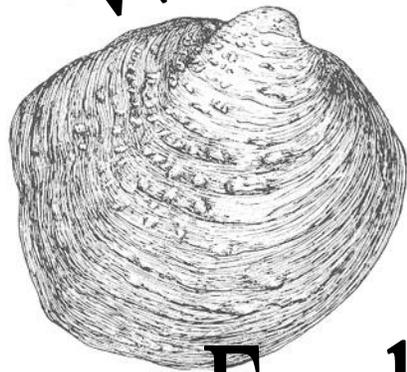
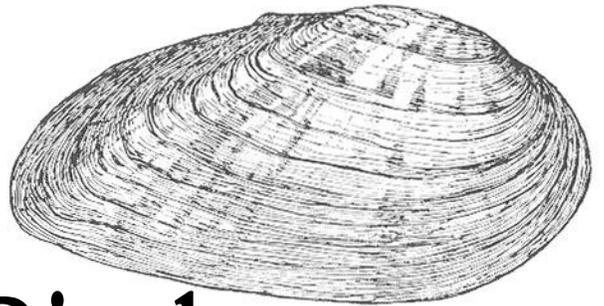


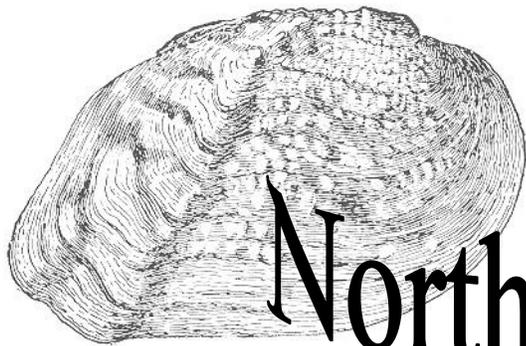
Workbook and Key



to the



Freshwater Bivalves



of

North Carolina

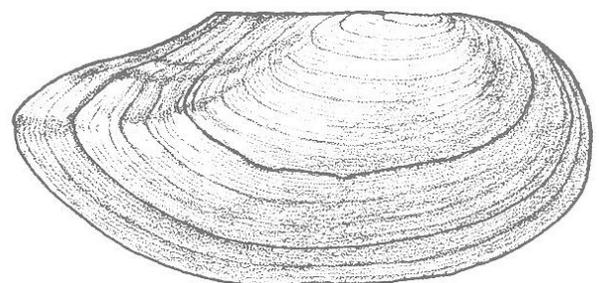
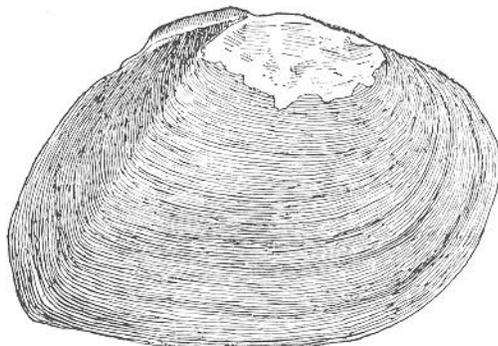


Arthur E. Bogan

North Carolina Museum of Natural Sciences

Workbook Sponsor

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2017

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I wish to thank the North Carolina Department of Transportation for funding the workshop that initiated this workbook. V. Charles Bruton, Phil Harris, Tim Savidge and Topsy Skinner, all of NCDOT, are gratefully acknowledged for all of their assistance and patience in pulling this workshop together. Tim Savidge initiated the idea of the workshop and has been instrumental in facilitating its occurrence. Jonathan Raine greatly assisted in the development of the color plates. Wendy Lovelady, Exhibits Department of the NCSM, assisted and trained me with the scanning of slides and the final printing of the color plates. John M. Alderman, Judith A. Johnson and Brian T. Watson of the NC Wildlife Resources Commission prepared the first draft of tables 2 and 3. John Alderman and Tim Savidge, both reviewed and expanded the information on the distribution of species in North Carolina. Cindy Bogan once again has been patient in teaching me some of the finer points of the use of Word and has helped format the whole workbook. Ms. Jamie Smith, Mollusk Collection Manager, NCSM, has patiently assisted with the preparation of materials and specimens for this workshop. This is a product of the NC Museum of Natural Sciences.

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Introduction:

This is a work in progress and is updated when new information becomes available. Unionid taxonomy is in a state of flux with the introduction and use of genetic sequence data combined with modern phylogenetic analyses. There is a manuscript in development at this time that covers the taxonomic changes since the last AFS Checklist was published (Turgeon et al. 1998). I have taken advantage of this summary of current literature to update the taxonomy used in this workbook. Some of the taxonomic changes will have to wait until the new manuscript is published. The published changes include:

Corbiculidae has been declared a junior synonym of Cyrenidae (Bierler et al. 2010)

Three unionid species have been added to the list of the North Carolina fauna: *Alasmidonta marginata*, based on museum records, *Potamilus alatus* recently reported and *Toxolasma parvum* documented as introduced into Falls Lake, [Neuse River basin], Wake County (Bogan et al. 2011). These additions bring the total unionid fauna to 58 species.

Placement of *Elliptio dilatata* was suggested as not belonging in the clade of *Elliptio* but ranked as a separate genus, *Eurynia* (Campbell and Lydeard, 2012a, b). However, this change has not been accepted here, awaiting a more complete analysis of the genus *Elliptio*.

Elliptio steinstansana and *Pleurobema collina*, the two spined species found in North Carolina have been combined under a new genus, *Parvaspina* based on mitochondrial and nuclear DNA analyses (Perkins et al., 2017).

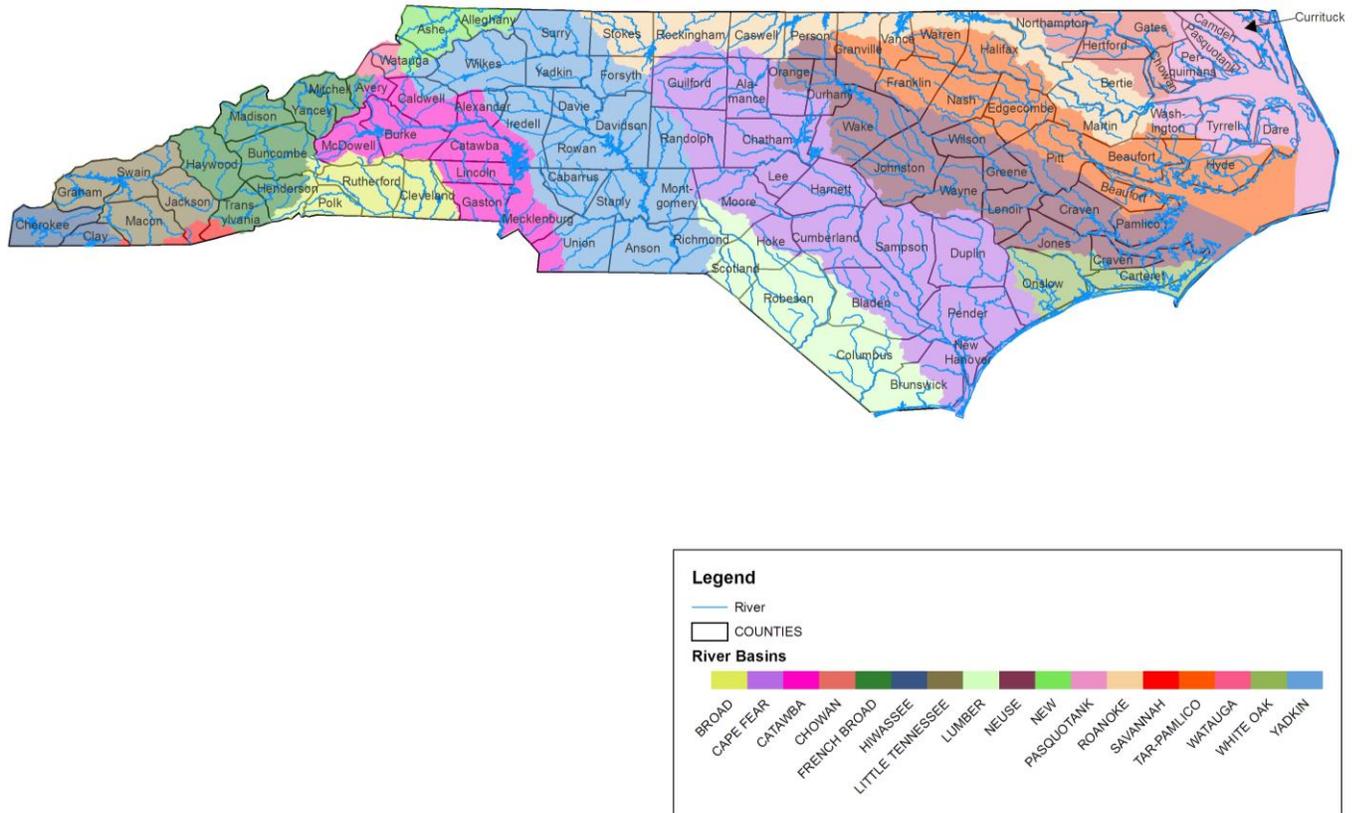
Elliptio waccamawensis a long recognized Lake Waccamaw endemic was placed in synonymy under *Elliptio congarea* based on DNA sequence analyses (McCartney et al., 2016).

Epioblasma florentina walkeri reported in western North Carolina based on museum specimens originally identified as *Epioblasma capsaeformis* was reclassified in the upper Tennessee River Basin as a subspecies separate from *walkeri* and renamed *Epioblasma florentina aureola* Jones and Neves, 2010.

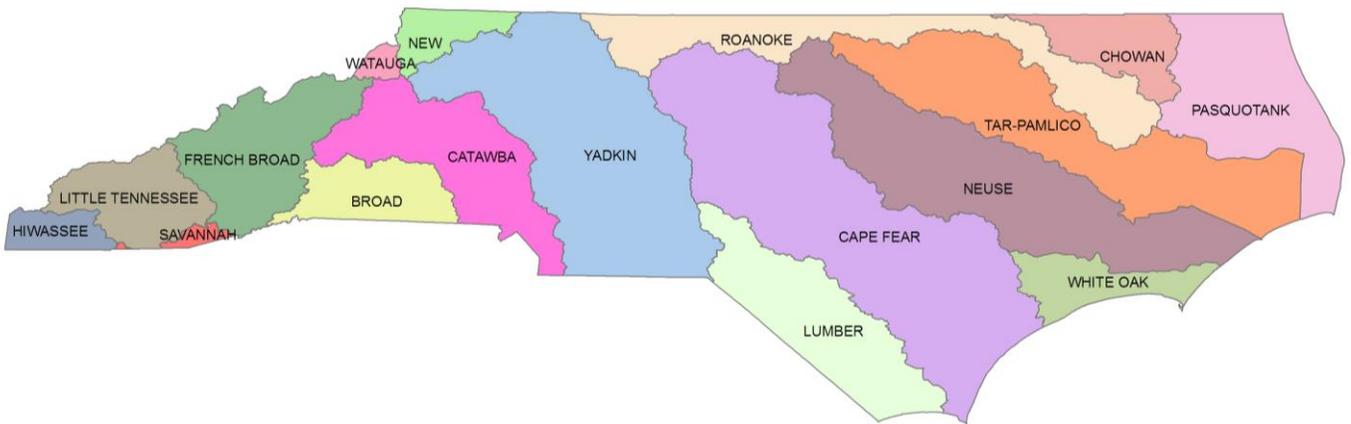
Lampsilis fullerhati, another Lake Waccamaw endemic was recently shown not to be a separate species, but a lake form of *Lampsilis radiata* (McCartney et al., 2016).

Villosa trabalis and *Villosa perpurpurea* were synonymized and moved to *Venustaconcha trabalis*, based on genetic analyses (Lane et al. 2016).

Arthur E. Bogan 6 February 2017.



Map created by Jamie M. Smith, North Carolina State Museum of Natural Sciences, 7 Nov 2007



Map 1. Map of the 17 river basins of North Carolina. Top map with counties and bottom map with only river basins identified. Maps produced by Jamie Smith.

Table 1. Seventeen river basins/drainages of North Carolina

Atlantic Slope River Basins:

1. Savannah River basin
- Santee-Cooper River basin
 2. Broad River drainage
 3. Catawba River drainage
- Pee Dee River basin
 4. Yadkin River
 5. Lumber River
6. Cape Fear River basin
7. White Oak River basin
- Tar-Pamlico Sound basin:
 8. Neuse River drainage
 9. Tar River drainage
- Albemarle Sound basin
 10. Roanoke River drainage
 11. Chowan River drainage
 12. Pasquatank River drainage

Mississippi River Basin

- Tennessee River sub-basin
 13. Hiwassee River drainage
 14. Little Tennessee River drainage
 15. French Broad River drainage
 16. Watuaga River drainage
- Ohio River sub-basin
 17. New River drainage

Table 2. List of Native Freshwater Unionid Bivalves of North Carolina

Alasmidonta heterodon (Lea, 1829) Dwarf Wedgemussel
Alasmidonta marginata Say, 1818 [Interior Basin]
Alasmidonta raveneliana (Lea, 1834) Appalachian Elktoe [Interior Basin]
Alasmidonta robusta Clarke, 1981 Carolina Elktoe
Alasmidonta undulata (Say, 1817) Triangle Floater
Alasmidonta varicosa (Lamarck, 1819) Brook floater
Alasmidonta viridis (Rafinesque, 1820) Slippershell Mussel [Interior Basin]
Anodonta couperiana Lea, 1840 Barrel Floater
Anodonta implicata Say, 1829 Alewife Floater
Cyclonaias tuberculata (Rafinesque, 1820) Purple Wartyback [Interior Basin]
Elliptio cistellaeformis (Lea, 1863) Box Spike
Elliptio complanata (Lightfoot, 1786) Eastern Elliptio
Elliptio congaraea (Lea, 1831) Carolina Slabshell [+*Elliptio waccamawensis* (Lea, 1863) Waccamaw Spike]
Elliptio dilatata (Rafinesque, 1820) Spike [Interior Basin]
Elliptio fisheriana (Lea, 1838) Northern Lance
Elliptio folliculata (Lea, 1838) Pod Lance
Elliptio icterina (Conrad, 1834) Variable Spike
Elliptio lanceolata (Lea, 1828) Yellow Lance
Elliptio marsupiobesa Fuller, 1972 Cape Fear Spike
Elliptio roanokensis (Lea, 1838) Roanoke Slabshell [+*Elliptio judithae* Clarke, 1981 Plicate Spike]
Epioblasma florentina aureola Jones and Neves, 2010 Golden Riffleshell [Interior Basin]
Fusconaia masoni (Conrad, 1834) Atlantic Pigtoe
Fusconaia subrotunda (Lea, 1831) Longsolid [Interior Basin]
Lampsilis cariosa (Say, 1817) Yellow Lampmussel
Lampsilis fasciola Rafinesque, 1820 Wavyrayed Lampmussel [Interior Basin]
Lampsilis radiata (Gmelin, 1791) Eastern Lampmussel [+*Lampsilis radiata conspicua* (Lea, 1872) Carolina Fatmucket; + *Lampsilis fullerkerati* Johnson, 1984 Waccamaw Fatmucket]
Lampsilis splendida (Lea, 1838) Rayed Pink Fatmucket
Lasmigona decorata (Lea, 1852) Carolina Heelsplitter
Lasmigona holstonia (Lea, 1838) Tennessee Heelsplitter [Interior Basin]
Lasmigona subviridis (Conrad, 1835) Green Floater [Atlantic/Interior Basin]
Leptodea ochracea (Say, 1817) Tidewater Mucket
Ligumia nasuta (Say, 1817) Eastern Pondmussel
Medionidus conradicus (Lea, 1831) Cumberland Moccasinshell
Parvaspina collina (Conrad, 1836) James Spiny mussel
Parvaspina steinstansana Johnson and Clarke, 1983 Tar River Spiny mussel
Pegias fabula (Lea, 1838) Littlewing Pearly mussel [Interior Basin]
Pleurobema oviforme (Conrad, 1834) Tennessee Clubshell [Interior Basin]
Pleuronaia barnesiana (Lea, 1838) Tennessee Pigtoe [Interior Basin]
Pleuronaia dolabelloides (Lea, 1840) Slabside Pearly mussel [Interior Basin]
Potamilus alatus (Say, 1817) Pink Heelsplitter [Interior Basin]
Ptychobranchus fasciolaris (Rafinesque, 1820) Kidneyshell [Interior Basin]
Pyganodon cataracta (Say, 1817) Eastern Floater
Pyganodon grandis (Say, 1829) Giant Floater [Atlantic (I)/Interior Basin]
Quadrula pustulosa (Lea, 1831) Pimpleback [Interior Basin]
Strophitus undulatus (Say, 1817) Creeper [Atlantic/Interior Basin]

Toxolasma lividum Rafinesque, 1831 Purple Lilliput [Interior Basin]
Toxolasma parvum (Barnes, 1823) Lilliput, [Atlantic slope; **Introduced**]
Toxolasma pullus (Conrad, 1838) Savannah Lilliput
Tritogonia verrucosa (Rafinesque, 1820) Pistolgrip [Interior Basin]
Unio merus carolinianus (Bosc, 1801) Florida Pondhorn
Utterbackia imbecillis (Say, 1829) Paper Pondshell [Atlantic/Interior Basin]
Venustaconcha trabalis (Conrad, 1834) Cumberland Bean [Interior Basin]
Villosa constricta (Conrad, 1838) Notched Rainbow
Villosa delumbis (Conrad, 1834) Eastern Creekshell
Villosa iris (Lea, 1830) Rainbow [Interior Basin]
Villosa modioliformis (Lea, 1834) Carolina Rainbow
Villosa vanuxemensis (Lea, 1838) Mountain Creekshell [Interior Basin]
Villosa vaughaniana (Lea, 1838) Carolina Creekshell

Table 3. Distribution of Unionidae in North Carolina's Atlantic Slope River Basins
 Within River Basin: X= Extant, H= Historic, I= Introduced, S= in S. Carolina, ScH=SC historic, V= in Virginia

Species	Savannah	Broad	Catawba	Pee-Dee	Lumber	Waccamaw	Cape Fear	White Oak	Neuse	Pamlico	Roanoke	Chowan	Pasquotank
<i>Alasmidonta heterodon</i>									X	X			
<i>Alasmidonta robusta</i>			X										
<i>Alasmidonta undulata</i>	S			X			X		X	X	X	X	
<i>Alasmidonta varicosa</i>	S		X	X			X		X		X		
<i>Anodonta couperiana</i>	S						H						
<i>Anodonta implicata</i>				X							X	X	
<i>Elliptio angustata</i>		X	X	X		X	X				X	X	
<i>Elliptio cystellaeformis</i>			X	X	X		X		X	X		X	
<i>Elliptio complanata</i>	S	X	X	X	X	X	X	X	X	X	X	X	
<i>Elliptio congaraea</i>	S			X		X	X		X	X		X	
<i>Elliptio fisheriana</i>											X	X	
<i>Elliptio folliculata</i>	S		S	X		X	X						
<i>Elliptio icterina</i>	S	X	X	X	X	X	X	X	X	X	X	X	
<i>Elliptio lanceolata</i>									X	X		V	
<i>Elliptio marsupiobesa</i>				S	X		X		X				
<i>Elliptio producta</i>	S		S	X		X	X						
<i>Elliptio roanokensis</i>	S			X			X		X	X	X		
<i>Elliptio shepardiana</i>						X		X					
<i>Elliptio viridula</i>					X	X	X		X	X			
<i>Fusconaia masoni</i>	ScH		H	X			X		X	X	X	V	
<i>Lampsilis cariosa</i>	S			X		X	X		X	X		X	
<i>Lampsilis n.sp.</i>				X					X	X			

Species	Savannah	Broad	Catawba	Pee-Dee	Lumber	Waccamaw	Cape Fear	White Oak	Neuse	Pamlico	Roanoke	Chowan	Pasquotank
<i>Lampsilis radiata</i>				X		X	X		X	X	X	X	
<i>Lampsilis splendida</i>	S					X	X						
<i>Lasmigona decorata</i>	S		X	X									
<i>Lasmigona subviridis</i>							H		X	X	X		
<i>Leptodea ochracea</i>	S			X		X				X	X	X	
<i>Ligumia nasuta</i>	S			X			X			H	X	X	
<i>Parvaspina collina</i>											VX		
<i>Parvaspina steinstansana</i>									X	X			
<i>Pyganodon cataracta</i>	S	X	X	X			X		X	X	X	X	X
<i>Pyganodon grandis</i>							I						
<i>Strophitus undulatus</i>		X	S	X			X		X	X	X	V	
<i>Toxolasma parvum</i>									I				
<i>Toxolasma pullus</i>	S			X		H	X		H		X		
<i>Unio merus carolinianus</i>	S	S	X	X	X	X	X			X		X	
<i>Utterbackia imbecillis</i>		X	S	X			X		X	X	X	X	X
<i>Villosa constricta</i>			X	X			X		X	X	X	X	
<i>Villosa delumbis</i>	S		X	X		X	X						
<i>Villosa modioliiformis</i>	S						X				X	X	
<i>Villosa vauhaniana</i>			X	X			X				X		
Total taxa for River Basin	20	7	17	27	6	15	29	3	23	22	21	20	2

Table 4 Distribution of Extant Unionidae in North Carolina's Interior Basin Within River Basin: X =Extant, H= Recently Extirpated, I=Introduced

Species	Hiwassee	Little Tennessee	Pigeon	French Broad	Watauga	New
<i>Actinonaia ligamentina</i>		A ³				
<i>Alasmidonta marginata</i> ²				H		
<i>Alasmidonta raveneliana</i>		X	X	X		
<i>Alasmidonta viridis</i>		X		X		
<i>Cyclonaias tuberculata</i>						X
<i>Elliptio complanata</i> (Introduced)				I		
<i>Elliptio dilatata</i>	X	X		A ³ H		X
<i>Epioblasma florentina aureola</i>				H		
<i>Fusconaia subrotunda</i>	X			A ³ X		
<i>Lampsilis fasciola</i>	X	X	H	A ³ X		
<i>Lasmigona holstonia</i>	H	X		X ¹		
<i>Lasmigona subviridis</i>					X	X
<i>Medionidus conradicus</i>				H		
<i>Pegias fabula</i>	X	X				
<i>Pleurobema oviforme</i>	X	X		X		
<i>Pleuronaia barnesiana</i>	X	X		A ³		
<i>Pleuronaia dolabelloides</i>	?					
<i>Potamilus alatus</i> ³				X		
<i>Ptychobranhus fasciolaris</i>				H		
<i>Pyganodon grandis</i>				X		
<i>Quadrula pustulosa</i>				?		
<i>Strophitus undulatus</i>				X		
<i>Tritigonia verrucosa</i>						H
<i>Utterbackia imbecillis</i>		X				
<i>Venustaconcha trabalis</i>	?					
<i>Villosa iris</i>	X	X		H		
<i>Villosa vanuxemensis</i>	X					
Total Taxa	11	10	2	18	1	4

¹T. Savidge (Pers. Comm. March 2002). ²S. Fraley (Pers. Comm.). ³T. Whyte (Pers. Comm. 4 Jan 2011).

Table 5. Status List of North Carolina freshwater bivalves

FEDERAL AND STATE**ENDANGERED [8]**

Alasmidonta heterodon
Alasmidonta raveneliana
Epioblasma florentina aureola ?[extirpated]
Lasmigona decorata
Parvaspina collina
Parvaspina steinstansana
Pegias fabula
Venustaconcha trabalis [extirpated]

STATE ENDANGERED [14]

Alasmidonta varicosa
Alasmidonta viridis
Anodonta couperiana
Cyclonaias tuberculata
Elliptio lanceolata
Elliptio waccamawensis [now *E. congarea*]
Fusconaia masoni
Lampsilis cariosa
Lasmigona holstonia
Lasmigona subviridis
Pleuronaia barnesiana
Toxolasma pullus
Villosa delumbis
Villosa vaughaniana

STATE THREATENED [10]

Alasmidonta undulata
Anodonta implicata
Elliptio roanokensis
Lampsilis fullerhati [= *L. radiata*]
Lampsilis radiata conspicua [= *L. radiata*]
Lampsilis radiata
Leptocea ochracea
Ligumia nasuta
Strophitus undulatus
Villosa vanuxemensis

STATE SPECIAL CONCERN [6]

Elliptio dilatata
Elliptio folliculata
Elliptio marsupiobesa
Lampsilis fasciola
Villosa constricta
Villosa iris

STATE EXTIRPATED [8]^{1,2}

Alasmidonta marginata
Epioblasma florentina aureola
Medionidus conradicus
Ptychobranchnus fasciolaris
Quadrula pustulosa
Toxolasma lividum
Tritogonia verrucosa
Venustaconcha trabalis

¹*Actinonaias pectorosa* listed by NCWRC as extirpated but not known from the state.

²*Fusconaia flava* listed by NCWRC as extirpated but not known from the state.

PRESUMED EXTINCT [1]

Alasmidonta robusta

INTRODUCED [1]

Toxolasma parvum

Table 6. A working list of the *Elliptio* taxa of North Carolina.
A preliminary idea of the relationships of North Carolina *Elliptio*

ELLIPTIO COMPLANATA GROUP

- Elliptio complanata* (Lightfoot, 1786) Eastern Elliptio [pl. 2, fig. 11] [+ *Elliptio mediocris* (Lea, 1863) *]
Elliptio congaraea (Lea, 1831) Carolina Slabshell [pl. 2, fig. 12] [+*Elliptio waccamawensis* (Lea, 1863) Waccamaw Spike [pl.4, fig. 20]
Elliptio roanokensis (Lea, 1838) Roanoke Slabshell [pl. 3, fig. 18] [+ *Elliptio judithae* Clarke, 1981 Plicate Spike]

ELLIPTIO ICTERINA GROUP

- Elliptio cistellaeformis* (Lea, 1863) Box Spike [pl. 2, fig. 10]
Elliptio icterina (Conrad, 1834) Variable Spike [pl. 3, fig. 15]] [+ *Elliptio raveneli* (Conrad, 1834) Carolina Spike*]
Elliptio marsupiobesa Fuller, 1972 Cape Fear Spike [pl.3, fig. 17]

ELLIPTIO LANCEOLATA GROUP [names used in North Carolina]

- Elliptio angustata* (Lea, 1831) Carolina Lance*
Elliptio emmonsii (Lea, 1857) *
Elliptio fisheriana (Lea, 1838) Northern Lance [pl. 11, fig. 61]
Elliptio folliculata (Lea, 1838) Pod Lance [pl. 3, fig. 14]
Elliptio lanceolata (Lea, 1828) Yellow Lance [pl. 3, fig. 16]
Elliptio nasutilus (Lea, 1863) *
Elliptio producta (Conrad, 1836) Atlantic Spike
Elliptio viridula (Lea, 1863) *

ELLIPTIO DILATATA GROUP

- Elliptio dilatata* (Rafinesque, 1820) Spike [Interior Basin] [pl. 3, fig. 13]

NON-Elliptio

- Elliptio steinstansana* Johnson and Clarke, 1983 Tar River Spinymussel [pl.4, fig. 19] and *Pleurobema collina* [pl. 7, fig. 37] have been placed in *Parvaspina* Perkins, Johnson and Gangloff, 2017.

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

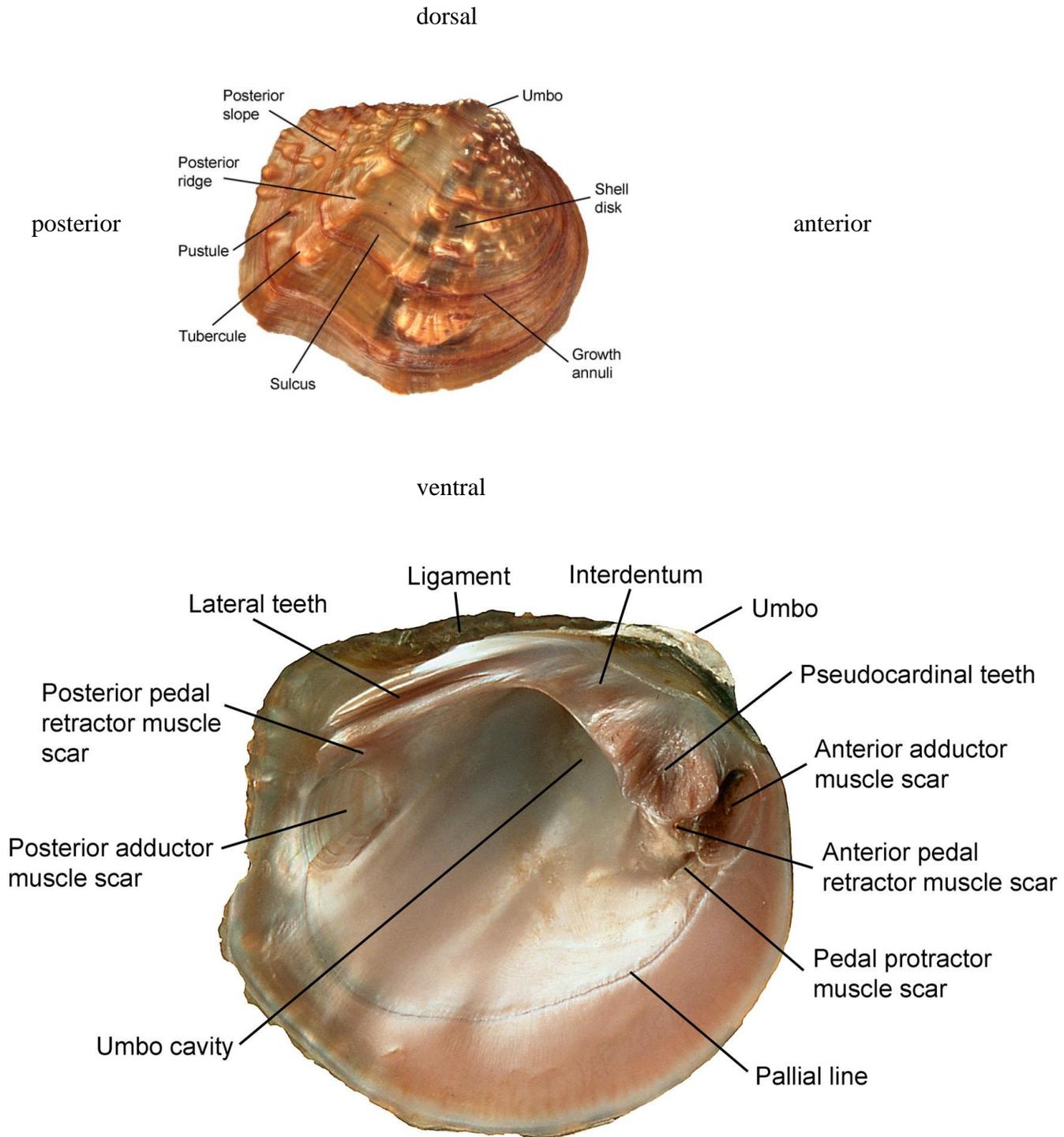
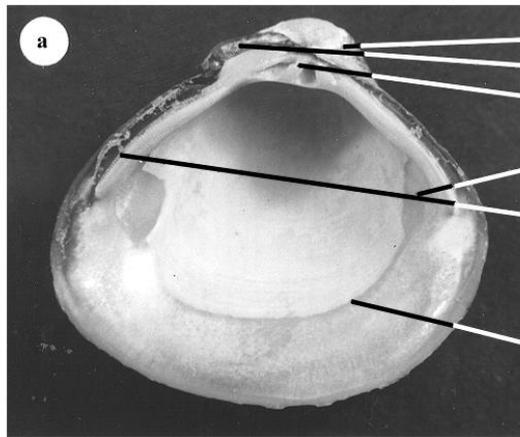


Figure 1. Morphology of a freshwater unionid shell, illustrating structures and terminology. Top figure: exterior of right valve; Bottom figure: interior of left valve (Reproduced with permission from Williams et al. (2008). Figures © Richard T. Bryant).

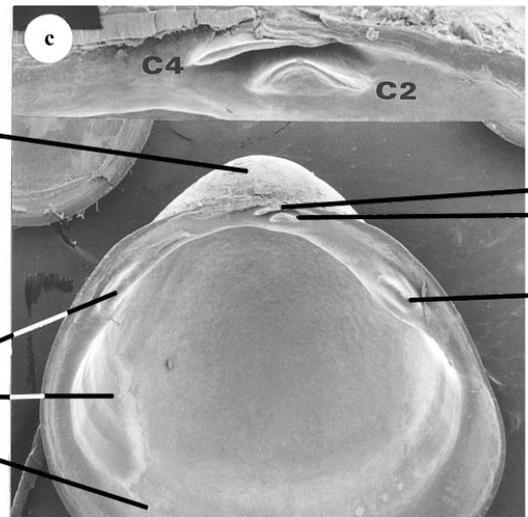
Figure 2. Internal shell features of left (a) and right (b) valves of *Corbicula fluminea* and of left (c) and right (d) valves of *Pisidium variable*, representing the Sphaeriidae. C2, C3, C4 are the cardinal teeth; AI, AII, AIII are the anterior lateral teeth; PI, PII, PIII are the posterior lateral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

**Cyrenidae
(+ Corbiculidae)**

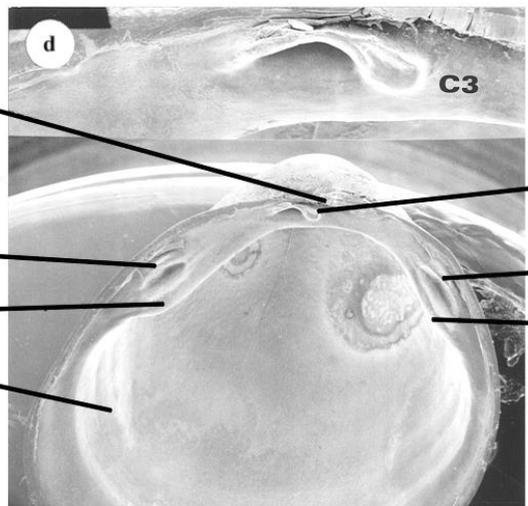
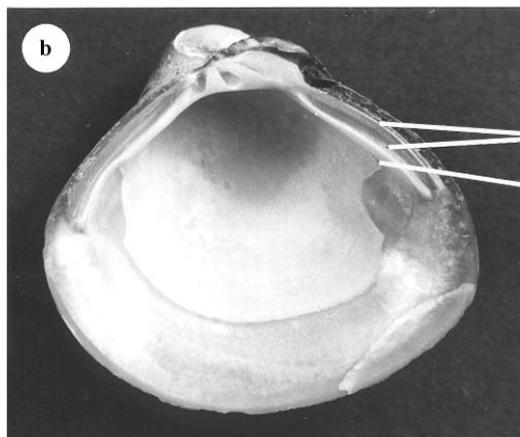
Sphaeriidae



1 cm



1 mm



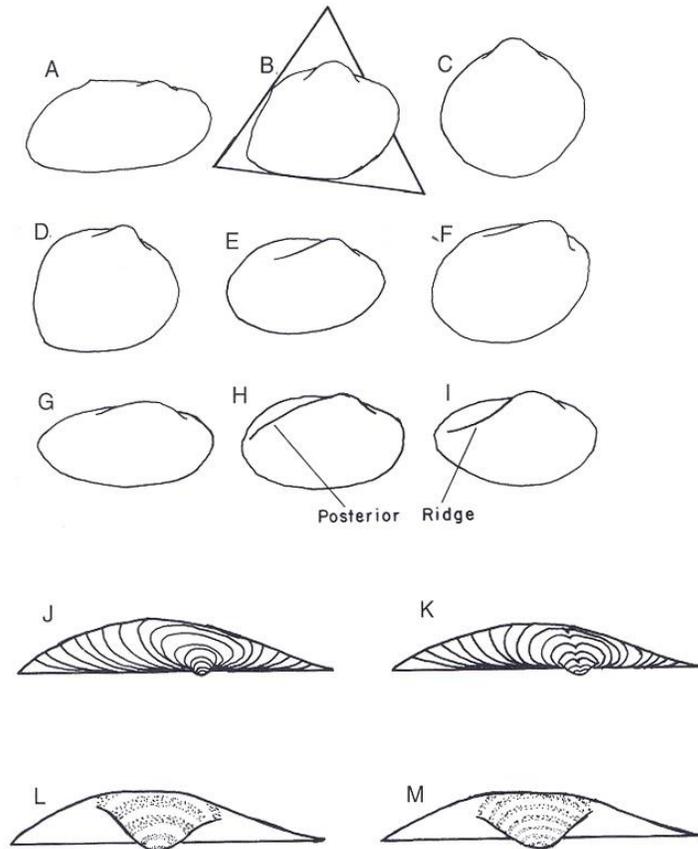


Figure 3. Illustrations of shell shape and umbo sculpture. Shell shape descriptions: (A) rhomboidal; (B) triangular or trigonal; (C) round; (D) quadrate; (E and F) oval or ovoid; and (G) elliptical. Posterior shell-ridge morphology: (H) posterior ridge convex; and (I) posterior ridge concave. Concentric 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).

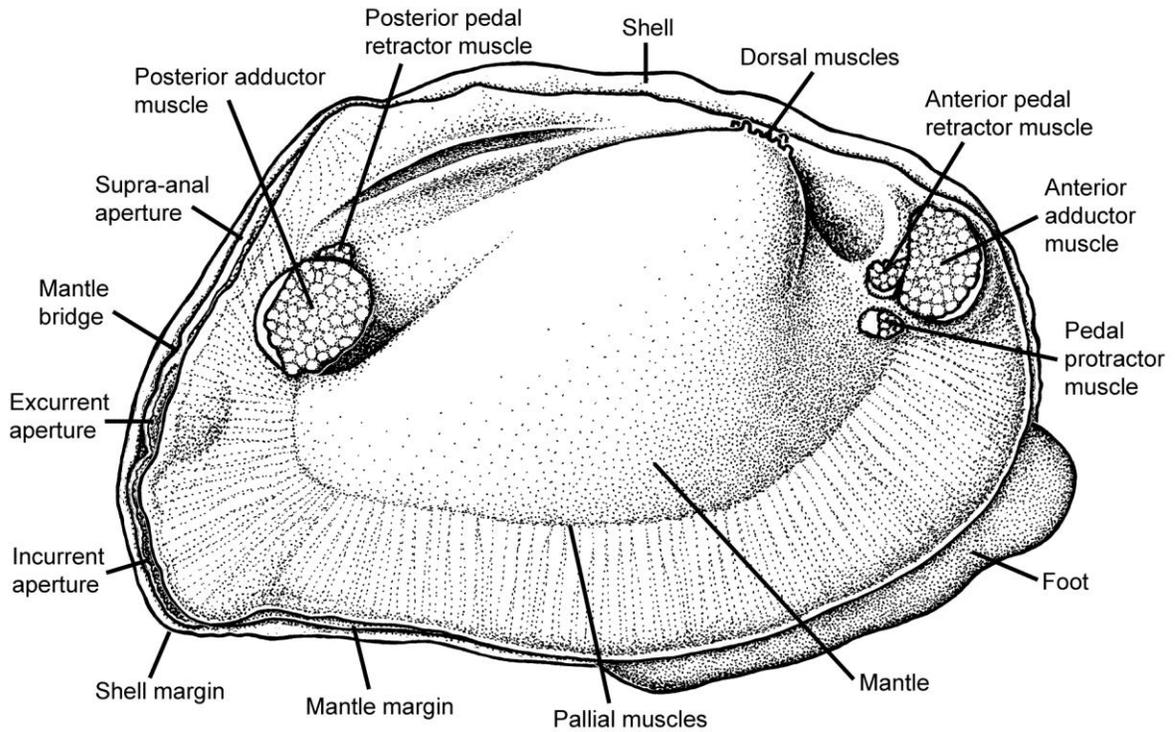


Figure 4. Anatomical features of a freshwater mussel with the right valve removed. Illustration by S. Trammell

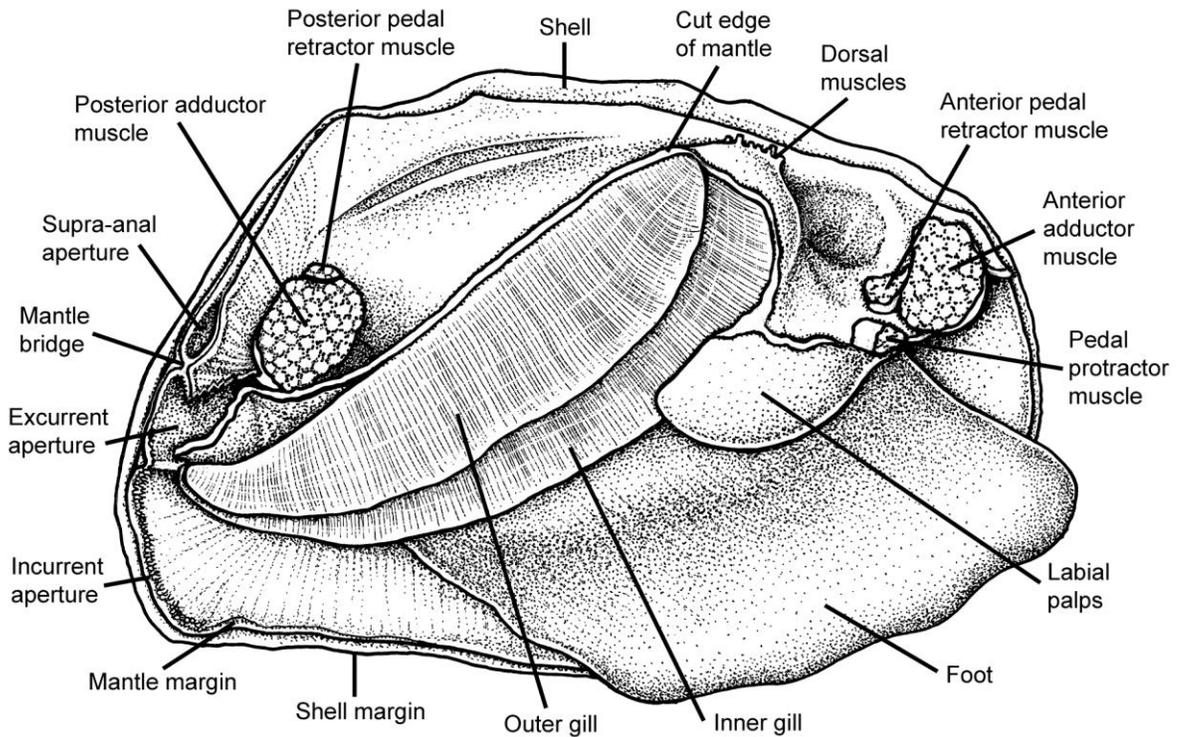
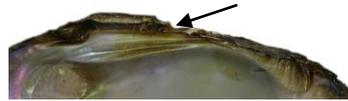


Figure 5. Anatomical features of a freshwater mussel with the right valve removed and the mantle cut away. Illustration by S. Trammell. [Figures reproduced with permission from Williams et al. 2008. Freshwater mussels of Alabama and the Mobile Basin in Georgia, Mississippi and Tennessee. University of Alabama Press, Tuscaloosa.]

Key to the freshwater bivalves of North Carolina

This key is primarily for the freshwater bivalves (Unionidae) found in North Carolina, but also includes representatives of other families that occur or may occur in freshwater including Sphaeriidae, Cyrenidae (+ Corbiculidae), Dreissenidae, and Mactridae. More detailed information and keys to species of Sphaeriidae and Cyrenidae found in North Carolina is provided by Mackie (2007).

1 a. shell hinge ligament external2



b. shell hinge ligament internal5



2 (1a) a. shell with lateral teeth extending anterior and posterior to true cardinal teeth3

b. shell lacking anterior lateral teeth and posterior lateral tooth when present, is posterior to pseudocardinal teeth, or all hinge development lost **Unionidae**7

3 (2a) a. valves with serrated lateral teeth, maximum shell length >25 mm **Cyrenidae** 4

b. valves with smooth, thin, lateral teeth, maximum shell length <25 mm **Sphaeriidae**



4 (3a) a. maximum shell length <50 mm, found only in freshwater

..... ***Corbicula fluminea***



b. maximum adult shell length > 50mm, brackish water, and tidal portions of rivers ***Polymesoda caroliniana***

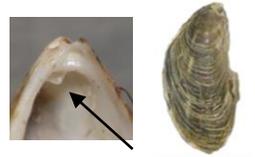


5 (1b) a. shell hinge with anterior and posterior laterals on either side of cardinal teeth, shell thick, obliquely ovate in outline found from brackish to freshwater **Mactridae** ***Rangia cuneata***



b. shell hinge without teeth, shell with a very sharp posterior ridge, shaped like a marine mussel, *Mytilus*, generally less than 30 millimeters, and attached to a hard substrate with byssal threads **Dreissenidae** 6

6 (5b) a. periostracum blue brown to tan usually without zigzag narrow lines, anterior end hooked sharply ventral, shell is elongate, rather narrow, ventral shell margin not distinctly flattened over whole ventral area, an apophysis is present on the anterior interior shelf, typically in brackish water but is carried by boat and barge traffic into freshwater*Mytilopsis leucophaeata*



b. periostracum light tan with various zigzag narrow lines across the shell, anterior portion of shell not hooked ventrally, ventral shell margin flattened. no apophysis present on the anterior interior shelf, freshwater, *Dreissena* [*D. polymorpha*, the Zebra Mussel is widespread in the Interior Basin and expanding its range, *D. bugensis*, the Quagga Mussel, is mostly restricted to the St. Lawrence seaway and Lake Erie but is slowly spreading. The Quagga Mussel shell is a more rounded shell and often lacks the zigzag lines and apparently gets into slightly brackish water.]



- 7 (2b) a. origin of shell is from rivers or lakes draining into the Atlantic Ocean (Table 1, Map 1).....8
- b. origin of shell is from rivers or lakes drainaing into the Mississippi River basin (Table 1, Map 1)37

ATLANTIC COAST

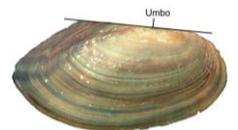
8 (7a) a. shell with hinge teeth absent or greatly reduced..... 9



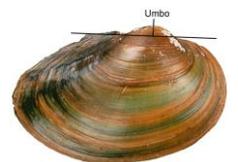
b. shell with pseudocardinal teeth present, with or without lateral teeth 14



9 (8a) a. umbo not projecting above the hinge-line (Figure © Richard T. Bryant)10



b. umbo projecting above the hinge-line (Figure © Richard T. Bryant)11



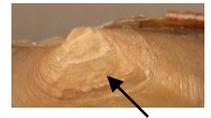
10 (9a) a. ventral margin slightly convex to straight (pl. 8, fig. 48)*Utterbackia imbecillis*

b. ventral margin rounded (pl. 2, fig. 7)*Anodonta couperiana*

11 (9b) a. umbo sculpture double looped, shell uniformly thin12



b. umbo sculpture consists of concentric bars13



12 (11a) a. umbo sculpture ridges all of the same height, common (pl.7, fig. 40)
 *Pyganodon cataracta*

b. umbo sculpture ridges with pronounced bump or raised area in the bottom of the loop, introduced (pl. 7, fig. 41).....*Pyganodon grandis*

13 (11b) a. nacre usually orange in the umbo cavity, pseudocardinal tooth area represented by a thickening near the umbo, ventral shell margin uniform thickness (pl. 8, fig. 43)..... *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. 2, fig. 8).....*Anodonta implicata*



14(8b) a. shell with lateral teeth absent or reduced, neither functional nor interlocking.....15



b. shell with well developed lateral teeth17



15 (14a) a. shell elongate to elongate oval, inflated thin shell 16

b. shell outline triangular, inflated but thin to thick shell, umbo sculpture consists of large bars extending down onto the disk of the shell (pl. 1, fig. 4)
 *Alasmidonta undulata*

16 (15a) a. shell elongate, kidney shaped, periostracum greenish to brownish with obscured rays in adults (pl. 1, fig. 5) *Alasmidonta varicosa*

b. shell elongate oval, periostracum yellowish background with wavy green rays, Long Creek Catawba River basin, known only from the type lot, extinct (pl. 1, fig. 3).....*Alasmidonta robusta*

17 (14b) a. right valve with two lateral teeth, small, rare (pl. 1, fig. 1)*Alasmidonta heterodon*

b. right valve with one lateral tooth..... 18

- 18 (17b) a. shell with spines on the umbo and down on to the disc of the shell, but may be lost in adults, oval in outline and typically a yellowish brown periostracum 19
- b. shell lacks any evidence of spines 20
- 19 (18a) a. shell from the Tar and Neuse River basins (pl. 4, fig. 19)...*Parvaspina steinstansana*
- b. shell from the Dan River drainage in the Roanoke River basin (pl. 7, fig. 37) *Parvaspina collina*
- 20 (18b) a. hinge plate in left valve with an additional small interdental or accessory tooth, giving the appearance of three pseudocardinal teeth, shell more or less compressed, shell shape rhomboid, periostracum dark green with numerous green rays, umbo sculpture consists of prominent bars..... 21
- b. left valve without extra interdental tooth..... 22
- 21 (20a) a. shell thick and maximum size 114 mm, maximum height 68 mm, restricted to the Pee Dee, Catawba and Wateree-Santee River drainages (pl. 5, fig. 29) *Lasmigona decorata*
- b. shell relatively thick, maximum size 62 mm, maximum height 33 mm, known from the Pamlico, Neuse, and Cape Fear River systems (pl. 6, fig. 31) *Lasmigona subviridis*
- 22 (20b) a. shell shape rectangular to broadly triangular shell, umbo cavity shallow, species is from an area extending from the Roanoke River Basin south to the headwaters of the Savannah River Basin (pl. 4, fig. 23) *Fusconaia masoni*
- b. shell shape elongate-oval, rectangular or rhomboid 23
- 23 (22b) a. shell shape rhomboid, or grading to rectangular 24
- b. shell shape elongate-oval..... 28
- 24 (23a) a. shell usually more than twice as long as high 25
- b. shell usually less than twice as long as high 27
- 25 (24a) 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. 6, fig. 34) .*Ligumia nasuta*
- b. no sexual dimorphism seen in shell 26



- 26** (25b) a. usually only slightly more than twice as long as height, 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.3, fig. 18)..... *Elliptio roanokensis*
- b. from two to more than three times as long as height, shell usually not heavy and thick, may exceed 130 mm in length, periostracum from yellow with rays to green to black [including *angustata*, *fisheriana*, *folliculata*, *producta*] (pl. 3, fig 14; pl. 11, fig. 61) the lanceolate *Elliptio* complex
- c. from two to more than three times as long as height, waxy yellow periostracum with no rays, shell length to about 86 mm. (pl. 3, fig. 16)*Elliptio lanceolata*
- 27** (24b) 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. 8, fig. 47)*Unio merus carolinianus*
- b. great variation in shell characteristics, often confused with many other taxa the *Elliptio complanata* complex (pls. 2, 3) [including *complanata*, *congregata*, *fraterna*, *roanokensis*]; those shells with short shell length, not too tall and inflated **AND** the *Elliptio icterina* complex] (pl. 3) [See Table 6 for species groups and figures for each species of *Elliptio*].
- 28** (23b) a. adult shell typically <40 mm in length, with a fuzzy or mat textured dark brown to black periostracum (pl. 8, fig. 45)*Toxolasma pullus*
- b. adult shell typically <40 mm in length with a fuzzy or mat textured dark brown to black periostracum, no sexual dimorphism, introduced to Falls Lake, Wake County [pl. 8, fig. 46)..... *Toxolasma parvum*
- c. adult shell >40 mm in length, lacking the pronounced fuzzy periostracum..... **29**
- 29** (28b) a. shell shape oval to elongate oval, periostracum very shiny to mat with rays..... **30**
- b. shell shape oval, periostracum dull yellow, without rays or with fine rays all over the shell, found in or near tidewater, nacre often a salmon color (pl. 6, fig. 32)*Leptodea ochracea*
- 30** (29a) a. periostracum shiny yellow, with fine green rays when present restricted to the posterior slope (pl. 5, fig. 25)*Lampsilis cariosa*
- b. periostracum mat to smooth but not shiny **31**

- 31 (30b) a. relatively large mussels, usually greater than 50 mm, often more than 80 mm in length 32
- b. relatively small mussels, usually less than 50 mm in length 34
- 32 (31a) a. posterior ridge very sharp, maximum shell length <60mm, restricted to the Lake Waccamaw drainage (pl. 5, fig. 27, 28) *Lampsilis radiata* [+*L. fullerkeri*]
- b. posterior ridge not sharp, but inflated, prominent or rounded..... 33
- 33 (32b) a. posterior ridge inflated and prominent, umbos inflated, (pl.11, fig. 63) *Lampsilis splendida*
- b. posterior ridge well rounded, umbos not inflated, maximum size >130 mm, shell broad and inflated, widespread, (pl. 5, fig. 28)..... *Lampsilis radiata*
- 34 (31b) a. periostracum greenish yellow, numerous green rays, shell relatively thin, oval to elongate oval, blade-like pseudocardinal teeth 35
- b. periostracum dark to black, shell thick, no green rays, shell shape oval to round (pl. 9, fig. 49) *Villosa constricta*
- 35 (34a) a. shell outline elliptical, numerous broad green rays, bluish white to pink or purple nacre (pl. 10, fig. 55) *Villosa modioliformis*
- b. shell outline elongate oval, rays not broad, nacre bluish white or iridescent 36
- 36 (35b) a. entire surface covered with narrow to very narrow green rays interrupted by growth lines (pl. 9, fig. 50) *Villosa delumbis*
- b. numerous continuous dark green rays over most of the shell (pl. 9, fig. 54) *Villosa vaughaniana*

MISSISSIPPI RIVER BASIN

- 37 (7b) a. lacking lateral teeth or all evidence of any hinge teeth..... 38
- b. shell with both pseudocardinal and lateral teeth present 45



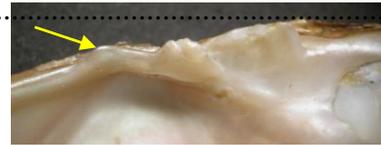
- 38 (37a) a. shell with pseudocardinal teeth but lacking lateral teeth 39



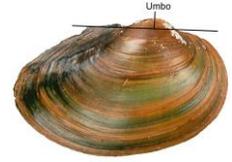
- b. shell with greatly reduced or totally lacking both pseudocardinal and lateral teeth 43



- 39 (38a) a. shell <28 mm, typically periostracum eroded off with periostracum restricted to narrow strip on shell margin, umbo sculpture heavy bars extending down on the disc of the shell, upper Little Tennessee River basin (pl. 6, fig. 36)*Pegias fabula*
- b. periostracum not eroded as above 40
- 40 (39b) a. hinge plate in left valve with an additional small interdental projection giving the appearance of a third pseudocardinal tooth41
- b. hinge without interdental projection, inflated, thin shelled, posterior ridge rounded, periostracum shiny, some rays apparent even in adults (pl. 1, fig. 2)*Alasmidonta raveneliana*
- c. hinge without interdental projection, inflated, thin shelled, posterior ridge rounded, posterior slope at steep angle to disc of the shell with a yellowish color, covered with fine plications, rays apparent even in adults (pl. 11, fig. 59)*Alasmidonta marginata*
- 41 (40a) a. a. shell thin, shell shape elongate oval, posterior ridge rounded not steep 42
- b. shell thickened anteriorly, shell shape ovate, rectangular to triangular, posterior ridge often angular, somewhat inflated, periostracum slightly glossy, with narrow and wide green rays (pl. 1, fig. 6)*Alasmidonta viridis*
- 42 (41a) a., umbo sculpture consists of six double looped concentric ridges, rest of shell smooth (pl. 5, fig. 30)*Lasmigona holstonia*
- b. umbo sculpture consists of 4-5 nodulous bars, first 2 concentric, double posterior ridge (pl. 6, fig. 31)*Lasmigona subviridis*
- 43 (38b) a. shell with pseudocardinal tooth consisting of a slight swelling or knob, lateral tooth consisting of a rounded ridge, umbo cavity copper colored, umbo centrally located (pl. 8, fig. 43) *Strophitus undulatus*
- b. hinge teeth completely absent 44

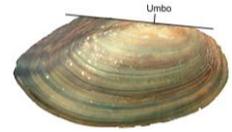


- 44 (43b) a. umbo elevated well above the hinge line, shell shape variable, ranging from oval, elliptical to rhomboid, umbo sculpture consists of double looped ridges with projections on the bottom of the loop (pl. 7, fig. 41) (Figure © Richard T. Bryant)



..... *Pyganodon grandis*

- b. umbo level with hinge line or below the level of the hinge line, shell shape elongate, inflated, dorsal and ventral margins nearly straight and parallel, umbo sculpture consists of 5-6 fine irregular concentric ridges (pl. 8, fig. 48) (Figure © Richard T. Bryant)



Utterbackia imbecillis

45 (37b) a. shell with sculpture on the external shell surface 46

b. shell with no plications, undulations, ridges, pustules or nodules..... 49

46 (45a) a. shell outline elongate, shell with prominent pustules or nodules and/or undulations, plications or ridges..... 47

b. shell outline round, shell with only prominent, well-defined pustules, knobs or nodules distributed across the shell 48

47 (46a) a. shell with undulations, ridges, or plications on the posterior slope, no pustules or nodules on the surface, shell elongate, with a rounded posterior ridge, inflated with a blue to blue-green nacre color (pl. 6, fig. 35)

..... *Medionidus conradicus*

b. shell with undulations, or ridges on the posterior slope and pustules on the shell disc or umbonal area, shell shape oval, elongate with a well-developed diagonal posterior ridge, nacre color white (pl. 11, fig. 62)..... *Tritogonia verrucosa*

48 (46b) a. pustules of uniform size, no broad green ray on umbo, periostracum of a uniform brownish, purple nacre, umbo cavity deep and compressed (pl. 2, fig. 9) *Cyclonaias tuberculata*

b. pustules generally large, often variable in size and shape, disc of the shell usually with a broad green stripe running down the disc of the shell with a variable number of pustules, varies from a very few to covering most of the shell, nacre color mostly white, umbo cavity deep and open not compressed (pl. 7, fig. 42)..... *Quadrula pustulosa*

49 (45b) a. shell shape round 50

b. shell shape not round 53

- 50 (49a) a. umbo central or nearly central in the dorsal margin 51
 - b. umbo anterior of the center of the shell..... 52
- 51 (50a) a. broad green ray extending from the umbo down only a short distance onto the disc of the shell, without pustules (pl. 7, fig. 42)..... *Quadrula pustulosa*



 - b. no broad green ray, shell with broad shallow to pronounced sulcus, fine green rays, shallow umbo cavity, well developed hinge teeth, female shells with a swollen, extended or expanded portion of the posterior slope and posterior ventral margin of the shell (pl. 4, fig. 21)..... *Epioblasma florentina aureola*
- 52 (50b) a. umbo cavity deep compressed (pl. 4, fig. 24)
 - *Fusconaia subrotunda*


 - b. umbo cavity shallow and open, shell with green rays at least on the umbo area with a thick shell, heavy lateral teeth, very shallow sulcus or missing, shallow to no umbo cavity (pl. 6, fig. 33) *Pleuroaia dolabelloides*


- 53 (49b) a. shell shape not oval..... 55
 - b. shell shape oval to oblong 54
- 54 (53b) a. shell shape oval, inflated, rayed, thin to thick shell, posterior ridge rounded or sharp, nacre variously white to pink or salmon (pl. 5, fig. 26)
 - *Lampsilis fasciola*
 - b. shell shape oblong to elongate oval, male shells are oval while female shells have a truncate posterior margin, purple nacre ranges from deep purple to copper (pl. 9, fig. 53)..... *Villosa vanuxemensis*
- 55 (53a) a. shell shape rectangular with shell compressed, posterior dorsal wing, purple nacre (pl. 11, fig. 60) *Potamilus alatus*
 - b. shell shape rectangular, triangular square or elongate but lacking posterior dorsal wing, nacre white or purple 56
- 56 (55b) a. shell shape rectangular, triangular, or square with sulcus 57
 - b. shell shape elongate, 2 to 4 times longer than high 58
- 57 (56a) a. shell shape rectangular, with green rays on the umbo (pl. 4, fig. 22)
 - *Pleuroaia barnesiana*
 - b. shell shape triangular to broadly triangular (pl. 7, fig. 38)..... *Pleurobema oviforme*

- 58** (56b) a. thin shelled, shell inflated, periostracum usually rayed, adult shell length >50 mm, shell hinge thin, usually heavily rayed (pl. 9, fig. 51)..... *Villosa iris* complex
 b. thick shelled..... **59**
- 59** (58b) a. shell compressed..... **60**
 b. shell inflated **61**
- 60** (59a) a. shell hinge massive, curved, nacre white, periostracum with interrupted green rays, nacre white or yellow (pl. 7, fig. 39) *Ptychobranthus fasciolaris*
 b. hinge lighter, straight, nacre purple to white, periostracum typically unrayedn nacre purple (pl. 3, fig. 13)..... *Elliptio dilatata*
- 61** (59b) a. periostracum smooth, color olive green with numerous rays, nacre white or purple (pl. 9, fig. 52)..... *Venustaconcha trabalis*
 b. periostracum mat, color ranges from greenish to black without rays, nacre purple (pl. 8, fig. 44)..... *Toxolasma lividum*

CYRENIDAE (+Corbiculidae)
***Corbicula fluminea* (Müller, 1776)**
INTRODUCED

Asian Clam

Plate 10, Figure 56, 57

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.

North 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. Umbos are high, full, directed inward, and elevated well above the hinge line, and centrally located. Thin, prominent concentric rings indicate growth periods. There are three cardinal teeth directly below the umbos 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 umbo 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 umbo 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 heterodon*****(Lea, 1829)****Dwarf Wedgemussel**

Plate 1, Figure 1

Synonymy:*Unio heterodon* Lea, 1829; Lea, 1829:428, pl. 8, fig. 11**Type Locality:** Schuylkill [River] and Derby [sic] Creek [mostly in Delaware County] P[ennsylvania]**General Distribution:** Clarke (1981:32, 34, Fig. 10) listed the distribution for the Dwarf Wedgemussel as occurring from the Neuse River basin, North Carolina, in the south, north to the Petitcodiac River Basin, New Brunswick, Canada. Distribution of *A. heterodon* is sporadic in the river basins between these two river basins.**North Carolina Distribution:** This species occurs in the Neuse and Pamlico River basins in North Carolina (Clarke, 1981; Table 2).**Description:** The shell is small, somewhat inflated and rather thin, thickened anteriorly, reaching a shell length of about 56 mm. Anterior margin sharply curved, ventral margin broadly curved to straight, and the posterior margin is roundly pointed near the base and broadly truncated above. The shells of males are more compressed and the shell shape is more ovate and elongate with a reduced posterior ridge, the posterior slope is not truncated. Female shells are more swollen around the posterior ridge and have a more distinct posterior ridge making the posterior slope appear truncated, thus making the whole shell appear more trapezoidal (Ortmann 1919:174). Posterior ridge well developed, extending to the posterior ventral margin and coming to a point. Umbos are low, rounded and projecting slightly above the hinge line, with umbo sculpture consisting of a few well developed ridges or bars, running parallel to the growth lines, subsequent umbo sculpture is double looped. This sculpture is visible only on young specimens.

Surface marked by uneven growth lines.

Left valve has two compressed, pseudocardinal teeth, and may have one to three lamellar lateral teeth. Right valve with one or two compressed, pseudocardinal teeth and two lamellar lateral teeth that extend to the end of the ligament. This is the reverse of the rest of the species with lateral teeth. Interdentum marked by an accessory dentacle in the left valve and a corresponding depression in the right valve, umbo cavity rather narrow and not very deep. Periostracum color varies from yellowish olive brown to green to black with some specimens with variable width, faint, reddish-brown rays. Nacre color is bluish white

Life History and Ecology: Fuller (1977:168) characterized the habitat of the Dwarf Wedgemussel as: "stable stream floors of sand and/or fine gravel, but like most other member of the subfamily Anodontinae, it has a considerable tolerance of sediment overlying formerly clean streambeds." Ortmann (1919) found this species gravid in February to April in Pennsylvania. Clarke (1981b:31-32, fig. 9) described the glochidium of the Dwarf Wedgemussel as depressed, pyriform with a straight hinge, with a ventral hook, glochidial length 0.325mm and height 0.255 mm. Hoggarth (1999:36, 39, figs. 19a-f) commented that glochidium was asymmetrical in outline and listed the length as 330-338 μm and height as 258-268 μm . Michaelson and Neves (1995) listed three fish species, which serve as hosts for the glochidia of the Dwarf Wedgemussel in laboratory studies: Tessellated Darter (*Etheostoma olmstedi*), Johnny Darter (*E. nigrum*) and the Mottled Sculpin (*Cottus bairdi*). Wicklow (1999) reported the Atlantic Salmon (*Salmo salar*) as a suitable host for the glochidia of this species.

Status: Endangered (Williams et al., 1993:10). This species is federally and state listed as endangered.**Remarks:** The generic placement of *A. heterodon* has been questioned (Fuller, 1977). Based on recent DNA analyses, it is suggested that the species *A. heterodon* should be moved

to a genus separate from *Alasmidonta*. This new placement would be *Pressodonta heterodon* (Bogan et al. 2007).

Alasmidonta marginata* Say, 1818*Elktoe**

Plate 11 fig. 59

Synonymy: *Alasmidonta marginata* Say, 1818;
Say, 1818:459, 460

Type Locality: Scioto River, Chillicothe, Ohio
General Distribution: Upper Interior drainage of the Ohio, Cumberland, and Tennessee River systems; St. Lawrence drainage from Lake Huron to the Ottawa River; Susquehanna River drainage (Burch, 1975).

North Carolina: Distribution: Known only from a single lot in the Academy of Natural Sciences of Drexel University, Philadelphia. ANSP 41057 was collected from [French Broad River basin] Buncombe County, North Carolina, without any date or collector recorded.

Description: shell elongated, somewhat rhomboid, inflated, thin when young, thick and solid when old. Mature individuals attain an average length of about 75 mm. Anterior end is sharply rounded; the ventral margin is straight and the posterior margin nearly so, and they meet in a blunt, squared point. The posterior ridge is high and sharply angled, producing a broadly truncated posterior end; there are numerous fine, radial ridges on the posterior slope extending upward toward the margin. Umbos are large, inflated, elevated, nearly centrally located on hinge line; sculpture consists of 3–4 heavy, rounded, usually double-looped bars. The pseudocardinal teeth are thin, elongated, low; one in the right, sometimes the left, has partially divided pseudocardinal which appears as an additional interdental projection. Lateral teeth are lacking, but appear as a thickened hinge line. The umbo cavity is moderately deep, and there is no interdentum. Periostracum is yellowish brown or greenish, usually marked with numerous greenish or blackish rays, plus many darker spots which appear in connection with the rays. Nacre is bluish white with a slight iridescence, occasionally with shades of pink (Parmalee and Bogan 1998:56-57).

Life History and Ecology: The Elktoe reaches its greatest abundance in small, shallow rivers with a moderately fast current such as the upper Clinch and Power rivers in East Tennessee. A mixture of fine gravel and sand comprises the most suitable substrate for this mussel. Baker (1928) records this species as being bradyctictic in Wisconsin, the reproductive season extending from mid-July to mid-June. The white sucker (*Catostomus commersoni*), northern hog sucker (*Hypentelium nigricans*), shorthead redhorse (*Moxostoma macrolepidotum*), rockbass (*Ambloplites rupestris*), and warmouth (*Lepomis gulosus*) have been reported by Howard and Anson (1922) as hosts for the glochidia of this mussel (Parmalee and Bogan, 1998:57).

Status: Special Concern (Williams et al., 1993:10).

Remarks: This record was discovered by S. Fraley (Pers. Comm. 28 July 2015).

Alasmidonta raveneliana
(Lea, 1834)

Appalachian Elktoe

Plate 1, Figure 2

Synonymy:

Margaritana raveneliana Lea, 1834; Lea, 1834:106, pl. 17, fig. 50

Type Locality: French Broad and Swananoë [*sic*] rivers, North Carolina.

General Distribution: The Appalachian Elktoe is restricted to the tributaries of the Tennessee River in East Tennessee and western North Carolina.

North Carolina Distribution: This species is found in the Nolichucky River, Little Tennessee River basin and the French Broad River in western North Carolina (Clarke, 1981b, T. Savidge, Pers. Comm. March 2002)

Description: The Appalachian Elktoe is oblong, somewhat kidney-shaped in outline, moderately inflated, and thin-shelled but not fragile. The anterior margin is sharply rounded, and the posterior margin is broadly rounded, coming to a rounded point close to the posterior ventral margin. The ventral margin is nearly straight or slightly concave, and the dorsal margin is nearly straight posterior to the umbos. The posterior ridge is rounded and often double; the posterior slope is slightly concave, but not as acute as in the Elktoe (*Alasmidonta marginata*). The umbos are moderately full, rounded, and situated on the anterior third of the shell and slightly above the hinge line. Umbo sculpture consists of a few fairly heavy straight or slightly double looped bars, which terminate at the posterior ridge. The Appalachian Elktoe reaches a maximum length of about 80 mm (Clarke, 1981b). Specimens > 120 mm have been seen in the Pigion and Little Rivers (T. Savidge, Pers. Comm. March 2002).

The left valve has a single small, compressed, pyramidal pseudocardinal tooth; the lateral tooth is reduced to a swelling or ridge and is not an articulating tooth. The left valve also has a moderate-sized interdental projection. The

right valve has a single small compressed pyramidal pseudocardinal tooth and a single reduced ridge along the hinge line in place of the lateral tooth. Umbo cavity is quite shallow. Adductor muscle scars are shallow, becoming somewhat deeper and more distinct in large mature individuals. Dorsal muscle scars are present and consist of one or two short grooves. The pallial line is absent in some individuals, complete and distinct in others. The periostracum varies from yellowish brown in younger specimens to dark brown or black in adults with faint, often interrupted green rays. The surface is mostly smooth, but interrupted by concentric growth lines. There may be some fine plications on the posterior slope on juvenile specimens. Nacre color varies from a uniform bluish white to greenish, sometimes with a purplish tint, to salmon or pinkish in the center of the shell and umbo cavity. (Parmalee and Bogan, 1998).

Life History and Ecology: *Alasmidonta raveneliana* may be locally common in some rivers, such as the Little Tennessee and Nolichucky in North Carolina, where it inhabits sand and gravel substrates among cobbles and boulders and under flat rocks, usually in moderate current at depths of less than three feet. Ortmann (1921) reported that the breeding season ended in May, the species being bradyctytic. Fish hosts for the glochidia of *Alasmidonta raveneliana* as the Banded Sculpin (*Cottus carolinae*) (Moorman and Gordon, 1993; Watters, 1994; Gordon and Moorman, 2002).

Status: Endangered (Williams et al., 1993:10). The U.S. Fish and Wildlife Service has developed a recovery plan for this species (U.S. Fish and Wildlife Service, 1996). This species federally and state listed as endangered. The U.S. Fish and Wildlife Service (2001) has proposed critical habitat for the Appalachian Elktoe.

Remarks: *Alasmidonata raveneliana* was confirmed as a species separate from *A. marginata* in DNA studies (Bogan et al. 2007).

The populations in the Little Tennessee are genetically separate from those of the French Broad River drainage and should be treated as separate conservation units at this time (Bogan et al., 2007).

***Alasmidonta robusta* Clarke, 1981**
Carolina Elktoe

Plate 1, Figure 3

Synonymy:

Alasmidonta robusta Clarke, 1981: Clarke, 1981b:81-84, figs. 23, 27

Type Locality: Long Creek, a tributary of the Catawba River, Mecklenburg County, North Carolina.

General Distribution: Long Creek, tributary of the Catawba River, Mecklenburg County, North Carolina (Clarke, 1981b).

North Carolina Distribution: Long Creek, tributary of the Catawba River, Mecklenburg County, North Carolina (Clarke, 1981b).

Description: The Carolina Elktoe is known from five specimens. The length ranges from 42 to 66 mm; the height ranges from 26 to 42 mm; the width ranges from 18 to 33 mm. The holotype is 66 mm long, 43 mm high and 33.2 mm wide. The following abbreviated description is taken from Keferl and Shelly (1988). A more complete description can be obtained from Clarke (1981b). The shell of the Carolina Elktoe is thin and sturdy, the anterior margin is well rounded; the ventral margin broadly curved; the posterior end forms a round point below the center. The periostracum is glossy, pale greenish-yellow with broad greenish rays that diminish at the posterior ridge. The posterior slope is covered with corrugations that are perpendicular to the posterior margin of the posterior slope. The Carolina Elktoe has a large interdental projection in the left valve. See Keferl and Shelly (1988) for a comparison with *Alasmidonta varicosa* (Lamarck, 1819) (Adams et al., 1990).

Life History: Nothing is known of the about the specific habitat of the Carolina Elktoe. Long Creek, its only collection site, is a small creek with a fairly steep gradient and substrates that vary from mud to bedrock. The stream has numerous deep isolated pools separated by rapids over small rocks, boulders and bedrock.

Host fish information on this species is unknown (Adams et al., 1990).

Status: According to Keferl and Shelly (1988), *Alasmidonta robusta* was not found in any part of the Catawba or Pee Dee river systems (Adams 1990). A thorough search of its only known locality yielded no specimens. Based upon current data this species is probably extinct. Clarke (1981b). Williams et al. (1993:10) listed it as extinct.

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

Plate 1, Figure 4

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 Catawba River of North Carolina.**North Carolina Distribution:** This species is found in the Chowan, Pamlico, Roanoke, Neuse, Cape Fear, and Pee Dee River basins (Clarke, 1981b; Table 2)**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 rounded but often indistinct, the posterior slope somewhat compressed. Umbos are more or less full inflated and somewhat elevated above the hinge line, umbo 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 (Clarke, 1981b). Posterior slope sometimes marked by oblique ridges or corrugations. Periostracum is smooth and shiny.

Left valve has a single short, stumpy, sculptured pseudocardinal tooth with a smaller tooth anterior. There is usually a well-developed interdental projection present. Right valve has a single short stumpy often-sculptured pseudocardinal tooth. The interdental area is broad and flat, with the lateral teeth absent. The umbo 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 the authors 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. Host fishes 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*), 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 listed as State Threatened in North Carolina.**Remarks:** *Alasmidonta undulata* is a good species and has nothing to do with *Alasmidonta triangulata* (Lea, 1858) of the Apalachicola River Basin as suggested by Clarke (1981) (Bogan et al., 2007)

Alasmidonta varicosa
(Lamarck, 1819)

Brook Floater

Plate 1, Figure 5

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 South Carolina (Clarke, 1981).

North Carolina Distribution: The Brook Floater is found in Roanoke, Neuse, Cape Fear, Pee Dee and Catawba River basins in North Carolina (Clarke, 1981b; Table 2).

Description: Shell shape is oblong, long rhomboid, thin-shelled, but slightly thickened anteriorly, 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 and slightly concave and covered with numerous, low corrugations or ridges. Umbos are narrow and bluntly pointed and located about 1/3 the distance from the anterior end and project only slightly above the hinge line. Umbo 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. Umbo 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 umbo 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 deeply buried during the summer but sitting up on top of the substrate in January and February when water temperatures are at the coldest. 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; Neddeau 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 listed as State Endangered in North Carolina, effective July 1, 2002.

Remarks: *Alasmidonta varicosa* is polyphyletic as currently used. Recent analyses of DNA sequence data have shown a population identified as *A. varicosa* in the Uwharrie River drainage to be a distinct and separate species (Bogan et al., 2007)

Alasmidonta viridis
(Rafinesque, 1820)

Slippershell Mussel

Plate 1, Figure 6

Synonymy:

Unio viridis Rafinesque, 1820; Rafinesque, 1820:293

Type Locality: Ohio River.

General Distribution: Upper Mississippi River drainage; Ohio, Cumberland, and Tennessee rivers; lower and middle sections of the St. Lawrence River systems: Lake Huron, Lake St. Clair, and Lake Erie drainages in Canada (Clarke, 1981a).

North Carolina Distribution: This species is known from the Little Tennessee, Mills and French Broad Rivers (Table 3).

Description: The shell is small, rhomboid, moderately solid, and slightly inflated. Maximum shell length of adult specimens seldom exceeds 55 mm. The anterior end is rounded; the posterior end is squared or obliquely truncated. The posterior ridge is high, rounded, and usually ends as a blunt point at the base of the shell. Umbos are moderately swollen, only slightly elevated; sculpture consists of 5–6 irregular, heavy loops, the first one or two are diagonal to the hinge line, and the others are somewhat concentric. The surface has uneven growth lines, the rest periods appear as raised, dark-lined ridges. The pseudocardinal teeth in both valves are somewhat rudimentary, or they appear as elevated, triangular projections, usually doubled in the left valve. Lateral teeth are indistinct, being represented as a slight swelling of the hinge line. The umbo cavity is relatively shallow; the interdentum is narrow or absent. There is a well developed interdental projection on the hinge of the left valve. The periostracum in young shells is a dull eggshell white, greenish or yellowish, with numerous wavy green rays; the colors are darker and the rays less distinct in old shells. The nacre is a dull white, and the posterior margin is slightly iridescent. (Parmalee and Bogan, 1998).

Life History and Ecology: A species of small creeks and shallow streams today, *A. viridis* once inhabited the shoals and riffles of large rivers such as the French Broad and Holston before impoundment. The Slippershell Mussel may typically be found living in a substrate composed of sand and fine gravel, although in stretches where there is a continuous current this small naiad will thrive in a mud and sand bottom among the roots of aquatic vegetation. Host fish for the glochidia include the Banded Sculpin (*Cottus carolinae*) and probably the Mottled Sculpin (*C. bairdi*) and Johnny Darter (*Etheostoma nigrum*) (Zale and Neves, 1982c; Watters, 1994). Baker (1928:186) states that the species in Wisconsin is “[p]robably bradyctytic, with mature glochidia in the fall (September).” Individuals of this species have been observed spawning in January and February in the upper Little Tennessee River, North Carolina (Ahlstedt, pers. comm., 1994). Females lay on the substrate surface while spawning.

Status: Special Concern (Williams et al., 1993:10). This species is considered State Endangered in North Carolina, effective July 1, 2002.

Remarks: *Alasmidonta viridis* has been shown in recent DNA sequence analyses not to belong to *Alasmidonta* but represents a separate and distant clade. The subgenus *Pressodonta* was erected for *A. viridis*. Bogan et al. (2007) have elevated this subgenus to generic level with the new combination *Pressodonta viridis*.

Anodonta couperiana* Lea, 1840*Barrel Floater**

Plate 2, Figure 7

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 drainage basin in North Carolina.

North Carolina Distribution: This species has been extirpated from one of its two known locations in North Carolina. The barrel floater was once known from the Greenfield Lake basin near Wilmington and the lower Cape Fear River (Morrison, 1972; Adams et al., 1990). Vidrine (1980) documents this species from Bladen County (Adams et al., 1990). However, there are no recent records of the Barrel Floater in North Carolina (J. Alderman, Pers. Comm. July 2002).

Description: The barrel floater may reach over 100 mm in length. Like other *Anodonta*, this species also lacks pseudocardinal and lateral teeth. The shell of the barrel floater is similar to that of *Utterbackia imbecillis* in that the umbos do not extend above the dorsal margin. However, the barrel floater's height to length ratio is around 2 compared with 1.5 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 host fish for this species is unknown.

Status: Williams et al. (1993:10) listed as special concern. This species is listed as State Endangered.

Anodonta implicata* Say, 1829*Alewife Floater**

Plate 2, Figure 8

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, North Carolina (Adams et al., 1990).

North Carolina Distribution: This species is found in the Chowan River, Roanoke and Pee Dee River systems in North Carolina (Shelley, 1983; Adams et al., 1990; Table 2).

Description: Shell shape is elliptical, oblong to ovate in outline, approaching sub cylindrical 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. Umbos are moderately full and slightly raised above the hingeline, umbo 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 umbo 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 umbo 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 host fish. Nedeau 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. Wiles (1975) reported the time when *A. implicata* has mature glochidia is from 11 May, 18 August, 29 September, 15 October and 1 December, 1971 and 9 May 1972 in Nova Scotia. Identification of fish containing glochidia was inconclusive (Wiles, 1975). The Alewife (*Alosa pseudoharengus*) has been reported as a host fish for this mussel (Davenport and Warmuth, 1965).

Status: Currently Stable (Williams et al., 1993:10). This species is considered State Threatened in North Carolina.

***Cyclonaias tuberculata* (Rafinesque, 1820)**

Purple Wartback

Plate 2, Figure 9

Synonymy:

Obliquaria (Rotundaria) tuberculata Rafinesque, 1820;
Rafinesque, 1820:103

Type Locality: Ohio River and its tributaries.

General Distribution: Upper Mississippi River drainage generally; Lake St. Clair drainage, and from Pennsylvania northwest to southern Michigan and northwestern Wisconsin (Mathiak, 1979), south to Iowa, Missouri, and Arkansas. In Canada, Lake Erie and the Sydenham River in southern Ontario (Clarke, 1981a). It occurs throughout the Tennessee and Cumberland river drainages.

North Carolina Distribution: This species is restricted to the New River, Allegheny County, in North Carolina (Table 3).

Description: The shell is compressed (among specimens in streams) to slightly inflated (among specimens in large rivers), solid, subquadrate to circular in outline. Mature individuals may attain a length of 130 mm. Umbos are depressed (in stream forms) to moderately swollen, rather prominent (in large river forms); sculpture consists of numerous fine, irregular, broken ridges, each made up of alternating zigzag bars and loops which continue down the valve until the nodules appear; there is often a shallow, narrow furrow or depression centrally on the umbonal area. A wing like depression above the low dorsal ridge, more extensive in stream forms. Center and posterior surfaces are covered with rounded or elongated tubercles that parallel the growth lines; tubercles are more numerous in stream forms. The anterior end and ventral margins are broadly rounded; the posterior end is occasionally rounded, usually squarely or obliquely truncated.

The left valve has two narrow but heavy, divergent pseudocardinal teeth, deeply serrated between, sometimes almost meeting anteriorly; the two lateral teeth are short, heavy, and

slightly curved. The right valve has a single, massive, ragged, slightly triangular-shaped pseudocardinal tooth, usually with a small tubercular tooth on either side. The umbo cavity is compressed and deep; the interdentum is wide and flat. The periostracum is a dull yellowish brown to dark brown; young shells occasionally have traces of greenish rays. The nacre varies from a uniform deep purple, often with a coppery tinge along the margin, to light purple with the center (within the pallial line) nearly white; the posterior margin is iridescent (Parmalee and Bogan 1998:68-69).

Life History and Ecology: This mussel typically inhabits a gravel/mud bottom, usually in areas of current or riffles; in water less than two feet in depth, but can occur at depths up to 20 feet. The species is tachytictic, and the reproductive period lasts from June to August. Initial studies by Hove et al. (1994) showed the Channel Catfish (*Ictalurus punctatus*) and Yellow Bullhead (*Ameiurus natalis*) as suitable hosts for glochidia of this mussel. Additional testing of the yellow bullhead confirmed it as a valid host species (Hove et al., 1994). Subsequently, Hove (1997) has reconfirmed the channel catfish as a host species and has added two new host species for the glochidia of the Purple Wartback: the Flathead Catfish (*Pylodictis olivaris*) and the Black Bullhead (*Ameiurus melas*) (Parmalee and Bogan, 1998). **Status:** Special Concern (Williams et al., 1993:11). This species is by the Natural Heritage Program as significantly rare in North Carolina.

Elliptio cistellaeformis* (Lea, 1863)*Box Spike**

Plate 2, Figure 10

Synonymy:

Unio cistellaeformis Lea, 1863; Lea, 1863:192

Type Locality: Neuse River, near Raleigh, North Carolina.

General Distribution: Restricted to the Atlantic river basins from the Catawba to the Pamlico River basins in North Carolina (Table 2).

North Carolina Distribution: This species is found in the Catawba, Pee Dee Lumber, Cape Fear, Neuse, Pamlico River basins in North Carolina (Table 2).

Description: “Shell smooth, oblong, very much inflated, flattened at the side, inequilateral, obtusely angular behind, rounded before; substance of the shell somewhat thick; umbos somewhat prominent; ligament rather short and dark brown; epidermis dark brown, without rays, with rather close marks of growth; umbonal slope swollen and rounded; posterior slope broad, flattened, scarcely carinate; cardinal teeth small, tuberculate, double in both valves; lateral teeth rather long, lamellar and nearly straight; anterior cicatrices distinct, large and well impressed; posterior cicatrices confluent, large and slightly impressed; dorsal cicatrices placed over the centre of the cavity of the umbos; cavity of the shell deep and wide; cavity of the umbos rather shallow and rounded; nacre white and iridescent: (Lea, 1863:19-20). The shell is very inflated with a very straight ventral margin.

Life History: The host fish for the glochidia of this species is unknown. It is found along the banks often among the tree roots.

Status: Williams et al. (1993:11) listed the status as unknown.

Elliptio complanata
(Lightfoot, 1786)

Eastern Elliptio

Plate 2, Figure 11

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.

North Carolina Distribution: This species is wide spread in the Atlantic Slope rivers in North Carolina from the Chowan south to the Broad River. It is introduced into the French Broad River in Buncombe County (T. Savidge, Pers. Comm. March 2002) (Table 2).

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 often straight, posterior margin broadly rounded ending at or near the base in a point or biangulation. Posterior ridge is broad and double and rounded to angular. The posterior slope is flat. Umbos are low and uninflated, umbo 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 is essentially absent. Umbo 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). Females were reported with mature glochidia in Nova Scotia from 15 June to July 23, 1974 (Wiles, 1975). Based on glochidial measurements compared with glochidia removed from fish, Wiles (1975) identified Banded Killifish (*Fundulus diaphanous*) as a potential host fish for *E. complanata* in Nova Scotia with suggestions of other possible fish hosts. 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). The Bluegill (*Lepomis macrochirus*) and the Pumpkinseed (*Lepomis gibbosus*) have subsequently been added as host fish in the laboratory (Watters et al., 2005).

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

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

Plate 2, Figure 12

Synonymy:*Unio congaraeus* Lea, 1831; Lea, 1831:72, pl. 6, fig. 4*Elliptio waccamawensis* (Lea, 1863); Lea 1863:193.**Type Locality:** Congaree River, South Carolina**General Distribution:** This species is known from the Ogeechee River system in Georgia north to the Pamlico River system of North Carolina (Johnson, 1970; Table 2).**North Carolina Distribution:** *Elliptio congaraea* is known from the Pamlico, Neuse, Cape Fear and Pee Dee River systems in North Carolina (Johnson, 1970; Table 2).**Description:** "Shell rhomboid, subcompressed, rather thin to subsolid, somewhat inequilateral; umbos 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, wrinkled on the dorsal 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; umbo cavities not deep; muscle scars superficial; nacre purplish, often lurid in the shell cavities." (Simpson 1914:615).**Life History:** The host fish for the glochidia of *Elliptio congaraea* are unknown. However, there is information on the synonym, *Elliptio waccamawensis*. 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. Host fish 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/m². Highest recorded density was 132.3/m². Densities of *E. waccamawensis* were positively correlated with light penetration and pH; densities were negatively correlated with: sediment pheopigment and mean sediment size (\emptyset units). *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 *Elliptio congaraea* as special concern. This species is not State listed in North Carolina at this time. *Elliptio waccamawensis* was listed by Williams et al. (1993:11) as special concern. *Elliptio waccamawensis* was listed as State Endangered effective July 1, 2002.**Remarks:** *Elliptio waccamawensis* was determined to belong with *E. congaraea* and was placed as a synonym of *E. congaraea* fide McCartney et al. (2016).

Elliptio dilatata
(Rafinesque, 1820)

Spike

Plate 3, Figure 13

Synonymy:

Unio (Euryntia) dilatata Rafinesque, 1820; Rafinesque, 1820:297

Type Locality: *Unio dilatatus*: no type locality published, but generally considered to be Ohio River.

General Distribution: Entire Mississippi River drainage from the St. Lawrence River and its tributaries south to northern Louisiana and west to the tributaries of the Red River, Oklahoma. Howells et al. (1996) report a single locality on the San Marcos River in Texas. With reference to Canada, Clarke (1981a:268) states that the Spike is “[c]ommon in the Great Lakes and their tributaries from Lake Michigan to Lake Erie; uncommon in Lake Ontario and in the St. Lawrence River.” (Parmalee and Bogan, 1998).

North Carolina Distribution: The Spike is known from the Hiwassee, Little Tennessee, French Broad and New River basins in North Carolina (Ortmann, 1918; Table 3)

Description: The shell is compressed to slightly inflated, attenuate, solid, and thick. Mature individuals inhabiting impounded stretches of large rivers become especially large and develop extremely thick shells, many attaining a length of 120 mm. Umbos are depressed and flattened; sculpture consists of 4–5 pronounced loops, running parallel with the growth lines. The anterior end is broadly rounded, the ventral margin is straight or slightly curved, and the posterior end is sharply pointed and often compressed behind the strongly developed, rounded posterior ridge. Concentric rest lines are often prominent. The left valve has two triangular, divergent, compressed pseudocardinal teeth, usually roughened or finely serrated; the two lateral teeth are heavy, rough, widely separated, and the inner surface is usually rough. The right valve has a heavy, triangular pseudocardinal

tooth; the lateral tooth is low, thick, and roughened. The interdentum is moderately wide; the umbo cavity is usually very shallow or absent. Periostracum of young shells is light brown, greenish, or yellowish green, often faintly rayed; old valves are dark greenish brown to black. The nacre varies from white through salmon to deep purple (Parmalee and Bogan 1998:80).

Life History and Ecology: *Elliptio dilatata* is somewhat generalized relative to the size of rivers, which it inhabits, and depths at which it may occur. A firm substrate composed of coarse sand and gravel with moderately strong current appears to provide the most suitable habitat, but also can be found in soft mud. Baker (1928) indicated the species was tachytictic, the reproductive season occurring from mid-May to August. The Gizzard Shad (*Dorosoma cepedianum*), Flathead Catfish (*Pylodictis olivaris*), White Crappie (*Pomoxis annularis*), Black Crappie (*P. nigromaculatus*), and the Yellow Perch (*Perca flavescens*) have been listed by Fuller (1974) as host species for the glochidia. Under laboratory conditions Luo (1993) was able to infect the Rainbow Darter (*Etheostoma caeruleum*), Banded Sculpin (*Cottus carolinae*), and Rockbass (*Ambloplites rupestris*) with glochidia of the Spike (Parmalee and Bogan, 1998).

Status: Currently Stable (Williams et al., 1993:11). This species is listed as State Special Concern in North Carolina.

Elliptio fisheriana**Northern Lance**

Plate 11, Figure 61

Synonymy:*Unio fisherianus* Lea, 1838; Lea 1838:8, plate 4, fig. 8.*Unio emmonsii* Lea, 1857; Lea 1857:86; Lea 1862:56, plate 2, fig. 203.**Type Locality:** Head of Chester River, [Kent Co.] Maryland. Type locality emended by Johnson (1970:333).**General distribution:** Northern Lance is known from the Roanoke River basin of North Carolina and Virginia north to the Potomac River basin of Maryland and Pennsylvania and the rivers of western Delaware.**North Carolina Distribution:** This species is reported from the Roanoke River basin, but may also occur in the Chowan River basin.**Description:** Elongate (rarely exceeding 100 mm), compressed, thin, beaks low, posterior ridge subangular to angular, posterior end bluntly rounded, ventral margin broadly curved, anterior end rounded, periostracum olive, green to brown and black with age, often with faint rays, beak cavity very shallow, nacre white to purplish, posteriorly iridescent. (Bogan and Ashton, 2016).**Life History and Ecology:** there is Bogan and Ashton (2016) reported this species “often found in mud or clay of runs and pools near the stream bank, occasionally found buried in the slope of the bank. Typically, they are the second most abundant mussel of coastal streams.”O’Dee and Watters (2000) reported this species as tachtictic and list host fish as “Bluegill, *Lepomis macrochirus*; Green sunfish, *Lepomis cyanellus*; Johnny darter, *Etheostoma nigrum*; Largemouth bass, *Micropterus salmoides*; and White shiner, *Luxilus albeolus*.”**Status:** Williams et al. (1993) list this species as of special concern.**Remarks:** This species was listed as a junior synonym of *Elliptio lanceolata* by Johnson (1970). However, phylogenetic work on the lanceolate *Elliptio* found in the rivers of Virginia and northern North Carolinadocumented the validity of *E. lanceolaria* as a separate species (Bogan et al. 2009). This same work focused on the rest of the lance shaped animals in Virginia and the Roanoke River basin in North Carolina. These specimens were identified as four separate shell shapes but represent a single separate species, *Elliptio fisheriana* (Bogan et al. 2009).

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

Plate 3, figure 14

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 Savannah River north to the Waccamaw and Cape Fear River basins in North Carolina (Johnson, 1970; Table 2).**North Carolina Distribution:** This species is found in the Cape Fear, Waccamaw and Pee Dee River basins. (Johnson, 1970; Morrison, 1972; Table 2)**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 of inner shell surface varies from bluish to pink. The hinge has pyramidal pseudo-cardinal 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; umbos 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 umbos; cavity of the shell small; cavity of the umbo 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. Host fish 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 near by 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 listed as Sate Special Concern in North Carolina.

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

Plate 3, Figure 15

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 2).**North Carolina Distribution:** This species is found in from the Broad River basin north to the Roanoke River basin (Johnson, 1970; Table 2).**Description:** “Shell oblong, subelliptical or subrhomboid, convex, solid, inequilateral; umbos 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 host fish are known for the glochidia of this species.**Status:** Williams et al. (1993:11) listed as currently stable.

Elliptio lanceolata* (Lea, 1828)*Yellow Lance**

Plate 3, figure 16

Synonymy:*Unio lanceolatus* Lea, 1828; Lea, 1828:266, pl. 3, fig. 2**Type Locality:** Tar River at Tarborough [Edgecombe County], North Carolina (Johnson, 1970).**General Distribution:** The yellow lance is known from the Tar, Roanoke, James, and Rappahannock drainages (A. Gerberich, pers. comm.) (Adams et al., 1990).**North Carolina Distribution:** The Yellow Lance is restricted to the Pamlico and Neuse River systems (Table 2).**Description:** This elongate freshwater mussel grows to approximately 86 mm long. Shells are over twice as long as tall. The periostracum is usually bright yellow over the entire surface in younger individuals. Older individuals may have a brown discoloration at the posterior end of the shell. (Uniformly brown individuals are also found; however, yellow and brown individuals are not found at the same stations.) The nacre may range from salmon to white to an iridescent blue color. The posterior ridge is distinctly rounded and curves dorsally toward the posterior end. Rays are usually never present; however, one individual has been observed with three wide, prominent green rays on the posterior third of the shell in the Tar River Drainage Basin (Adams et al., 1990). Brownish growth rests are clearly evident on the periostracum. The pallial line and adductor muscle scars are distinct. The posterior adductor muscle scars are less impressed than the anterior adductor muscle scars. The lateral teeth are long - two on the left valve and one on the right valve. Two pseudocardinal teeth are on each valve. On the left valve one is before the other with the posterior tooth tending to be vestigial. On the right valve, the two pseudocardinal teeth are parallel with the more anterior one rather vestigial. (Adams et al., 1990)**Life History:** *Elliptio lanceolata* prefers clean, coarse to medium size sands as substrate. On

occasion, specimens are also found in gravel substrates. This species is found in the main channels of drainages down to streams as small as three feet across. Gravid females have been found in the Tar River Drainage Basin in June (Alderman, unpubl. data). As verified by Tankersley (1988), the glochidia are hookless. The fish host for this species has not been determined.

Status: Williams et al. (1993:11) listed as endangered. The existence of the Yellow Lance in the Roanoke Drainage Basin has not been verified in recent years. In the Tar River, this species has declined (Alderman 1988) since A. Clarke (1983) completed his survey for the Tar River spiny mussel (Adams et al., 1990). This species is listed as State Endangered effective July 1, 2002.**Remarks:** Recently, DNA sequence analyses of *Elliptio* species placed *E. lanceolata* outside of the clade comprising the genus *Elliptio* (Bogan et al., 2003). However, phylogenetic work on the lanceolate *Elliptio* found in the rivers of Virginia and northern North Carolina documented the validity of *E. lanceolaria* as a separate species (Bogan et al. 2009).

Elliptio marsupiobesa* Fuller, 1972*Cape Fear Spike**

Plate 3, Figure 17

Synonymy:*Elliptio marsupiobesa* Fuller, 1972; Fuller, 1972:1-10**Type Locality:** Cape Fear River, 0.1 miles downstream from Carvers Creek, Cumberland County, North Carolina.**General Distribution:** *Elliptio marsupiobesa* is only known from the Cape Fear River, North Carolina.**North Carolina Distribution:** *Elliptio marsupiobesa* is only known from the Cape Fear River in Cumberland and Bladen counties**Description:** The Cape Fear spike may reach about three inches in length. The anterior third of the shell is considerably thicker than the posterior third, and the shell appears to significantly thicken as individuals grow. The shell is distinctly wedge shaped without sexual dimorphism. The swollen posterior ridge is keeled and the posterior slope is narrow and concave. Adults have one or two radial grooves on the posterior slopes. Growth rests are clearly expressed in the shells. The periostracum of young individuals is smooth with a shiny, yellow-brown color. Green rays may be present on the posterior half of the shell. Older individuals are a dark brownish-black with roughened margins and posterior slopes. (Adams et al., 1990).**Life History:** As provided by Fuller (1972), the Cape Fear spike was found in muddy, loose, sandy substrates below logjams. It was not found in firm, sandy substrates. Fuller (1972) found gravid females around the middle of June. Nothing is known about the fish hosts or ecology of the species (Adams et al., 1990).**Status:** Williams et al. (1993:1) listed as currently stable. This species is listed as State Special Concern.

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

Plate 3, Figure 18

Synonymy:*Unio roanokensis* Lea, 1838; Lea, 1838:27, pl. 8, fig. 21.*Elliptio judithae* Clark, 1986; Clarke 1986:78-96.**Type Locality:** Roanoke River, between Tarboro, North Carolina and Norfolk, Virginia.**General Distribution:** The Roanoke Slabshell ranges from the Chowan River in Virginia to the Savannah River in Georgia.**North Carolina Distribution:** This species is found in the Chowan, Roanoke, Pamlico, Neuse, Cape Fear and Pee Dee River systems (Table 2).**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. In the Tar River, the Roanoke Slabshell is usually found associated with the deeper channels near shore in relatively fast flowing 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 listed as State Threatened.**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 incumbent papillae being subdivided into smaller papillae, and irregularly developed branchial septa. These characteristics distinguish the Roanoke Slabshell from *Elliptio complanata*. Clarke (1986) described *Elliptio judithae* from the Neuse River. The holotype of *E. judithae* is from the Neuse River at Seven Springs, Wayne County, North Carolina. Paratypes are from the Neuse River above the U. S. Route 301 bridge near Smithfield, Johnston County, and at Milburne, 7 miles east of Raleigh, in Wake County. His description of the species matched that of smaller individual Roanoke Slabshells (Adams et al., 1990). **Status:** Williams et al. (1993) did not list this species but assumed it was a synonym of *Elliptio roanokensis*.

***Epioblasma florentina aureola* Jones and Neves, 2010**

Golden Riffleshell

Plate 4 Figure 21

Synonymy:

Truncilla walkeri Wilson and Clark, 1914: Wilson and Clark 1914:46-47, Plate 1 Figure 1. [in partim]

Epioblasma florentina aureola Jones and Neves, 2010; Jones and Neves 2010:85-89. Figures 5,6,11,12.

Type Locality: Just below the ford of the East Fork Stones River, near Waterville [Rutherford County], Tennessee. [Cumberland River drainage].

General Distribution: The taxon, *Epioblasma florentina walkeri* was wide spread in the headwaters of the Tennessee and Cumberland River drainages. Recent populations of the Tan Riffleshell have been reported from the Duck River, Hiwassee River in Tennessee, Middle Fork Holston River, Clinch River, Indian Creek in southwest Virginia and the Big South Fork Cumberland River, Tennessee (Parmalee and Hughes, 1994; Rogers et al., 2001; Jones et al., 2004?; Jones et al., 2006). **North Carolina**

Distribution: Tan Riffleshell is known from two museum lots from the French Broad River, Asheville, Buncombe County, North Carolina [identifications by D.H. Stansbery and confirmed by J.W. Jones].

Description: Shell relatively small, seldom exceeds 60 mm in length, shell outline irregularly elliptical or obovate; valves inequilateral, subinflated, and rather solid; anterior end is regularly rounded; posterior end in males protrudes only slightly, while in females posterior margin more rounded, hinge ligament short; posterior ridge of the male shell appears faintly doubled, ending in a slight biangulation posteriorly, scarcely visible in females; shallow radial depression in front of the posterior ridge; female shells somewhat pronounced, rounded, thin extra pallial swelling, usually not darker in color than the rest of the shell, defined from rest of the shell by anterior and posterior sulci; ventral margin often serrated; umbo quite full, elevated, and located slightly anterior of middle in male

shells and in anterior third of females; shell surface usually marked by uneven growth lines; umbo cavity shallow.

Pseudocardinal teeth small, triangular to compressed, double in the left valve, single in the right, with narrow interdentum separating them from lateral teeth; lateral teeth short and curved; double in left valve, single or sometimes double in right valve, anterior muscle scars well impressed, posterior scars shallow; pallial line distinct only anteriorly, nacre color is a bluish white, periostracum dull brownish green or yellowish green in color with numerous feeble green rays more or less evenly distributed over entire surface, posterior end of female shell is especially thin and iridescent.

The big river form, *Epioblasma florentina florentina*, is more swollen in contrast to the headwater form, *Epioblasma florentina aureola*. Males of the two forms differ in the percentage of shell height to shell length, while females differ in the percentage of shell diameter to shell length (Ortmann, 1924).

Life History and Ecology: Extant populations of *Epioblasma florentina aureola* in the Clinch (Virginia) and Hiwassee (Tennessee) river drainages occur in a substrate of coarse sand, gravel, and some silt, in current and in less than three feet of water (Parmalee and Hughes, 1994). Life history information is limited for this species. Rogers et al. (2001) working with the Indian Creek population in southwest Virginia, reported collecting gravid females of the Tan Riffleshell [now Golden Riffleshell] from February through August with glochidia being released principally in May and June. A fecundity estimate of almost 20,000 glochidia from one female was made. Laboratory tests of the Tan Riffleshell glochidia [now Golden riffleshell] resulted in identification of five species of fish as suitable hosts including: *Cottus bairdi* [Banded Sculpin] or *Cottus carolinae* [Mottled Sculpin], *Etheostoma blennioides* [Greenside Darter], *Etheostoma*

flabellare [Fantail Darter], *Etheostoma rufineatum* [Redline Darter] (Watson and Neves, 1996; Rogers et al., 2001). Maximum age of individuals from this population was estimated as 11 years based on shell thin sections (Rogers et al., 2001).

Status: Endangered (Williams *et al.* 1993:11). The Tan Riffleshell mussel is federally listed as endangered. The U.S. Fish and Wildlife Service has developed a recovery plan for *Epioblasma florentina walkeri* (U.S. Fish and Wildlife Service, 1984) and has created a watershed implementation schedule for the *E. florentina walkeri* recovery plan (U.S. Fish and Wildlife Service, 1989). Adams *et al.* (1990) following the identification of Ortmann (1918) as *Epioblasma capsaeformis*, presumed this species extirpated in North Carolina. Using the corrected identification of this species, *Epioblasma florentina aureola*, the taxon is presumed extirpated in North Carolina.

Remarks: We have information that two federally endangered taxa of *Epioblasma* occurred in North Carolina and are based on the same specimens. Ortmann (1918:593) while discussing the distribution of *Truncilla capsaeformis* notes “goes up, in the French Broad, to Asheville, N. C. (Walker Coll.)” Ortmann (1918:618) provided the individual locality data for the species from the French Broad River, Asheville, Buncombe County, North Carolina and included *Truncilla capsaeformis* (= *Epioblasma capsaeformis*) and noted it was reported by Call. We have no evidence at this time of the report presumably by R.E. Call. The *Epioblasma florentina walkeri* [now *E. f. aureola*] specimens collected by Hardy (now at Ohio State University Museum [OSUM] and Smithsonian Institution [USNM]) may in fact be those attributed to the Call report cited by Ortmann (1918).

There is a single female specimen of *Epioblasma walkeri* [now *E. f. aureola*] in the Ohio State University Museum collection [OSUM 57118] and eight valves from the

Smithsonian Institution mollusk collections [USNM 29888], both from the French Broad River, Asheville, Buncombe County, NC. Both the OSUM and USNM lots were collected by J.F. Hardy and the OSUM collection catalog notes “all had small Smithsonian exchange labels and were wrapped 2 per packet – wrapping was either Cincinnati newspaper dated 1874 or pages of U.S. Govt. reports dated 1874. –All Smithsonian labels have same data. D.H. Stansbery Jan. 1995” (S. Fraley, Pers. Comm. Nov. 2006).

The lot in the Smithsonian Institution Mollusk Collection [USNM 29888] currently identified as *Epioblasma walkeri* contains 8 valves representing two males and two female specimens. The original identification of the lot was *Unio capsaeformis* listed on the museum label.

A single male specimen of *Epioblasma florentina aureola* is housed in the University of Michigan, Museum of Zoology, Mollusk Collection (UMMZ 54369) with no other locality data than Buncombe County, North Carolina. This specimen was acquired from the Alabama Museum of Natural History in 1932. This specimen was originally identified as *E. capsaeformis* but has been re-examined and identified as *E. f. walkeri* [now *E. f. aureola*] (S. Fraley, Pers. Comm. J. Jones Pers. Comm.).

An additional specimen of *Epioblasma florentina walkeri* was located in the Florida Museum of Natural History, Gainesville, from Buncombe Co. NC (FLMNH 64243). This specimen was originally identified as *Unio capsaeformis*, written inside of the shell. Identification of this specimen has not been verified.

Epioblasma florentina had been split into two subspecies based on shell morphology, a big river form, *Epioblasma florentina florentina* and the headwater form, *Epioblasma florentina walkeri*. These two purported subspecies represented two extremes of a cline. The shell form occurring in big rivers is presumed extinct and the shell form occurring in head

water streams is very restricted. Turgeon et al. (1988, 1998) did not recognize subspecies. The US Fish and Wildlife Service has listed *E. f. walkeri* as a subspecies and endangered. *Epioblasma florentina aureola* was split from *E. f. walkeri* and recognized for the upper Tennessee River specimens and different from the Cumberland River subspecies, *E. f. walkeri* (Jones and Neves, 2010). The form *E. f. aureola* is not listed by US Fish and Wildlife Service as endangered but due to its very limited distribution it should be listed as endangered.

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

Plate 4, Figure 23

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 Drainage 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 drainage basins (Johnson 1970).

North Carolina Distribution: This species is known from the Catawba, Pee Dee, Cape Fear, Neuse, Pamlico, and Roanoke River basins (Aarons Creek) (Johnson, 1970; Table 2).

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 sands, 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). Watters and O'Dee (1997) O'Dee and Watters (2000) identified the Bluegill (*Lepomis macrochirus*) and the Shield Darter (*Percina peltata*) as potential fish hosts for *Fusconaia masoni* glochidia.

Status: Williams et al. (1993:11) listed as threatened. This species is listed as State Endangered, effective July 1, 2002.

Remarks: *Fuscaonaia masoni* was included in an analysis of *Fusconaia flava* (Rafinesque, 1820) and was placed in the *Fusconaia* clade (Burdick and White, 2007).

Fusconaia subrotunda* (Lea, 1831)*Long-solid**

Plate 4, Figure 24

Synonymy:*Unio subrotundus* Lea, 1831; Lea, 1831:117, pl. 18, fig. 454**Type Locality:** Ohio**General Distribution:** Ohio, Cumberland, and Tennessee River systems (Simpson, 1914:893).**North Carolina Distribution:** This species is reported from the Hiwassee and French Broad rivers (Ortmann, 1918; Table 2).**Description:** The big river form of *Fusconaia subrotunda* has a shell that is oval to broadly elliptical or oblong in outline, solid, and inflated. Umbos are high, full, and turned forward over the lunule; sculpture consists of a few subnodular ridges or wrinkles. The anterior margin is broadly rounded, and the ventral and posterior margins are slightly curved to nearly straight; lacking a distinct posterior ridge, the dorsal slope is evenly curved. The shell surface is generally sculptured with low, wide, concentric ridges. Mature individuals may reach a length of 130 mm. Shells of the medium-sized to small river forms, *Fusconaia subrotunda kirtlandiana* are more compressed and Ortmann (1919) noted that the two forms graded into one another and the separation was artificial.

The left valve has two low, heavy triangular pseudocardinal teeth, widely separated with deep striations; the two lateral teeth are moderately long and straight. The right valve has a heavy, triangular serrated pseudocardinal tooth usually with a low tooth or roughened area on either side. The lateral tooth is broad, serrated, and often doubled for most of its length. Muscle scars are deeply impressed, the interdentum is usually wide, and the umbo cavity is deep and somewhat compressed. The periostracum is a dull straw yellow to greenish brown, becoming blackish in old individuals. Some may show subtle green rays, primarily on the umbos. The nacre is pearly white and iridescent posteriorly (Parmalee and Bogan 1998:120-121).

Life History and Ecology: The small to medium-sized river forms of *Fusconaia subrotunda* typically are found in currents, usually in riffle areas, at a depth of less than two feet. The big river form, such as specimens formerly inhabiting the Ohio, Allegheny and Monongahela rivers lived at depth, in strong current, and on a gravel substrate. The more compressed small river form was widespread living in gravel and sand substrates with good current (Ortmann, 1919). The Longsolid, like other species of *Fusconaia* for which the breeding season is known, is probably tachytictic, the females becoming gravid during the summer. Host fish for the glochidia is unknown.**Status:** Special Concern (Williams et al., 1993:11).

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

Plate 5, Figure 25

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).

North Carolina Distribution: This species is known from the Pee Dee, Waccamaw, Cape Fear, Neuse, and Pamlico basins (Johnson, 1970; Table 2).

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. Umbos moderately swollen but not elevated much above the hingeline, located anterior of the middle of the shell, umbo sculpture consist 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 stouter and ragged with age. Interdentum is practically absent, the umbo 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. The species is bradyctictic, releasing glochidia in the following spring or early summer. The Yellow Lampmussel is found in medium to larger 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 host fish 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 listed as State Endangered, effective July 1, 2002.

*Lampsilis fasciola***Rafinesque, 1820****Wavyrayed Lampmussel**

Plate 5, Figure 26

Synonymy:*Lampsilis fasciola* Rafinesque, 1820; Rafinesque, 1820:299**Type Locality:** Kentucky River.**General Distribution:** “Great Lakes drainage in the tributaries of lake Michigan, Lake Huron, Lake St. Clair and Lake Erie, and Ohio–Mississippi drainage south to the Tennessee River system” (Clarke, 1981a).**North Carolina Distribution:** The Wavyrayed Lampmussel occurs in a large number of medium-sized rivers including the Hiwassee, Little Tennessee, Pigeon, and French Broad rivers (Ortmann, 1918, Table 3).**Description:** The shell is elliptical or subovate, fairly thin to solid and heavy; it is generally inflated, especially so as a marsupial swelling in some females. Mature individuals may reach a length of 90–100 mm. The anterior end is broadly rounded; the ventral margin is straight to slightly curved; the posterior end is rounded (in some females) to bluntly pointed (in males). The posterior ridge is broadly rounded; the posterior-dorsal margin is occasionally compressed, appearing alate. Umbos are full, depressed, and only slightly elevated above the hinge line; sculpture consists of several indistinct, fine, wavy ridges. The surface is shiny, usually with numerous raised rest lines.

The left valve has two triangular, short, thick, rather widely separated pseudocardinal teeth; the two lateral teeth are short, thick, nearly straight, and widely separated. The right valve has a large, coarsely serrated, heavy, erect pseudocardinal tooth, sometimes with a suggestion of a smaller tooth on either side as slightly roughened, raised areas; the lateral tooth is wide, short, and elevated. The interdentum is narrow or absent; the umbo cavity is wide and moderately deep. The periostracum is light yellow or yellowish green, the umbos often tinged with reddish

brown; the surface is densely patterned with green rays of varying widths, characteristically wavy in appearance, and often interrupted at the lines of growth. The nacre is white or bluish-white as a result of iridescence, especially posteriorly (Parmalee and Bogan, 1998).

Life History and Ecology: *Lampsilis fasciola* is a species typical of small to medium-sized rivers, usually occurring at depths of three feet or less. This mussel appears tolerant of habitat conditions unfavorable to many species, and, under favorable circumstances, including moderate current and a stable substrate composed of mud, sand, and gravel, it may become quite abundant locally. In spite of the extensive range and local abundance of the Wavyrayed Lampmussel, its reproductive period remains unknown, although there is some evidence to suggest it is bradyctictic. In their detailed study of fish hosts of four species of Lampsiline mussels, Zale and Neves (1982a) found that glochidia of *Lampsilis fasciola* parasitized only Smallmouth Bass (*Micropterus dolomieu*). Brian Watson, in experimenting with potential fish hosts for the glochidia of this mussel, was able to get glochidia to parasitize and transform on Largemouth Bass (*Micropterus salmoides*) (S. A. Ahlstedt, pers. comm., 1996; Parmalee and Bogan, 1998).

Status: Currently Stable (Williams et al., 1993:12). This species is listed as State Special Concern.

Lampsilis radiata
(Gmelin, 1791)

Eastern Lampmussel

+*Lampsilis radiata conspicua* (Lea, 1874)

Carolina Fatmucket

+ *Lampsilis fullerkerati* Johnson, 1984

Waccamaw Fatmucket

Plate 5, Figure 27, 28

Synonymy:

Mya radiata Gmelin, 1791; Gmelin, 1791:3220

Unio conspicuus Lea, 1872; Lea, 1872:156

Lampsilis fullerkerati Johnson, 1984; Johnson 1984:305-319.

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.

North Carolina Distribution: The Eastern Lampmussel is found in the Pee Dee, Waccamaw, Cape Fear, Neuse, and Pamlico basins (Johnson, 1970, Keferl and Shelley, 1988; Table 2). The Carolina Fatmucket is found in the headwaters of the Yadkin-Pee Dee and Neuse river basins in North Carolina (Table 2).

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 93 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. Umbos are rather sharp but are not full or very high, umbo 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 umbo, 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, umbo 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. Wiles (1975) reported gravid females from 11 May, 18 August, 29 September and 1 December, 1971 and 9 May 1972. Strayer and Jirka (1997:60) recorded this species from creeks, lakes and rivers. The authors have found the Eastern Lampmussel in sand substrate with good current. 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). Both the Eastern Lampmussel, the Carolina Fatmucket and the Waccamaw

Fatmucket have been listed as State Threatened, effective July 1, 2002.

Remarks: today *Lampsilis radiata conspicua* is a junior synonym of *L. radiata*. *Lampsilis fullerhati* was determined by analysis of genetic sequence data to be a lake form of *Lampsilis radiata* (McCartney et al. 2016). They listed *L. fullerhati* as a junior synonym of *L. radiata*.

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

Plate 11, Figure 63

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. Umbos elevated and
very full, inflated. Umbo 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. Umbo 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 5, Figure 29

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 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. Today the Carolina Heelsplitter has been found in two populations in tributaries to the Pee Dee River drainage in North and South Carolina; six populations in the Catawba River drainage in South Carolina; in a tributary to the Saluda River in South Carolina; and two populations in the Savannah River basin in South Carolina. (Clarke, 1985, Keferl and Shelley, 1988) (Adams et al., 1990; L. Zimmerman, Pers. Comm. April 2007).

North Carolina Distribution: Keferl and Shelley (1988) did not find any evidence of *L. decorata* in the Saluda River drainage. Keferl and Shelley (1988) did find the species living in Waxhaw Creek (Catawba River drainage) Union County, North Carolina; Duck and Goose creeks (Pee Dee River system), Union County, North Carolina; and Lynches River (Pee Dee River system), Lancaster and Chesterfield counties, South Carolina. At the present time living specimens of the Carolina Heelsplitter have been found from just eleven localities in four different drainages: Pee Dee, Catawba, Saluda and Savannah River drainages.

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 umbos are depressed and project a little above the hinge line. The umbo 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 one 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 and none had any glochidia. 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 szepticus*), 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) has developed a recovery plan for this species. The U.S. Fish and Wildlife Service (2002) has designated critical habitat for the Carolina Heelsplitter.

***Lasmigona holstonia* (Lea, 1838)**
Tennessee Heelsplitter

Plate 5, Figure 30

Synonymy:

Margaritana holstonia Lea, 1838; Lea, 1838b:42, pl. 13, fig. 37

Type Locality: Holston River.

General Distribution: Upper Tennessee River drainage; (Simpson, 1914).

North Carolina Distribution: This species is known from Valley Creek, Cherokee County, North Carolina, Hiwassee River basin (Clarke, 1985; NCSM 56511); Iotla Creek, Little Tennessee River basin (NCSM 27400); Mills River, French Broad River basin (T. Savidge, Pers. Comm. March 2002).

Description: The shell is somewhat elongated, rhomboid, and moderately inflated; some very young juveniles are more oblong and compressed. Umbos are full but not high, projecting only slightly above the hinge line; sculpture consists of 4–5 strong, double-looped ridges; the last loop is low and almost straight. The anterior margin is broadly rounded, while the ventral margin is straight; the posterior end is broadly pointed to squared; the posterior ridge is pronounced but broadly rounded, in some specimens appearing doubled. The shell is thin but not fragile. Mature specimens seldom exceed 75 mm in length. The surface is roughened with irregular, recessed, darkened rest lines. The right valve has a single compressed, but moderately heavy, pseudocardinal tooth; the left valve has two low, compressed pseudocardinal teeth, angled anteriorly and, in both valves, nearly parallel with the hinge line. Lateral teeth appear as a thickening of the hinge line in each valve. The periostracum is an almost uniform dull greenish brown or yellowish brown, and most shells become a dark brown or black with age. The nacre is bluish white, often with a pale salmon wash in the umbo cavity area. (Parmalee and Bogan, 1998).

Life History and Ecology: *Lasmigona holstonia* is a species most often found inhabiting small shallow streams and

headwater creeks with some current, and it may become locally abundant in stretches of substrate composed of sand and mud. The reproductive period is unknown, but it is probably bradyctictic. Steg and Neves (1997) identified the Banded Sculpin (*Cottus carolinae*) and the Rock Bass (*Ambloplites rupestris*) with the possible additional hosts are Central Stone Roller (*Campostoma anomalum*), Striped Shiner (*Luxilus chrysocephalus*) and Warpaint Shiner (*Luxilus cogenis*) as host fish for the glochidia of the Tennessee Heelsplitter.

Status: Special Concern (Williams et al., 1993:13). This species is listed as State Endangered.

Remarks: *Lasmigona holstonia* is considered separate from the upper Coosa River drainage endemic, *Lasmigona etowaensis* (Conrad, 1849) (D. Campbell, Pers. Comm.).

Lasmigona subviridis**(Conrad, 1835)****Green Floater**

Plate 6, Figure 31

Synonymy:*Unio subviridis* Conrad, 1835; Conrad, 1835a:4 (appendix), pl. 9, fig. 1**Type Locality:** Schuylkill River, Juniata River, creeks in Lancaster County, Pennsylvania.**General Distribution:** New and Greenbrier rivers of the upper Kanawha River drainage, Virginia and West Virginia. Upper Savannah River system of South Carolina north to the Hudson River system, and westward through the Mohawk River and the Erie Canal to the Genesee River of New York (Johnson, 1980; Clarke, 1985).**North Carolina Distribution:** This small species is known from the Watauga and New river basins in western North Carolina and the Roanoke (Dan River), Tar, Neuse, and Cape Fear River basins in eastern North Carolina (Walter, 1954; Clarke, 1985; Shelley, 1987; Adams et al., 1990; T. Savidge, Pers. Comm. March 2002; Tables 2,3)**Description:** The shell is thin and slightly inflated; it is subovate, narrower in front, higher behind, and the upper margin forms a blunt angle with the posterior margin (Ortmann, 1919). The posterior ridge is low, rounded, and appears more as a slight swelling than as a ridge. Umbos are low and not extended beyond the hinge line; sculpture consists of 4–5 nodulous bars, the first two concentric, the others deeply double-looped (Johnson, 1970). Mature individuals reach a length of about 60 mm. The lateral teeth, one in the right valve, two in the left, are long, straight, and thin. The left valve has two lamellate pseudocardinal teeth, and the right valve has one; pseudocardinals are directed forward of the umbo and nearly parallel with the hinge line. The periostracum is a dull yellow or tan to brownish green, with variable concentrations of dark green rays. The nacre is

a dull bluish white, often with mottled shades or tints of salmon in the general umbo cavity area (Parmalee and Bogan 1998:145).

Life History and Ecology: Ortmann(1919:124) noted that *Lasmigona subviridis* is “adverse to very strong current, and prefers more quiet parts, pools or eddies with gravelly and sandy bottoms, and it also goes into canals, where it seems to flourish.” Pockets of sand and gravel among boulders provide a habitat for this mussel although it appears to be uncommon and localized. Ortmann (1919) stated that this species is normally hermaphroditic, and that it is bradytictic, with the reproductive season extending from August to May. Barfield and Watters (1998) reported direct development for the juveniles of the Green Floater. This is the only recently confirmed non-parasitic development for a North American unionid.**Status:** Threatened (Williams et al., 1993:13). This species is listed as State Endangered.

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

Plate 6, Figure 32

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*. This 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.

North Carolina Distribution: The Tidewater Mucket is known from the Waccamaw, Tar-Pamlico, Roanoke, Pee Dee and Chowan River basins (Adams et al., 1990; Table 2). Walter (1956) reported it from the Neuse.

Description: Shells of the Tidewater Mucket are relatively small, length 75 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. Umbos are moderately swollen and raised above the hingeline, umbo 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 umbos, two thin, distant lateral teeth. Right valve has two triangular compressed pseudocardinal teeth, and a single thin lateral tooth. The hingeline is narrow and rounded in the middle. The umbo 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. Host fish unknown. At least one of the host fish species is probably an anadromous species in light of the Tidewater Mucket's tidewater distribution.

Status: Special Concern (Williams et al., 1993:13). This species is listed as State Threatened in North Carolina, effective July 1, 2002.

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

Plate 6, Figure 34

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, North 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).**North Carolina Distribution:** The Eastern Pondmussel is known from the Pee Dee, Cape Fear, Pamlico, Roanoke, and Chowan River basins (Adams et al., 1990; Table 2).**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 umbo, becoming rounded posteriorly. Posterior slope is slightly concave near the umbos, becoming flatter near the posterior margin of the shell. Umbos are low, hardly raised above the hinge line and located in the anterior quarter of the shell, umbo 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 umbo 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 umbo 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 listed as State Threatened in North Carolina, effective July 1, 2002.

Medionidus conradicus**(Lea, 1834)****Cumberland Moccasinshell**

Plate 6, Figure 35

Synonymy:*Unio conradicus* Lea, 1834; Lea, 1834:63, pl. 9, fig. 23**Type Locality:** No locality given in the original description Johnson (1977:165) lists it as “no locality [Caney Fork of the Cumberland River, Tennessee],” apparently supplying this locality as the type locality.**General Distribution:** The Cumberland Moccasinshell is a Cumberlandian species endemic to the Tennessee and Cumberland River drainages.**North Carolina Distribution:** It was reported historically from the French Broad River, Buncombe County (Ortmann, 1918).**Description:** The shell is usually elongate and elliptical in outline, becoming arcuate in adults; it is relatively thin, but becomes thicker with age. The Cumberland Moccasinshell is a small species, seldom exceeding 60 mm in length. Shells are rounded anteriorly with a posterior ridge ending in a rounded point at the posterior end. The ventral margin is straight, becoming incurved in adult specimens. Valves are subinflated and subsolid. The male shell is generally more arcuate and broader in the posterior area. Female shells are generally somewhat more inflated along the middle of the ventral margin; this area may be faintly radially grooved. Umbos are only slightly inflated and elevated, being marked by fine, irregular corrugated ridges often tending to double loops. The posterior slope is marked by wrinkles or corrugations, which often extend onto the anterior portion of the shell.

The left valve has two short, stumpy pseudocardinal teeth and two slightly curved lateral teeth. The right valve has a single short, stumpy pseudocardinal tooth and a single lateral tooth. The umbo cavity is very shallow, often lacking. Anterior adductor muscle scars are deep, and the posterior scars are only slightly impressed. The pallial line is impressed

anteriorly where the shell is thicker. The periostracum is slightly shiny, tawny to yellowish green in color, and covered with weak, broken dark green rays, which break into arrowhead-shaped markings. The nacre color is bluish to dirty white and may be iridescent posteriorly (Parmalee and Bogan, 1998).

Life History and Ecology: The Cumberland Moccasinshell inhabits a substrate composed of sand and gravel, often living in cracks in the bedrock or under flat rocks. Usually it occurs at depths of less than three feet in moderate to strong current. Wilson and Clark (1914) and Ortmann (1918, 1924, 1925) noted that this mussel is typically a small stream inhabitant. Zale and Neves (1982b) identified the Fantail Darter (*Etheostoma flabellare*) and the Redline Darter (*E. rufilineatum*) as hosts for the glochidia; Stern and Felder (1978) list the Warmouth (*Lepomis gulosus*). Luo (1993) was able to infect the Rainbow Darter (*Etheostoma caeruleum*) and Striped Darter (*E. virgatum*) with glochidia of the Cumberland Moccasinshell under laboratory conditions. The breeding season for *M. conradicus* begins with gravid females occurring from early September on with glochidia present in mid-September; they are not discharged until mid- to late May (Ortmann, 1921). The glochidia appear in river drift from January to May and June, but are absent in July and August; they reappear in river drift in September through early November (Zale and Neves, 1982a, b).**Status:** Williams et al. (1993:13) listed as Special Concern. It is considered extirpated in North Carolina (Table 4).

***Pegias fabula* (Lea, 1838)
Littlewing Pearlymussel**

Plate 6, Figure 36

Synonymy:

Margaritana fabula Lea, 1838; Lea, 1838b:44, pl. 13, fig. 39

Type Locality: Stones River, Tennessee. Cumberland River, Tennessee (Simpson, 1914).

General Distribution: Tennessee and Cumberland River systems, formerly widespread from southern Kentucky (Rockcastle County) and southwestern Virginia (Lea, Russell, Smyth, Tazewell, and Washington counties), through the tributary stream system of the Tennessee and Cumberland rivers in East Tennessee and southwest to Lauderdale County, Alabama (Ortmann, 1925) (Parmalee and Bogan, 1998).

North Carolina Distribution: This species is known from the Hiwassee and Little Tennessee River basins (Table 3).

Description: The Littlewing Pearlymussel is a small species: adults rarely exceed 35 mm in length. Valves are thickened anteriorly with a sharp posterior ridge, in front of which is a wide radial depression that ends in a basal sinus. There is another ridge above the posterior ridge, making the shell decidedly biangulate and truncate behind. Valves of the female possess a wider posterior slope behind the ridge and a more truncated posterior end than do those of the male. Umbo sculpturing consists of heavy, subconcentric ridges, these being most prominent and persistent on the posterior ridges.

The left valve has an irregular triangular pseudocardinal tooth under the umbo, sometimes with a vestige of another in front of it. Lateral teeth appear as short, faint, irregular ridges. The right valve has a single triangular pseudocardinal tooth in front of the umbo. Umbo cavities are rather deep and compressed; anterior muscle scars are deeply impressed. The periostracum is usually eroded away in mature individuals; a few dark brownish or olive green rays are apparent along the base of

the shell in young specimens. The nacre is whitish on the anterior ventral third, flesh-colored or salmon in the umbo cavities. The shells exhibit sexual dimorphism, one of the characters, which separates *Pegias* from species belonging to the genus *Alasmidonta* (Simpson, 1900, 1914; Stansbery, 1976) (Parmalee and Bogan, 1998).

Life History and Ecology: This very small unionid inhabits cool, clear, high-gradient streams. It is usually found lying on top of or partially imbedded in sand and fine gravel between cobbles in only 6 to 10 inches of water, often just at the head of riffles. Ortmann (1914) collected a gravid female of this species in mid-September, suggesting that *Pegias fabula* is bradytictic, a winter breeder. Ahlstedt (in Neves, 1991:271) states that “[f]ish hosts are unknown for this species; however, based on field observations, the Banded Sculpin, *Cottus carolinae*, and Redline Darter, *Etheostoma rufilineatum*, may be likely hosts. These fish were observed under large flat rocks and were present on gravel shoals where live specimens of *Pegias fabula* were found.” Layzer and Anderson (1992) identified the host fish for *Pegias fabula* as the Greenside Darter (*Etheostoma blennioides*) and Emerald Darter (*E. baileyi*).

Status: Williams et al. (1993:13) listed as endangered. This species is federally and state listed as Endangered. Adams et al. (1990) list it as extirpated in North Carolina.

Parvaspina collina**(Conrad, 1837)****James Spiny mussel**

Plate 7, Figure 37

Synonymy:*Unio collina* Conrad, 1837; Conrad, 1837:65, pl. 36, fig. 2**Type Locality:** North River, a branch of James River, Virginia.**General Distribution:** The James Spiny mussel is found in the James River basin in Virginia and the Dan River drainage of the Roanoke River basin (Simpson, 1914; T. Savidge, Pers. Comm.).**North Carolina Distribution:** This species is restricted to the Dan River drainage of the Roanoke River basin in North Carolina (T. Savidge Pers. Comm.)**Description:** “Shell rhomboid, convex, subsolid, inequilateral, with moderately full, high umbos, their sculpture a number of strong, slightly double-looped ridges; posterior ridge full, rounded, ending behind at the base of the shell in a rounded point; growth lines elevated into slight, concentric ridges; besides this sculpture there are generally one or two sharp, prominent tubercles or spines placed on a line running from the umbos to a little behind the central base, though these are sometimes entirely wanting [as many as nine spines on one valve in the Dan River, North Carolina (T. Savidge, March 2002); epidermis smoky, greenish-brown, showing the rest marks, subshining; left valve with two subcompressed, irregular pseudocardinals and two straight, delicate laterals; right valve with a compressed pseudocardinal, with a vestigial one in front of and behind it, with one lateral; umbo cavities shallow; nacre bluish-white, slightly thicker at the anterior end.” (Simpson, 1914:501).**Life History:** Hove and Neves (1994) reported the Blacknose Dace (*Rhinichthys atratulus*), Bluehead Chub (*Nocomis leptocephalus*), Central Stoneroller (*Campostoma anomalum*), Rosefin Shiner (*Lythurus ardens*), Rosyside Dace (*Clinostomus funduloides*), Satinfish Shiner (*Cyprinella analostana*), MountainRedbelly Dace (*Phoxinus oreas*) as hosts for the glochidia for the James Spiny mussel. They reported that the mussel “occupied sediment of cobble and sand in reaches with slow to moderate currents.” The females were gravid between 23 May and 9 August. *Pleurobema collina* was found living in second and third order streams at depths of 0.3 to 2 meters (Hove and Neves, 1994).**Status:** Williams et al. (1993:13) listed as endangered. This species is federally listed as Endangered (USFWS, 1988).**Remarks:** Recently, DNA sequence analyses of *Elliptio* species placed *E. steinstansana* outside of the clade comprising the genus *Elliptio* and sister to *Pleurobema collina*. These two taxa, *E. steinstansana* and *P. collina*, form a clade separate from *Pleurobema* and *Elliptio* (Bogan et al., 2003). These two species have been placed in the new genus *Parvaspina* Perkins, Johnson and Gangloff, 2017.

***Parvaspina steinstansana*
(Johnson and Clarke, 1983)
Tar River Spiny mussel**

Plate 4, Figure 19

Synonymy:

Elliptio steinstansana Johnson and Clarke, 1983; Johnson and Clarke, 1983:289-298

Type Locality: Near Tarboro in Edgecombe County, North Carolina

General Distribution: This species is found in the Pamlico and in the lower Neuse River basins of North Carolina (Johnson and Clarke, 1983, J. Alderman, Pers. Comm.).

North Carolina Distribution: The Tar River Spiny mussel is restricted to the Tar River basin and one site on a tributary in the lower Neuse River Basin (Johnson and Clarke, 1983; Alderman, 1988; J. Alderman, Pers. Comm.).

Description: This small, subrhomboid mussel grows to approximately 60 mm long. Short spines (up to 5 mm long) are found on most specimens. As many as 12 spines have been found on juveniles; however, adults tend to lose some of their spines as they mature. In general, spines arranged in a radial row slightly anterior of the posterior ridge on one valve are symmetrically positioned with the spines on the opposite valve. Some individuals may have two rows of spines on each valve. The smooth, orange-brown to dark brown periostracum may be rayed in younger individuals. The shell is significantly thicker toward the anterior end, and the nacre is usually pink in this area. The posterior end of the shell is thinner with an iridescent bluish white color. Two or more linear ridges, originating within the umbo cavity and extending to the ventral margin, can be found on the interior surface of the shell. The distance between these ridges widens toward the ventral margin. Johnson and Clarke (1983) provide additional descriptive material.

Life History: It appears that the Tar River Spiny mussel's preferred habitat includes the following: relatively fast flowing, well oxygenated, circumneutral pH water; relatively silt-free, uncompacted, gravel/coarse sand

substrate; sites prone to significant swings in water velocity (Adams et al., 1990). The Tar River spiny mussel is probably a tachytictic reproducer with gravid females present at some time from April through August (Widlak 1987). The glochidia have not been described and the fish host is unknown.

Status: Williams et al. (1993:11) listed as endangered. This species is federally and state listed as Endangered. The U.S. Fish and Wildlife Service has developed a recovery plan for this species (U.S. Fish and Wildlife Service, 1992).

Remarks: Recently, DNA sequence analyses of *Elliptio* species placed *E. steinstansana* outside of the clade comprising the genus *Elliptio* and sister to *Pleurobema collina*. These two taxa, *E. steinstansana* and *P. collina*, form a clade separate from *Pleurobema* (Bogan et al., 2003). Based on additional sequence data, these two species have been placed in the new genus *Parvaspina* Perkins, Johnson and Gangloff, 2017.

Pleurobema oviforme
(Conrad, 1834)

Tennessee Clubshell

Plate 7, Figure 38

Synonymy:

Unio oviformis Conrad, 1834; Conrad, 1834:46, 70, pl. 3, fig. 6

Type Locality: Tennessee. Haas (1969a) records the Holston River as the type locality.

General Distribution: Tennessee and Cumberland River drainages (Ortmann, 1925).

North Carolina Distribution: The Tennessee Clubshell is known from the Hiwassee, Little Tennessee, and French Broad rivers (Ortmann, 1918; Table 2).

Description: The shell is solid, obovate, elliptical to nearly rhomboid in outline, and slightly to moderately inflated. Ortmann (1925:341) commented that “[i]n the Tennessee at the Mussel Shoals it is represented by the more swollen *holstonense*, and in the headwaters it passes into the compressed *argenteum*.” Umbos are only moderately full, high, turned forward, and extend only slightly beyond the hinge line; the umbo cavity is shallow, and the interdentum is wide. The anterior end is broadly rounded, and the ventral margin is slightly curved; the posterior end is bluntly pointed and sometimes somewhat truncated. The posterior ridge is low, rounded, and often indistinct. Old individuals may attain a length of 90 mm, although the majority of adults seldom exceed 70 mm in length.

Pseudocardinal teeth, two in the left valve, one with vestiges of two others in the right, are stout, triangular, deeply serrated, and erect; they project ventrally from the hinge line at nearly a 90° angle; the one in the right valve is directed more posterior-ventrally. Lateral teeth, two in the left valve, one in the right, are erect, heavy, long, and straight. Muscle scars are large and deeply impressed. The surface is roughened by evenly spaced, concentric, often darkened rest lines. The periostracum is a dull straw yellow, greenish yellow, or gray brown, typically patterned with narrow and/or wide

broken green rays, primarily on the umbonal and disc areas. The nacre is a silvery or bluish white. (Parmalee and Bogan, 1998).

Life History and Ecology: Viable populations of *Pleurobema oviforme* in Tennessee typically may be found in small, shallow (less than two feet in depth) streams and rivers with good current and a substrate of coarse gravel and sand. The breeding season of this species is unknown, although it may be tachytictic; Kitchel (1985) reported peak densities of glochidia during mid-July. Weaver et al. (1991) have shown, under both natural and laboratory conditions, that the Whitetail Shiner (*Cyprinella galactura*), Common Shiner (*Luxilus cornutus*), River Chub (*Nocomis micropogon*), Central Stoneroller (*Camptostoma anomalum*), and Fantail Darter (*Etheostoma flabellare*) may serve as host fish for glochidia of the Tennessee Clubshell (Parmalee and Bogan, 1998).

Status: Special Concern (Williams et al., 1993:13).

Pleuonaia barnesiana* (Lea, 1838)*Tennessee Pigtoe**

Plate 4, Figure 22

Synonymy:*Unio barnesianus* Lea, 1838; Lea, 1838b:31, pl. 10, fig. 26**Type Locality:** Cumberland River, Tennessee.**General Distribution:** Cumberland and Tennessee River systems (Simpson, 1914).**North Carolina Distribution:** This species is known only from the Hiwassee and Little Tennessee River basins (Table 3).**Description:** The shell of *Pleuonaia barnesiana* is highly variable in outline, dimension, color, and pattern, factors that resulted in the recognition of three subspecies, which may in reality reflect a headwaters-to-big-river cline and individual variations.Shells of *Pleuonaia barnesiana* are strong, occasionally very thick and heavy, oval, and somewhat truncated to triangular in outline, especially in *P. b. bigbyensis*. Mature specimens may reach a length of 90–95 mm. The posterior ridge is usually distinct but typically rounded; the anterior and ventral margins are broadly rounded, while the posterior margin is straight. Umbos are only slightly inflated to rather high and full. The surface is usually evenly roughened with fine, uneven growth lines.

The left valve has two erect pseudocardinal teeth; the more dorsal one is often short and triangular, and the anterior tooth is elongated and bladelike. The two lateral teeth are moderately long and straight; in some individuals they are relatively short, slightly curved, and widely separated. The right valve has a large, erect, elongated pseudocardinal tooth, usually with a smaller low tooth on either side; the lateral tooth is long and straight, sometimes with a second low tooth present. Often the pseudocardinal teeth project ventrally at a 90° angle from the lateral teeth. The umbo cavity is shallow to nearly wanting; the interdentum is usually wide. Muscle scars are deeply impressed. The periostracum of

juveniles is a dull yellowish olive or brown with a satiny appearance, becoming dark brown to blackish with age. Some individuals are marked with a few to many dark green rays. The nacre color is white, and some specimens have a faint salmon wash (Parmalee and Bogan, 1998).

Life History and Ecology: The Tennessee Pigtoe is probably tachytictic, spawning in late spring and being gravid into midsummer, based on data for other species of *Fusconaia* (*F. cor* and *F. cuneolus*) found living in the same rivers and under the same habitat conditions as *P. barnesiana* (Neves, 1991). Host fish for the glochidia unknown (Parmalee and Bogan, 1998).**Status:** Special Concern (Williams et al., 1993:11). This species is listed as State Endangered, effective July 1, 2002.**Remarks:***Fusconaia barnesiana* and *Lexingtonia dolabelloides* are moved to the genus *Pleuonaia* Frierson (1927) based on phylogenetic analyses of DNA sequence data (Campbell et al., 2005; Bogan et al., unpublished data) and shell morphology. These two species form a clade distinct from *Fusconaia* Simpson, 1900 and *Quadrula Rafinesque*, 1820 (Campbell et al., 2005; Bogan et al., unpublished data). The type species of *Lexingtonia* Ortmann, 1914, *Unio subplana* Conrad, 1837 has been shown to be a junior synonym of *Fusconaia masoni* (Conrad, 1834) so *Lexingtonia* becomes a junior synonym of *Fusconaia* (Bogan et al., unpublished data).

Pleuonaia dolabelloides
(Lea, 1840)

Slabside Pearlymussel

Plate 6, Figure 33

Synonymy:

Unio dolabelloides Lea, 1840; Lea, 1840:288

Type Locality: Holston River, Tennessee.

General Distribution: Tennessee River system, from Lee and Tazewell counties, southwestern Virginia to Mussel Shoals (formerly), Alabama.

North Carolina Distribution: This species was probably known historically from the French Broad, Little Tennessee or the Hiwassee River basins. It was not covered by Adams et al. (1990).

Description: Although generally subtriangular in outline, this mussel exhibits considerable variability in shell shape. The majority of individuals possess a wide, flat disc, extending from the umbo to the ventral margin. Valves are moderately inflated and very solid; large, mature specimens may reach a length of 85 mm. Umbos are prominent with the umbonal area arched forward and located near the anterior end. The anterior end of the shell is obliquely truncate above and rounded to the base; the posterior slope is truncated. The ventral margin of the shell is curved, and the dorsal slope is strongly curved. The posterior ridge is narrowly rounded but distinct, although not as elevated as the radial swelling in front of it. The surface of the shell is often irregularly and concentrically sculptured as a result of pronounced growth rings. Umbo cavities are shallow; muscle scars are deep, and the pallial line is well impressed anteriorly. Sculpture consists of 6–8 fine, rather crowded, irregular, and wavy bands, which are distinct anteriorly, becoming indistinct in the middle.

The left valve possesses two pseudocardinal teeth; the upper tooth is triangular, and the lower tooth is bladelike, separated from two short, curved lateral teeth by a broad interdentum. The right valve has a triangular pseudocardinal tooth, occasionally with a

smaller tooth before and behind it. There is typically a single large lateral tooth, although occasionally a vestigial tooth below is present. The periostracum is greenish yellow (in juveniles) to tawny or brownish with a few broken green rays or blotches in some specimens, especially young individuals. The nacre color is white or, more rarely, straw-colored. (Parmalee and Bogan, 1998).

Life History and Ecology: *Pleuonaia dolabelloides* [+*Lexingtonia dolabelloides*] once occurred in shoal areas of the Tennessee River as well as in small to medium-sized streams and rivers, such as the Clinch, Powell, Duck, and Hiwassee (the form *L. d. conradi*). Ortmann (1918) arbitrarily separated the big river species, *L. dolabelloides*, from the headwater form, *L. d. conradi*, on the basis of the shell diameter and length; specimens with a diameter, which is 50% of the length or greater are *dolabelloides* and those less than 50% are *conradi*. A moderately strong current and a substrate composed of sand, fine gravel, and cobbles appear to provide the most suitable habitat for this species. It is probably tachytictic; Ortmann (1921) recorded finding unripe glochidia early in July. Six species of minnows have been found naturally infested with glochidia: Popeye Shiner (*Notropis ariommus*), Rosyface Shiner (*N. rubellus*), Saffron Shiner (*N. rubricroceus*), Silver Shiner (*N. photogenis*), Telescope Shiner (*N. telescopus*), and Tennessee Shiner (*N. leuciodus*) (Kitchel, 1985; Kitchel in Neves, 1991) (Parmalee and Bogan, 1998).

Status: Threatened (Williams et al., 1993:13). *Pleuonaia dolabelloides* has been proposed as Endangered for inclusion in the federal list of *Endangered and Threatened Wildlife and Plants*. The Slabside Pearlymussel is restricted to thinly scattered or isolated populations in primarily the Clinch, Powell, Elk, Duck, and Hiwassee rivers in Tennessee, the North Fork and Middle Fork Holston rivers in Virginia, and the Paint Rock River in Alabama (Parmalee and Bogan, 1998).

Remarks: *Fusconaia barnesiana* and *Lexingtonia dolabelloides* are moved to the genus *Pleuronaia* Frierson (1927) based on phylogenetic analyses of DNA sequence data (Campbell et al., 2005; Bogan et al., Campbell and Lydeard, 2012??unpublished data) and shell morphology (Williams et al., 2008). These two species form a clade distinct from *Fusconaia* Simpson, 1900 and *Quadrula* Rafinesque, 1820 (Campbell et al., 2005; Bogan et al., unpublished data). The type species of *Lexingtonia* Ortmann, 1911, *Unio subplana* Conrad, 1837 has been shown to be a junior synonym of *Fusconaia masoni* (Conrad, 1834) so *Lexingtonia* becomes a junior synonym of *Fusconaia* (Bogan et al., unpublished data).

Potamilus alatus* (Say, 1817)*Pink Heelsplitter**

Plate 11, Figure 60

Synonymy:*Unio alatus* Say, 1817; Say, 1817:pl. 4, fig. 2*Potamilus alata megapterus* Rafinesque, 1820; Rafinesque, 1820:314-315*Metaptera megaptera* Rafinesque, 1820; Rafinesque, 1820:300, pl. 80, figs.**Type locality:** Ohio River.**Total distribution:** The Pink Heelsplitter ranges throughout the Mississippi River drainage from western Pennsylvania to Minnesota, west to Kansas and Nebraska, south to Arkansas. In the St. Lawrence River system, it occurs from Lake Huron to Lake Champlain, also in the Canadian Interior Basin in parts of the Red River of the North and the Winnipeg River.**North Carolina Distribution:** There has been a single report of the Pink Heelsplitter from the French Broad River, at Hot Springs, Madison County (S. Fraley, September 7, 2002) and another dead shell collected in the French Broad River at Paint Creek Road [NCSM 47179].**Shell Description:** The Pink Heelsplitter is large, moderately thick, compressed, and ovate in outline, generally with a high posterior wing which often makes the shell triangular in appearance. There is often a smaller anterior wing. The shape of the dorsal margin will be affected by the degree of erosion of this wing. Maximum shell length is about 185 mm. The anterior end is evenly rounded, the ventral margin is slightly convex to almost straight posteriorly, and the dorsal margin ascends posteriorly to meet at a sharp angle with the posterior margin. The posterior margin is straight dorsally, becoming rounded ventrally. Posterior ridge evenly rounded. The posterior slope is compressed and blends into the posterior dorsal wing. The female shell is slightly more swollen, and the ventral margin is more broadly rounded posteriorly. Sexual dimorphism is slight and not always obvious.

Umboes are low and only slightly elevated above the hinge line; sculpture consists of 3-4 narrow bars; the first is subconcentric, the rest double-

looped. The umbo cavity is open and shallow and marked by an irregular almost vertical row of dorsal muscle scars. '

The left valve has two knobby, erect pseudocardinal teeth and two slightly curved lateral teeth. There is no interdentum. The right valve has one erect, triangular, sculptured pseudocardinal, often with a small tooth anteriorly; there is one slightly curved lateral tooth. Anterior adductor muscle scar impressed, while the posterior adductor muscle scar is shallow but distinct. The pallial line is impressed. The periostracum is dark greenish, often with green rays in young specimens that become obscured as the epidermis color changes to dark brown or black with age. The nacre color is always a dark purple and is iridescent posteriorly (Parmalee and Bogan 1998:197-198).

Life History and Ecology: Ortmann (1919) collected this species in the Ohio River in riffles in fine to coarse gravel and in Lake Erie, firm sand on the north shore on open areas with no shore vegetation and in two to three feet of water. Ortmann (1919:254) reported that "the species seems to breed all the year round, and the breeding seasons appear to overlap in June and July." The Pink Heelsplitter is found in a variety of habitats, from sandy bottoms in shallow lakes and soft sandy river overbanks to coarse gravel in good current areas up to about three feet in depth. Hoggarth (1999:80-84, figs.50A-F) described the glochidium of *Potamilus alatus* as ax-head shaped with a length 206-227 μm and a height of 371-386 μm , without a ventral hook. Watters (1994a) and Weiss and Layzer (1995) list the Freshwater Drum (*Aplodinotus grunniens*) as the host for the glochidia of *Potamilus alatus*. Shema (2002) found the Pink Heelsplitter grew to 44 mm in shell length in 18 weeks. The only reported glochidial host for *P. alatus* is *Aplodinotus grunniens* (Freshwater Drum) (Sciaenidae), which was based on laboratory trials and observations of natural infestations (Howard, 1913; Brady et al., 2004; Williams et al. 2008).**Status:** Currently Stable (Williams et al.,

1993:13). It is only known from two specimens on the edge of its range in North Carolina.

Ptychobranthus fasciolaris
(Rafinesque, 1820)

Kidneyshell

Plate 7, Figure 39

Synonymy:

Obliquaria (Ellipsaria) fasciolaris Rafinesque, 1820;
 Rafinesque, 1820:203

Type Locality: Muskingum River, Ohio.

General Distribution: Ohio, Tennessee, and Cumberland River systems; Lower Peninsula of Michigan, Kansas, Arkansas, Oklahoma, and Louisiana (Simpson, 1914); Pennsylvania west to Illinois, south to Tennessee.

North Carolina Distribution: Ortmann (1918) reported this species from the French Broad River (Table 2).

Description: The shell is elongate, elliptical, and compressed; it is solid, heavy, and thick in old individuals. The anterior end is rounded, and the posterior end is bluntly pointed. The posterior-dorsal ridge is prominent but rounded. Senile individuals may reach a length of 150 mm, although the majority of mature individuals seldom exceed 120–130 mm. Umbos are flattened, compressed, and low; sculpture consists of several fine, indistinct, wavy ridges. The surface is marked with numerous, usually prominent, coarse rest lines. The left valve has two low, thick, heavy, serrated triangular pseudocardinal teeth; the two lateral teeth are nearly straight, short, heavy, and usually widely separated. The right valve has a heavy, somewhat compressed, and pyramidal elevated pseudocardinal tooth, sometimes with a low, roughened tubercular tooth on either side; the lateral tooth is wide, heavy, elongated, and serrated. The interdentum is long and wide; the umbo cavity is shallow. The periostracum is yellow or yellowish green, becoming a dark chestnut brown in old shells; most individuals are patterned with dark green rays that are usually wide, often wavy, and usually interrupted or broken. Some individuals lack rays. The nacre is pearly white, and the posterior half or third is iridescent (Parmalee and Bogan 1998:202).

Life History and Ecology: The Kidneyshell appears tolerant of a variety of habitat conditions, although rivers with moderately strong current and a substrate of coarse gravel and sand, usually firmly packed. It is often found on the edges of weed beds with good current. *Ptychobranthus fasciolaris* may be found at depths of less than three feet up to those as great as 18 to 24 feet in large rivers (reservoirs) such as the Ohio River. Ortmann (1919) records the species as bradytictic; the breeding season in Pennsylvania begins in August with the discharging of glochidia taking place in June through August. White et al. (1996) identified the following fish as suitable glochidial hosts for *P. fasciolaris* by comparison of genetic data from glochidia removed from fish with genetic data from known adult mussels. These fish included: Greenside Darter (*Etheostoma blennioides*), Fantail Darter (*Etheostoma flabellare*), Johnny Darter (*Etheostoma nigrum*) and Banded Darter (*Etheostoma zonale*). Watters et al. (2005) listed the Brook Stickleback (*Culaea inconstans*) as a glochidial host for *P. fasciolaris* in the laboratory.

Status: Currently Stable (Williams et al., 1993:14). Ortmann (1918) listed this species as widely distributed but nowhere abundant. Adams et al. (1990) presumed it to be extirpated in North Carolina. This species is presumed extirpated in North Carolina.

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

Plate 7, Figure 40

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).**North Carolina Distribution:** This is a wide-ranging species and is found in North Carolina from the Broad River basin north to the Pasquotank River Basin (Johnson, 1970; Table 2).**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. Umbos are usually full and elevated above the hingeline, umbo sculpture consists of 5-7 double-looped ridges without the nodulous point on the loops 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 umbo 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. Wiles (1975) reported finding gravid females with mature glochidia from 8 November, 1970, 11 May, 29 September, 15 October and 1 December 1971 and 9 May 1972 in Nova Scotia. 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.

Pyganodon grandis* (Say, 1829)*Giant Floater**

Plate 7, Figure 41

Synonymy:*Anodonta grandis* Say, 1829; Say, 1829:341**Type Locality:** Fox River of the Wabash River, Indiana.**General Distribution:** This common mussel is found throughout the Mississippi and Missouri River drainages, the St. Lawrence drainage and the Canadian Interior Basin from western Ontario to Alberta (Burch, 1975), in the Gulf of Mexico drainage area of Louisiana and Texas (Clarke, 1973), and in the Red River drainage, Texas and Oklahoma.**North Carolina Distribution:** The Giant Floater has been reported from the French Broad River (Table 2) and has been introduced into Jordan Lake of the Cape Fear River.**Description:** The shell is variable, usually elongated, ovate, often somewhat elliptical or rhomboid, thin to moderately solid, and inflated to swollen in the umbo area. The anterior end is broadly rounded, but the posterior end is rather bluntly pointed; the dorsal margin usually forms a sharp angle with the posterior end. Umbos are swollen, typically flush with the hinge line or moderately elevated; sculpture consists of 4–5 heavy bars, the first two concentric, the rest strongly double-looped. Individuals may become extremely large under ideal habitat conditions; mature specimens may reach a length of 130–140 mm. Both valves are edentulous; the hinge line is usually slightly thickened. The umbo cavity is shallow. There are pronounced fine concentric ridges on the surface indicative of rest periods. The periostracum is yellowish green and occasionally faintly rayed in young shells and dark green or brown to black in old shells, often with the umbonal area a lighter ash brown. The nacre is a dull white, somewhat iridescent, and occasionally tinged or washed with cream, pink, or salmon (Parmalee and Bogan, 1998:207-208).**Life History and Ecology:** *Pyganodon grandis* occurs in western Pennsylvania rivers possessing a substrate of sand and gravel, but it, like all closely related species within the genera *Anodonta* and *Utterbackia* that are found in the state, reaches its greatest abundance and individual size in reservoirs, backwaters, lakes, and ponds having a mud bottom with little or no current. The diversity of fish hosts for the glochidia of this floater (e.g., gar, *Lepisosteus* sp.; catfish, *Ictalurus* sp.; sunfish, *Lepomis* sp.; freshwater drum, *Aplodinotus grunniens*, according to Oesch, 1984; Watters, 1994) may well be the primary factor contributing to its extensive geographical range, abundance, and adaptability. Watters et al. (2005) added to the long list of laboratory host fish confirming three exotic species Goldfish (*Carassius auratus*), Guppy (*Poecilia reticulata*) and Round Goby (*Neogobius melanostomus*). Baker (1928) reported the bradyctytic reproductive period for *Pyganodon* (*Anodonta*) *grandis* in Wisconsin as extending from August to April or May. Ortmann (1919) reported similar dates for Pennsylvania but noted the species discharges glochidia in early spring (April) and that for Pennsylvania was very late.The greatly inflated shell and elevated umbos that are more or less centrally located on the dorsal margin of *Pyganodon g. corpulenta* [Ortmann (1919) used *Anodonta grandis footiana* for this form restricted to Lake Erie in Pennsylvania] are characters that appear to clearly distinguish this form or subspecies from the somewhat more compressed and elongated shell of *Pyganodon g. grandis*. Some researchers (e.g., van der Schalie and van der Schalie, 1950) considered these naiads to be distinct species, and, although the shells of these two subspecies appear quite different, certain local populations suggest a cline or intermediate form on the basis of shell obesity and position and elevation of the umbos. Stream gradient (current) and type of substrate

may be the primary factors in influencing shell characters of these subspecies.

The Stout Floater attains a maximum size and abundance in impounded sections of large rivers, such as Allegheny and Ohio rivers.

Quiet, mud-bottomed sections of rivers and lakes provide ideal habitat for this floater; it may be found at depths that vary from one foot to 20 feet or more.

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

Quadrula pustulosa* (Lea, 1831)*Pimpleback**

Plate 7, Figure 42

Synonymy:*Unio pustulosus* Lea, 1831; Lea, 1831:76, pl. 7, fig. 7**Type Locality:** Ohio; Alabama River.

Ortmann (1919) lists only the Ohio River as the type locality.

General Distribution: The entire Mississippi River drainage, from New York and Pennsylvania west to the Dakotas, and south to eastern Texas and Louisiana.**North Carolina Distribution:** Lea described *Unio pernodosus* from specimens sent by B.W. Budd with locality data of North Carolina. Ortmann (1918) considered *U. pernodosa* a synonym of *Quadrula pustulosa* but was skeptical of this record. The occurrence of this species needs to be verified in North Carolina (Adams et al., 1990).**Description:** Shells of this common mussel, which seldom exceed 80 mm in length, are rounded to somewhat quadrate, solid, and moderately to greatly inflated. Umbos are high, full, and turned forward; sculpture consists of 3–4 coarse ridges. The anterior end is rounded, while the posterior end is squarish or sharply truncated. The posterior ridge is prominent and rounded. The posterior two-thirds of the surface is usually densely covered with rounded tubercles or pustules, occasionally with a few low, narrow ridges on the posterior slope. Some individuals may be totally lacking in pustules or possess only a very few.

The pseudocardinal teeth, two in the left valve and one in right, are triangular, elevated, and roughened (divergent in the right). In the left valve, the anterior pseudocardinal tooth is bladelike, more elevated, and the larger of the two. The lateral teeth, one in the right valve and two in the left, are short, slightly curved, and heavy. Muscle scars and the pallial line are deeply impressed. The umbo cavity is deep and somewhat compressed. The periostracum is yellowish green or brown in young shells, often with a broad broken green ray extending from

the umbo toward the ventral margin; it is dark brown to black in old shells. The nacre is white and iridescent posteriorly (Parmalee and Bogan, 1998).

Life History and Ecology: Like the Mapleleaf, *Quadrula pustulosa* is rather generalized in habitat preference and can maintain abundant and viable populations in shallow to deep sections of large reservoirs, as well as in small to medium-sized free-flowing rivers. It is usually found in a substrate consisting of coarse gravel, sand, and silt. However, in Pennsylvania the Pimpleback was restricted to the larger rivers and Ortmann (1919) reported it from “deep, strongly flowing waters, with a gravelly bottom.” The Pimpleback is tachytictic, being gravid from about mid-June to mid-August. The Shovelnose Sturgeon (*Scaphirhynchus platyrhynchus*), Black Bullhead (*Ameiurus melas*), Brown Bullhead (*A. nebulosus*), Channel Catfish (*Ictalurus punctatus*), Flathead Catfish (*Pylodictis olivaris*), and the White Crappie (*Pomoxis annularis*) are listed by Fuller (1974) as host fish for glochidia of this mussel. (Parmalee and Bogan, 1998).**Status:** Currently Stable (Williams et al., 1993:14). The Pimpleback has not been seen in North Carolina in recent time and is presumed extirpated in the state.

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

Plate 8, Figure 43

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.**North Carolina Distribution:** The Creeper is widely distributed in the Atlantic slope drainages including the Broad, Pee Dee, Cape Fear, Neuse, Pamlico, and Roanoke. It is reported from the French Broad of the Tennessee River basin (Johnson, 1970; Table 2).**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. Umbos 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 umbo; the pseudocardinal tooth in the right valve appears

as a low, thick swelling anterior to the umbo. Lateral teeth are absent or suggested by a thickened hinge line. The umbo 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 (Wicklowsky and Beisheim, 1998; Watters et al., 1999; Gray et al., 1999). Wicklowsky 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*), Rainbow Darter (*Etheostoma caeruleum*), Bluegill (*Lepomis macrochirus*), Green Sunfish (*Lepomis cyanellus*) and Redbreast Sunfish (*Lepomis auritus*) (Watters et al., 2005; Eads et al., 2007). However, the Creeper is one of the few freshwater mussels able to complete its life cycle without a fish host; 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 listed as State Threatened in North Carolina as it appears to be declining throughout its range.

Toxolasma lividum**Rafinesque, 1831****Purple Lilliput**

Plate 8, Figure 44

Synonymy:*Toxolasma lividus* Rafinesque, 1831; Rafinesque, 1831:2**Type Locality:** Rockcastle River [Kentucky].**General Distribution:** The Purple Lilliput is known from the Ohio River Basin west of Pennsylvania, including Ohio, Michigan, Illinois, Indiana, and Kentucky. It occurred in the Tennessee and Cumberland River drainages in Tennessee, Virginia, and Kentucky. Oesch (1984) reported the Purple Lilliput from streams in southern Missouri. Also known from the Arkansas River in Arkansas and Oklahoma.**North Carolina Distribution:** recorded from Hot Springs on the French Broad River, Madison County, North Carolina. Ortmann (1918) accepted the record but did not examine the specimens. Johnson (1970) suggested the specimens may be *Villosa vanuxemensis* (Adams et al., 1990).**Description:** The Purple Lilliput is short, solid, inflated, and elliptical in outline, with a distinct lunule. Shell length seldom exceeds 35 mm. The anterior end is uniformly rounded; the dorsal margin is nearly straight; the ventral margin is straight; the posterior margin has a sharp point above and is broadly rounded below. The posterior ridge is low and rounded. The male shell is short and elliptical to almost rhomboidal in outline with a bluntly rounded posterior margin. The female shells are shorter and somewhat more inflated and have an angular marsupial swelling at the posterior ventral margin. Umbos are full and elevated; sculpture consists of irregular ridges, which curve upward behind and become nodulous at the posterior ridge. The umbo cavity is open and shallow, and the interdentum is narrow or absent.

The left valve has two erect, triangular, compressed pseudocardinal teeth and two long, nearly straight lateral teeth. The right valve has

a large elongate pseudocardinal tooth, often with a vestige of another above, and a long lateral tooth often with a vestigial lateral or small shelf below it. Adductor muscle scars are impressed; the pallial line is impressed anteriorly. The periostracum has irregular growth lines; color varies from dark brown to black and is rayless. The nacre color is usually a deep purple, lighter beyond the pallial line, but sometimes it is a creamy white, becoming iridescent posteriorly. (Parmalee and Bogan, 1998).

Life History and Ecology: Ahlstedt (in Neves, 1991) reported the Purple Lilliput from small to medium-sized rivers in mud, sand, and gravel substrates. This species has also been found on shallow, rocky gravel points or sandbars in Wheeler Reservoir, Alabama. Ortmann (1921) reported gravid females in May and July. Watters (1994) listed the Green Sunfish (*Lepomis cyanellus*) and Longear Sunfish (*L. megalotis*) as fish hosts for the glochidia of *Toxolasma lividum* (Parmalee and Bogan, 1998)**Status:** Special Concern (Williams et al., 1993:14). This species is considered extirpated in North Carolina (Table 4).**Remarks:** The gender of *Toxolasma* recently has been determined to be neuter (Lee, 2006). This results in a change of ending to *Toxolasma lividum*

Toxolasma parvum* (Barnes, 1823)*Lilliput**

Plate 8, Figure 46

Synonymy:*Unio parvus* Barnes, 1823; Barnes, 1823:pl. 13, fig. 18**Type Locality:** Fox River, Wisconsin**General Distribution:** Native range of the Lilliput (*Toxolasma parvum*) is restricted to the Mississippi River basin from Minnesota to southern Louisiana and Texas, from the headwaters of the Ohio in western Pennsylvania, west to the Missouri River drainage of South Dakota and Kansas and tributaries to Lake Erie and Lake Michigan (Bogan et al. 2011).**North Carolina Distribution:** The Lilliput has been introduced and is restricted to Falls Lake Reservoir, Neuse River, North Carolina.**Description:** The Lilliput is a small species with maximum shell length of about 30 mm. The shell is rather solid and subelliptical in outline, often quite inflated. Anterior and posterior ends are evenly rounded; the ventral margin is nearly straight to very slightly curved and almost parallel with the dorsal margin. A posterior ridge is lacking; posterior slope is flattened and somewhat compressed. Male shells are less swollen than those of the females, and the posterior end is narrower, sometimes coming almost to a point. The female shell is more swollen than the male shell, and posterior end is more broadly rounded and very blunt. Umbos are more or less inflated but only slightly elevated above the hinge line. Sculpture consists of 5–6 relatively strong, subconcentric, distinct bars; latter bars become subangular posteriorly. Umbo cavity is open and shallow; there is no interdentum.

The left valve has two erect, compressed, triangular pseudocardinal teeth and two moderately strong, straight lateral teeth. The right valve has one compressed, erect triangular pseudocardinal and a single straight lateral tooth. The anterior adductor muscle scar deep, and posterior adductor muscle scar is shallow.

Dorsal muscle scars are present. Pallial line is impressed anteriorly. Periostracum is usually dark greenish or gray, sometimes dark brown to black, and rayless; growth lines may be coarse and elevated. Nacre color is typically silvery white, iridescent posteriorly, often with a tinge of pale yellow within the umbo cavities. (Parmalee and Bogan 1998:232).

Life History and Ecology: The Lilliput is found typically in the shallows of lakes, ponds, and reservoirs, as well as in small to large rivers, where it lives in mud, sand, or fine gravel. Ortmann (1919) and Baker (1928) reported gravid females in May, June, and July with eggs present in August, the species probably being bradytictic. Watters (1994a) lists the following fish hosts for the glochidia of *Toxolasma parvum*: bluegill (*Lepomis macrochirus*), green sunfish (*L. cyanellus*), orangespotted sunfish (*L. humilis*), warmouth (*L. gulosus*), and white crappie (*Pomoxis annularis*). Hove (1995b) confirmed the green sunfish as a suitable host (Parmalee and Bogan 1998:232-233).**Status:** Currently Stable (Williams et al., 1993:14).**Remarks:** The Lilliput was reported as introduced into New Jersey and more recently into Falls Lake, Wake County, North Carolina. The North Carolina introduction was first documented in 2007 (Bogan et al. 2011). This species has been reported as being hermaphroditic (Williams et al. 2008).

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

Plate 8, Figure 45

Synonymy:

Unio pullus Conrad, 1838; Conrad, 1838:100, pl. 55, fig. 2

Type Locality: Wateree River, South Carolina (Johnson, 1970).

General Distribution: The range of the Savannah Lilliput is from the Altamaha River System in Georgia to the Neuse River System in North Carolina (Johnson, 1970).

North Carolina Distribution: This species is known from the Pee Dee, Waccamaw, Cape Fear, and the Neuse River basins (Johnson, 1967; Fuller, 1977; Porter and Horn, 1980; Shelley, 1987; Adams et al., 1990).

Description: *Toxolasma pullus* has a small, oval or elliptical shell. Male shells are significantly larger than the female shells (Hanlon and Levine, 2004). 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.

Hanlon and Levine (2004) reported the University Lake population in Orange County, North Carolina to be gravid from 27 April until 9 August and the sex ratio was 1:1. They determined hybrid sunfish (*Lepomis machrochirus* x *L. cyanellus*) were good laboratory host fish for *T. pullus*. *Toxolasma pullus* from University Lake were aged between three and nine years, with an average age of 5.2 years for males and 4.7 for females (Hanlon and Levine, 2004).

Status: Williams et al. (1993:14) listed as threatened. This species is listed as State Endangered, effective July 1, 2002. This species may be extirpated from the Neuse River and Lake Waccamaw (J. Alderman, Pers. Comm. July 2002).

Tritogonia verrucosa
(Rafinesque, 1820)

Pistolgrip

Plate 11, Figure 62

Synonymy:

Obliquaria verrucosa Rafinesque, 1820; Rafinesque, 1820:48, pl. 81, figs. 10–12

Type Locality: Ohio River.

General Distribution: Generally found throughout the Mississippi River drainage, from western Pennsylvania west to southern Minnesota, south and west to Oklahoma and Texas; the Cumberland, Tennessee, and Alabama River systems (Ortmann, 1919).

North Carolina Distribution: The Pistolgrip is known only from the New River basin, a tributary to the Ohio River (Table 3).

Description: The shell is solid and an elongated rhomboid in outline, rather compressed but with a distinct, elevated, and rounded posterior ridge. In the same population, shells of old males may reach a length of 160 mm, while those of females may reach 120 mm. Shell size varies greatly in this species and is apparently dependent upon local habitat conditions. The anterior end is broadly rounded, and the ventral margin is slightly curved; the posterior end is squarely or obliquely truncated in the male, more compressed and expanded into a broad wing in the female. Although sexual dimorphism is usually apparent in the shells of mature specimens, it is not well defined in many individuals. Ortmann (1919:45) commented that “the female shell is on the average more flattened and compressed than that of the male.” The entire shell surface, with the occasional exception of the posterior ridge and slope, is densely covered with rather small, low tubercles. The posterior slope is usually sculptured with several parallel-elevated ridges or plications. Umbos are compressed to slightly swollen, barely elevated above the hinge line. The left valve has two solid, triangular, divergent, roughened pseudocardinal teeth; the two lateral teeth are long and straight. The right

valve has a large, heavy, triangular, serrated pseudocardinal, with a small tubercular tooth on either side. The lateral tooth is solid, high, straight, and finely striated. The interdentum is narrow; the umbo cavity is moderately deep. The anterior pallial line and muscle scars are deeply impressed, the posterior scars weakly so. The periostracum is a dark olive or yellowish tan, unrayed, becoming brown to black in old shells. The nacre is white and iridescent posteriorly. (Parmalee and Bogan, 1998:235).

Life History and Ecology: Because of its apparent adaptability to a variety of habitat conditions, *Tritogonia verrucosa* may be found living at river depths of one foot up to 20 feet and in a substrate composed of coarse gravel, sand, and/or mud. Under favorable conditions, including a stable substrate and moderate current, the Pistolgrip may become locally numerous. The species is tachytictic, and the reproductive period occurs from April to August (Ortmann, 1919; Utterback, 1915–1916). Howells (1996) reported the Flathead Catfish (*Pylodictis olivaris*) to be a suitable fish host for this species. Pepi and Hove (1997) have added the Yellow Bullhead (*Ameiurus natalis*) to the list of host fish for the glochidia of this species (Parmalee and Bogan, 1998).

Status: Currently Stable (Williams et al., 1993:14). The Pistolgrip is considered extirpated in North Carolina (Table 4).

Remarks: *Tritogonia* has long been considered as monotypic genus but close to *Quadrula* anatomically. Recent genetic analyses support the inclusion of the species *verrucosa* in the genus *Quadrula* (Serb et al., 2003).

Unio carolinianus
(Bosc, 1801)

Florida Pondhorn

Plate 8, Figure 47

Synonymy:

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

Type Locality: “en Caroline”, the Carolinas.

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

North Carolina Distribution: This species is found in the Catawba, Yadkin, Lumber, Waccamaw, Cape Fear, Neuse, Pamlico, and Roanoke River basins in North Carolina (Johnson, 1970; Table 2).

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 slight 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.

Right valve with a single triangular pseudocardinal tooth and a single lateral tooth. Left valve with two ragged subequal pseudocardinal, often with a vestigial tooth

above it; one lateral tooth. Umbo cavities compressed, but with several scars deep, posterior scars faint. Pallial line distinct. Nacre white, bluish white or pinkish to lurid purple.” (Johnson, 1970:341)

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

Status: Williams et al. (1993:14) listed as currently stable.

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

Plate 8, figure 48

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).

North Carolina Distribution: The Paper Pondshell occurs in the Broad, Catawba, Yadkin, Cape Fear, Neuse, Pamlico, Roanoke, Chowan, and Pasquotank River basins (Johnson, 1970, Table 2).

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 umbos. 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. Umbos 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 umbo 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 bradyctytic; 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 host fish 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 host fish. 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 North Carolina.

***Venustaconcha trabalis* (Conrad, 1834)**

Cumberland Bean

Plate 9, Figure 52

Synonymy:

Unio trabalis Conrad, 1834; Conrad, 1834:27, 72 pl. 3, fig. 5.

Type Locality: Flint River, Alabama.

General Distribution: The small Cumberland Bean is restricted to the upper Cumberland River system in Kentucky, formerly the main channel of the Tennessee River upstream from Muscle Shoals, Alabama, and in streams of the upper Tennessee River drainage in Tennessee and Virginia (Parmalee and Bogan, 1998).

North Carolina Distribution: This species was probably part of the fauna and is treated as such. However, Ortmann (1918) observed that this species was absent from the eastern tributaries to the Tennessee River in Tennessee. *Venustaconcha trabalis* is present in the Hiwassee River just downstream of the North Carolina state line in Tennessee (Parmalee and Hughes, 1994).

Description: Shells of the Cumberland Bean are solid and elongate with inflated, inequilateral, and irregularly oval valves. The anterior end is rounded, and the ventral margin slightly rounded to straight, converging with the posterior-dorsal surface in a rounded point. The posterior ridge is somewhat full and rounded. The male shell is slightly narrowed at its center and is drawn out posteriorly; this elongation is obliquely truncated above and ends in a rounded point below. Female shells are higher and more evenly ovate and only slightly truncated behind and above the posterior ridge. The ventral margin is rather evenly curved. Umbos are high, situated near the anterior end where the shell is thickest, and sculptured with a few coarse, double-looped ridges. Female shells reach a slightly larger size than males, attaining a maximum length of about 55 mm.

The left valve has two solid triangular pseudocardinal teeth, a narrow interdentum, and two long, straight, relatively heavy lateral

teeth. The right valve has three pseudocardinals: the central tooth is large, sculptured, and triangular, while the anterior and posterior teeth are much reduced. The single lateral tooth is long, sometimes with a vestige of a second tooth below. The umbo cavity is shallow with a few dorsal scars. Adductor muscle scars and the pallial line are well impressed. The periostracum is a dingy olive green with numerous faint wavy green rays. The surface is marked by irregular growth lines. The nacre color is a bluish white or white with a bluish or greenish iridescence posteriorly (Parmalee and Bogan, 1998).

Life History and Ecology: The Cumberland Bean has been collected in small rivers and streams in a typically gravel or sand and gravel substrate with fast current in riffle areas. The animal is bradyctictic. Probable host fish for *Venustaconcha trabalis* have been determined, based on laboratory experiments, as the Arrow Darter (*Etheostoma sagitta*), Barcheek Darter (*E. obeyense*), Fantail Darter (*E. flabellare*), Johnny Darter (*E. nigrum*), Rainbow Darter (*E. caeruleum*), Snubnose Darter (*E. simoteron atripinne*), Sooty Darter (*E. olivaceum*), Striped Darter (*E. virgatum*), and Stripetail Darter (*E. kennicotti*). However, the Arrow Darter is not found within the known range of *Venustaconcha trabalis* and the Johnny Darter and Rainbow Darter both produced very few juveniles per fish (Layzer and Anderson, 1991, 1992, J. B. Layzer, pers. comm., 1997) (Parmalee and Bogan, 1998).

Status: Williams et al. (1993:15) listed as endangered. This species is federally listed as endangered. It is presumed to be extirpated in North Carolina.

Remarks: *Villosa trabalis* was moved to *Venustachoncha* and *Villosa perpurpurea* was listed as a junior synonym of *V. trabalis* (Lane et al. 2016).

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

Plate 9, Figure 49

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 Rappahanock River basin south to the Catawba River basin of North Carolina (Johnson, 1970; H.D. Athearn Museum collection; Table 2).**North Carolina Distribution:** This species is found in the Catawba, Pee Dee, Cape Fear, Neuse, Pamlico, Roanoke, and Chowan River basins in North Carolina (Johnson, 1970; Table 2).**Description:** “Shell rather small and short, subelliptical, subsolid, subcompressed; umbos 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 and 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 are subspatulate 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 offish. 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.

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

Plate 9, Figure 50

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 Rainbow 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 2). The record from the Neuse is probably a new species of *Lampsilis* (J. Alderman, Pers. Comm. July 2002).**North Carolina Distribution:** This species' range includes the Catawba, Pee Dee, Waccamaw, and Cape Fear River basins (Johnson, 1970; Table 2).**Description:** "Shell long ovate, very thin and fragile, ventricose; ligament margin slightly elevated; anterior side rather narrow; posterior margin rounded; umbos 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.

Villosa iris* (Lea, 1829)*Rainbow**

Plate 9, figure 51

Synonymy:*Unio iris* Lea, 1829; Lea, 1829:439, pl. 11, fig. 18**Type Locality:** Ohio.**General Distribution:** The Rainbow is found throughout the Tennessee, Cumberland, and Ohio River basins, the upper Mississippi River, and the St. Lawrence River system from Lake Huron to Lake Ontario including their tributaries (Burch, 1975; Clarke, 1981a).**North Carolina Distribution:** The Rainbow is reported from the Hiwassee, Little Tennessee, and historically from the French Broad rivers (Ortmann, 1918; Dawley, 1965; Table 3).**Description:** The Rainbow shell outline is elongate elliptical to long ovate, subcompressed to somewhat inflated; the shell is thicker anteriorly, becoming quite thin posteriorly. The anterior end is evenly rounded, the dorsal margin is almost straight to slightly convex, and the ventral margin is also almost straight to broadly curved. The posterior ridge is low and rounded. The male shells are more sharply pointed posteriorly, while the female shell is expanded posteriorly, producing a marsupial swelling and thus becoming more broadly rounded. Umbos are low and compressed; sculpture consists of 4–6 bars, the first concentric, the rest irregular, interrupted ridges, tending to become double-looped. The umbo cavity is open and shallow with a few dorsal muscle scars. The maximum shell length attained is about 75 mm.

The left valve has two triangular, somewhat compressed, slightly sculptured pseudocardinal teeth, which run parallel with the hinge line, and two long, straight, thin lateral teeth. The right valve has one subcompressed pseudocardinal and one long, straight, and thin lateral tooth. The anterior adductor muscle scar is well impressed; the posterior adductor muscle scar is quite shallow. The pallial line is impressed anteriorly. The shell surface is covered with faint growth lines. The

periostracum is yellowish to greenish yellow with numerous dark green rays varying from narrow to wide, complete to interrupted. The nacre color varies from white to salmon, pink and purple, and is iridescent posteriorly (Parmalee and Bogan, 1998:247).

Life History and Ecology: Ortmann (1919) reported *Villosa iris* as bradyctictic with glochidia from July to May. The Rainbow lives in riffles and along the edges of emerging vegetation, such as *Justicia* beds, in gravel and sand in moderate to strong current. It becomes most numerous in clean, well-oxygenated stretches at depths of less than three feet.Watters (1994) lists the following fish hosts for the glochidia of *Villosa iris*: Largemouth Bass (*Micropterus salmoides*), Smallmouth Bass (*M. dolomieu*), Spotted Bass (*M. punctulatus*), Suwannee Bass (*M. notius*), Rockbass (*Ambloplites rupestris*), and Western Mosquitofish (*Gambusia affinis*). Watters et al. (2005) added the Mottled Sculpin (*Cottus beldingi*) as a laboratory host for the glochidia of *Villosa iris*. O'Connell and Neves (1999) examined the immunological response of host fish Rockbass (*Ambloplites rupestris*) and non-host fish, Carp (*Cyprinus carpio*) and Goldfish (*Carassius auratus*) to the glochidia of the Rainbow documenting specific humoral defense factors that reacted immunologically to glochidia tissue (Parmalee and Bogan, 1998).**Status:** Currently Stable (Williams et al., 1993:14). This species is listed as State Special Concern (Table 4).

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

Plate 10, Figure 55

Synonymy:*Unio modioliformis* Lea, 1834: Lea, 1834:97, pl.13, fig40**Type Locality:** Santee Canal, South Carolina.**General Distribution:** Known from the Savannah River system north to the Cape Fear River Basin of North Carolina (Johnson, 1970).**North Carolina Distribution:** The Carolina Rainbow was found in the Waccamaw and Cape Fear River basins (Johnson, 1970; Table 2). Porter (1985) did not report this species from Lake Waccamaw.**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. Umbos 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 umbo 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: No information on the breeding season or host fish for this species was encountered, but it is assumed to be bradyctytic, holding glochidia from September to May, as is the case in other members of the genus *Villosa* (Parmalee and Bogan, 1998).**Status:** Currently Stable (Williams et al., 1993:15). Porter (1985) did not report this species from Lake Waccamaw nor did Adams (1990) find it in Greenfield Lake**Remarks:** Based on geography and preliminary analyses, this species has been split from *V. vibex* of the Gulf Coast (Williams pers. Comm).

Villosa vanuxemensis* (Lea, 1838)*Mountain Creekshell**

Plate 9, figure 53

Synonymy:*Unio vanuxemensis* Lea, 1838; Lea, 1838b:36, pl. 11, fig. 31**Type Locality:** Cumberland River, Tennessee.**General Distribution:** *Villosa vanuxemensis* is a Cumberlandian species restricted to the Tennessee and central Cumberland River basins (Ortmann, 1918, 1924). Upper Coosa River system (Conasauga River, northern Georgia)(Parmalee and Bogan, 1998)**North Carolina Distribution:** The Mountain Creekshell is reported from the Hiwassee River basin (Table 3).**Description:** The Mountain Creekshell varies in outline from elliptical to somewhat obovate, the shell being rather solid and inflated. The anterior end is broadly rounded, the dorsal margin is straight to convex, and the ventral margin is broadly rounded to almost straight. The posterior ridge is slightly developed. Male shells are elongated elliptical in outline with the posterior margin rather sharply pointed, the point occurring in about the middle of the posterior margin. The female shell is marked by a prominent marsupial swelling along the posterior ventral margin; the shell is truncated beyond this to a point about two-thirds the way up the posterior margin. Shells in old females have a strong constriction posterior to the marsupial swelling. Umbos are low, sculpture consists of several ridges drawn up in the middle. The umbo cavity is open and shallow. Maximum shell length rarely exceeds 70 mm. The left valve has two short, compressed triangular pseudocardinal teeth and two slightly curved, thin lateral teeth. The right valve has one short, compressed pseudocardinal and one curved, thin lateral tooth. The anterior adductor muscle scar is well impressed, while the posterior adductor muscle scar is shallow. The pallial line is impressed anteriorly. The periostracum varies from a tan or olive to dark brown, becoming black with age; rays are indistinct or absent. The nacre color varies

from a light lavender or pinkish purple, to shades of copper or very dark purple (Parmalee and Bogan, 1998).

Life History and Ecology: The Mountain Creekshell is found in gravel and sand substrates in riffles and along the edges of *Justicia* beds in very clean water at depths of less than three feet. It, along with *V. iris*, is a species most often encountered in small headwater creeks and streams. *Villosa vanuxemensis* is bradytictic, holding glochidia from September to their release in May (Ortmann, 1921). Watters (1994) lists the following fish hosts for the glochidia of *Villosa vanuxemensis*: Banded Sculpin (*Cottus carolinae*), Black Sculpin (*C. baileyi*), Mottled Sculpin (*C. bairdi*), and the Slimy Sculpin (*C. cognatus*) (Parmalee and Bogan, 1998).**Status:** Special Concern (Williams et al., 1993:15). This species is listed as State Threatened in North Carolina (Table 4).

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

Plate 9, Figure 54

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).

North Carolina Distribution: The Carolina Creekshell has been collected recently from creeks in the Catawba, Pee Dee, and Cape Fear River basins (Adams et al., 1990; J. Alderman, Pers. Comm. July 2002).

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 umbos 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 Creek, Goose Creek and Lick Creek 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 Sunfish (*Lepomis auritus*) (Eads et al., 2007).

Status: Williams et al. (1993:14) listed as special concern. This species is listed as State Endangered in North Carolina.

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.
- Arcuate - bent in a bow or arched.
- Umbo - 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.
- Umbo cavity - the cavity on the inside of each valve leading into the umbo, under the interdentum.
- Umbo sculpture - raised ridges or undulations on the umbo.
- Biangulate - having two angles.
- Bradyctitic - 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 umbo 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 populations 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.

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Websites for Freshwater Mollusks of North America

North Carolina Atlas of freshwater mussels and endangered fish

<http://www.newwildlife.org/Conserving/Species#5528115-mollusks>

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

Tom Watters, Ohio State University, Museum of Biodiversity, Bivalves

<http://www.biosci.ohio-state.edu/~molluscs/OSUM2/biv.html>

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

Freshwater Mollusk Conservation Society

<http://molluskconservation.org/>

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://ellipse.inhs.uiuc.edu:591/mollusk/>

This website is a searchable database of over 18,000 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 Non-indigenous aquatic species

<http://nas.er.usgs.gov/>

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/zebramussel/>

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 collector's website with loads of good information and links.

Mussel project

<http://mussel-project.uwsp.edu/db/db.php?p=div&l=spp&n=2788>

A database of names and pictures of some specimens.

Unio Gallery at Missouri State University

<http://unionid.missouristate.edu/>

A site with conglutinate pictures, videos and mantle lures.

Also visit individual museums for on line databases of museum mollusk collections: USNM, ANSP, NCSM, OSUM, UF, CMNH, UMMZ, MCZ-Harvard are some of the larger collections.

[These sites are active at this time, 2 February 2017.]



Fig. 1 *Alasmidonta heterodon*



Fig. 2 *Alasmidonta raveneliana*

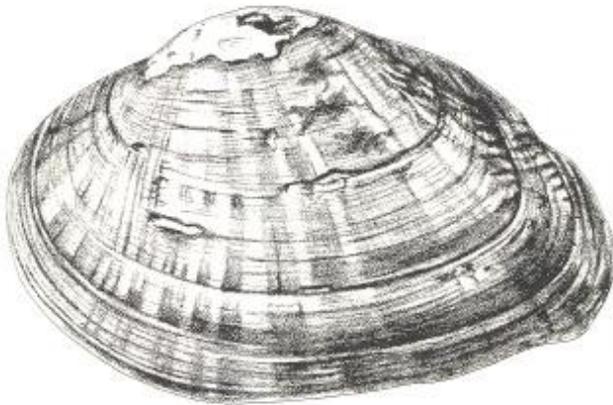


Fig. 3 *Alasmidonta robusta*



Fig. 4 *Alasmidonta undulata*



Fig. 5 *Alasmidonta varicosa*



Fig. 6 *Alasmidonta viridis*



Fig. 7 *Anodonta couperiana*



Fig. 8 *Anodonta implicata*



Fig. 9 *Cyclonaias tuberculata*



Fig. 10 *Elliptio cistellaeformis*



Fig. 11 *Elliptio complanata*



Fig. 12 *Elliptio congaraea*



Fig. 13 *Elliptio dilatata*



Fig. 14 *Elliptio folliculata*



Fig. 15 *Elliptio icterina*



Fig. 16 *Elliptio lanceolata*



Fig. 17 *Elliptio marsupiobesa*



Fig. 18 *Elliptio roanokensis*



Fig. 19 *Parvaspina steinstansana*



Fig. 20 *Elliptio waccamawensis*



Fig. 21 *Epioblasma f. aureola*



Fig. 22 *Pleuronaia barnesiana*



Fig. 23 *Fusconaia masoni*



Fig. 24 *Fusconaia subrotunda*



Fig. 25 *Lampsilis cariosa*



Fig. 26 *Lampsilis fasciola*



Fig. 27 *Lampsilis fullerkati*



Fig. 28 *Lampsilis radiata*



Fig. 29 *Lasmigona decorata*



Fig. 30 *Lasmigona holstonia*



Fig. 31 *Lasmigona subviridis*



Fig. 32 *Leptodea ochracea*



Fig. 33 *Pleuronaia dolabelloides*



Fig. 34 *Ligumia nasuta*



Fig. 35 *Medionidus conradicus*



Fig. 36 *Pegias fabula*



Fig. 37 *Parvaspina collina*



Fig. 38 *Pleurobema oviforme*



Fig. 39 *Ptychobranthus fasciolaris*



Fig. 40 *Pyganodon cataracta*



Fig. 41 *Pyganodon grandis*



Fig. 42 *Quadrula pustulosa*



Fig. 43 *Strophitus undulatus*



Fig. 44 *Toxolasma lividum*
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Fig. 45 *Toxolasma pullus*



Fig. 46 *Toxolasma parvum*



Fig. 47 *Unio merus carolinianus*



Fig. 48 *Utterbackia imbecillis*



Fig. 49 *Villosa constricta*



Fig. 50 *Villosa delumbis*



Fig. 51 *Villosa iris*



Fig. 52 *Venustaconcha trabalis*



Fig. 53 *Villosa vanuxemensis*



Fig. 54 *Villosa vaughaniana*



Fig. 55 *Villosa modioliformis*



Fig. 56 *Corbicula fluminea*



Fig. 57 *Corbicula fluminea*
inside view



Fig. 58 *Dreissena polymorpha*



Fig. 59. *Alasmidonta marginata*



Fig. 60. *Potamilus alatus*



Fig. 61. *Elliptio fisheriana*



Fig. 62. *Tritogonia verrucosa*



Fig. 63. *Lamprolasmis splendida*