rare since sedimentation significantly affects such areas, as many as five live individuals have been found in a one-meter square area. This species is less common in sand, cobble, and mixed substrates of sand, silt, and detritus. Little is known about other aspects of its life history or ecology (Adams et al., 1990). Gravid individuals are usually found during late June (Alderman, unpubl. data). Watters and O'Dee (1997) and O'Dee and Watters (2000) identified the Bluegill (*Lepomis macrochirus*) and the Shield Darter (*Percina peltata*) as potential fishhosts for *Fusconaia masoni* glochidia.

**Status:** Williams et al. (1993:11) listed as Threatened. This species is proposed as State Endangered in South Carolina (Table 4).

**Remarks:** See remarks under *Elliptio roanokensis* relating to the incurrent papillae and distinguishing this species.

***Lampsilis cariosa* (Say, 1817)****Yellow Lampmussel**

Plate 3, Figure 15

**Synonymy:***Unio cariosus* Say, 1817; Say, 1817:no pagination, pl. 3, fig. 2*Unio crocatus* Lea, 1841; Lea, 1841:31**Type Locality:** Delaware and Schuylkill rivers; [Susquehanna River] Wilkes Barre; [Luzerne County; all Pennsylvania] Johnson (1947) restricted the type locality to Schuylkill River, near Philadelphia, Pennsylvania.**General Distribution:** The Yellow Lampmussel extends from the Ogeechee River Basin, Georgia, north to Nova Scotia and Cape Breton Island, and westward in the St. Lawrence River Basin to the lower Ottawa River drainage and the Madawaska River (Johnson, 1970).**South Carolina Distribution:** This species is known from the Savannah, Cooper-Santee, Pee Dee, and Waccamaw River basins (Johnson, 1970; Table 3).**Description:** Shell shape is obovate, shell thickness begins as thin in juveniles becoming thicker with age, moderately inflated, shell length 120 mm. Anterior margin is rounded, ventral margin slightly curved, posterior margin bluntly rounded. Male shells elliptical and somewhat elongate in outline with the ventral margin evenly convex. Female shells are subovate to obovate in outline with the ventral margin expanded near the posterior margin, sloping up to a very bluntly rounded posterior margin. Posterior ridge is poorly developed and rounded, posterior slope slightly convex to flat. Beaks moderately swollen but not elevated much above the hingeline, located anterior of the middle of the shell, beak sculpture consists of about five poorly defined bars, the first ridge concentric with the remainder slightly

double-looped. Periostracum is waxy and shiny.

Left valve with two compressed pseudocardinal teeth, the posterior tooth low and immediately under the umbo, two delicate lateral teeth. Right valve has a single compressed pseudocardinal tooth, and a single lamellar lateral tooth. The pseudocardinal teeth tend to become more stumpy and ragged with age. Interdentum is narrow but obvious compared with *Leptodea ochracea*. The beak cavity is open and moderately deep. Periostracum is waxy yellow, often with a trace of green in it, Rays are either absent or restricted to the posterior slope or slightly in front of it. The rays are variable in width, but usually thin, sharp and dark green to black, contrasting with the yellow of the background. Older specimens become brownish and lose much of the luster. Nacre color bluish white, often tinged with cream or salmon.**Life History and Ecology:** Ortmann (1919) observed that gravid females were seen in August, with glochidia appearing only in late August. In North Carolina, Alderman (unpubl. data) has observed gravid females throughout the year; however, the majority are seen during the cooler months of the year. The species is bradyctictic, releasing glochidia in the following spring or early summer. The Yellow Lampmussel is found in small creeks up to large rivers often in sand in bedrock cracks, but also is found in silt, sand, gravel, and cobble substrates. Wick and Huryn (2002) have identified the Yellow Perch (*Perca flavescens*) and the White Perch (*Morone americana*) as hostfish for the Yellow Lampmussel in Maine. Fishes recently shown to serve as glochidial hosts for *L. cariosa* in laboratory trials include Largemouth bass (*Micropterus*

*salmoides*), Smallmouth bass  
(*Micropterus dolomieu*), Black crappie  
(*Pomoxis nigromaculatus*) and White  
bass (*Morone chrysops*) (Eads et al.,  
2007; C. Eads, Pers. Comm., August  
2007).

**Status:** Threatened (Williams et al.,  
1993:12). This species is proposed as  
State Endangered in South Carolina.

***Lampsilis radiata*****(Gmelin, 1791)****Eastern Lampmussel**

Plate 3, Figure 16

**Synonymy:***Mya radiata* Gmelin, 1791; Gmelin, 1791:3220*Unio conspicuus* Lea, 1872; Lea, 1872:156**Type Locality:** Ortmann (1919:296)

reported the locality of Malabar listed by Gmelin (1791) as incorrect and noted Lamarck (1819) had listed it from Saratoga Lake in New York and recommended "if there should not be any other earlier record, we might select this as the type locality." Simpson (1914) listed Virginia as the type locality. Johnson (1970) restricted the type locality to Potomac River, District of Columbia (approximately opposite, Fairfax Co., Virginia). We use the Saratoga Lake, New York as the type locality.

**General Distribution:** The Eastern Lampmussel occurs discontinuously north from the Pee Dee River of South Carolina to the St. Lawrence River Basin, extending west to Lake Ontario (Johnson, 1970).

**South Carolina Distribution:** The Eastern Lampmussel is found in the Pee Dee and Cooper-Santee River basins (Johnson, 1970, Keferl and Shelley, 1988; Table 3).

**Description:** Shell shape is subelliptical to subovate in outline, shell valves are thick and solid, shell valves vary from hardly inflated to quite inflated, shell length is often greater than 120 mm. Anterior end rounded, ventral margin straight to gently curved, posterior margin rounded. Male shells elongate and not expanded posteriorly, while female shells are expanded in the postbasal area, but the amount of swelling is variable and some females are difficult to distinguish from male

shells. Posterior ridge low to absent, the posterior slope is broad. Beaks are rather sharp but are not full or very high, beak sculpture consists of delicate, doubly-looped sculpture, periostracum roughed by close concentric wrinkles.

Left valve has two pseudocardinal teeth, the posterior one located under the beak, and two straight lateral teeth. The right valve has two separate pseudocardinal teeth, the upper is smaller and compressed, and has a single straight lateral tooth. Interdentum is lacking, beak cavity is shallow, compressed. Periostracum is yellowish or brownish green with dark green or black rays over the entire surface, rays are not well defined. Nacre color is white, may be tinged with pink or salmon or may be completely pink or salmon.

**Life History and Ecology:** Ortmann (1919) reported gravid females with eggs on 22 August and gravid females with glochidia on 20 August. He seemed to think the species is bradyctytic, possibly with overlapping ends to the breeding season. Ortmann (1919) reported the Eastern Lampmussel from the Delaware River in fast current in gravel substrate, and in a sandy substrate in the lake like portion of the lower Delaware River. Strayer and Jirka (1997:60) recorded this species from creeks, lakes and rivers. The authors have found the Eastern Lampmussel in many different substrates with currents ranging from none to significant. The Black Crappie, (*Pomoxis nigromaculatus*) Largemouth Bass (*Micropterus salmoides*), Pumpkinseed (*Lepomis gibbosus*), Rock Bass (*Ambloplites rupestris*), Smallmouth Bass (*Micropterus dolomieu*), and Yellow Perch (*Perca flavescens*) have been identified as hostfish for the

glochidia of this mussel (Watters, 1994; Tedla and Fernando, 1969).

**Status:** Currently Stable (Williams et al., 1993:12). This species is proposed as State Threatened in South Carolina (Table 4).

***Lampsilis splendida* (Lea, 1838)****Rayed Pink Fatmucket**

Plate 3, Figure 17

**Synonymy:***Unio splendidus* Lea, 1838; Lea, 1838:70, pl. 19, fig. 61**Type Locality:**

Altamaha River, near Darien, [McIntosh Co.]; Altamaha [River] Liberty [now Long Co.], both Georgia.

**General Distribution:**

The Rayed Pink Fatmucket occurs from the Altamaha and Ogeechee rivers in Georgia north to the Cape Fear River Basin in North Carolina (Johnson, 1970; Table 3).

**South Carolina Distribution:**

This species occurs in the Savannah River Basin, the Wateree River and the Santee River both in the Cooper-Santee River Basin and the Waccamaw River of the Pee Dee River Basin (Table 3).

**Description:** Shell shape is elongate oval, greatly inflated with a shell length of 110 mm. Anterior end rounded, posterior end of the male broader and bluntly pointed, female shell more broadly rounded, ventral margin in males usually vary from slightly concave to gently rounded, female posterior ventral margin inflated, dorsal margin straight. Posterior ridge rather sharp, often with a secondary ridge, posterior slope wrinkled. Beaks elevated and very full, inflated. Beak sculpture consists of several strong almost straight bars. Periostracum wrinkled giving the surface a fuzzy appearance, entire surface yellowish-green to reddish brown and the entire surface covered with numerous wide and narrow green rays, becoming dark brown with the rays obscured in old specimens. Left valve with two compressed pseudocardinal teeth, slightly in front of the umbo, with two lateral teeth, the

lower being larger. Right valve with two pseudocardinal teeth and one lateral tooth, truncated posteriorly. Beak cavities deep and open. Nacre color varies from bluish white but often pinkish and iridescent ranging to a light purple.

**Life History and Ecology:**

Johnson (1970) reports this species occurring on sandbars and gravelly substrates in swift water in large rivers and also in lakes.

**Status:** Special Concern (Williams et al., 1993:12). This species is proposed as State Special Concern (Table 4).

***Lasmigona decorata* (Lea, 1852)**  
**Carolina Heelsplitter**

Plate 3, Figure 18

**Synonymy:**

*Unio decoratus* Lea, 1852; Lea, 1852:257, pl. 13, fig. 6

**Type Locality:** Abbeville District, South Carolina.

**General Distribution:** Historically the Carolina Heelsplitter was recorded from the Abbeville District, Savannah River Basin in South Carolina, and around Mecklenburg County in North Carolina (Clarke, 1985). Johnson (1970) assumed that the records from the Abbeville District, South Carolina were in the Savannah River system. Alderman (1995) documented an extant population in the Savannah River Basin. The range of *L. decorata* is from small streams in the Pee Dee and Catawba River basin in North and South Carolina, and the Catawba, Saluda and Savannah River basins in South Carolina.

**South Carolina Distribution:** Keferl and Shelley (1988) did not find any evidence of *L. decorata* in the Saluda River drainage. Keferl and Shelley (1988) reported it in the Lynches River (Pee Dee River system), Lancaster and Chesterfield counties, South Carolina. Alderman (2002) reported two populations from tributaries to the Savannah River in the Abbeville District of South Carolina and one in the Catawba River Basin.

*Lasmigona decorata* is now known from a creek population in the Pee Dee River basin in Chesterfield, Kershaw and Lancaster counties, eight creeks in the Catawba River basin in Lancaster and Chester counties, a single creek in the Saluda River basin, Saluda County, and two creeks in the Savannah River basin in Edgefield, Greenwood and McCormick counties. (Table 3).

**Description:** The Carolina Heelsplitter can reach a length of 118 mm, with a height of 68 mm and a width of 39 mm. Based on some specimens collected by Keferl and Shelley (1988) from three different streams and rivers, the mean length is 78 mm, the mean height is 43 mm and the mean width is 27 mm. The shell is an ovate trapezoid. The dorsal margin is straight and may end with a slight wing. The umbo is flattened. The beaks are depressed and project a little above the hinge line. The beak sculpture is double looped. The unsculptured shell can have a yellowish, greenish, or brownish periostracum. The Carolina Heelsplitter can have greenish or blackish rays. The lateral teeth may or may not be well developed; in most cases they are thin. The pseudocardinal teeth are lamellar and parallel to the dorsal margin, and there is a slight interdentum. The nacre varies from an iridescent white to a mottled pale orange (Adams et al., 1990).

**Life History:** Historically the Carolina Heelsplitter was collected in creeks, streams, a river, and ponds. The ponds were probably millponds. Keferl and Shelley (1988) found *L. decorata* living in two small streams and a small river. All specimens found were in shaded areas, either in a ponded portion of a small stream, or in runs along steep banks with a moderate current. All specimens were found in less than three feet of water during low waters of summer and fall. The substrates included soft mud, sand, muddy-sand, and sandy-gravel. Almost nothing is known about the life history and ecology of *Lasmigona decorata*. Living specimens of *L. decorata* have been collected in late June, August, and late October. Alderman (unpubl data) has documented one gravid female seen during October 1996. Fishes recently shown to serve as glochidial hosts for *L.*

*decorata* in laboratory trials include Bluehead chub (*Nocomis leptcephalus*), Creek chub (*Semotilus atromaculatus*), Golden shiner (*Notemigonus crysoleucas*), Highfin shiner (*Notropis altipinnis*), Rosyside dace (*Clinostomus funduloides*), Satinfin shiner (*Cyprinella analostana*), Spottail shiner (*Notropis hudsonius*), Sandbar shiner (*Notropis scepticus*), Whitefin shiner (*Cyprinella nivea*), Bluegill (*Lepomis macrochirus*) and Warmouth (*Lepomis gulosus*) (C. Eads, Pers. Comm., August 2007).

**Status:** Williams et al. (1993:13) listed as Endangered. This species is federally and state listed as Endangered. The U.S. Fish and Wildlife Service (1997) developed a recovery plan for this species. The U.S. Fish and Wildlife Service (2002) has designated critical habitat for the Carolina Heelsplitter.



***Leptodea ochracea* (Say, 1817)****Tidewater Mucket**

Plate 4, Figure 19

**Synonymy:**

*Unio ochraceus* Say, 1817; Say, 1817: no pagination, pl. 2, fig. 8

**Comment:** The generic placement of *Unio ochraceus* Say, 1817 is unsettled (see Bereza and Fuller, 1975; Morrison, 1976; Porter and Horn, 1980; Kat, 1983; Adams et al. 1990). Stiven and Alderman (1992) presented an analysis of some populations of *Lampsilis* and used *Elliptio complanata* as the outgroup. In this study, *Leptodea ochracea* fell outside of the *Lampsilis* and *Elliptio* clades, suggesting *L. ochracea* does not belong in the genus *Lampsilis*. Smith (2000) has proposed moving this species to the genus *Ligumia* based on anatomical and larval characters. We (Bogan, unpubl.) have noted major anatomical differences in anal position and characters between *Ligumia recta* (type species of *Ligumia*) and *Ligumia nasuta*, which raise the question of the monophyly of *Ligumia*. These data coupled with the observation of Davis and Fuller (1981) that *L. recta* and *L. nasuta* are not closely related based on their immunological analyses, leads us to retain *L. ochracea* in its recent placement in *Leptodea* until DNA tests provide a clearer indication of *L. ochracea*'s generic placement.

**Type Locality:** Delaware and Schuylkill Rivers. Johnson (1947) restricted the type locality to the Schuylkill River, near Philadelphia, Pennsylvania.

**General Distribution:** Atlantic Coast rivers from Cape Breton, Nova Scotia, Canada south to the Savannah River, Georgia (Johnson, 1970).

**South Carolina Distribution:** The Tidewater Mucket is known from the Waccamaw and Savannah river basins (Adams et al., 1990; Table 3). Recently found in the Pee Dee River in North Carolina.

**Description:** Shells of the Tidewater Mucket are usually relatively small, length at times nearly 100 mm, elliptical to ovate in outline with a thin to subsolid, strong, subinflated shell. Anterior margin rounded, ventral margin evenly rounded, posterior margin evenly rounded. Male shells are more elliptical with the posterior margin somewhat pointed. Female shells are more ovate

and the posterior margin is truncated. Posterior ridge is well developed ending in a blunt point about half way up from the base on the posterior margin. Beaks are moderately swollen and raised above the hingeline, beak sculpture consists of a few straight, strong ridges with the later ridges becoming weakly double-looped. Periostracum is slightly shiny to mat.

Left valve with two small compressed pseudocardinal teeth located in front of the beaks, two thin, distant lateral teeth. Right valve has two triangular compressed pseudocardinal teeth, and a single thin lateral tooth. The interdentum is virtually nonexistent in this species. The hingeline is narrow and rounded in the middle. The beak cavity is open and moderately deep. Periostracum is dull, not a bright yellow but grayish, greenish, or brownish olive and the rays have a different character. The rays are sometimes absent but when present are indistinct and blackish and grayish or greenish, rather fine and are found across the shell or most of the shell. The rays become obscure on the posterior slope. Nacre is white to reddish pink.

**Life History and Ecology:** The Tidewater Mucket is gravid in the autumn and releases glochidia in the spring (Ortmann, 1919). Ortmann (1919) reported *L. ochracea* as occurring in estuaries, ponds, and canals with muddy bottoms. Hostfish unknown. At least one of the hostfish species is probably an anadromus species in light of the Tidewater Mucket's tidewater distribution.

**Status:** Special Concern (Williams et al., 1993:13). This species is proposed as State Threatened in South Carolina (Table 4).

***Ligumia nasuta* (Say, 1817)****Eastern Pondmussel**

Plate 4, Figure 20

**Synonymy:***Unio nasuta* Say, 1817; Say, 1817: no pagination, pl. 4 fig. 1**Type Locality:** Delaware and Schuylkill [rivers near Philadelphia, Philadelphia Co. Pennsylvania].**General Distribution:** The Eastern Pondmussel occurs from the Savannah River Basin, South Carolina, north to the St. Lawrence River Basin, westward through the Mohawk River and Erie Canal and west to Lake Erie in Pennsylvania, Ohio and Michigan (Johnson, 1970).**South Carolina Distribution:** The Eastern Pondmussel is known historically from the Savannah River Basin and from the Pee Dee, and Cooper-Santee River basins (Johnson, 1970; Table 3). An extant population in the Savannah River Basin of Georgia has been documented (Alderman, unpubl. data).**Description:** Shell shape elongated, subelliptical, thin to subsolid and is more or less compressed, shell length 102 mm. Anterior margin rounded, ventral margin broadly curved, posterior margin is rounded and drawn out into a posterior angle or blunt point near the midline of the shell. Sexual dimorphism in the shells is well marked. The posterior margin of the male shell tapers evenly to a blunt point, while the ventral margin has a uniform curve. The female shell has the ventral margin expanded in the postbasal region, becoming a broad rounded projection, behind which the ventral margin turns upward abruptly. Posterior ridge well developed, distinct and angled near the beak, becoming rounded posteriorly. Posterior slope is slightly concave near the beaks,

becoming flatter near the posterior margin of the shell. Beaks are low, hardly raised above the hinge line and located in the anterior quarter of the shell, beak sculpture consists of 5–7 fine bars, subconcentric becoming double looped. Periostracum is subshiny with irregular growth lines and sometimes marked by a few nearly vertical ribs below the posterior ridge.

Left valve has one or two compressed, subtriangular, pseudocardinal teeth, two delicate, long lateral teeth. Right valve has one, sometimes two compressed pseudocardinal teeth and a long lamellar lateral tooth. The interdentum is lacking and the beak cavity is shallow.

Periostracum is dark olive green to brownish and often with faint dark green, straight and narrow rays present, especially in juvenile specimens. The rays may be completely absent. Nacre is bluish white, some with salmon in the beak area, iridescent posteriorly.

**Life History and Ecology:** The Eastern Pondmussel was reported gravid from mid-September through early July, discharging glochidia in June and July (Ortmann, 1919:272). Ortmann (1919:274-275) reported this species from fine sand substrates, in deep water with a mud and vegetable debris, at the edge of a riffle in gravel. He reported it from Lake Erie at Presque Isle Bay living in sandy, gravelly, and muddy substrates in one to 15 feet of water and occurring in the beach-pools of Presque Isle in sandy and sand/mud substrates. Fishes recently shown to serve as glochidial hosts for *L. nasuta* in laboratory trials include Bluegill (*Lepomis macrochirus*), Pumpkinseed (*Lepomis gibbosus*) and Largemouth bass (*Micropterus salmoides*) (C. Eads, Pers. Comm., August 2007).

**Status:** Special Concern (Williams et al., 1993:13). This species is proposed as State Endangered in South Carolina.

***Pyganodon cataracta* (Say, 1817)****Eastern Floater**

Plate 4, Figure 21

**Synonymy:***Anodonta cataracta* Say, 1817; Say, 1817: no pagination, pl. 3, fig. 4**Type Locality:** Deep part of milldam, Johnson (1970) restricted the locality to: deep part of milldam [presumably near Philadelphia, Philadelphia Co. Pennsylvania].**General Distribution:** The Eastern Floater extends from the Alabama-Coosa River drainage, the Coctawhatchee and upper Apalachicola River basins, and on the Atlantic slope from the Altamaha River Basin of Georgia north to the lower St. Lawrence River Basin, possibly extending west to Michigan (Johnson, 1970).**South Carolina Distribution:** This is a wide-ranging species and is found in South Carolina from the Savannah, Cooper-Santee, Pee Dee, and Waccamaw River basins (Johnson, 1970; Table 3).**Description:** Shell shape is ovate, subelliptical and elongate, shells of juveniles not much inflated but much more inflated in adult shells, shells are uniformly thin, often with a low post dorsal wing, shell length 135 mm. Anterior margin evenly rounded, ventral margin is broadly rounded and the posterior margin comes to a tapered point about in the midline. Posterior ridge is moderately developed, often with an indication of being biangulate. Ortmann (1919) observed that the female shells of this species may exhibit swelling of the valves posterior to the middle, however, not all females exhibit this character. Beaks are usually full and elevated above the hingeline, beak sculpture consists of 5-7 double-looped ridges without the nodulous point on theloops as found in *Pyganodon grandis*.

Periostracum is usually smooth.

The Eastern Floater has no hinge teeth or any indication of swellings in this area.

The beak cavity is open and relatively shallow. Periostracum is light to dark green, rarely becoming brownish or black, often quite brightly colored, with concentric light and dark bands and with dark green rays most distinct on the disc of the shell, broad green rays on the posterior slope are often well developed, giving the area a much darker color.

Nacre is bluish-white.

**Life History and Ecology:** Ortmann (1919:155) discussed the variability of shell thickness and shape in *Pyganodon cataracta* and recognized three generalized shell forms: "the pond-forms being generally thinner, while the creek-forms are thicker... *A. cataracta* is also quite variable in the convexity of the valves; and the inflation, if present, is restricted to the disk, and does not extend to the umbos." He (Ortmann, 1919:155) remarked "The various forms of *A. cataracta* ... are all connected by intergrades, and they seem to be special reactions to special environmental conditions, although we are not in all cases sure what are the essential features of the environment, which are active." Ortmann (1919:158) reported the ecology of the various shell forms of the Eastern Floater as: the pond-form in small ponds with muddy bottoms, the creek-form in small rivers and creeks with gravel substrates, in good current, including riffles or in quiet pools in gravel, sand or mud, the short high form is found in the bigger rivers on muddy substrates. Ortmann (1919) reported the Eastern Floater as gravid from early August through late April, with glochidia being discharged in April and no charged females reported for May.

The Common Carp (*Cyprinus carpio*), Bluegill (*Lepomis macrochirus*), Pumpkinseed (*Lepomis gibbosus*), Threespine Stickleback (*Gasterosteus aculeatus*), White Sucker (*Catostomus commersoni*), and Yellow Perch (*Perca flavescens*) have been listed as potential hostfish for the glochidia of this species (Watters, 1994; Gray et al., 1999). Fish recently shown to serve as glochidial host for *P. cataracta* in laboratory trials includes Highfin Shiner (*Notropis altipinnis*) (Eads et al., 2007).

**Status:** Currently Stable (Williams et al., 1993:14). This species is considered Currently Stable.

***Strophitus undulatus* (Say, 1817)**  
**Creeper** [formerly the squawfoot]

Plate 4, Figure 22

**Synonymy:**

*Anodonta undulata* Say, 1817; Say, 1817:pl. 3, fig. 5

**Type Locality:** None given for *Anodonta undulata* Say, 1817. Johnson (1970:367) restricted the type locality to Schuylkill River, near Philadelphia, Philadelphia Co. Pennsylvania. For *Alasmodonta edentula* Say, 1829: Wabash River, Indiana.

**General Distribution:** Canadian Interior Basin in the Red River–Nelson River system from western Ontario to eastern Saskatchewan, and throughout the Great Lakes–St. Lawrence northern drainage system (Clarke, 1981a). Entire Mississippi River drainage from Minnesota to central Texas, Pennsylvania to Tennessee; Atlantic coastal drainage from Nova Scotia to the upper Savannah River system of South Carolina (Johnson, 1970).

**South Carolina Distribution:** The Creeper is widely distributed in the Atlantic slope drainages including the Savannah, Cooper-Santee and Pee Dee River basins (Johnson, 1970; Table 3).

**Description:** The shell is elliptical, somewhat rhomboid, solid, compressed, and thin when young, moderately inflated and thick in mature and old individuals. The anterior end is rounded, and the posterior end is bluntly pointed and often obliquely truncated. The posterior ridge is broadly rounded and either compressed or quite pronounced (especially in old shells). Shell length is usually less than 110 mm. Beaks are depressed, only slightly elevated above the hinge line; sculpture consisting of 3–4 heavy concentric bars, somewhat oblique to the hinge line, rounded anteriorly, and angled posteriorly.

The pseudocardinal tooth in the left valve is represented by an elongated, low thickening of the hinge line below the beak; the pseudocardinal tooth in the right valve appears as a low, thick swelling anterior to the beak. Lateral teeth are absent or suggested by a thickened hinge line. The beak cavity is shallow. The periostracum is yellowish or greenish, marked by greenish, often wavy rays; old shells are dark brown or black and usually rayless. The nacre is white or bluish white and iridescent around the margins, the center, and occasionally along the pallial line where it may also be cream-colored or salmon (Parmalee and Bogan, 1998).

**Life History and Ecology:** *Strophitus undulatus* appears adaptable to a variety of aquatic habitats, from the high gradient small streams to the main channel of the upper Allegheny River in finer sediments to large gravel, usually deeply buried. It typically inhabits depths of no more than three or four feet. This species appears to spend the summer and fall buried beneath the surface and is found up on the surface of the substrate during the coldest parts of the year along with *Alasmodonta undulata*, *Alasmodonta varicosa* (AEB Pers. Obs. and W. Lellis, Pers. Comm. January, 1995). It has been shown experimentally that the glochidia of this species may develop on the fins and skin of the Largemouth Bass (*Micropterus salmoides*) and the Creek Chub (*Semotilus atromaculatus*) (Baker, 1928), and that the Rio Grande Killifish (*Fundulus zebrinus*) and Green Sunfish (*Lepomis cyanellus*) may serve as natural hosts for the glochidia of this mussel (Fuller, 1978). In addition, Hove (1995) has identified seven fish as definite hosts for the glochidia of the Creeper: Spotfin Shiner (*Cyprinella*

*spiloptera*), Fathead Minnow (*Pimephales promelas*), Yellow Bullhead (*Ameiurus natalis*), Black Bullhead (*Ameiurus melas*), Bluegill (*Lepomis macrochirus*), Largemouth Bass (*Micropterus salmoides*), and Walleye (*Stizostedion vitreum*). The Common Shiner (*Luxilus cornutus*), Fallfish (*Semotilus corporalis*), Golden Shiner (*Notemigonus crysolucas*), Longnose Dace (*Rhinichthys cataractae*), Slimy Sculpin (*Cottus cognatus*), and Yellow Perch (*Perca flavescens*) have been added recently as potential hosts for the Northeastern United States populations of the Creeper (Wicklow and Beisheim, 1998; Watters et al., 1999; Gray et al., 1999). Wicklow and Beisheim (1998) reported the larvae of the Northern Two-Lined Salamander (*Eurycea bislineata*) served as potential hosts for the glochidia of the Creeper. Fishes recently shown to serve as glochidial hosts for *S. undulatus* in laboratory trials includes White shiner (*Luxilus albeolus*), Fantail darter (*Etheostoma flabellare*), Bluegill (*Lepomis macrochirus*), Green sunfish (*Lepomis cyanellus*) and Redbreast sunfish (*Lepomis auritus*) (Eads et al., 2007). However, the Creeper is one of the few freshwater mussels able to complete its life cycle without a fishhost; the glochidia undergo a complete development in the female before being expelled (Lefevre and Curtis, 1910). Having direct development of the glochidia, resulting in the elimination of the parasitic stage on fish, is probably a primary factor in the species' wide distribution and local abundance. It is bradytictic, the reproductive period extending from July to April and May (Baker, 1928). Ortmann (1919) noted that the interim between breeding

seasons occurs in Pennsylvania from the end of May to early July.

**Status:** Currently Stable (Williams et al., 1993:14). This species is proposed as State Endangered in South Carolina as it appears to be declining throughout its range (Table 4).

***Toxolasma pullus* (Conrad, 1838)****Savannah Lilliput**

Plate 4, Figure 23

**Synonymy:***Unio pullus* Conrad, 1838; Conrad, 1838:100, pl. 55, fig. 2*Carunculina patrickae* Bates, 1966; Bates, 1966:1-9**Type Locality:** Wateree River, South Carolina (Johnson, 1970).**General Distribution:** The range of the Savannah Lilliput is from the Altamaha River Basin in Georgia to the Neuse River Basin in North Carolina (Johnson, 1970).**South Carolina Distribution:** This species is known from the Savannah, Cooper-Santee, and Pee Dee River basins (Johnson, 1970; Table 3).**Description:** *Toxolasma pullus* has a small, oval or elliptical shell. A large specimen would be 30 to 35 mm long, with a height of 19-20 mm and a width of 15-16 mm. The shell is somewhat inflated. The shells are sexually dimorphic. The females have a broader more truncated posterior end, whereas the males have a narrower rounded posterior end and a point below the median line. The ventral margin is curved in males and straight in females. The posterior ridge is double, sometimes broadly rounded, but usually angular. The umbos are prominent. The periostracum is satiny and coarse because of the numerous closely spaced growth lines. The periostracum is most frequently blackish. Johnson (1970) reports that the periostracum is sometimes brownish, greenish or olivish and with obscure, very fine green rays. The left valve has two triangular pseudocardinal teeth. The right valve has a fairly large triangular tooth. The nacre is bluish white with a pink to purplish iridescence at the posterior end (Adams et al., 1990).**Life History and Ecology:** The Savannah Lilliput lives in still shallow

water near the banks of streams and ponds in mud or sand (Johnson, 1970). "I have always found the Savannah Lilliput near the shore in less than 6 inches of water usually in a sandy or silty sand substrate. They seem to exist in small colonies. They are easiest to find when the water is low and still dropping. Nothing is known about the life history of the Savannah Lilliput." (Adams et al., 1990).

**Status:** Williams et al. (1993:14) listed as Threatened. This species is proposed as State Endangered in South Carolina (Table 4). This species may be extirpated from Lake Waccamaw (J. Alderman, Pers. Comm. July 2002).**Remarks:** Bates (1966) described *Carunculina patrickae* from the Savannah River. This taxon is characterized by very heavy beak sculpture extending well down onto the disk of the shell. It is now considered a synonym of *T. pullus*.



***Unio merus carolinianus***  
**(Bosc, 1801)**

**Eastern Pondhorn**

Plate 4 Figure 24

**Synonymy:**

*Unio caroliniana* Bosc, 1801; Bosc, 1801:142, pl. 23, fig. 2

**Type Locality:** “ en Caroline”, the Carolinas.

**General Distribution:** The Eastern Pondhorn ranges along the South Atlantic Slope from the Ocmulgee River, Georgia north to the Chowan River Basin of Virginia (Johnson, 1970).

**South Carolina Distribution:** This species is found in all river basins from the Savannah north to the Pee Dee and Waccamaw River basins in South Carolina (Johnson, 1970; Table 3).

**Description:** “ Shell medium to large reaching 114 mm in length. Outline rhomboid or long rhomboid. Valves subinflated or inflated, subsolid. Anterior end regularly rounded or slightly truncated, posterior end usually somewhat produced. Ventral margin slightly incurved. Dorsal margin slightly curved, generally forming a sharp angle with the almost straight posterior margin. Hinge ligament long and narrow, located posteriorly of the umbos. Posterior ridge rounded, ending in a point or feeble biangulation at the base of the shell, sometimes rendering older specimens a bit arcuate. Posterior slope often with two radial sulci. Umbos low to slightly elevated, located in the anterior quarter of the shell, their sculpture consisting of five or six heavy ridges that form a rounded angle on the posterior ridge, in front of which they tend to be corrugated. Periostracum generally black and slightly roughened, but with a satiny sheen over most of the surface. Sometimes the surface is smooth and shiny, especially in the

umbonal area, and may then be brownish-yellow or yellowish mixed with green, not rayed.

Left valve with two ragged subequal pseudocardinal often with a vestigial tooth above it; one lateral tooth. Beak cavities compressed, but with several scars deep, posterior ones faint. Pallial line distinct. Nacre is white, bluish white or pinkish to lurid purple.” (Johnson, 1970:341).

**Life History:** Johnson (1970) reported *Unio merus* living in smaller streams and ponds on buddy bottoms. The hostfish for this species is unknown.

**Status:** Williams et al. (1993:14) listed as Currently Stable.

**Remarks:** See remarks under *Elliptio roanokensis* relating to the incurrent papillae and distinguishing this species. The common name Florida Pondhorn is a misnomer and we have changed the common name to the Eastern Pondhorn to more accurately reflect its range.

***Utterbackia imbecillis* (Say, 1829)****Paper Pondshell**

Plate 5, Figure 25

**Synonymy:***Anodonta imbecillis* Say, 1829; Say, 1829:355**Type Locality:** Wabash River.

**General Distribution:** The Paper Pondshell is found throughout the Mississippi River and Great Lakes drainages, from southern Michigan south to Georgia and northern Florida (Clench and Turner, 1956), west to Kansas, Oklahoma, and Texas, and southwest to extreme northeastern Mexico. It also occurs sporadically along the Atlantic Coast as far north as Eastern Pennsylvania (Fuller and Hartenstine, 1960).

**South Carolina Distribution:** The Paper Pondshell occurs throughout South Carolina and has been reported from the Savannah, Edisto, and Cooper-Santee River basins (Johnson, 1970; Hoeh, 1991; Table 3).

**Description:** The shell is thin, oblong, and inflated. Juveniles, however, are greatly compressed. In especially favorable habitat, individuals may exceed 100 mm in length and become extremely inflated, almost circular in cross section at the beaks. The posterior ridge is moderately angled; the dorsal and ventral margins are nearly straight and parallel. The anterior end is rounded; the posterior end is rather pointed. Beaks are flattened and usually flush with the hinge line; sculpture consists of 5–6 fine, irregular, often broken, somewhat concentric ridges, which are somewhat wavy, forming indistinct double loops. Rest periods are usually marked by distinct concentric ridges, edged with black. Both valves are edentulous; the hinge line is only very slightly thickened. The periostracum is yellowish or greenish with numerous

fine green rays. The nacre is bluish white or silvery, and the outside margins and posterior end are iridescent; the shallow beak cavities are often cream or light yellowish brown (Parmalee and Bogan, 1998).

**Life History and Ecology:** *Utterbackia imbecillis* is found in backwaters, ponds and impoundments and thrives in a mud and fine sand substrate. Once it becomes established in a farm pond, borrow pit, or drainage canal, the Pond Mussel may become quite numerous. The species is probably bradytictic; Ortmann (1909) suggested that it is an autumn breeder in Pennsylvania, noting gravid individuals in May and June. According to Sterki (1898), this species is hermaphroditic, and Baker (1928) indicated that the parasitic developmental stage of glochidia on fish is often omitted. However, Tucker (1927) listed the Green Sunfish (*Lepomis cyanellus*) as a host for the Paper Pondshell, and Fuller (1978) reported the Creek Chub (*Semotilus atromaculatus*) as another. Stern and Felder (1978) also recorded the Western Mosquitofish (*Gambusia affinis*), Warmouth (*Lepomis gulosus*), Bluegill (*L. macrochirus*), and Dollar Sunfish (*L. marginatus*) as hostfish for the Paper Pondshell in Louisiana. Watters (1994), citing Trdan and Hoeh (1982) and others, added the Banded Killifish (*Fundulus diaphanus*), Largemouth Bass (*Micropterus salmoides*), Pumpkinseed (*Lepomis gibbosus*), Rockbass (*Ambloplites rupestris*), and Yellow Perch (*Perca flavescens*) to the list of hostfish. Hove et al. (1995), based on laboratory experiments, added the Spotfin Shiner (*Cyprinella spiloptera*) and Black Crappie (*Pomoxis nigromaculatus*) to the list of fishes parasitized by glochidia of the Paper Pondshell. Watters (1997) had identified

26 exotic fish species, the tadpoles of the bullfrog and northern leopard frog, adult African clawed frogs, and larval tiger salamanders as surrogate hosts for the glochidia of *Utterbackia imbecillis* (Parmalee and Bogan, 1998).

**Status:** Currently Stable (Williams et al., 1993:14). This species is considered stable in South Carolina.

***Villosa constricta* (Conrad, 1838)****Notched Rainbow**

Plate 5, Figure 26

**Synonymy:***Unio lienosus* var. *constrictus* Conrad, 1838;

Conrad, 1838:91, pl.49, fig. 4

**Type Locality:** North River, Rockbridge County, Virginia.**General Distribution:** The Notched Rainbow occurs from the Rappahannock River Basin south to the Cooper-Santee River Basin in South Carolina (H. Athearn, Museum of Fluvial Mollusks, December, 2003; Johnson, 1970; Table 3).**South Carolina Distribution:** This species is found in Pee Dee and Cooper-Santee River basins in South Carolina (Johnson, 1970; Table 3).**Description:** "Shell rather small and short, subelliptical, subsolid, subcompressed; beaks not elevated, their sculpture evenly doubly-looped ridges; surface nearly smooth or marked with irregular concentric growth lines; rather shining, yellowish-green, or bottle-green, feebly rayed; hinge somewhat solid; there are two pseudocardinals in the left valve and one tooth often with a faint second in the right; one straight lateral in the right valve and two in the left; anterior muscle scars separate, somewhat impressed; posterior scars faint; nacre bluish, sometimes purplish in the center, slightly thicker in front. The female shell is pointed behind a little more than midway up from the base, and between this point and the small marsupial swelling the outline is generally a little emarginated. The male shell is often subrhomboid, the posterior point being generally less than midway up for the base." (Simpson, 1914:111).**Life History:** The breeding season for the Notched Rainbow begins in August and ends in June. The glochidia aresubspatulate in outline. This species is found in sand in rather good current (Johnson, 1970). Eads et al. (2006) studying *Villosa constricta* in the upper Neuse River basin in North Carolina aged specimens from 3 to 14 years. They infected 16 species of fish. Bluegill (*Lepomis macrochirus*) produced only two metamorphosed juveniles while the Fantail Darter (*Etheostoma flabellare*) was more productive and considered a good laboratory host species.**Status:** Williams et al. (1993:14) listed as Special Concern. This species is proposed as State Endangered in South Carolina (Table 4).**Remarks:** Separation of the various live *Villosas* is often a difficult task while conducting field surveys. However, when females are available, careful examination of the marsupial gill helps with identifications. Being careful means using your fingernails to carefully and slowly pry open the valves just a few millimeters to allow examination of the outer rim of the marsupial part of the outer demibranchs. As observed by J.M. Alderman during the past 20 years, *V. vaughaniana* usually has an ivory band on the outer rim; *V. modioliformis* usually has a darkened, rectangular area at the end of each water tube separated from the next pigmented area by unpigmented tissues; and usually *V. constricta* and *V. delumbis* both have black bands. At this point, separation of live *V. constricta* females from live *V. delumbis* females is usually accomplished by examination of periostracum color and ray characteristics (see shell description section in each species' account).

***Villosa delumbis* (Conrad, 1834)  
Eastern Creekshell**

Plate 5, Figure 27

**Synonymy:**

*Unio delumbis* Conrad, 1834; Conrad, 1834: 35, pl. 5, fig. 3

**Type Locality:** Small streams near Cooper River, South Carolina.

**General Distribution:** The Eastern Creekshell is found from the Ocmulgee River drainage of the Altamaha River Basin in Georgia north to the Cape Fear River Basin of North Carolina (Johnson, 1970; Table 3). The record from the Neuse is probably a new species of *Lampsilis* (J. Alderman, Pers. Comm. July 2002).

**South Carolina Distribution:** This species' range in South Carolina includes the Savannah, Salkehatchee-Combahee, Edisto, Cooper-Santee, Pee Dee, and Waccamaw River basins (Johnson, 1970; Table 3).

**Description:** "Shell long ovate, very thin and fragile, ventricose; ligament margin slightly elevated; anterior side rather narrow; posterior margin rounded; beaks only moderately full; margin of the ligament slope rounded, very oblique; within bluish, highly iridescent; cardinal teeth lamellar; cavity capacious." (Simpson, 1914:52). The female shell is very enlarged on the posterior end while the male is oval in shell outline. The periostracum is yellow marked by numerous green rays, interrupted by the prominent growth lines.

**Life History:** Johnson (1970) reported this species living in mud or soft sand, rich in vegetation, in small creeks and rivers. Fishes recently shown to serve as glochidial hosts for *V. delumbis* in laboratory trials include Bluegill (*Lepomis macrochirus*), Green sunfish (*Lepomis cyanellus*), Redbreast sunfish

(*Lepomis auritus*), Redear sunfish (*Lepomis microlophus*) and Warmouth (*Lepomis gulosus*) (Eads et al., 2007).

**Status:** Williams et al. (1993:14) listed as Currently Stable. This species is proposed as State Special Concern in South Carolina (Table 4).

**Remarks:** See the remarks under *Villosa constricta* for notes on distinguishing the gravid female *Villosa* species.

***Villosa modioliformis* (Lea, 1834)****Eastern Rainbow**

Plate 5, Figure 28

**Synonymy:***Unio modioliformis* Lea, 1834; Lea, 1834-:97, pl. 13, fig 40**Type Locality:** Santee Canal, South Carolina.**General Distribution:** The Eastern Rainbow ranges from the Altamaha River Basin up the South Atlantic Coast to the Cape Fear River Basin of North Carolina (Johnson, 1970).**South Carolina Distribution:** The Eastern Rainbow is found in the Savannah, Salkehatchee-Combahee, Edisto, Cooper-Santee, and Pee Dee River basins (Johnson, 1970; Table 3).**Description:** Shells vary from thin to subsolid, being elliptical to elongate obovate in outline. The anterior and posterior margins are evenly rounded, and the ventral margin is straight to slightly curved in males and often arcuate in females. The dorsal margin is straight. The shell varies from slightly compressed to inflated. Male shells are often subrhomboid with a bluntly pointed posterior margin, while female shells are slightly inflated with a broadly rounded posterior margin. The posterior ridge is broadly rounded. Beaks are only moderately inflated and slightly elevated above the hinge line; sculpture consists of a few double looped ridges. The shell length of adults averages about 60 mm but may reach 100 mm.

The left valve has two slightly compressed pseudocardinal teeth, the anterior tooth being longer and higher; the two lateral teeth are rather short and delicate. The right valve has a single pseudocardinal tooth, sometimes with a dorsal vestigial tooth and a single short lateral tooth. The beak cavity is fairly shallow and open. Adductor muscle

scars are shallow, not impressed; the pallial line is lightly impressed. The periostracum is smooth and shiny, but interrupted by irregular growth lines. Color varies from a greenish yellow to olive brown, the surface covered with rather broad, unbroken to slightly wavy dark green rays over the entire surface. Some individuals have the rays restricted to the posterior area or are occasionally rayless. The nacre color is a bluish white, often becoming iridescent posteriorly (Parmalee and Bogan, 1998).

**Life History and Ecology:** Johnson (1972:238) reported that *Villosa modioliformis* [as *V. vibex*] “[l]ives in small rivers, creeks, and lakes, in mud or soft sand, particularly where rich in vegetable detritus.” Haag et al. (1997) have shown through laboratory fishhost identification experiments for *V. vibex* used three species of bass (*Micropterus*) and *V. modioliformis* might be expected to use bass or other centrarchids as hosts for its glochidia. No information on the breeding season for this species was encountered, but it is assumed to be bradytictic, holding glochidia from September to May, as is the case in other members of the genus *Villosa* (Parmalee and Bogan, 1998).**Status:** This species is proposed as State Endangered in South Carolina (Table 4)**Remarks:** See the remarks under *Villosa constricta* for notes on distinguishing the gravid female *Villosa* species.Based on zoogeography and preliminary DNA analyses, the Atlantic Slope populations and the Mobile Basin populations of *Villosa vibex* are different. We have used the first available name for the Atlantic Slope populations, *Unio modioliformis* and have chosen the common name of Eastern Rainbow.

***Villosa vaughaniana* (Lea, 1838)  
Carolina Creekshell**

Plate 5, Figure 29

**Synonymy:**

*Unio vaughanianus* Lea, 1838; Lea, 1838:5, pl. 3, fig. 5

**Type Locality:** Sawney's Creek, near Camden (Kershaw County), South Carolina.

**General Distribution:** The only published record found for the Carolina Creekshell is Sawney's Creek (Catawba River system), near Camden, South Carolina, its type locality. It is known from creeks in the Pee Dee River Basin in North Carolina (Adams et al., 1990).

**South Carolina Distribution:** The Carolina Creekshell has been collected from creeks in the Cooper-Santee River Basin in North Carolina and the Pee Dee River Basin (Adams et al., 1990; J. Alderman, Pers. Comm. July 2002; Table 3).

**Description:** With the exception of the original description by Lea in 1838, the only other description found for *V. vaughaniana* was in Simpson (1914). The description in Simpson (1914) is accurate, but it was based on two female specimens. The following description of the Carolina Creekshell is based upon twenty specimens (male and female) from Densons Creek, Montgomery County, North Carolina.

The somewhat inflated shell is elliptical in the male and obovate in the female. The largest male was 60 mm long, 33 mm high and 22 mm wide. The largest female was 54 mm long, 30 mm high, and 20 mm wide. The anterior margin of both sexes is rounded. The posterior end is pointed about 2/3 of the way from the ventral margin. In the male, the posterior margin below the point is a gradual curve and above the point it is straight in older males, but a gradual curve that blends

with the dorsal margin in younger individuals. In the female, there is a distinct posterior basal swelling. There can also be a slight constriction between the basal swelling and the posterior point. The ventral margin in males is generally a gentle curve, but in females, it is usually straight. The beaks extend a little above the dorsal margin. The shell is moderately shiny with strong irregular growth lines. The periostracum is a greenish yellow to a dark brownish yellow with numerous, continuous dark green rays covering most of the shell. The overall appearance of the shell can sometimes be a uniform dark brown, but actual color is a dark brownish yellow with numerous dark green rays.

The left valve has two moderately large, triangular, serrated pseudocardinal teeth. The anterior tooth is more pointed and directed slightly towards the anterior end. When the left valve is viewed from the dorsal side both pseudocardinal teeth protrude noticeably. The right valve also has two pseudocardinal teeth. The larger posterior tooth is either like a thick blade or is pointed; it is also usually parallel to the dorsal margin. There are two well-developed lateral teeth in the left valve and one in the right valve. The nacre is shiny, iridescent white or bluish white, frequently with a pale salmon shade deepening toward the ventral margin. Some specimens do not show any salmon shading (Adams et al., 1990).

**Life History:** Most of the Carolina Creekshells Alderman collected were found near the bank in the shaded pools of small streams. They were usually in muddy or silty gravel and in shallow water. Gravid females were found on August 23, 24, and 26, 1987 in Second, Goose, and Lick creeks of the Pee Dee River system. In the streams examined this species was not usually associated

with *V. constricta*, which was usually found in shallow running water (Adams et al., 1990). Fishes recently shown to serve as glochidial hosts for *V. vaughaniana* in laboratory trials include Bluegill (*Lepomis macrochirus*), Green sunfish (*Lepomis cyanellus*), Pumpkinseed (*Lepomis gibbosus*) and Redbreast (*Lepomis auritus*) (Eads et al., 2007).

**Status:** Williams et al. (1993:14) listed as Special Concern. This species is proposed as State Endangered in South Carolina (Table 4).

**Remarks:** See the remarks under *Villosa constricta* for notes on distinguishing the gravid female *Villosa* species.

Keferl (Pers. Comm.) was not able to find any live specimens at the type locality.



## GLOSSARY OF BIVALVE TERMS

- Alate - with an extension or wing on the dorsal edge of the shell.
- Angular (subangulate) - having either the anterior or posterior margins forming a relatively acute (sharp) angle.
- Anterior - front or forward.
- Apophysis – a small pointed shell projection located under the posterior edge of the anterior adductor muscle plate, for the attachment of a muscle. Found in *Mytilopsis* but lacking in *Dreissena*.
- Arcuate - bent in a bow or arched.
- Beak - the raised portion of the dorsal margin of a shell; formed by the embryonic shell around which the rest of the shell develops distally in a concentric manner.
- Beak cavity - the cavity on the inside of each valve leading into the beak, under the interdentum.
- Beak sculpture - raised ridges or undulations on the umbo.
- Biangulate - having two angles.
- Bradyctytic - mussels which are long-term breeders; females retain glochidia in their gills typically over the winter.
- Byssus, byssal threads - a bundle of tough threads secreted by the byssal gland in the foot of a bivalve, used to anchor the bivalve to some hard substrate.
- Cardinal teeth - teeth located between the lateral teeth in Corbiculidae and Sphaeriidae.
- Chevron - shaped like a wide angled V.
- Clinal variation - the graded variation in morphology exhibited by a species in mollusks from headwater areas to the mouth of the highest order stream.
- Compressed (subcompressed) - flattened out or pressed together.
- Concentric - having a common center, such as ridges or loops radiating from the beak of a mussel valve.
- Conspecific - pertaining to individuals or populations of the same species.
- Corrugated - marked by wrinkles or ridges and grooves.
- Crescentic - shaped like the figure of the crescent moon with a convex and a concave edge.
- Decorticate - to remove the outer covering, in mollusks the epidermis.
- Disc - the middle or central portion of the exterior of a valve; distinct from the posterior slope or other areas immediately adjacent to the margin of the valve.
- Discoidal - round and flat like a disc.
- Dorsal - the top or back; in mussels, the hinge area.
- Edentulous - lacking both pseudocardinal and lateral teeth.
- Effuse - spread out broadly.
- Elliptical (subelliptical) - elongated, having the form of an ellipse.
- Elongate - long or extended.
- Emarginate - having a shallow notching at the margin.
- Endangered - this status at the state level includes peripheral forms which may be common in another part of its range, but whose continued existence within the political boundaries of the state is in danger of extirpation. At the national level, this status means the organism is in danger of extinction, and included on or being considered for the U.S. List of Endangered Fauna and Endangered and

- Threatened Plant Species of the United States, under the Endangered Species Act of 1973 (Cooper et al., 1973:x).
- Epidermis - exterior or outside (corneous) layer of the shell.
- Extinct - a species which has no living representatives; all individuals are no longer extant.
- Extirpated - the extinction of a species within a portion of its range.
- Form - an animal with questionable taxonomic status; that is, one exhibiting variation but the extent or degree is not well enough known to determine whether it is a species, subspecies or simply individual or population variation.
- Fusiform - tapering toward each end.
- Gills - a thin plate-like paired structure within the mantle cavity, which serves as a respiratory organ in aquatic mollusks and in female unionids all of the gills or certain portions of the gills serve as the marsupium.
- Globose - globe-like, spherical.
- Glochidium (plural - glochidia) - the bivalve larvae of unionids which are generally parasitic on the gills of fish.
- Gravid female - a female that has embryos in the marsupium.
- Growth lines - compact lines of temporarily arrested growth or rest periods appearing on the epidermis of the shell as a raised or darker concentric line.
- Hinge ligament - an elastic, elongate, corneous structure that unites the two valves dorsally along the hinge plate.
- Holotype - single specimen designated as the "type" by the author in the publication of a new species level taxon.
- Inequilateral - in a bivalve, having the two ends unequal, i.e., one end is wider or thicker than the other.
- Inflated (subinflated) - moderately to greatly inflated.
- Interdentum - a flattened area of the hinge plate between the pseudocardinal and lateral teeth.
- Iridescent - showing colors like those of a rainbow.
- Lachrymose - term describing teardrop-shaped pustules.
- Lateral teeth - the elongated, raised and interlocking structures along the hinge line of the valve.
- Lectotype - one of a series of syntypes that, subsequent to the publication of an original description of a species level taxon, is selected (by publication) to serve as the type specimen for that taxon.
- Lunule - depressed area immediately anterior to the umbo.
- Marsupial swelling - a section of the posterior ventral margin of the female unionid shell which is enlarged or inflated to provide space for expansion of the marsupium with the development of the glochidia.
- Marsupium (marsupial pouch) - in unionids, a brood pouch for eggs and developing glochidia, formed by a restricted portion of the outer gill, the complete outer gill or all four gills.
- Muscle scar - the area of attachment of a muscle to the inside of the shell; e.g., the anterior adductor muscle scar is the location of attachment for the anterior adductor muscle.
- Nacre - the interior iridescent, thin layer of a mussel shell.

- Naiad - formerly a tribe of Mollusca nearly equivalent taxonomically to the family Unionidae, often used as a synonym of unionid.
- Nodule (subnodulous) - a small rounded mass of irregular shape.
- Oblique - slanting; angled, but not horizontal or vertical.
- Obovate - (subobovate) - ovate.
- Orbicular (suborbicular) - having the form of an orb; circular or nearly circular in outline.
- Oval, Ovate (subovate) - egg-shaped, broadly elliptical.
- Pallial line - an indented groove or line approximately parallel with the ventral margin of a bivalve shell that marks the line of muscles attaching the mantle to the shell.
- Paratype - each specimen of a type series other than the holotype designated in the original publication of the taxon.
- Periphery - the external boundary on a surface, edge.
- Periostracum - see epidermis.
- Plications - parallel ridges on the surface of the shell.
- Posterior - hind or rear.
- Posterior ridge - a ridge on the exterior of a mussel shell, extending from the umbo to the posterior margin.
- Posterior slope - the area across the dorsal portion of the valve extending from the umbo to the posterior margin, often above the posterior ridge.
- Pseudocardinal teeth - triangular-shaped hinge teeth near the anterior-dorsal margin of the shell.
- Pustule - small, raised structure on the external or outside surface of the shell (see also tubercle).
- Quadrangle (subquadrangle) - square, or nearly square in outline.
- Radial furrow - a groove or depression; in naiads a groove running from the umbo area toward the shell margin.
- Radiating - proceeding outward from a central point.
- Rare- seldom appearing, occurring widely separated in space; extremely few in number.
- Rectangular - a shape with four sides possessing four right-angles.
- Rest mark - see growth lines.
- Rhomboid (subrhomboid) - having generally four distinct sides, two sides being longer than the others.
- Semicircular - a partial or incomplete circle.
- Serrated - notched or grooved.
- Sexual dimorphism - a condition in which males and females of the same species are morphologically different, usually indicated by an expanded posterior marsupial area in the female in contrast to a more pointed or bluntly rounded area in the male.
- Sinus - a character of some unionids that have a depression above or below the posterior ridge.
- Solid (subsolid) - shells that are thick and heavy.
- Special Concern - This status covers cases where the organism exists in small populations over a broad range, may be over exploited which may pose a threat, the organism are especially vulnerable to specific pressures, or any other reasons identified by experienced researchers (Cooper et al., 1973:x).

- Species - group of interbreeding natural populations that are reproductively isolated from all other such groups.
- Striae - impressed or raised lines on a shell.
- Striate - having striae.
- Subspecies - a geographically defined aggregate of local populations within a species that differ morphologically and/or physiologically from other aggregations of local populations within that species.
- Sulcus (plural - sulci) - a longitudinal furrow or depression.
- Sympatric - pertaining to populations of two or more closely related species that occupy identical or broadly overlapping geographical areas.
- Syntype - one of a series of specimens of the same taxon that formed the material studied by the original author to describe a new species level taxon, from which no type specimen (holotype) was designated.
- Tachytictic - mussels which are short-term breeders; i.e., glochidia are found in the gills of the female only during the summer.
- Taxon - any formal taxonomic unit or category of an organism; e.g., a species or genus.
- Threatened - This status at the state level includes forms that are likely to become Endangered in the foreseeable future if certain conditions are not met. This includes forms that exhibit a considerable decrease in numbers beyond normal population's fluctuations or a documented range contraction, but are not yet considered Endangered. At the national level this applies to the Endangered Species Act of 1973 (Cooper et al., 1973:x).
- Trapezoid (subtrapezoid) - a shape having four distinct sides with two sides parallel.
- Triangular (subtriangular) - a shape having three sides and three angles, like a triangle.
- Truncate (subtruncate) - having the end squared off.
- Tubercle (tuberculate) - small, raised, rounded knob on the outside of the shell.
- Tuberculate - having tubercles on the outside of the shell.
- Type - a designated specimen or specimens of an organism that serves as the basis for the original name and description of any species level taxon.
- Umbo/umbone - the dorsally raised, inflated area of the bivalve shell.
- Unionids - refers to any member of the freshwater bivalve mollusks that belong to the superfamily Unionoidea.
- Undulation - pattern with waves; raised ridges or bars.
- Valve - the right or left half of a mussel (or unionid) shell.
- Ventral - the underside or bottom.

The following volumes, in addition to *Webster's Unabridged Dictionary*, were used to compile the definitions used in the glossary.

- Burch, John B. 1962. *How to know the eastern land snails*, Pictured Key Nature Series, WM. C. Brown Company Publishers, Dubuque, Iowa, 214 pp. 519 fig.
- Burch, John B. 1975. *Freshwater Unionacean Clams (Mollusca: Pelecypoda) of North America*. Malacological Publications, Hamburg, Michigan, 204 pp. 252 fig.
- Leonard, A. Byron. 1954. Handbook of Gastropods in Kansas. *University of Kansas Museum of Natural History Miscellaneous Publication* No. 20, pp. 1-224, 22 pl.
- Murray, Harold D. and A. Byron Leonard. 1962. Handbook of Unionid Mussels in Kansas, *University of Kansas Museum of Natural History Miscellaneous Publication* No. 28, pp. 1-184, 45 pl. 42 fig.
- Parmalee, Paul W. 1967. The Freshwater Mussels of Illinois. *Illinois State Museum, Popular Science Series*, Vol. 8, pp 108, 35 pl. 4 fig.
- Pennak, Robert W. 1964. *Collegiate dictionary of zoology*, The Ronald Press Company, New York. 583 pp.

## LITERATURE CITED

- Adams, W.F., J.M. Alderman, R.G. Biggins, A.G. Gerberich, E.P. Keferl, H.J. Porter, and A.S. Van Devender. 1990. A report on the conservation status of North Carolina's freshwater and terrestrial molluscan fauna. N.C. Wildlife Resources Commission, Raleigh. 246 pp, Appendix A, 37 pp.
- Alderman, J.M. 1988. Tar River spiny mussel annual performance report. in: Annual performance report for the N.C. Wildlife Resources Commission - Wildlife Management, October, 1987-June, 1988. 41:192-218.
- Baker, F.C. 1928. The fresh water Mollusca of Wisconsin. Part II. Pelecypoda. *Bulletin of the Wisconsin Geological and Natural History Survey. University of Wisconsin*. 70(2):i-vi + 1-495.
- Bereza, D.J. and S.L.H. Fuller. 1975. Notes on "*Lampsilis*" *ochracea* (Say) (Mollusca: Bivalvia). [abstract]. *The ASB Bulletin* 22(2):42.
- Bosc, L.A.G. 1801. *Histoire naturelle des Coquilles, Contenant leur description, les moeurs de animaux qui les habitent et leurs usages*. Vol. 3. de l'Imprimerie de Crapelet, Paris.
- Burch, J.B. 1975. *Freshwater Unionacean clams (Mollusca: Pelecypoda) of North America*. Rev. ed. Malacological Publications. Hamburg, Michigan. 204 pp.
- Burch, J.Q. 1944. Checklist of west American Mollusks. *Minutes. Conchological Club of Southern California* 38:18.
- Clarke, A.H. 1973. The freshwater molluscs of the Canadian Interior Basin. *Malacologia* 13(1-2):1-509.
- Clarke, A.H. 1981a. *The freshwater molluscs of Canada*. National Museum of Natural Sciences, National Museum of Canada, Ottawa, Canada. 446 pp.
- Clarke, A.H. 1981b. The tribe Alasmidontini (Unionidae: Anodontinae), Part I. *Pegias*, *Alasmidonta* and *Arcidens*. *Smithsonian Contributions to Zoology* No. 326. iii + 101 pp.
- Clarke, A.H. 1985. The tribe Alasmidontini (Unionidae: Anodontinae), Part II: *Lasmigona* and *Simpsonaias*. *Smithsonian Contributions to Zoology* No. 399. iii + 75 pp.
- Clarke, A.H. 1992. Note regarding *Elliptio judithae* Clarke, 1986. *Malacology Data Net* 3(1-4):98.
- Clench, W.J., and R.D. Turner. 1956. Freshwater mollusks of Alabama, Georgia, and Florida from the Escambia to the Suwannee River. *Bulletin of the Florida State Museum, Biological Sciences* 1(3):97-239, pls. 1-9.
- Conrad, T.A. 1834. *New freshwater shells of the United States, with coloured illustrations; and a monograph of the genus Anculotus of Say; also a synopsis of the American naiades*. J. Dobson, 108 Chestnut Street, Philadelphia, Pennsylvania. 1-76, 8 pls.
- Conrad, T.A. 1835a. Additions to, and corrections of, the Catalogue of species of American Naiades, with descriptions of new species and varieties of Fresh Water Shells. Pp. 1-8, pl. 9. Appendix to: *Synoptical table to New freshwater shells of the United States, with coloured illustrations; and a monograph of the genus Anculotus of Say; also a synopsis of the American naiades*. J. Dobson, 108 Chestnut Street, Philadelphia, Pennsylvania.
- Conrad, T.A. 1835b-1840. *Monography of the Family Unionidae, or naiades of Lamarck, (fresh water bivalve shells) or North America, illustrated by figures drawn on stone from nature*. J. Dobson, 108 Chestnut Street, Philadelphia, Pennsylvania. 1835, 1:1-12, [pp. 13-16 not published], pls. 1-5; 1836, 2:17-24, pls. 6-10; 1836, 3:25-32, pls. 11-15; 1836, 4:33-40, pls. 16-19; 1836, 5:41-48, pls. 21-25; 1836, 6:49-56, pls. 26-30; 1836, 7:57-64, pls. 32-36; 1837, 8:65-72, pls. 36-40; 1837, 9:73-80, pls. 41-45; 1838, 10:81-94, 2i, pls. 46-51; 1838, 11:95-102, pls. 52-57; 1840, 12:103-110, pls. 58-60; [1840], 13:111-118, pls. 61-65.
- Counts, C.L. III. 1986. The zoogeography and history of the invasion of the United States by *Corbicula fluminea* (Bivalvia: Corbiculidae). *American Malacological Bulletin Special Edition* No. 2:7-39.
- Davenport, D. and M. Warmouth. 1965. Notes on the relationship between the freshwater mussel *Anodonta imbecilis* Say and the alewife *Pomolobus pseudoharengus* (Wilson). *Limnology and Oceanography* 10 supplement: R74-R78.
- Davis, G.M. and S.L.H. Fuller. 1981. Genetic relationships among recent Unionacea (Bivalvia) of North America. *Malacologia* 20(2):217-253.
- Eads, C.B., A.E. Bogan and J.F. Levine. 2006. Status and life-history of *Villosa constricta* (Conrad, 1838) (Notched Rainbow), in the Upper Neuse River basin, North Carolina. *Southeastern Naturalist* 5(4):649-660.
- Eads, C.B., M.E. Raley, E.K. Schubert, A.E. Bogan, and J.F. Levine. 2007. Propagation and culture of freshwater mussels for release into North Carolina waters. Final report submitted to North Carolina Department of Transportation. 87 pp.

- Fuller, S.L.H. 1973. *Fusconaia masoni* (Conrad 1834) (Bivalvia: Unionacea) in the Atlantic drainage of the Southeastern United States. *Malacological Review* 6:105-117.
- Fuller, S.L.H. 1974. Clams and mussels (Mollusca: Bivalvia). Pp. 215–273, In: C. W. Hart, Jr., and S. L. H. Fuller, editors. *Pollution Ecology of Freshwater Invertebrates*. Academic Press, New York. 389 pp.
- Fuller, S.L.H. 1977. Freshwater and terrestrial mollusks. In: John E. Cooper, Sarah S. Robinson, John B. Fundeburg (eds.) *Endangered and Threatened Plants and Animals of North Carolina*. North Carolina State Museum of Natural History, Raleigh.
- Fuller, S.L.H. and R.H. Hartenstine. 1960. *Anodonta imbecillis* Say (Bivalvia: Unionidae) in the Delaware River Basin. *The Nautilus* 94(1):4.
- Gmelin, J.F. 1791. *Systema Naturae*. 13<sup>th</sup> edition. Leipzig. Vol.1 part 6:3021-3910.
- Gray, E.S., W.A. Lellis, J.C. Cole, and C.S. Johnson. 1999. Hosts of *Pyganodon cataracta* (eastern floater) and *Strophitus undulatus* (squawfoot) from the upper Susquehanna River basin, Pennsylvania. *Triannual Unionid Report* 18:6.
- Haag, W.R., M.L. Warren, Jr., and M. Shillingsford. 1997. Identification of hostfishes for *Lampsilis altilis* and *Villosa vibex*. *Triannual Unionid Report* 12:13.
- Haas, F. 1969. Superfamilia Unionacea. *Das Tierreich* (Berlin) 88:x + 663 pp.
- Heard, W.H. 1975. Determination of the endangered status of freshwater clams of the Gulf and Southeastern States. Term. Rpt. Office Endangered. Species, Bureau of Sport Fisheries and Wildlife, U.S. Dept. Int.
- Hoeh, W.R. 1991. The evolution and consequences of simultaneous hermaphroditism in the freshwater mussel genus *Utterbackia* (Bivalvia: Unionidae). Unpublished Dissertation in Biology, University of Michigan, Ann Arbor. 97 pp.
- Hoggarth, M.A. 1999. Description of some of the glochidia of the Unionidae (Mollusca: Bivalvia). *Malacologia* 41(1):1-118.
- Hove, M.C. 1995. Early life history research on the squawfoot, *Strophitus undulatus*. *Triannual Unionid Report* 7:28–29.
- Hove, M.C., R.A. Engelking, M.E. Peteler, and E.M. Peterson, 1995. *Anodontoides ferussacianus* and *Anodonta imbecillis* host suitability tests. *Triannual Unionid Report* 6:22.
- Johnson, R.I. 1946. *Anodonta implicata* Say. *Occasional Papers on Mollusks, Harvard University, Museum of Comparative Zoology* 1:109-116.
- Johnson, R.I. 1947. *Lampsilis cariosa* Say and *Lampsilis ochracea* Say. *Harvard University, Museum of Comparative Zoology, Occasional Papers on Mollusks*: 1(12):145-156.
- Johnson, R.I. 1948. the authorship of *Elliptio complanata*. *The Nautilus* 62(1):36.
- Johnson, R.I. 1967. *Carunculina pulla* (Conrad), an overlooked Atlantic drainage unionid. *The Nautilus* 80:177-131.
- Johnson, R.I. 1970. The systematics and zoogeography of the Unionidae (Mollusca: Bivalvia) of the southern Atlantic Slope region. *Bulletin of the Museum of Comparative Zoology* 140(6):263-449.
- Johnson, R.I. 1972. The Unionidae (Mollusca: Bivalvia) of Peninsular Florida. *Bulletin of the Florida State Museum, Biological Sciences* 16(4):181–249 + addendum.
- Johnson, R.I. 1977. Monograph of the genus *Medionidus* (Bivalvia: Unionidae) mostly from the Apalachicola region, southeastern United States. *Occasional Papers on Mollusks, Harvard University, Museum of Comparative Zoology* 4(56):161-187.
- Johnson, R.I. 1984. A new mussel, *Lampsilis (Lampsilis) fullerkeri* (Bivalvia: Unionidae) from Lake Waccamaw, Columbus County, North Carolina, with a list of the other Unionid species of the Waccamaw River system. *Occasional Papers on Mollusks, Harvard University, Museum of Comparative Zoology* 4:305-319.
- Kat, P.W. 1983. Morphologic divergence, genetics, and speciation among *Lampsilis* (Bivalvia: Unionidae). *Journal of Molluscan Studies* 49:133-145.
- Keferl, E. P., and R. M. Shelley. 1988. The final report on a status survey of the Carolina Heelsplitter, *Lasmigona decorata* and the Carolina Elktoe, *Alasmidonta robusta*. U. S. Department of the Interior, Fish and Wildlife Service, 27 pages, 19 figures, 7 tables.
- Lamarck, J.B.P.A. 1815–1822. *Histoire naturelle des Animaux sans Vertébrés*. 8 volumes.
- Layzer, J.B., and R.M. Anderson. 1991. Fishhosts of the endangered Cumberland bean pearly mussel (*Villosa trabalis*). *NABS Bulletin* 8(1):110.
- Layzer, J.B., and R.M. Anderson. 1992. Impacts of the coal industry on rare and endangered aquatic organisms of the upper Cumberland River Basin. Final Report to Kentucky Department of Fish and Wildlife Resources, Frankfurt, KY, and Tennessee Wild Resources Agency, Nashville, TN.

- Lea, I. 1828. Description of six new species of the genus *Unio*, embracing the anatomy of the oviduct of one of them, together with some anatomical observations on the genus. *Transactions of the American Philosophical Society* 3[New Series]:259–273, pls. 3–6.
- Lea, I. 1829. Description of a new genus of the family of naiades, including eight species, four of which are new; also the description of eleven new species of the genus *Unio* from the rivers of the United States: with observations on some of the characters of the naiades. *Transactions of the American Philosophical Society* 3[New Series]:403–457, pls. 7–14.
- Lea, I. 1831. Observations on the naiades, and descriptions of new species of that and other families. *Transactions of the American Philosophical Society* 4[New Series]:63–121, pls. 3–18.
- Lea, I. 1834. Observations on the naiades; and descriptions of new species of that, and other families. *Transactions of the American Philosophical Society* 5[New Series]:23–119, pls. 1–19.
- Lea, I. 1838. Description of new freshwater and land shells. *Transactions of the American Philosophical Society* 6[New Series]:1–154, pls. 1–24.
- Lea, I. 1840. Descriptions of new fresh water and land shells. *Proceedings of the American Philosophical Society* 1(13):284–289.
- Lea, I. 1852. Descriptions of new species of the family Unionidae. *Transactions of the American Philosophical Society* 10: 253–294, pls. 12–29.
- Lea, I. 1863. Descriptions of twenty-four new species of Unionidae of the United States. *Proceedings of the Academy of Natural Sciences of Philadelphia* 15:191–194.
- Lefevre, G., and W.C. Curtis. 1910. Experiments in the artificial propagation of fresh-water mussels. *Bulletin of the Bureau of Fisheries* 28(1908):615–626. Issued separately as U.S. Bureau of Fisheries Document 671.
- Lightfoot, J. 1786. *A catalogue of the Portland Museum, lately the property of the duchess Dowager of Portland, deceased, which will be sold at auction by Mr. Skinner and Co.* London. vii + 194 pp.
- Luo, M. 1993. Hostfishes of four species of freshwater mussels and development of an immune response. Unpublished M.S. thesis in Biology, Tennessee Technological University, Cookeville. v + 32 pp.
- Mathiak, H.A. 1979. *A river survey of the unionid mussels of Wisconsin 1973–1977.* Sand Shell Press. Horicon, Wisconsin. 75 pp.
- McMahon, R.F. and A.E. Bogan. 2001. Mollusca: Bivalvia. Pp. 331–429. IN: J.H. Thorpe and A.P. Covich. *Ecology and classification of North American freshwater invertebrates.* 2<sup>nd</sup> edition. Academic Press.
- Morrison, J.P.E. 1976. Species of the genus *Unio*. *Bulletin of the American Malacological Union, Inc.* 1976:10–11.
- Neddeau, E.J., M.A. McCollough and B.I. Swartz. 2000. *The freshwater mussels of Maine.* Maine Department of Inland Fisheries and Wildlife, Augusta.
- Neves, R.J. 1991. Mollusks. Pp. 251–320, In: K. Terwilliger, editor. *Virginia's Endangered Species. Proceedings of a Symposium.* Department of Game and Inland Fisheries, Commonwealth of Virginia. 672 pp.
- O'Dee, S.H., and G.T. Watters. 2000. New or confirmed host identification for ten freshwater mussels. pp. 77–82 in R.A. Tankersley, D.I. Warmolts, G.T. Watters, B.J. Armitage, P.D. Johnson, and R.S. Butler (eds.). *Freshwater Mollusk Symposia Proceedings. Part I. Proceedings of the Conservation, Captive Care and Propagation of Freshwater Mussels Symposium.* Ohio Biological Survey Special Publication, Columbus.
- Ortmann, A.E. 1909. The breeding season of Unionidae in Pennsylvania. *The Nautilus* 22(9):91–95; 22(10):99–103.
- Ortmann, A.E. 1914. Studies in naiades (cont.). *The Nautilus* 28(2):20–22; 28(3):28–34; 28(4):41–47; 28(5[sic]):65–69.
- Ortmann, A.E. 1919. A monograph of the naiades of Pennsylvania. Part III: Systematic account of the genera and species. *Memoirs of the Carnegie Museum* 8(1):xvi–384, 21 pls.
- Parmalee, P.W. and A.E. Bogan 1998. *Freshwater mussels of Tennessee.* University of Tennessee Press, Knoxville.
- Porter, H.J. 1985. Molluscan census and ecological interrelationships. Rare and endangered fauna of Lake Waccamaw, of Lake Waccamaw, North Carolina watershed system. North Carolina endangered species restoration final report - period: 1978–1981. Prepared for the N. C. Wildl. Res. Comm. Univ. N. C. Inst. Mar. Sci., Morehead City, NC. Vol. 1–2.

- Porter, H.J., and K.J. Horn. 1980. Freshwater mussel glochidia from Lake Waccamaw, Columbus County, North Carolina. *Bulletin of the American Malacological Union, Inc.* 1980:13-17.
- Porter, H.J., and K.J. Horn. 1983. Habitat distribution of sympatric populations of selected lampsiline species (Bivalvia: Unionoida) in the Waccamaw Drainage of eastern North and South Carolina. *American Malacological Bulletin* 1:61-66.
- Porter, H.J., and K.J. Horn. 1984. Freshwater Mollusca of upper Waccamaw River, North and South Carolina. (Abstr.) *Journal of the Elisha Mitchel Scientific Society* 97:270.
- Rafinesque, C.S. 1820. Monographie des coquilles bivalves fluviatiles de la Rivière Ohio, contenant douze genres et soixante-huit espèces. *Annales générales des sciences Physiques, a Bruxelles* 5(5):287–322, pls. 80–82.
- Rafinesque, C.S. 1831. *Continuation of a monograph of the bivalve shells of the river Ohio, and other rivers of the western states. By Prof. C. S. Rafinesque. (Published at Brussels, September, 1820) Containing 46 species, from No. 76 to no. 121. Including an appendix on some bivalve shells of the rivers of Hindustan, with a supplement on the fossil bivalve shells of the Western states, and the Tulosites, a new genus of fossils.* Philadelphia, Pennsylvania. 8 pp.
- Say, T. 1817. Article Conchology. In: W. Nicholson, editor. *American Edition of the British Encyclopedia or Dictionary of Arts and Sciences, Comprising an Accurate and Popular View of the Present Improved State of Human Knowledge.* Vol. 2. 1st ed. No pagination. Pls. 1–4. Samuel A. Mitchel and Horace Ames, Philadelphia, Pennsylvania.
- Say, T. 1829. Descriptions of some new terrestrial and fluviatile shells of North America. *The Disseminator of Useful Knowledge; containing hints to the youth of the United States, from the School of Industry*, New Harmony, Indiana 2(19):291–293, 23 September 1829; 2(20):308–310 7 October 1829; 2(21):323–325, 21 October 1829; 2(22):339–341, 4 November 1829; 2(23):355–356, 18 November 1829.
- Shelley, R.M. 1987. Unionid mollusks from the upper Cape Fear River Basin, North Carolina, with a comparison of the faunas of the Neuse, Tar, and Cape Fear drainages (Bivalvia: Unionacea). *Brimleyana* 13:67-89.
- Simpson, C.T. 1900. Synopsis of the naiades, or pearly fresh-water mussels. *Proceedings of the United States National Museum* 22(1205):501–1044.
- Simpson, C.T. 1914. *A descriptive catalogue of the naiades, or pearly fresh-water mussels.* Parts I–III. Bryant Walker, Detroit, Michigan, xii + 1540 pp.
- Smith, D.G. 2000. On the taxonomic placement of *Unio ochraceus* Say, 1817 in the genus *Ligumia* (Bivalvia: Unionidae). *The Nautilus* 114(4):155-160.
- Stansbery, D.H. 1976. The status of endangered fluviatile mollusks in central North America. II. *Pegias fabula* (Lea, 1838). Ohio State University Research Foundation, [report for the U.S. Department of the Interior, Fish and Wildlife Service]. Final No. 2, 6 pp., 1 map, 2 figs. Also listed as: Ohio State University, Museum of Zoology Reports 1976(10):1–8, 1 pl., 1 map.
- Sterki, V. 1898. Anodonta imbecillis, hermaphroditic. *The Nautilus* 12(8):87–88.
- Stern, E.M., and D.L. Felder. 1978. Identification of hostfishes for four species of freshwater mussels (Bivalvia: Unionidae). *The American Midland Naturalist* 100(1):233–236.
- Stiven, A.E. and J. Alderman. 1992. Genetic similarities among certain freshwater mussel populations of the *Lampsilis* genus in North Carolina. *Malacologia* 34(1-2):355-369.
- Strayer, D.L. and K.J. Jirka. 1997. The pearly mussels of New York State. *New York State Museum Memoir* 26. 113 pp, 27 color plates.
- Tedla, S. and C.H. Fernando. 1969. Observations on the glochidia of *Lampsilis radiata* (Gmelin) infesting yellow perch, *Perca flavescens* (Mitchill) in the Bay of Quinte, Lake Ontario. *Canadian Journal of Zoology* 47: 705-712.
- Trdan, R. J., and W.R. Hoeh. 1982. Eurytopic host use by two congeneric species of freshwater mussel (Pelecypoda: Unionidae: Anodonta). *The American Midland Naturalist* 108:381–388.
- Tucker, M.E. 1927. Morphology of the glochidium and juvenile of the mussel *Anodonta imbecillis*. *Transactions of the American Microscopical Society* 46(4):286–293.
- U.S. Fish and Wildlife Service. 1997. Recovery plan for Carolina Heelsplitter (*Lasmigona decorata*) Lea. U.S. Fish and Wildlife Service, Atlanta, GA. 30 pp.
- U.S. Fish and Wildlife Service. 2002. Endangered and Threatened Wildlife and Plants: Designation of Critical habitat for the Carolina Heelsplitter. *Federal Register* 67(127)[July 2, 2002]: 44502-44522.
- Utterback, W.I. 1915. The naiades of Missouri. *The American Midland Naturalist* 4(3):41–53; 4(4):97–152; 4(5):181–204, 4(6):244–273.



- Utterback, W.I. 1916. The naiades of Missouri. *The American Midland Naturalist* 4(7):311–327; 4(8):339–354; 4(9):387–400; 4(10):432–464, pls. 1–28.
- Wick, P.C. and A.D. Huryn. 2002. Biology and natural history of *Lampsilis cariosa* and *Leptodea ochracea* (Unionidae) in Maine. [Abstract] *Bulletin of the North American Benthological Society* 19(1):175–176.
- Vidrine, M.F. 1980. Systematics and coevolution of unionicolid water-mites and their unionid hosts in the eastern United States. Ph.D. dissertation, Univ. of Southeastern Louisiana, Lafayette. 661 pp. + i–xviii.
- Watters, G.T. 1994. An annotated bibliography of the reproduction and propagation of the Unionoidea (Primarily of North America). *Ohio Biological Survey Miscellaneous Contributions* No. 1, 158 pp.
- Watters, G.T. 1997. Surrogate hosts: transformation on exotic and non-piscine hosts. *Triannual Unionid Report* 11:35.
- Watters, G.T., S.W. Chordas, S.F. O'Dee, and J. Reiger. 1999. Host identification studies for six species of Unionidae. *Abstracts, Symposium of the Freshwater Mollusk Conservation Society*, Chattanooga, Tennessee.
- Watters, G.T. and S.H. O'Dee 1997. Identification of potential host: *Elliptio fisheriana* (Lea, 1838), *Fusconaia masoni* (Conrad, 1834), *Fusconaia flava* (Rafinesque, 1820), and *Pleurobema clava* (Lamarck, 1819). *Triannual Unionid Report* No. 13:38.
- Wick, P.C. and A.D. Huryn. 2002. Biology and natural history of *Lampsilis cariosa* and *Leptodea ochracea* (Unionidae) in Maine. [Abstract] *Bulletin of the North American Benthological Society* 19(1):175–176.
- Wicklow, B.J. 1999. Life history of the endangered dwarf wedgemussel, *Alasmodonta heterodon*: glochidial release, phenology, mantle display behavior, and anadromous fishhost relationship. Abstract, Symposium of the Freshwater Mollusk conservation Society, First Annual Meeting, Chattanooga, Tennessee.
- Wicklow, B.J. and P.M. Beisheim. 1998. Life history studies of the squawfoot mussel *Strophitus undulatus* in the Piscataquog River watershed, New Hampshire. Abstracts. Freshwater Mussel Symposium: conservation, captive care, and propagation, Columbus, Ohio.
- Wicklow, B.J. and L.D. Richards. 1995. Determination of hostfish species for glochidia of the endangered freshwater mussel *Alasmodonta varicosa*. Fifth Annual Northeastern Freshwater Mussel Meeting. U.S Fish and Wildlife Service. Concord, New Hampshire.
- Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of the freshwater mussels of the United States and Canada. *Fisheries* 18(9):6–22.

## INTRODUCTION TO THE LITERATURE ON THE FRESHWATER BIVALVES OF SOUTH CAROLINA

- Alderman, J.M. 1991. North Carolina Status surveys for *Fusconaia masoni*, *Elliptio lanceolata* and *Toxolasma pullus*. Nongame Project Report to U.S. Fish and Wildlife Service and Nongame and Endangered Wildlife Program, Div. of Wildlife Management, N.C. W. R. C. 54 pp.
- Alderman, J.M. 1995? Status survey for the Savannah Lilliput, *Toxolasma pullus* (Conrad, 1838). Report to the U.S. Fish and Wildlife Service. Cooperative Agreement No. 14-16-004-89-954. 107 pp.
- Alderman, J.M. 1995. Freshwater mussel inventory of the Stevens Creek Subbasin, Long Creek Ranger District, Sumter National Forest, South Carolina. A report prepared for the U.S. Forest Service.
- Alderman, J.M. 1998. Survey for the endangered Carolina heelsplitter (*Lasmigona decorata*) in South Carolina. Report submitted to the South Carolina Dept. of Natural Resources.
- Alderman, J.M. 2002. *Lasmigona decorata* monitoring and habitat evaluation: interim report. Report to the U.S. Forest Service, Francis Marion and Sumter National Forests. 22 pp.
- Bartram, W. 1791. *Travels through North and South Carolina, Georgia, east and west Florida, etc.*
- Bates, J.M. 1966. A new species of *Carunculina* (Unionidae: Pelecypoda) from the Savannah River, South Carolina. *Occasional Papers of the Museum of Zoology, University of Michigan* No. 646. 9 pp. + 1 plate.
- Britton, J.C., and S.L.H. Fuller. 1980. Freshwater bivalve Mollusca (Unionidae, Sphaeriidae, Corbiculidae) of the Savannah River Plant, South Carolina. Savannah River Plant National Environmental Research Park Program, U.S. Department of Energy SRO-NERP-3. 1980. 37 pp. + 5 maps.
- Burch, J.B. 1973. Freshwater Unionacean clams (Mollusca: Pelecypoda) of North America. *Biota of Freshwater Ecosystems. Identification Manual* 11. U.S. Environmental Protection Agency. 176 pp.
- Burch, J.B. 1975a. *Freshwater Unionacean clams (Mollusca: Pelecypoda) of North America*. [Revised Edition]. Malacological Publications. Hamburg, Michigan. 204 pp.
- Burch, J.B. 1975b. *Freshwater sphaeriacean clams (Mollusca: Pelecypoda) of North America*. Malacological Publications, Hamburg, Michigan. pp. xi, 1-96.
- Cahoon, L.B. and D.A. Owen. 1996. Can suspension feeding by bivalves regulate phytoplankton biomass in Lake Waccamaw, North Carolina. *Hydrobiologia* 325(3):193-200.
- Clarke, A.H. 1981b. The tribe Alasmidontini (Unionidae: Anodontinae), Part I. *Pegias*, *Alasmidonta*, and *Arcidens*. *Smithsonian Contributions to Zoology* No. 326. iii + 101 pp.
- Clarke, A.H. 1985. The tribe Alasmidontini (Unionidae: Anodontinae), Part II: *Lasmigona* and *Simpsonaias*. *Smithsonian Contributions to Zoology* No. 399. iii + 75 pp.
- Coney, C.C., G.C. DeCamp, and M.E. Harrelson. 1983. The Bivalvia of the Great Pee Dee River in Florence County, South Carolina. (Abstract). *Bulletin of the South Carolina Academy of Science* 45:87.
- Coney, C.C., S.L.H. Fuller, G.M. Davis, R.H. Moore, and J.M. Shipley 1983. Adaptive radiation and convergence in the Cape Fear River basin Unionidae (Mollusca: Bivalvia). *Bulletin of the South Carolina Academy of Science* 45:37-38.
- Coney, C.C., R. H. Moore, and S.P. Kool. 1981. comparative shell morphometrics and soft anatomy in disjoint populations of *Elliptio lanceolata* (Lea, 1828) complex. *Bulletin of the American Malacological Union for 1981* pp. 37.
- Coney, C.C., R. H. Moore, and S.P. Kool. 1983. Organ growth in bivalves: an analysis of growth patterns in a topotypic population of *Elliptio lanceolata* (Lea, 1828). *American Malacological Bulletin* 1:94-95.
- Davis, G.M. 1983a. Relative roles of molecular genetics, anatomy, morphometrics and ecology in assessing relationships among North American Unionidae (Bivalvia). pp. 193-222 IN: G.S. Oxford and D. Rollinson (eds.). Protein polymorphism: Adaptive and taxonomic significance. *Systematics Association Special Volume* No. 24, Academic Press.
- Davis, G.M. 1983b. Genetic relationships among North American Pleurobemini and Amblemini (Bivalvia: Unionidae) with emphasis on *Elliptio*, *Unio*, *Elliptioideus*, and *Quincuncina*. (Abstract). *American Malacological Bulletin* 1:109-110.
- Davis, G.M. and S.L.H. Fuller. 1981. Genetic relationships among recent Unionacea (Bivalvia) of North America. *Malacologia* 20(2):217-253 + 2 appendices.

- Davis, G.M. W.H. Heard, S.L.H. Fuller, and C. Hesterman. 1981. Molecular genetics and speciation in *Elliptio* and its relationship to other taxa of North American Unionidae (Bivalvia). *Biological Journal of the Linnean Society* 15:131-150.
- Davis, G.M. and M. Mulvey 1993. Species status of Mill Creek *Elliptio*. Publication of the Savannah river site National Environmental Research Park Program. SRO-NERPO-22. 58 pp.
- Didonato, G.T. and A.E. Stiven. 2000. Three year variation in shell growth of the mussel, *Elliptio waccamawensis* (Lea), in Lake Waccamaw, a bay lake in North Carolina. *The Journal of the Elisha Mitchell Scientific Society* 116(4):324-333.
- Fuller, S.L.H. 1972. An undescribed structural feature in the marsupium of *Elliptio lanceolata* (Lea, 1828) (Unionidae). *The Nautilus* 86:85-86.
- Fuller, S.L.H. 1973. *Fusconaia masoni* (Conrad, 1834) (Bivalvia: Unionacea) in the Atlantic Drainage of the southeastern United States. *Malacological Review* 6:105-117.
- Fuller, S.L.H. 1974. A misunderstood fresh-water mussel from the Savannah River system in South Carolina (Bivalvia: Unionidae). (Abstract). *ASB (Association of Southeastern Biologists) Bulletin* 21(2):55-56.
- Fuller, S.L.H. 1979. Freshwater mussels (Mollusca: Bivalvia: Unionidae). *Proceedings of the South Carolina Endangered Species Symposium*. 1:114-125.
- Fuller, S.L.H., and J.W. Richardson. 1977. Amensalistic competition between *Corbicula manilensis* (Philippi), the Asiatic clam (Corbiculidae), and fresh-water mussels (Unionidae) in the Savanna River of Georgia and South Carolina (Mollusca: Bivalvia). (Abstract). *ASB Bulletin* 24(2):52.
- Fuller, S.L.H., F.W. Grimm, T.L. Laavy, H.J. Porter, and A.H. Shoemaker. 1980. Status report: fresh water and terrestrial mollusks. pp. 55-59 in D. M. Forsythe and W. B. Ezell, Jr.(eds.) *Proceedings of the First South Carolina Endangered Species Symposium*, South Carolina Wildlife and Marine Resources Department, Columbia, SC 201 pp.
- Gibbes, L.R. 1848. Molluscous animals of South Carolina. *Geology of South Carolina* pp. xix-xxii. Appendix.
- Horn, K.J. and H.J. Porter. 1981. Correlations of shell shape of *Elliptio waccamawensis*, *Leptodea ochracea*, and *Lampsilis* sp. (Bivalvia, Unionidae) with environmental factors in Lake Waccamaw, Columbus County, North Carolina. *The Bulletin of the American Malacological Union, Inc.* 1981:1-3.
- Johnson, R.I. 1967. *Carunculina pulla* (Conrad), an overlooked Atlantic drainage unionid. *The Nautilus* 80(4):127-131.
- Johnson, R.I. 1970. The systematics and zoogeography of the Unionidae (Mollusca: Bivalvia) of the southern Atlantic Slope Region. *Bulletin of the Museum of Comparative Zoology* 140(6):263-449.
- Johnson, R.I. 1997. Comments on "the final report" of a massive search for *Lasmigona decorata* (Lea, 1852) and *Alasmidonta robusta* Clarke, 1981 (Bivalvia: Unionidae) from the Carolinas. *Occasional-Papers-on-Mollusks-Museum-of-Comparative-Zoology-Harvard-University*. 5(71):371-378.
- Kat, P.W. 1983. Morphologic divergence, genetics, and speciation among *Lampsilis* (Bivalvia: Unionidae). *Journal of Molluscan Studies* 49(2):133-145.
- Keferl, E.P. 1987. A preliminary report on a status survey of the Carolina heelsplitter, *Lasmigona decorata* and the Carolina elktoe, *Alasmidonta robusta*. Report to U.S. Fish and Wildlife Service, Asheville and North Carolina State Museum of Natural History. 15 pp, appended field station data.
- Keferl, E.P. 1991. A status survey for the Carolina heelsplitter (*Lasmigona decorata*), a freshwater mussels endemic to the Carolinas. Report prepared for U.S. Fish and Wildlife Service and North Carolina Wild Resources Commission. 29 pp + data sheets and maps.
- Keferl, E.P. and R.M. Shelley. 1988. The final report on a status survey of the Carolina heelsplitter, *Lasmigona decorata* and the Carolina elktoe, *Alasmidonta robusta*. Report to the U.S. Fish and Wildlife Service, Asheville, NC. 46 pp.
- Kool, S.P., C.C. Coney, D.H. Stansbery, and A.E. Bogan. 1981. Fresh-water mollusks of the Little Pee Dee River in South Carolina. (Abstract). *Bulletin of the South Carolina Academy of Science* 43:93.
- Lea, I. 1842. On fresh water and land shells (cont.). *Proceedings of the American Philosophical Society* 2(23):224-225.
- Lea, I. 1857. Description of twelve new species of naiades from North Carolina. *Proceedings of the Academy of Natural Sciences of Philadelphia* 9:85-86.
- Lea, I. 1858. Descriptions of new species of Unio, from Tennessee, Alabama, and North Carolina. *Proceedings of the Academy of Natural Sciences of Philadelphia* 10:40-41.

- Lea, I. 1859. Descriptions of seven new species of Uniones from South Carolina, Florida, Alabama and Texas. *Proceedings of the Academy of Natural Sciences of Philadelphia* 11(1859):154-155.
- Lea, I. 1868. Descriptions of seven new species of Unio from North Carolina. *Proceedings of the Academy of Natural Sciences of Philadelphia* 20:160-161.
- Mazýck, W.G. 1913. Catalog of Mollusca of South Carolina. Contributions from the Charleston Museum 2:xvi + 39 pp.
- Moore, R.H., and C.C. Coney. 1983. Aquatic fauna of the Congaree Swamp National Monument. *Bulletin of the South Carolina Academy of Science* 45:103.
- Moore, R.H., C.C. Coney, and M.R. Creitz. 1983. Comparisons of morphometric and soft anatomy characters between topotypic populations of *Elliptio lanceolata* (Lea, 1828) and *E. angustata* (Lea, 1831). *American Malacological Bulletin* 1:95.
- Mulvey, M., and G.M. Davis. 1993. Morphological and electrophoretic approaches to the identification of *Elliptio* species on the Savanna River site, South Carolina. (Abstract). pp. 183 in K.S. Cummings, A.C. Buchanan, and L.M. Koch. (eds.). Conservation and Management of Freshwater Mussels. Proceedings of a UMRCC Symposium, 12-14 October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois. 189 pp.
- Porter, H.J. 1985. Rare and endangered fauna of Lake Waccamaw, North Carolina watershed system. vols. 1 & 2. North Carolina Endangered Species Restoration. N.C. Wildlife Resources Commission, Raleigh, pp. 1-358.
- Porter, H.J., and K.J. Horn. 1981. Freshwater Mollusca of upper Waccamaw River, North and South Carolina. (Abstract). *Journal of the Elisha Mitchell Scientific Society* 97:270.
- Porter, H.J., and K.J. Horn. 1981. Freshwater mussel glochidia from Lake Waccamaw, Columbus County, North Carolina. *Bulletin of the American Malacological Union, Inc.* 1980:13-17.
- Porter, H.J., and K.J. Horn. 1983. Habitat distribution of sympatric populations of selected lampsiline species (Bivalvia: Unionoida) in the Waccamaw drainage of eastern North and South Carolina. *American Malacological Bulletin* 1:61-68.
- Porter, H.J., and K.J. Horn. 1981. Freshwater Mollusca of upper Waccamaw River, North and South Carolina. (Abstract). *Journal of the Elisha Mitchell Scientific Society* 97:270.
- Porter, H.J., and K.J. Horn. 1983. Habitat distribution of sympatric populations of selected lampsiline species (Bivalvia: Unionoida) in the Waccamaw drainage of eastern North and South Carolina. *American Malacological Bulletin* 1:61-66.
- Rehder, H.A. 1949. Some land and freshwater mollusks from the coastal region of Virginia and North and South Carolina. *The Nautilus* 62:121-126.
- Shelley, R.M. 1972. In defense of naiades. *Wildlife in North Carolina*. March:1-7.
- Stansbery, D.H., and W.J. Clench. 1978. The Mollusca of Lake Waccamaw in North Carolina. (Abstract). *Bulletin of the American Malacological Union, Inc.* 1978:63.
- Stiven, A.E., and J. Alderman. 1992. Genetic similarities among certain freshwater mussel populations of the *Lampsilis* genus in North Carolina. *Malacologia* 34(1-2):355-369.
- U.S. Fish and Wildlife Service. 1997. Recovery plan for Carolina Heelsplitter (*Lasmigona decorata*) Lea. U.S. Fish and Wildlife Service, Atlanta, GA. 30 pp.

## Websites for Freshwater Mollusks of North America

### North Carolina Atlas of freshwater mussels and endangered fish

[http://www.ncwildlife.org/pg07\\_WildlifeSpeciesCon/pg7b1.htm](http://www.ncwildlife.org/pg07_WildlifeSpeciesCon/pg7b1.htm)

Website with pictures and information on the status of the federal and state listed freshwater bivalves of North Carolina. Constructed by John Alderman and Judith Johnson, NC Wildlife Resources Commission.

### G. Thomas Watters Electric Elliptio Land

[http://www.biosci.ohio-state.edu/~molluscs/OSUM2/elliptio\\_land.htm](http://www.biosci.ohio-state.edu/~molluscs/OSUM2/elliptio_land.htm)

This is part of the website for the Ohio State University Museum of Zoology, Mollusk Collection, this is the only website with a variety of pictures of some of the *Elliptio*.

### Freshwater Mollusk Conservation Society

<http://ellipse.inhs.uiuc.edu/fmcs/>

Society formed for the conservation of freshwater mollusks with good links to other sites.

### Illinois Natural History Mollusk Collection

<http://www.inhs.uiuc.edu/cbd/collections/mollusk.html>

This site has a lot of information on mollusk collections around the world, curators of those collections, and links to the freshwater mollusk bibliography.

Compiled by Kevin Cummings and Chris Mayer.

### Freshwater Mollusk Bibliography

<http://www.inhs.uiuc.edu/cbd/collections/mollusk.html>

This website is a searchable database of over 14,000 articles, book chapters, theses, dissertations and gray literature reports dealing with freshwater mollusks. Compiled by Kevin Cummings, Arthur Bogan, G. Thomas Watters, and Chris Mayer.

### USGS Florida Caribbean Science Center/ Non-indigenous species

[http://cars.er.usgs.gov/Nonindigenous\\_Species/nonindigenous\\_species.html](http://cars.er.usgs.gov/Nonindigenous_Species/nonindigenous_species.html)

This site has great pictures, distribution maps and information on the major aquatic invasive species.

### USGS zebra Mussel Information

<http://nas.er.usgs.gov/taxgroup/mollusks/default.asp>

Good source of maps showing the invasion of North America by both the zebra and quagga mussels.

### Conchologists of America

<http://www.conchologistsofamerica.org/home/>

Amateur shell collectors website with loads of good information and links.

If these websites do not answer your questions go to the web browser [www.google.com](http://www.google.com) and type in a key word with great results. These sites are active at this time, May, 2008.



Fig. 1 *Alasmidonta undulata*



Fig. 2 *Alasmidonta varicosa*



Fig. 3 *Anodonta couperiana*



Fig. 4 *Anodonta implicata*



Fig. 5 *Elliptio angustata*



Fig. 6 *Elliptio complanata*





Fig. 7 *Elliptio congaraea*



Fig. 8 *Elliptio folliculata*



Fig. 9 *Elliptio fraterna*



Fig. 10 *Elliptio icterina*



Fig. 11 *Elliptio producta*



Fig. 12 *Elliptio roanokensis*



Fig. 13 *Elliptio waccamawensis*



Fig. 14 *Fusconaia masoni*



Fig. 15 *Lampsilis cariosa*



Fig. 16 *Lampsilis radiata*



Fig. 17 *Lampsilis splendida*



Fig. 18 *Lasmigona decorata*





Fig. 19 *Leptodea ochracea*



Fig. 20 *Ligumia nasuta*



Fig. 21 *Pyganodon cataracta*



Fig. 22 *Strophitus undulatus*



Fig. 23 *Toxolasma pullus*



Fig. 24 *Uniomerus carolinianus*



Fig. 25 *Utterbackia imbecillis*



Fig. 26 *Villosa constricta*



Fig. 27 *Villosa delumbis*



Fig. 28 *Villosa modioliformis*



Fig. 29 *Villosa vaughaniana*



Fig. 30 *Corbicula fluminea*



Fig. 31 *Dreissena polymorpha*



Fig. 32 *Mytilopsis leucophaeta*