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Date: 2/5/2008 2:52:35 PM
Subject: FW: Vogtle
cc: "Michael R Sackschewsky" <michael.sackschewsky@pnl.gov>, "^PNNL NRC Vogtle" <nrc.vogtle@pnl.gov>

Mike, Nancy,
This is the mussel survey report referred to by the FWS in their comment letter on the Vogtle DEIS.

Becky

From: Ed_Eudaly@fws.gov [mailto:Ed_Eudaly@fws.gov]
Sent: Tuesday, February 05, 2008 11:27 AM
To: Krieg, Rebekah
Cc: Lora_Zimmerman@fws.gov; Strant_Colwell@fws.gov
Subject: Vogtle

As requested I am attaching mussel survey report. Please contact Lora Zimmerman if you have questions about mussels.

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Mike, Nancy,

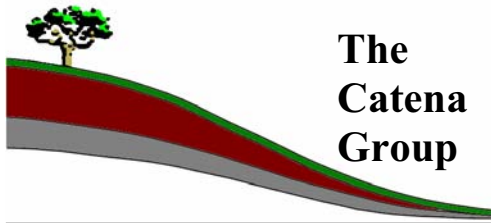
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Catena
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Freshwater Mussel Surveys
The Savannah River from Augusta to Savannah:
South Carolina & Georgia

Prepared For:

International Paper & U. S. Fish and Wildlife Service

Prepared By:

**The Catena Group
Hillsborough, North Carolina**

December 17, 2007

A handwritten signature in blue ink, reading "Timothy W. Savidge", is written over a horizontal line.

Timothy W. Savidge

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1.0 INTRODUCTION

The freshwater mussel fauna (Unionidae) of North America is the richest in the world, consisting of approximately 297 species and subspecies (Turgeon et al. 1988), with much of the higher classification of taxa still unresolved. The greatest species diversity occurs in the southeastern United States (Neves 1993). Johnson (1970) recognized 37 species as comprising the Southern Atlantic Slope Unionoid Faunal Province of North America, and reported 21 of those as occurring in the Savannah River Basin, a major drainage of the Southern Atlantic Slope in the southeastern United States.

The cumulative effects of the modification of aquatic habitats through impoundment, channelization, and dredging, along with sedimentation and water pollution, have resulted in dramatic declines in the freshwater mussel fauna of North America. (Williams et al. 1993) considers 72% of this fauna to be extinct, endangered, threatened, or of special concern, and only 24% as stable.

1.1 Background and Objectives

The collection of freshwater mussel fauna from the Savannah River Basin has a rich history. At least 25 unionoid species were described from the SRB during the 19th century. Many of these species were later synonymized by Johnson (1970) with other species, the majority of which were placed into three species complexes of the genus *Elliptio*: *E. complanata*, *E. icterina*, and *E. lanceolata*. While the concept of composite species complexes is widely accepted, a number of the synonyms assigned by Johnson (1970) are disputed by many researchers and many taxonomic uncertainties remain.

The advancement of molecular genetic technologies provides additional tools in resolving taxonomic disputes by allowing for better understanding of the phylogenetic relationships of freshwater mussels and their geographic distributions. A critical component of this type of study is to develop a suite of microsatellite DNA markers for each species from topotypic material, for comparison between species, as well as within the species across their respective geographic ranges.

Although many collections of freshwater mussels have been made in the Savannah River Basin in recent years, much of the knowledge of the mussel fauna has been limited to scattered locales, often in the smaller tributaries, and shallow water habitats. With the exception of long term monitoring of freshwater mussel populations in the vicinity of the Savannah River Site (Bouchard et al. 2001, Patrick, Cairns and Roback 1967), and a survey in the Augusta Shoals area in 2001 (Entrix 2002), there have been relatively few collections in the main-stem of the river between Augusta and Savannah, especially in the deep water habitats. Therefore, in an effort to obtain additional information of species within this section of river, The Catena Group, Inc. (TCG) was retained by the US Fish and Wildlife Service (USFWS) Charleston, South Carolina Field Office and International Paper (IP), who provided matching funds for the project. This project complements other survey efforts in the basin initiated by the USFWS.

The objectives of this study consisted of two components; 1) Determine species composition and distribution within the study area, and 2) Collect topotypic material of species named from the Savannah River for establishment of microsatellite DNA markers and collection of other species for comparisons with other material across their respective geographic ranges. Species targeted for collection of topotypic material include the

Atlantic spike (*Elliptio producta*), pod lance (*E. folliculata*), both of which were synonymized by Johnson (1970) with *E. lanceolata*, the variable spike (*E. icterina*), the brother spike (*E. fraterna*) and the Atlantic pigtoe (*Fusconaia masoni*), the latter two species have not been recorded in the Savannah River basin in recent years.

2.0 STUDY AREA

The Savannah River Basin drains 10,577 square miles (mi²) of North Carolina (175 mi²), South Carolina (4,581 mi²), and Georgia (5,821 mi²) and encompasses three physiographic regions: the Blue Ridge Province, the Piedmont Province, and the Coastal Plain Province. Within the three states, the basin includes portions of 44 counties and borders two major metropolitan centers, Augusta and Savannah. The Savannah River forms near Hartwell, Georgia at the confluence of the Seneca and Tugaloo Rivers and flows southeasterly for 296 river miles (RM) before emptying into the Atlantic Ocean. A series of three reservoirs (Hartwell, Richard B. Russell and J. Strom Thurmond/Clarks Hill) were constructed in the upper 120 miles of the river for hydro-electric/flood control, recreation, and development purposes.

This study encompassed the portion of the river from the Augusta Shoals region (RM 203) near the Fall Line, downstream to the tidewater region (RM 22.8) near Savannah (Figure 1). There are no large reservoirs located on this reach and the river is generally free-flowing; however it has been altered throughout the years by various navigation projects that have involved dredging, and elimination of numerous bends (cut off bends).

3.0 METHODS

Timed qualitative mussel surveys were performed at 39 survey sites (Figures 2a-d) on August 1-3 and October 17-19, 2006. Site numbers (1-39) were assigned sequentially to each area surveyed. Selection of general survey locations were based on pre-survey evaluations to avoid areas recently searched and to concentrate on areas where target species would likely be collected. Specific survey sites were accessed by motorboat and selected based on ease of access and habitat characteristics.

All habitat types (riffle, run, pool, slack water, etc.) within each site were sampled, with a concentration on deep water habitats. Mussel surveys were conducted primarily using SCUBA. At least 2 divers were utilized at all survey sites, with one SCUBA equipped person serving as surface support. The divers were equipped with AGA full face masks and underwater communication systems (buddy phones) to ensure diver to diver and diver to surface contact. Hand held underwater lights were used to illuminate the river bottom. Mask/snorkel and tactile (hand grubbing) methodologies were also used in shallow water habitats.

The dive crew consisted of TCG personnel Tim Savidge (TS), Tom Dickinson (TD), and Chris Sheats (CS). In addition, Lora Zimmerman (LZ) of the USFWS (all dates), Mark Hughes (MH) of IP (August 1-3), Eric Kruger (EK) of the South Carolina chapter of The Nature Conservancy (August 1) and Jim Williams (JW) of the U. S. Geological Survey (October 17-19) assisted with survey logistics, mussel identification/sorting and surface support, as well as supplementing survey efforts in shallow water habitats. The individual dates and survey sites are shown in Table 1.

Table 1. Survey Dates by Water Body and Survey Team

Survey Date	Water Body(s) Surveyed (Site #)	Survey Team
8-1-06	Savannah River (1-7)	TS, TD, CS, MH, LZ, EK
8-2-06	Savannah River (8-14)	TS, TD, CS, MH, LZ,
8-3-06	Savannah River (15-19)	TS, TD, CS, MH, LZ,
10-17-06	Savannah River (20-26)	TS, TD, CS, LZ, JW
10-18-06	Savannah River (27-32)	TS, TD, CS, LZ, JW
10-19-06	Savannah River (33-39)	TS, TD, CS, LZ, JW

At most of the survey sites, habitat was first evaluated by traversing the bottom of the stream channel to locate the most productive habitats and to ensure full coverage of all habitat types. Survey efforts were then concentrated in the areas with the most suitable habitat for target species and the highest concentrations of mussels. Some of the sites were not surveyed in this manner due to time constraints, current, or channel width. In these cases, only one side of the channel was surveyed. The speed at which the team proceeded upstream depended on stream width, survey conditions (depth, clarity, etc.), habitat characteristics and the presence of mussels. Timed searches were employed at each site. The amount of time spent at each survey site was determined by survey conditions and safety concerns (strong currents, debris, etc.). Survey distances between sites varied, as sites were chosen based on best suitable habitat for the target species and accessibility to these habitats.

Mussels were collected and brought to the surface for identification and returned to the substrate. Specimens kept as vouchers or for DNA analysis were preserved in 95% ethanol and deposited in the North Carolina State Museum of Natural Sciences (NCSM).

Catch per unit effort (CPUE) for each mussel species were calculated at each surveyed site. Searches were also conducted for relict shells. The presence of a shell was equated with presence of that species; however the shells found were not factored into the CPUE. Representative photographs of each mussel species collected were taken when possible.

While conducting freshwater mussel surveys, aquatic snails, and fish were also observed, and/or captured. A relative abundance (Rare, Uncommon, Common, Abundant and Very Abundant) was assigned to each snail species observed at each site, fish species were simply recorded as present.

4.0 RESULTS

A total of 26 freshwater mussel species were identified during the survey efforts. Table 2 lists the species found, number of sites where the species was located, highest recorded CPUE for the species, and the site number where the highest CPUE was recorded. Species numbers and CPUE for each site are provided in Appendix A.

Table 2: Mussel Species Located

Species	# of Sites Where Found	Highest CPUE (#/survey hour)	Site # of Highest CPUE
<i>Alasmidonta arcula</i> ** (arc mussel)	1	1.17	12
<i>Alasmidonta undulata</i> (triangle floater)	1	0.89	27
<i>Anodonta couperiana</i> (barrel floater)	4	3.39	28
<i>Anodonta implicata</i> (alewife floater)	2	4.80	24
<i>Elliptio angustata</i> (Carolina lance)	9	14.10	7
<i>Elliptio complanata</i> (eastern elliptio)	27	163.93	19
<i>Elliptio congarea</i> (Carolina slabshell)	33	282.50	17
<i>Elliptio fisheriana</i> (northern lance)	5	2.99	11
<i>Elliptio folliculata</i> (pod lance)	10	10.45	11
<i>Elliptio fraterna</i> (brother spike)	3	1.00	1
<i>Elliptio hopetonensis</i> ** (Altamaha slabshell)	15	22.41	9
<i>Elliptio icterina</i> (variable spike)	34	43.59	7
<i>Elliptio lazarus</i> (=arctata) (delicate spike)	3	16.67	7
<i>Elliptio producta</i> (Atlantic spike)	15	9.60	34
<i>Elliptio roanokensis</i> (Roanoke slabshell)	19	133.33	31
<i>Elliptio</i> sp.*	1	6.52	13
<i>Fusconaia masoni</i> ** (Atlantic pigtoe)	2	2.31	3
<i>Lampsilis cariosa</i> (yellow lampmussel)	12	3.45	9
<i>Lampsilis dolabraeformis</i> ** (Altamaha pocketbook)	1	1.49	11
<i>Lampsilis splendida</i> (rayed pink fatmucket)	17	10.34	39
<i>Leptodea ochracea</i> (tidewater mucket)	1	0.83	6

Species	# of Sites Where Found	Highest CPUE (#/survey hour)	Site # of Highest CPUE
<i>Pyganodon cataracta</i> (eastern floater)	6	3.42	26
<i>Toxolasma pullus</i> (Savannah lilliput)	1	0.85	26
<i>Uniomereus carolinanus</i> (Florida pondhorn)	11	10.40	24
<i>Utterbackia imbecillis</i> (paper pondshell)	2	1	37
<i>Villosa delumbis</i> (eastern creekshell)	18	3.5	37

* An unusual form, likely *E. icterina*

** Putative ID pending genetics analysis

The Asian clam (*Corbicula fluminea*) was found at all of the sites and was the most abundant mollusk.

4.1 Site Habitat Conditions and Mussel Distribution

With the exception of sites within the vicinity of Augusta Shoals, mussels were generally unevenly distributed across the river channel, which is reflective of the distribution and quality of microhabitats within a particular river segment. In general mussels were most abundant in the thalweg at the base of the river bank, and rare to absent in the shifting sand dominated runs in the center of the channel. Brief summaries of the habitat and molluscan fauna of each stream site surveyed are provided below to accompany the complete site species list provided in Appendix A.

Site 1. RM 203: This site is located within the Augusta Shoals area adjacent to a small island close to the Georgia side of the river. The surveyed habitat consists of a cobble/sand/boulder run with a maximum depth of 8 feet. Five species were found, with the variable spike (42 individuals) and the eastern elliptio (28 individuals) being the most abundant. Two individuals of brother spike, one of the targeted species, were found and kept for DNA analysis. Searches were conducted for a total of 2 person-hours. The aquatic snails gravel elimia (*Elimia catenaria*) and a campeloma (*Campeloma sp.*) were common.

Site 2. RM 202.8: This site is located within riffle/run habitat along the bank on the Georgia side of the river in the Augusta Shoals area. Substrate is dominated by cobble, sand and gravel, and water depth ranged from 1-6 feet. Six species were found, with the variable spike (50 individuals) and the eastern elliptio (18 individuals) being the most abundant. Specimens tentatively identified as Atlantic pigtoe (1 live individual, 1 weathered shell) were also found and kept for DNA analysis (See further discussion, Sec. 5.0). Searches were conducted for a total of 2.5 person-hours. The aquatic snails gravel elimia and a campeloma sp. were common.

Site 3. RM 202.2: This site is located in the Augusta Shoals area. The two divers traversed the river bottom from the Georgia side to the South Carolina side. Habitat

consists of sand/cobble banks sloping to sand/gravel runs over bedrock in the center of the channel. The maximum depth was 22 feet, with an average of 15. Concentrations of mussels were found in pockets across the river bottom. Six species were found, with the Carolina slabshell (65 individuals), variable spike (32 individuals), and the eastern elliptio (32 individuals) being the most abundant. Specimens of *Elliptio* with characteristics resembling the Altamaha slabshell (*Elliptio hopetonensis*), which is believed to be an Altamaha River endemic, were found (17 individuals). This species was found at 15 of the surveyed sites (see further discussion Sec. 5.0). The highest CPUE of the tentatively identified Atlantic pigtoe (3 individuals) occurred at this site. Searches were conducted for a total of 1.3 person-hours.

Site 4. RM 193.2: This site is located near Beech Island downstream of Augusta. The two divers traversed the river bottom from the Georgia side to the South Carolina side. Habitat consists of mud flats with emergent vegetation along both banks that gradually slope to a shifting sand dominated channel approximately 20 feet deep. Only two species, Carolina slabshell (1 individual) and variable spike (2 individuals) were found, all occurring along the slope on the Georgia side of the river in pockets of sand and pebble. Searches were conducted for a total of 0.83 person-hours. The aquatic snail gravel elimia and a campeloma sp. were uncommon.

Site 5. RM 195.8: A brief survey was conducted at this deepwater site located close to a bridge piling of the SC Highway 28 crossing in the center of the channel. Substrate is composed almost entirely of shifting sand and Asian clam shell. Only one shell of the variable spike was found, however the Asian clam is extremely abundant. Searches were conducted for a total of 0.17 person-hours at depth of 20 meters.

Site 6. RM 196.2: This site is located in a 17-foot deep run along the bank on the South Carolina side of the river. Substrate consists of sand and gravel, and there is a large amount of submerged timber at the base of the slope. Seven mussels species were found sporadically at the base of the slope and in the moderately sloping bank, with the variable spike (41 individuals) and the Carolina slabshell (5 individuals) being the most abundant. The targeted Atlantic spike (1 individual) and the only individual of the tidewater mucket located during the study were found at this site. Searches were conducted for a total of 1.2 person-hours.

Site 7. RM 201.5: This site is located below the Kings Mill Gate at the mouth of a channel connected to the Augusta Canal. The habitat is characterized as a slow moving, 20 feet deep run with sand and bedrock substrate. A large amount of old glass bottles and other trash items (metal, tires, etc.) occur on the river bottom. Nine species were found, with the variable spike (34 individuals) and the Carolina slabshell (19 individuals) being the most abundant. The site had highest CPUE for the delicate spike and Carolina lance. Searches were conducted for a total of 0.78 person-hours.

Site 8. RM 122: This site is located along the bank on the South Carolina side of the river in a sand/gravel run. Most mussels were found at the base of the moderately steep banks. Eight species were found, with the Carolina slabshell (71 individuals) and the Roanoke slabshell (18 individuals) being the most abundant. Searches were conducted for a total of 1.0 person-hour.

Site 9. RM 123: This site is located along the bank on the Georgia side of the river in a sand/gravel run. A narrow (< 10 feet wide) sandy flat shelf occurs along the bank before sharply sloping to the bottom. Mussels were abundant at the base of the slope, but were also found in the shallow (< 2 feet) shelf habitat. Nine species were found, with the Carolina slabshell (133 individuals) and the Altamaha slabshell (26 individuals) being the most abundant. Searches were conducted for a total of 1.16 person-hours at a maximum depth of 14 feet.

Site 10. RM 119.5: This site occurs in a large gradually sloping sandbar extending from the South Carolina side of the river approximately 35 feet to the center channel run, which is approximately 10 feet deep. Substrate consists entirely of unconsolidated sand. One individual of the yellow lampmussel was found in 0.4 person-hours of search time.

Site 11. RM 118.9: This site is located in a sandy/cobble run with a maximum depth of 12 feet just upstream of the US 301 crossing along the Georgia side of the river. Eleven species were found, with the Carolina slabshell (92 individuals) and the Roanoke slabshell (33 individuals) being the most abundant. One individual *Lampsilis* with characteristics resembling the Altamaha pocketbook (*Lampsilis dolabraeformis*), which is believed to be an Altamaha River endemic, was found (see further discussion Sec. 5.0). This site yielded highest CPUE for pod lance (7 individuals) and northern lance (2 individuals). Searches were conducted for a total of 0.67 person-hours at an average depth of 4 meters.

Site 12. RM 120.7: (Fat Meat Point Cut): This site is located in a cut-off bed (Fat Meat Point Cut) along the Georgia side of the river. Surveys began at the mouth of the cut-off channel and proceeded upstream approximately 300 feet for 0.85 person hours. The approximately 40 foot wide channel consists of muddy banks that slope fairly sharply to a sand/silt channel at a depth of 14 feet. Of the eleven species found, the Carolina slabshell (44 individuals) and the variable spike (10 individuals) were the most abundant. One individual *Alasmidonta* with characteristics resembling the Altamaha arc mussel (*Alasmidonta arcuata*), which is believed to be an Altamaha River Basin endemic was found (see further discussion Sec. 5.0).

Site 13. RM 124.2: This site is located in a run with strong current just below Johnson's Landing. The substrate was sand and pebble, with a large amount of old timber embedded in the channel bottom and banks. Mussels are fairly abundant along the thalweg, but do to the large amount of woody debris and strong current, they were difficult to collect. Mussel habitat is also present along the banks in submerged root mats that have accumulated fine sediments. Of the twelve species found, the Carolina slabshell (42 individuals) and the Roanoke slabshell (28 individuals) were the most abundant. This was the site where the unidentified *Elliptio* (*Elliptio* sp.) was located (See further discussion Sec.5.0). Searches were conducted for a total of 0.92 person-hours at an average depth of 14 feet.

Site 14. RM 124.3: (Johnson's Landing): A brief (0.5 person-hour) survey was conducted along the bank at the boat ramp of Johnson's landing. The bank has been stabilized with rip-rap for approximately 60 feet upstream and downstream of the boat ramp to a depth of 7.5 feet. Seven species were found, with the Carolina slabshell (50 individuals) and the Roanoke slabshell (28 individuals) being the most abundant.

Site 15. RM 68: This site is located on the inside of a fairly narrow bend on the South Carolina Side of the river, near an IP tract of land. The banks slope gradually to a maximum depth of 10 feet. The substrate is dominated by shifting sand in the channel and a sandy mud on the banks. A large amount of woody debris and detritus is also present. Of the nine species found, the eastern elliptio (40 individuals) and the Carolina slabshell (30 individuals) were the most abundant. Searches were conducted for a total of 1.0 person-hour.

Site 16. RM 69.5: This site is located along the Georgia side of the river bordered by an area of nearly vertical exposed marl cliffs. The bank, which consists of marl outcrop and hard-pack clay/bedrock, slopes sharply down to a coarse sand bottom approximately 20 feet deep. Mussels were found in concentrations in the coarse sand at the base of the slope, but were also found scattered in depressions and crevices of the hard-pack clay/marl slope. Seven species were found at this site, with the Carolina slabshell (40 individuals) and the Roanoke slabshell (36 individuals) being the most abundant. Searches were conducted for a total of 0.46 person-hours.

Site 17. RM 70: This site, located on the Georgia side of the river, is very similar to Site 16; however, the slope of the bank is more gradual. Mussels were fairly abundant within the marl dominated slopes, as well as at the base of the slope in coarse sand. Six species were found, with the Carolina slabshell (113 individuals) and the Roanoke slabshell (39 individuals) being the most abundant. Searches were conducted for a total of 0.4 person-hours.

Site 18. RM 64.7: This site occurs in a shallow (2-3 feet), sandy mud flat that extends 30-40 feet from the bank on the South Carolina side of the river towards the center of the channel. There is a fairly dense thicket of black willow (*Salix nigra*) in the adjacent, partially inundated floodplain. Hand grubbing and mask and snorkel were used to survey for 1.25 person hours. Five species were found, with the eastern elliptio (37 individuals) being the most abundant, followed by the eastern creekshell and variable spike (five individuals each), the rayed pink fatmucket (2 individuals) and the pod lance (1 individual).

Site 19. RM 64.1: (Hog Branch): This site is adjacent to a boat ramp at the mouth of Hog Branch and the Savannah River. Three divers searched Hog Branch from the confluence upstream approximately 150 feet. The substrate is dominated by mud and detritus, with large amounts of woody debris. Of the six species found, the eastern elliptio (300 individuals) was the most abundant followed by the rayed pink fatmucket (12 individuals). This site yielded the highest CPUE for the eastern elliptio in the entire study. Searches were conducted for a total of 1.83 person-hours.

Site 20. RM 185.5: This site occurs adjacent to an actively eroding bank on the South Carolina side of the river. The bank slopes sharply to a sand/gravel run approximately 12 feet deep. Only 1 live Carolina slabshell and 1 relict shell of the variable spike were found in 0.75 person-hours of survey time.

Site 21. RM 183: This site occurs at Bradford Point near the mouth of Fritz Cut in a sand and gravel dominated run with a maximum depth of 12 feet. Mussels were generally uncommon, with the Carolina slabshell (35 individuals) being the most abundant,

followed by Altamaha slabshell (5 individuals), variable spike (5 individuals) and eastern elliptio (2 individuals). Searches were conducted for a total of 1.25 person-hours.

Site 22. RM 181.8: This site occurs along a large sand bar and associated backwater slew that extends from the mouth of Bailey's Cut on the Georgia side of the river into the center of the river channel. The substrate consists of shifting sand and gravel and the maximum depth searched was 10 feet. Only seven individuals of Carolina slabshell and one shell of variable spike were located in a total of 1.0 person-hour.

Site 23. RM 178.8: This site occurs in a deep (20 feet) run dominated by sand and gravel at the base of the sharply sloping bank on the South Carolina side of the river. Mussels are generally rare, only yielding two Carolina slabshell, one variable spike, and one Florida pondhorn. Searches were conducted for a total of 0.67 person-hours.

Site 24. RM 173.2: (Lower Silver Bluff Cut): This site occurs within a cut-off bend in the vicinity of Lower Silver Bluff sandbar and run habitat near its mouth. Substrate is dominated by sand and clay. Thirteen species were found, with the Carolina slabshell (22 individuals) and the Florida pondhorn (13 individuals) the most abundant. This is one of only 4 sites where the barrel floater (1 individual) and one of only two sites where the alewife floater (6 individuals) were found. Searches were conducted for a total of 1.25 person-hours at an average depth of 6 feet.

Site 25. RM 173.3: A brief (0.33 person-hour) survey was conducted in the sand/pebble run in the main river channel above the mouth of the Lower Silver Bluff cut off bend (Site 24). No mussels were found in a total of 0.33 person-hours at an average depth 10 feet.

Site 26. RM 169.6: (Cut Off # 22): This site is located in a cut-off bend (Cut # 22) along the South Carolina side of the river near Gray's Landing. Surveys began at the mouth of the cut-off channel and proceeded upstream approximately 300 feet for 1.17 person hours. The relatively shallow (maximum depth 8 feet) slack-water habitat consists of a sandy mud substrate. Low numbers of ten species were found, with the variable spike and eastern floater (5 individuals each) being the most abundant. This is the only site where the Savannah lilliput (1 individual) was located, although it is important to note that typical habitat for this species was not targeted during this study.

Site 27. RM 54.1: (Upper End Dyke, Field 3): This site occurs in the vicinity of a jetty structure jutting into the channel from the Georgia side of a relatively straight and narrow section of the river. The jetty has created a hydraulic break allowing some accumulations of finer sediments, however there is enough flow to maintain a well sorted substrate of sand, mud and pebble. The bank slopes gradually to a depth of 10 feet, and mussels are fairly abundant and distributed evenly throughout. Of the twelve species, the Carolina slabshell (108 individuals) and the eastern elliptio (71 individuals) were the most abundant. This was the only site where the triangle floater (1 individual) and one of three where the brother spike (1 individual) were located. Both were kept for deposit at the NCMNS (See further discussion Sec. 5.0). Searches were conducted for a total of 1.12 person-hours at an average depth of less than 6 feet.

Site 28. RM 52.1: This site consisted of relatively shallow (maximum depth of 8 feet) slack water habitat near the mouth of Strong Creek on the Georgia side of the river.

Substrate was dominated by mud and sand. Of the nine species found, the eastern elliptio (31 individuals) and the variable spike (12 individuals) were the most abundant. The highest recorded CPUE for the barrel floater occurred at this site. Searches were conducted for a total of 1.77 person-hours at an average depth of 5 feet.

Site 29. RM 51.4: (Lagoon at Chair Maker Point): This site occurs in a shallow (2 feet) lagoon within a cutoff bend near Chair Maker Point. The slack-water channel appears to be connected to the mainstem only during high-water events. Substrate is dominated by mud and silt. Six species were found, with the eastern elliptio (6 individuals) being the most abundant. Searches were conducted for a total of 1.67 person-hours. The aquatic snail pointed campeloma (*Campeloma decisum*) was uncommon, with a patchy distribution.

Site 30. RM 51.4: The bank along the South Carolina side of the river was surveyed by mask and snorkel to a depth of 3 feet near the mouth of Chair Maker Point lagoon (Site 29). Substrate is dominated by sand and detritus. Six species were found, with the eastern elliptio (58 individuals) and the variable spike (19 individuals) being the most abundant. Searches were conducted for a total of 1.2 person-hours.

Site 31. RM 48.3: This site occurs adjacent to a relatively steep bluff downstream Berry's Landing. The stream bottom slopes sharply from the bluffs to a depth of 20 feet. Substrate consists of hard pack marl-clay with accumulated sand and pebble in depressions in the clay. Coarse sand extends from the base of the slope towards the center of the channel. Mussels occur in fairly high numbers within the hard clay. Of the eight species found, the Roanoke slabshell (60 individuals) and eastern elliptio (32 individuals) were the most abundant. One individual delicate spike was collected and kept as a voucher and DNA analysis (See further discussion Sec. 5.0). Searches were conducted for a total of 0.45 person-hours.

Site 32. RM 44.8: (Ebenezer Creek): This site occurs at the mouth of Ebenezer Creek on the Georgia side of the river. Two divers searched the sand/pebble dominated run to a depth of 10 feet, and three people surveyed the muddy banks to a depth of 3 feet using mask/snorkel and hand grubbing. The SCUBA crew located nine species, with the eastern elliptio (80 individuals), the Carolina slabshell (73 individuals) and variable spike (25 individuals) being the most abundant. The tactile/snorkel crew located eleven species, with the eastern elliptio (122 individuals) and variable spike (35 individuals) being the most abundant. The Roanoke slabshell (5 individuals) was only found using SCUBA, while the Altamaha slabshell (2 individuals), barrel floater (1 individual), Carolina lance (1 individual) and eastern floater (1 shell), were found by mask/snorkel-hand grubbing. Searches were conducted for a combined total of 1.98 person-hours. The CPUE for each species was compared by survey method (See further discussion Sec. 5.0)

Site 33. RM 27.9: This site occurs in a deep (16 feet) sandy-clay run just upstream of the I-95 crossing on the South Carolina side of the river. Only one yellow lampmussel and 1 shell of Carolina slabshell were found in 0.67 person-hours of survey time.

Site 34. RM 27.6: This site occurs within a slow moving run formed by a jetty/groin just upstream of the I-95 crossing on the Georgia side of the river. Substrate is dominated by sand and clay, with varying levels of silt depending on proximity to groin pilings. Mussels were generally found in clusters where silt deposition was minimal. Seven

species were located, with the eastern elliptio (76 individuals) and the Carolina slabshell (22 individuals) being the most abundant. This highest CPUE recorded during the study for the rayed-pink fatmucket and Atlantic spike occurred here. Searches were conducted for a total of 1.25 person-hours at a maximum depth of 18 feet.

Site 35. RM 22.8: (Front River East Bank): The lower 27 miles of the Savannah River is dominated by a salt-marsh delta with a network of tidal creeks and rivers. Flow from the river is diverted into three major channels (Front River, Middle River and Back River) in this area. The Back River delineates the boundary between Georgia and South Carolina until it converges again with the Front River. This site occurs in the Front River on the eastern bank near the head of Steamboat River, which is a tidal creek connecting the Front River and Middle River, approximately one mile upstream of the GA 25 crossing. The bottom drops sharply from the adjacent marsh to a depth of 20 feet. The substrate is dominated by sand and detritus. No mussels were found; only one shell of the Asian clam was observed in a total of 0.67 person-hours of survey time.

Site 36. RM 22.8: (Front River West Bank): This site occurs on the west bank of the Front River, opposite of Site 35. The bottom slopes sharply from the bank to a depth of 15 feet. The substrate consists of hard pack clay with sand and pebble. A large amount of woody debris is also present. No freshwater mussels were found shells of the Asian clam were found in fairly large numbers, however no living individuals were observed. The dark false mussel (*Mytilopsis leucophaeata*) a brackish water species was found covering most of the woody debris present. In addition, marine crabs and shrimp were also observed. Searches were conducted for a total of 0.4 person-hours.

Site 37. RM 26.2: (McCoy's Cut): This site occurs on the South Carolina side of the river at the head of McCoy's Cut. Divers traversed the entire width of McCoy's Cut, where the depth varied from 2 to 10 feet and the substrate is dominated by sand and gravel. Only one shell of the Carolina slabshell was located in of 0.5 person-hours of survey time. The Asian clam was common.

Site 38. RM 26.3: This site occurs in a deep (20 feet) run in the river approximately 950 feet upstream of the head of McCoy's Cut (Site 37) on the South Carolina side. Substrate is dominated by sand and pebble. Of the four species located, the Roanoke slabshell (22 individuals) was the most abundant followed by the Carolina slabshell (14 individuals), variable spike (2 individuals) and eastern elliptio (1 individual). Searches were conducted for a total of 0.43 person-hours.

Site 39. RM 29.7: (Big Collis Creek): This site occurs at the mouth of Big Collis Creek. Two divers searched the sand/cobble dominated run in the river at a maximum depth of 20 feet, and three people surveyed the muddy banks in Big Collis Creek upstream of the mouth to a depth of 3 feet using mask/snorkel and hand grubbing. The SCUBA crew located seven species, with the Carolina slabshell (92 individuals), Roanoke slabshell and eastern elliptio (21 individuals each) being the most abundant. The tactile/snorkel crew located four species, with the variable spike (15 individuals) and eastern elliptio (14 individuals) being the most abundant. The Roanoke slabshell, pod lance (1 individual), and Atlantic spike (1 individual) were found only using SCUBA. Searches were conducted for a combined total of 1.32 person-hours. The CPUE for each species was compared by survey method (See further discussion Sec. 5.0)

5.0 DISCUSSION

These surveys provide new and updated information for the lower portions of Savannah River. The majority provide new location information for the species found due to the fact many of the sites, particularly deep water habitats, had not been previously evaluated for Unionid fauna. Significant extensions of known ranges for species such as the alewife floater, Altamaha fatmucket, Altamaha slabshell and arc mussel, as well as potential confirmation of historically known species such as Atlantic pigtoe, tidewater mucket, and brother spike were documented with the survey efforts.

5.1 The Mussel Fauna of the Savannah River

Twenty four species of freshwater mussels are reported to occur in the Savannah River Basin in South Carolina (Bogan and Alderman 2004). This study confirms the high species diversity (for Atlantic Slope drainages) of this river basin, as at least 23 species were recorded. Five of the species identified, the alewife floater, northern lance, Altamaha slabshell, Altamaha fatmucket and arc mussel are not reported by Bogan and Alderman (2004), which would bring the total number of species in the basin to 29. It is very possible that the *E. complanata* and *E. icterina* complexes are represented by several species, which would further raise the number of species known from the basin.

5.1.1 Mussel species found during the surveys

Depending on the results of the genetic analysis, potentially 25 species of freshwater mussels were found during these survey efforts. Brief descriptions of each of these species are provided below. The original species descriptions along with Bogan and Alderman (2004) and Johnson (1970) should be consulted for more detailed descriptions. Representative photographs of these species are provided on the accompanying data CD.

Alasmidonta arcula (Altamaha arc mussel) - This species was described from the Altamaha River in Liberty (now Long) County, Georgia (Lea, 1836). Its range is reported to be restricted to the Altamaha River system, Georgia (Johnson 1970). The shell shape is triangular and very inflated. The anterior end is rounded and the ventral shell margin is straight or slightly rounded. The umbos are centrally located, very full and elevated above the hinge line. The periostracum is yellowish green with broad green or black rays. Habitat is reported as sandy mud below sandbars in sluggish water and eddies (Johnson 1970). This species is considered threatened (Williams et al., 1993). This species differs from the triangle floater (*Alasmidonta undulata*), which was collected at Site 27 RM 54.1 (Upper End Dyke, Field 3), by having more centrally located and fuller umbos, a much sharper posterior slope, and being less elongate.

Although this species is believed to be endemic to the Altamaha River Basin, a specimen of *Alasmidonta* was collected at Site 12. RM 120.7 (Fat Meat Point Cut) that conchologically has characteristics of this species as opposed to the triangle floater that is known to occur in the Savannah River Basin. Because of these distinctive characteristics, this specimen was tentatively identified as Altamaha arc mussel and preserved in 95% ethanol for DNA analysis and deposited in the NCSM. Another specimen tentatively identified as such was collected during the complementary survey effort coordinated by the USFWS in July 2006 and preserved and deposited in the same manner. These DNA sequences of the specimens will then be compared with that of topotypic material from

the Altamaha River, as well as the specimen from the Savannah River identified as triangle floater (see below and further discussion, Sec. 5.3).

Alasmidonta undulata (triangle floater) - This species was described from the Schuylkill River near Philadelphia (Say, 1817). Its range extends from the Savannah River in South Carolina/Georgia north to the lower St. Lawrence River. The shell shape is subtriangular to ovate and inflated. The anterior and ventral shell margins are rounded. The periostracum is dull yellowish green with distinct green rays of varying width and length. This species is considered special concern throughout its range (Williams et al., 1993), and is proposed as endangered in South Carolina (Bogan and Alderman 2004).

This species can occur in a variety of habitats in small streams to large rivers, usually in quiet waters with some current in a variety of substrates. Only one live individual was found at Site 27 RM 54.1 (Upper End Dyke, Field 3) along the muddy bank in approximately 7 feet of water. This individual was preserved in 95% ethanol and deposited in the NCSM to allow genetic comparison to the specimens identified as Altamaha arc mussel.

Anodonta couperiana (barrel floater) - This species was described from the Altamaha River Basin near Darien in McIntosh County, Georgia (Say 1829). Its distribution ranges from the Cape Fear River Basin south to Florida's Apalachicola region. The shell is oblong to ovate with a broadly rounded ventral margin. The umbos of barrel floater do not extend above the dorsal margin. Like other *Anodonta*, the species lacks pseudocardinal and lateral teeth. The species has been recorded to lengths over 100mm. The shell surface is usually smooth and shiny with yellowish, green-brown periostracum and fine green rays in younger individuals becoming darker with age. This species is considered special concern (Williams et al. 1993).

This species was found in fairly low numbers at four sites in shallow, slack water habitats with fine substrates. The low number of occurrences (sites and individuals) is partially attributable to the deep water habitats focus of this study (see further discussion Sec. 5.2).

Anodonta implicata (alewife floater) - This species was described from a pond in Danvers, Massachusetts (Say 1829). Its reported distribution ranges from rivers in New Brunswick, Canada south to the Pee Dee River Basin in South Carolina (Bogan and Alderman 2004). The shell is elliptical, oblong to ovate in outline and rather thick, with a pronounced thickening of the anterior ventral margin. The species has been recorded to lengths of 142 mm. The shell surface is usually smooth and shiny but may be rough with yellowish, green-brown periostracum in younger individuals becoming dark brown to black with age. Habitats include ponds, over-bank pools, streams and rivers with a variety of substrates, including silt, sand and gravel. Its distribution is tied closely to the distribution of its host fish, which is reported (Davenport and Warmuth 1965) to be the anadromous alewife (*Alosa pseudoharengus*). This species is considered currently stable throughout its range (Williams et al. 1993), but is proposed as threatened in South Carolina (Bogan and Alderman 2004).

While this species was found in low numbers at only two study sites (Sites 24 & 26), this represents an expansion of its known range into the Savannah River Basin. While the species is reported from ponds and other slack-water habitats throughout its range, populations in the southern portion of its range, (Roanoke River, Cape Fear River, Pee

Dee River) typically occupy deep water run habitats (personal observations). Since these habitat types were surveyed extensively during this study, the low number of sites where encountered and low number of individuals may be indicative of its rarity in the river.

Elliptio angustata (Carolina lance) - This species was described from the Cooper River, South Carolina (Lea 1831). The shell is more than twice as long as high coming to a posterior point, below the midline between the dorsal and ventral margins. The dorsal margin is straight and essentially parallel to the ventral margin. Umbos are slightly elevated with beak sculpture consisting of strong ridges. (Johnson 1970) synonymized this species and over 20 other named species of lance-shaped elliptio mussels into *Elliptio lanceolata*. Recent genotypic and phenotypic analysis suggests that some of these formally described species are valid, including “true” *Elliptio lanceolata* (type locality-Tar River). The Carolina lance ranges from the Ogeechee, Georgia north to the Potomac River in Maryland and Virginia. Williams et al. (1993) list this species as special concern.

This species was found at seven sites within the study area, usually in deep run habitats with some coarse substrate. It was most commonly associated with the Carolina slabshell. This species is very similar in appearance to the pod lance (*E. folliculata*) differing only by being more inflated, and broader. It is unclear whether these are two separate species, or one species with marked clinal variation within its range.

Elliptio complanata (eastern elliptio) - This species was described as *Mya complanata* from the Potomac River in Maryland (Lightfoot 1786). Shell characteristics are highly variable. Shell shape is typically trapezoidal to rhomboid, and compressed to inflated. The usually straight ventral margin is mostly parallel with the dorsal margin and the posterior margin is broadly rounded. Shell thickness varies from thin to solid. Johnson (1970) synonymized the following species described from the Savannah River Basin with *E. complanata*: *E. complanatus subinflatus* (Conrad 1835), *E. abbevilensis* (Lea 1857), *E. savannahensis* (Lea 1857), *E. latus* (Lea 1860), *E. quadrilaterus* (Lea 1863), *E. differtus* (Lea 1872) and *E. cirratus* (Lea 1874). This species is widely distributed along the Atlantic Slope from Altamaha River Basin in Georgia north to the St. Lawrence River Basin, and west to Lake Superior and parts of the Hudson Bay Basin. It can be found in a variety of habitats from large rivers and, lakes to small headwater streams. The species is widespread and common throughout its range and considered “Stable” (Williams, Warren et al. 1993).

Occurring at 27 of the 39 surveyed sites, this species was one of the most common and abundant. Several forms occurred throughout the study area, often within a particular site. This species generally occupied multiple habitat types within a particular site. However, due to time constraints and not being the focus of this study, efforts to correlate different forms with different habitat types were not attempted. It is unclear whether the variations in shell morphology within the study area, as well as within particular sites, represent ecophenotypic or genotypic variability. The large amount of variability in shell morphology observed in the study area suggests that the Savannah River would be a good location to study this (see Sec. 6.0).

Elliptio congraera (Carolina slabshell) - This species was described from the Congaree River, South Carolina by (Lea 1831). Five species (*E. sordidis*, *E. gibbesianus*, *E.*

rufusculus, *E. forbesianus*, and *E. buxeus*) described from the Savannah River Basin (Lea 1852) were synonymized with *E. congaraea* (Johnson 1970). The range of this species extends from the Ogeechee River, Georgia north to the Chowan River, North Carolina. The shell is rhomboid and subcompressed with moderately full beaks. The front of the shell is wedge-shaped, with the posterior end obliquely truncate above and biangulate below. The posterior slope usually has numerous cross corrugations or wrinkles. The periostracum is greenish-yellow or tawny. (Williams et al. 1993) lists this species as Special Concern.

This species was found at 33 sites, usually occurring in deep run habitats dominated by coarse sand/pea gravel and fairly swift flow. It had the highest single CPUE from a particular site, with 282.50 per person-hour at site 17. It was most commonly associated with the Carolina lance.

Elliptio fisherianus (northern lance) - This species was described from the Chester River in Maryland (Lea 1838). The shell is more than twice as long as high coming to a posterior point, usually at or above the midline between the dorsal and ventral margins. The dorsal ridge is angled. The smooth periostracum of the northern lance is usually yellowish-green with darker green rays, becoming black with age. Johnson (1970) synonymized this species and 25 other named species of lance-shaped elliptio mussels into *Elliptio lanceolata*. Recent genotypic and phenotypic analysis suggests that some of these formally described species are valid, including “true” *Elliptio lanceolata* (type locality, Tar River). Northern populations are thinner and more elongate than those from the south. The nacre may be purple or white. The northern lance likely encompasses several lanceolate elliptios, with similar characteristics that were described from a number of river basins along the Atlantic Slope. Included in this is *Elliptio sagittiformis* from the Oconee River of the Altamaha River Basin. The name *E. fisherianus* is used for these forms as it is the oldest one, however if DNA analysis of these specimens from the Savannah River are distinct from topotypic material from the Chester River, another name, such as *E. sagittiformis*, may be warranted. Because of taxonomic uncertainty, the status of this species is undetermined.

The northern lance was found at five sites in shallow, slack water habitats with softer substrates. All of the other lanceolate elliptio species (*E. angustata*, *E. folliculata* and *E. producta*) identified during this study were found primarily in deep run habitats with coarse sand and gravel substrates.

Elliptio folliculata (pod spike) - This species was described from the Savannah River, Georgia by Lea (1838). The reported range of this species extends from the Ogeechee River, Georgia north to the Cape Fear River basin, North Carolina (Bogan and Alderman 2004). The shell is narrow and uninflated, resembling a straight-edged razor. The dorsal and ventral shell margins are parallel and the anterior-dorsal margin is angular. The umbos are flat and scarcely prominent. The periostracum is dark-brown to black and nacre color varies from bluish to pink. Williams et al. (1993) list this species as Special Concern.

This species, which was one of the ones targeted for this study, was observed at 10 sites and was typically found in sandy run habitats. This species closely resembles the Carolina lance (see description above of *E. angustata*). Several individuals were collected

for genetics analysis to develop the suite of microsatellite DNA markers for this species and allow for comparisons to other lanceolate elliptios along the Atlantic Slope.

Elliptio fraterna (brother spike) - This species was described from the Abbeville District in streams of the Savannah River basin by Lea (1852). It is believed to be restricted in range to the Savannah River basin. The shell shape is elongate, rather thin and subrhomboid, with a blunt posterior end and a mostly straight ventral margin. The posterior slope is slightly concave and covered with corrugations or ridges that extend from near the beaks to the often double posterior margin. Periostracum is smooth and often shiny reddish brown to yellowish brown, often covered with fine green rays that become obscured with age. Nacre color is variable, reported as white, pink, salmon, and purple. Shells of this species resemble *E. congaraea*, but the brother spike is consistently much thinner and more compressed (Johnson 1970). Williams et al. (1993) list this species as Endangered. According to NatureServe (Nature Serve 2007), the brother spike was last reported from the Savannah River drainage in 1972 (Britton and Fuller, 1979), and at that time was the only record from that drainage since its original description in 1852 (Britton and Fuller, 1979). This lack of collection during recent efforts has led to speculation of extirpation.

The brother spike was located in very low numbers (one per site) at three locations. These specimens were collected for genetics analysis to develop the suite of microsatellite DNA markers for this species and allow for comparisons to other elliptio species.

Elliptio hopetonensis (Altamaha slabshell) - This species was described from the Altamaha River near Darien, GA by Lea (1838). Its range is reported to be restricted to the Altamaha River system, Georgia (Johnson 1970). Shell shape is typically rhomboidal, with a significant posterior wing. The ventral margin is mostly straight and the posterior ridge is swollen and the dorsal ridge inflated. The periostracum is usually dark reddish brown to greenish brown with fine green rays. This species is one of the largest elliptios, reaching lengths in excess of 125 mm. Williams et al. (1993) lists this species as special concern.

Although this species is believed to be endemic to the Altamaha River Basin, an elliptio species that conologically exhibits characteristics of the Altamaha slabshell as opposed to any other elliptio species known from the Savannah River Basin was found in relatively large numbers at 15 sites. Because of these distinctive characteristics, these specimens were tentatively identified as Altamaha slabshell, and several were preserved in 95% ethanol for DNA analysis and deposited in the NCSM. This species was also identified as occurring in the Savannah River during a collection effort coordinated by the USFWS in July 2007. The DNA sequences of the specimens will then be compared with that of topotypic material from the Altamaha River, as well as other elliptio species (see further discussion, Sec. 5.3).

Elliptio icterina (variable spike) - Described from the Savannah River near Augusta Georgia (Conrad 1834), this highly variable species represents a complex of nearly 50 species (Johnson 1970). The shell shape is oblong, subelliptical, or subrhomboid, with a prominent posterior ridge, and moderately elevated beaks. The periostracum is usually

smooth and greenish yellow to tawny-brown. This species is considered common and currently stable throughout its range (Williams et al. 1993).

Variable spike was the most common mussel species located during the survey efforts, being found at 34 of the 39 sites. Several forms of this species occurred throughout the study area, and often within a particular site. This species generally occupied multiple habitat types within a particular site. However, due to time constraints, and not being the focus of this study, efforts to correlate different forms with different habitat types were not attempted. It is unclear whether the variations in shell morphology within the study area, as well as within particular sites, represent ecophenotypic or genotypic variability. The large amount of variability in shell morphology throughout the study area suggests that the Savannah River would be a good location to study this, especially since the variable spike was described from the Savannah River (see Sec. 6.0). Several individuals were collected for genetics analysis to develop the suite of microsatellite DNA markers for this species and allow for comparisons to other elliptio species.

Elliptio lazarus (= *arctata*) (delicate spike) - This species was described from the Savannah River by Lea (1852) and was later synonymized by Johnson (1970) under *Elliptio arctata*, a species described by Conrad (1834) from the Alabama River of the Mobile River Basin. Johnson lists the range the delicate spike as west to the Alabama-Coosa River system, the Apalachicola/Chattahoochee/Flint River Basin, and along the Atlantic slope from the Savannah River Basin north to the Cape Fear River Basin. The shell is generally small, elongated, subelliptical, with a distinctly arcuate ventral margin. Valves are compressed and subsolid with a prominent mid-dorsal hinge ligament. Periostracum is usually greenish to yellowish with green rays, becoming dark brown in older individuals. Williams et al. (1993) list this species as special concern.

It is unlikely that *E. arctata* from the Mobile River Basin is the same species as the specimens from the Savannah River described as *E. lazarus*. For these reasons, the name used for this report is *E. lazarus*. Further genetic analysis is expected to support these species as being genetically distinct. This species was located at three survey sites, generally found in run habitats in association with hard substrate under rocks. Several individuals were collected for genetics analysis to develop the suite of microsatellite DNA markers for *E. lazarus* and allow for comparisons to topotypic material of *E. arctata* and other elliptio species.

Elliptio producta (Atlantic spike) - This species was described from the Savannah River, Georgia by Conrad (1836). The range of this species extends from the Savannah River, Georgia north to the Potomac River Basin in Maryland and Virginia. The Atlantic spike was once synonymized with *Elliptio lanceolata* (Johnston 1970), but is now considered a separate species. The anterior shell margin is rounded and the posterior margin roundly pointed with the most posterior point slightly above the midline of the shell. The periostracum is often shiny, dark reddish brown to greenish brown, generally with out rays. Shell nacre is variable shades of purple. Williams et al. (1993) list this species as Special Concern.

The Atlantic spike was found at 15 sites during the study and several specimens were kept for genetics analysis. It was generally found in low numbers in a variety of habitats. Specimens were collected for genetics analysis to develop the suite of microsatellite

DNA markers for this species and allow for comparisons to other lanceolate elliptio species.

Elliptio roanokensis (Roanoke slabshell) - The Roanoke slabshell was described from the Roanoke River (exact location unknown) by (Lea 1838). The reported range extends from the Connecticut River in Massachusetts south to the Savannah River in Georgia (Walter 1954)). Based on shell morphologies, Johnson (1970) synonymized this and 100 other species into the *Elliptio complanata* complex, however it is now widely recognized as being a valid species. The periostracum is generally very smooth, often with placations (furrows) and reddish yellow in color. Shells of this species reach lengths exceeding 150 mm. Williams et al. (1993) list this species as Special Concern.

It was found at 19 sites, usually in deep run habitats dominated by coarse sand/ gravel, and fairly swift flow. It was most commonly associated with the Carolina lance and Carolina slabshell.

Elliptio sp. (elliptio mussel) - This name applies to an individual elliptio mussel collected at Site 13. It is likely an unusual form of the *E. icterina* complex that did not resemble any of the described types.

Fusconaia masoni (Atlantic pigtoe) - The Atlantic pigtoe was described by Conrad (1834) from the Savannah River in Augusta, Georgia. Its range extends from the Ogeechee River Basin in Georgia north to the James River Basin in Virginia (Johnson 1970). The Atlantic pigtoe occurs in medium size streams to large rivers, but has experienced major declines throughout its entire range. The preferred habitat is a substrate composed of gravel and coarse sand, usually at the base of riffles, however, it can be found in a variety of other substrates and habitat conditions (personal observations). Shells of the Atlantic pigtoe are subrhomboidal in outline, with a parchment, or cloth-like yellow to dark brown periostracum. The posterior ridge is very distinct, and the umbos extend well above the dorsal margin. The dorsal margin is also marked by a short, thick hinge ligament. The Atlantic pigtoe has not been collected in South Carolina for more than 100 years (Bogan and Alderman 2004). Williams et al. (1993) list this species as endangered.

The Augusta Shoals area represents the best potential location for this species to occur in the entire study area. The four mussels collected at two sites (Site 2 and 3), with the exception of smooth as opposed to cloth-like periostracum, have concological characteristics like the Atlantic pigtoe. However, the Carolina slabshell, which is common in this area of the river, exhibits a wide range of shell morphology and often has shell attributes similar to the Atlantic pigtoe. Three of these specimens were kept for genetic analysis. Examination of the internal anatomy revealed dendritic (branched) papillae, a characteristic typical of the genus *Fusconaia*, and rarely seen in the genus *elliptio* (except *E. roanokensis*). Based on the combination of these characteristics, these specimens were tentatively identified as Atlantic pigtoe. The genetic sequences of these specimens will need to be compared with other material considered to be Atlantic pigtoe as well as to other species of *Fusconaia* and *Elliptio*.

Lampsilis cariosa (yellow lampmussel) - This species was described from the Schuylkill River near Philadelphia (Say 1817). Johnson (1970) synonymized *L. crocatus* (Lea 1841) described from the Savannah River with *L. cariosa*. The yellow lampmussel

extends from the Ogeechee River in Georgia north to Nova Scotia. The waxy-yellow shell is obovate in outline, with a rounded anterior margin and slightly curved posterior margin, and is rarely rayed. Like other members of this genus, this species is sexually dimorphic, with the shells of the male being more elongate, and the females more rounded, particularly in the posterior margin. This species is a Federal Species of Concern and is proposed as State Endangered in South Carolina (Bogan and Alderman 2004). Williams et al. (1993) list this species as Endangered.

This species was found at 12 sites, in fairly low numbers in mostly sandy substrate. The species was found in a variety of depths, from relatively shallow sand slopes to deeper sand and gravel runs.

Lampsilis splendida (rayed pink fatmucket) - This species was described from the Altamaha River, Georgia by Lea (1838). The species replaces the closely related eastern lampmussel (*Lampsilis radiata*) in the Atlantic slope region below the Pee Dee River system (Johnson 1970). The rayed pink fatmucket occurs from the Altamaha River north to the Cape Fear River basin while the eastern lampmussel extends from the Pee Dee River basin north the St. Lawrence River basin. The rayed pink fatmucket has an oval elongate shell shape and it is generally greatly inflated. As with other members of the genus, the species is sexually dimorphic: in the male, the posterior end is bluntly pointed, and in the female, it is more broadly rounded. The outer surface of the shell can be smooth to more commonly roughened by close concentric wrinkles. Perisotracum color ranges from yellowish-green to reddish-brown often with variable dark rays. Nacre color ranges from bluish white to light purple, but is most often a deep pink. (Williams et al. 1993) list this species as Special Concern.

Though it was found in shallow habitats at 17 sites, it may have been under-detected at some sites, as most of the survey efforts focused on deep water habitats. At Sites 32 and 39, where survey methodologies were compared (shallow/tactile vs. SCUBA), the CPUE of shallow vs. SCUBA for the rayed pink fatmucket was 7.05/hr vs. 0.88/hr and 10.34/hr vs. 1.37/hr, respectively (see further discussion Sec. 5.2.2).

Leptodea ochracea (Tidewater mucket) - The tidewater mucket was described from the Schuylkill River near Philadelphia (Say 1817). Johnson (1970) synonymized *L. rosaceus* Conrad (1849) described from the Savannah River with *L. ochracea*. The range of the tidewater mucket extends from Cape Breton, Nova Scotia Canada, south to the Savannah River, Georgia. The dull yellow to greenish shell is ovate to elliptical in outline, with evenly rounded anterior, ventral and posterior margins. Like members of the genus *Lampsilis*, this species is sexually dimorphic, with the shells of the male being more elongate, and the females more rounded, particularly in the posterior margin. The shells usually have fine greenish to grey rays across most of the shell. This species is reported to be fairly small in size (75 mm), however individuals collected by TCG in the Roanoke River, Virginia were measured up to 102 mm in length. Williams et al. (1993) list this species as Special Concern.

Only one individual was found during the study at Site 6. Another individual was collected during the complementary survey effort coordinated by the USFWS in July 2006. In parts of its range, this species can be locally common (personal observations). Its rarity in this study may be partially explained by the fact that typical habitat for this

species (slack-water habitats with muddy bottoms) were not extensively surveyed. However, the species was not recorded during the long term monitoring of freshwater mussel populations in the vicinity of the Savannah River Site (Bouchard et al. 2001) and there are very few historic and no recent records from the basin besides the two specimens collected for this project, suggesting its rarity in the system.

Pyganadon cataracta (eastern floater) - Described by Say (1817) in the deep part of a milldam presumably near Philadelphia, this species is wide ranging in the Atlantic drainages from the lower St. Lawrence River Basin south to the Altamaha River Basin, Georgia, and in the Alabama-Coosa River drainage, and the Apalachicola and Coctawhatchee River Basins, Florida. The shells of this species are uniformly thin, and lack hinge teeth. The shell shape is ovate, subelliptical and elongate, with an evenly rounded anterior margin and a broadly rounded ventral margin. The periostracum is light to dark green with broad green rays on the posterior slope. Ortman (1919) recognized three generalized shell forms, the pond form, the creek/small river form and the big river form, that were related to environmental conditions. The pond form occurs in small ponds with muddy substrates, and is characterized by very thin elongate inflated shells. The creek form occurs in riffle-pool habitats in gravel substrates, and is much thicker and more compressed. The big river form is generally short and inflated and occurs in soft substrates. This species is considered common and currently stable throughout its range (Williams et al. 1993).

This species was found at six sites in low numbers, which is likely attributable to its preferred slackwater habitats being minimally sampled. However, it was reported to be relatively uncommon during the long term (50 years) monitoring of freshwater mussel populations in the vicinity of the Savannah River Site (Bouchard et al. 2001).

Toxolasma pullus (Savannah lilliput) - Described by Conrad in 1838 from the Wateree River in South Carolina, this species ranges from the Altamaha River basin in Georgia north to the Neuse River basin in North Carolina. The Savannah lilliput is a small mussel (35 mm is a large specimen) with an oval or elliptical shell. Shells are usually inflated with a broadly rounded to angular double posterior ridge. Shells are sexually dimorphic. Periostracum is coarse due to numerous closely spaced growth lines and is brownish to greenish with fine rays that are usually not visible. Nacre is blueish white with a pink to purplish iridescence towards the posterior. Williams et al. (1993) list this species as threatened and it is listed as a Federal Species of Concern.

This species was only found at Site 26. The low number of occurrences is attributed to limited survey efforts in cut-off bend habitats in the upper and central sections of the study area (Figure 2b and 2c), as it was found at several sites in this section of river in large numbers during the complementary survey effort coordinated by the USFWS in July 2006. Additionally, during the long term (50 years) monitoring of freshwater mussel populations in the vicinity of the Savannah River Site, Bouchard et al. (2001) reported that the Savannah liliput was one of the most commonly encountered species in the 1990s, where it had not been detected prior to 1962. Changes in abundances of this and other species at the Savannah River Site were attributed in part to changes in habitat, channel modifications and river discharge patterns over that monitoring period.

Unio carolinianus (Florida pondhorn) - Described by (Bosc 1801-1804) from “the Carolinas,” this species ranges from Ocmulgee River in Georgia north to the Chowan River in Virginia. Johnson (1970) synonymized the *U. ineptus* Lea (1852) described from the Savannah River Basin with *U. carolinianus*. Shells are usually inflated rhomboid, to long rhomboid and reach lengths to 114 mm. The species generally exhibits a dark brown to black periostracum with a slightly roughened, satiny sheen. Teeth of the left valve contain two subequal pseudocardinals, often with a vestigial tooth above them, and one lateral tooth. This species is considered common and currently stable throughout its range (Williams et al. 1993).

Found at 11 sites, the Florida pondhorn was generally in shallow habitat in soft sediments, in fairly low numbers. The low numbers is likely partially attributable to study design, as the majority of survey time with this study was focused on deeper habitats. However, Bouchard et al. (2001) report that it was consistently uncommon during the 50 year monitoring at the Savannah River Site.

Utterbackia imbecillis (paper pondshell) - Described from the Wabash River in Indiana (Say 1829), this mussel occurs throughout the Mississippi River and Great Lakes drainages, as well as sporadically along the Atlantic slope. It has an extremely thin shell that is oblong and inflated. The dorsal and ventral margins are nearly straight and parallel. The periostracum is greenish yellow with fine green rays. This species is considered common throughout its range (Williams et al. 1993).

This species was found at sites 24 and 29 in low numbers (1 and 2 individuals respectively). This species typically occurs in lentic habitats, or ponded sections of lotic habitats, which were generally not targeted by this study.

Villosa delumbis (eastern creekshell) - This species, described by Conrad (1834) from small streams near the Cooper River South Carolina, ranges from Ocmulgee River, Georgia north to the Cape Fear River in North Carolina. Johnson (1970) synonymized *V. concavus* Lea (1852) described from the Savannah River Basin with *V. delumbis*. The eastern creekshell has a generally thin shell that is ovate in outline. Like other members of this genus, this species is sexually dimorphic, with the shells of the male being more elongate, and the females more rounded and swollen, particularly in the posterior margin. The periostracum is yellow with numerous green rays that are broken along the prominent growth lines. Williams et al. (1993) consider this species to be stable; however, Bogan and Alderman (2004) propose it a conservation status of special concern in South Carolina.

The eastern creekshell was found at 18 of the 39 sites in a variety of substrates; however, with the exception of Site 7, it was found predominately in shallow water. The two individuals found at Site 7 occurred in a 20 feet deep run. This species may have been under-detected at some of the sites, as most of the survey efforts focused on deep water habitats.

5.1.2 Mussel Species reported from the Savannah River Basin not found

Five species reported (Bogan and Alderman 2004) from the Savannah River Basin, the brook floater (*Alasmidonta varicosa*), the Carolina heelsplitter (*Lasmigona decorata*), eastern pondmussel (*Ligumia nasuta*), creeper (*Strophitus undulatus*), and southern

rainbow (*Villosa modioliformis*) were not found during this study. Each of these is discussed below:

Alasmidonta varicosa (brook floater) - Described by Lamarck (1819) from the Schuylkill River in Philadelphia County, Pennsylvania, this species ranges from the lower St. Lawrence River basin south to the Savannah River Basin. While still common in some areas, the species has experienced significant declines throughout its range. Shells of the brook floater are long rhomboid in outline, with a yellowish to greenish smooth perisotracum. Shell surfaces are partly to completely covered with dark greenish rays, becoming obscured with age. The posterior slope of the shell is flattened and slightly concave with numerous, low corrugations or varicose ridges. Williams et al. (1993) list this species as endangered.

This species occurs in a few scattered river and stream reaches in the piedmont and mountain regions of the basin, including the Chattooga River, a major tributary to the Tugaloo River in the upper part of the basin in Oconee County, South Carolina, and Rabun County, Georgia, and the Stevens Creek subbasin in Edgefield and McCormick counties, South Carolina. The population in the Chattooga River may be the strongest throughout its range (John Alderman, personal communication). Elsewhere, it is fairly rare. The Augusta Shoals area represents the best potential location for this species to occur within the study area. Although it was not found during this survey effort, it is likely present in low numbers, as a shell of this species was found in a survey of the Augusta Shoals area in 2001 (Entrix 2002),

Lasmigona decorata (Carolina heelsplitter) - The Carolina heelsplitter, originally described from the Savannah River Basin as *Unio decoratus* by (Lea 1852), synonymized with *Lasmigona subviridis* Conrad, (Johnson 1970), and later separated as a distinct species (Clarke 1985), is a federally Endangered freshwater mussel, historically known from several locations within the Catawba and Pee Dee River systems in North Carolina and the Catawba, Pee Dee, and Savannah River systems in South Carolina. The Carolina heelsplitter is characterized as having an ovate, trapezoid-shaped, unsculptured shell. The outer surface of the shell ranges from greenish brown to dark brown in color, with younger specimens often having faint greenish brown or black rays. The shell's nacre is often pearly white to bluish white, grading to orange in the area of the umbo (Keferl 1991). The hinge teeth are well developed and heavy and the beak sculpture is double looped (Keferl and Shelly 1988). Morphologically, the shell of the Carolina heelsplitter is very similar to the shell of the green floater (Clarke 1985), with the exception of a much larger size and thickness in *L. decorata* (Keferl and Shelly 1988). (Williams et al. 1993) and the South Carolina Wildlife Initiative Plan (2005) list this species as Endangered.

All of the currently extant populations occur in stream reaches within the Piedmont Physiographic Province, particularly within two northeast trending lithostratigraphic belts of the Carolina Terrace, the Carolina Slate Belt and the Charlotte Belt. Extant populations of this species in the Savannah River Basin occur in Little Stevens Creek/Mountain Creek/Sleepy Creek /Turkey Creek (Stevens Creek Subbasin) in Edgefield/McCormick counties, South Carolina and Cuffytown Creek (Stevens Creek Subbasin) in Greenwood/McCormick counties, South Carolina. Although it has never

been found in around Augusta Shoals, this area represents the best potential location for this species to occur within the study area.

Ligumia nasuta (eastern pondmussel) - This species was described from the Schuylkill River near Philadelphia (Say 1817). Bogan and Alderman (2004) report its range to extend from the Savannah River Basin in Georgia north to the St. Lawrence River Basin, Canada and westward through the Mohawk River and Erie Canal to Lake Erie in Pennsylvania, Ohio and Michigan. The elongate subelliptical shell reaches a length of 102 mm. The anterior margin is rounded, and the ventral margin is broadly curved. The posterior margin is rounded and slopes to a blunt posterior point near the midline of the shell. Like members of the genus *Lampsilis*, this species also is sexually dimorphic with the shells of the male being more elongate, and the females more rounded, particularly in the posterior margin. The periostracum is dark olive with dark narrow green rays. Williams et al. (1993) list this species as special concern.

Although habitats suitable for this species were surveyed during this study, it was not found. The species is present in fairly large numbers north of the Savannah River in portions of the Santee and Pee Dee River Basins in South Carolina; however, its presence in the Savannah River Basin is represented by one individual specimen from McBean Creek in Richmond/Burke County Georgia (John Alderman, personal communication). Based on this, it is likely that the eastern pondmussel is extremely rare in the study area if present at all.

Strophitus undulatus (creeper) - This species was described from the Schuylkill River near Philadelphia (Say, 1817). Its range extends throughout much of the Interior River Basin and Atlantic Slope regions. The shell is elliptical to rhomboid in outline and somewhat inflated. The anterior end is rounded, and the posterior end is bluntly pointed. The periostracum is yellowish green to brown, with dark green rays. This species occupies a variety of habitats, from high-gradient small streams, to larger rivers. (Williams et al. 1993) and the South Carolina's Comprehensive Wildlife Conservation Strategy (2005) list this species as special concern.

The Augusta Shoals area represents the best potential location for this species to occur within the study area, as populations in the Atlantic Slope drainages occur primarily in the Piedmont Physiographic Province (personal observations). Bouchard et al. (2001) reported that the creeper was uncommon near the Savannah River Site in the past and has not been found in recent years during the 50 year monitoring study.

Villosa modioliformis (*V. vibex*) (Atlantic southern rainbow) - This species, described by Conrad (1834) from "Santee canal" in South Carolina as *Unio modioliformis*, was synonymized with *Villosa vibex* by Johnston (1970). The holotype for *V. vibex* was described from the Black Warrior River, of the Mobile River Basin in the Gulf of Mexico drainage, thus it is unlikely that *V. vibex* from the Gulf of Mexico drainages is the same species as the specimens from South Carolina described as *V. modioliformis*. For these reasons, the name used for this species along the Atlantic slope is *V. modioliformis*. Further genetic analysis is expected to support these species as being genetically distinct. This species has a thin to subsolid shell that is elliptical to elongate obovate in outline. Like all *Villosa*, this species is sexually dimorphic. Periostracum is greenish yellow to olive brown, the surface covered with broad, unbroken to slightly wavy dark green rays

usually over the entire shell surface. Nacre color is bluish white, often becoming iridescent posteriorly. Williams et al. (1993) consider this species to be stable, and it is not currently ranked in South Carolina (SCDNR 2005).

On the Atlantic slope, this species is more often found in smaller water bodies than larger rivers such as the Savannah. It is known from several small stream reaches in the Stevens Creek subbasin in the Abbeville District of South Carolina. Its absence from this study is likely attributable to these factors; however, limited sampling effort in shallow water habitats may also be a contributing factor.

5.2 Factors affecting apparent abundance and diversity

In general, diverse and viable mussel populations occur throughout the Savannah River from Augusta to the Savannah River estuary around RM 26.3. Channel stability, and level of sorting of substrate appeared to be the most important factors determining abundance of mussels in all of the sites surveyed, with habitat complexity determining species richness. However, apparent mussel abundances (based on CPUE) for some species were influenced to a degree by survey methodologies.

5.2.1 Habitat stability and complexity

Although not quantified, bank and substrate stability appear to be major factors influencing mussel abundances. In general, the banks along the main-stem of the river in the northern section of the study area are highly eroded, from Site 4 at RM 193.2 down to Site 26 at RM 169.6 (Figure 2b), and mussel diversity and relative abundances (based on CPUE) were relatively low throughout this section (Site 20, 21, 22, 23, 25) when compared to main-stem sites in other sections of the study area (Appendix A). Only four species were found at Site 21, followed by three at Site 23, two at Sites 20 and 22 and none at Site 25. Conversely, the two cut off bend sites (Site 24, 26) in this section of the river had much higher species diversity (13 and 11 species, respectively).

Substrate stability is of equal importance in affecting mussel abundances as bank stability. Much of the habitat in the center of the channel of the Savannah is of poor quality for freshwater mussels due to unstable, shifting sediment. The sites where surveys were focused exclusively in these shifting sand habitats (Sites 5, 10, 33), produced only 1 live mussel each (Appendix A). Suitable mussel habitat in much of the river below the Augusta Shoals area is often restricted to narrow troughs, usually within the thalweg adjacent to river banks. The presence of marl outcroppings in the river at sites 16-17 and 31 seemed to correlate with high numbers of mussels.

Species diversity at a site was reflective of habitat complexity. Sites containing several microhabitats consistently exhibited higher diversity compared with sites with homogenous habitat. The three sites (Sites 32, 24 and 13) with the highest species diversity (13, 13 and 12 species respectively) had a mixture of substrate types at varying depths and flow rates. In general the cut off bends that were surveyed contained relatively high species diversity, as many retain some level of flow in the center of the channel, but also have slackwater habitats with finer substrates. Although species diversity was relatively high, it did not always correlate to high densities. For example, 10 species were located at Site 26. (Cut Off # 22), however, only 27 individuals were

found, with the eastern elliptio and variable spike being most common (5 individuals each).

5.2.2 Survey methodology and habitat partitioning by species

Consistent habitat partitioning by species was observed at most sites throughout the study area (discussed earlier in species accounts, Sec. 5.1.1). For example, barrel floater, eastern creekshell, rayed pink fatmucket and northern lance were almost always found in shallow soft sediment near the river banks, while the Carolina slabshell, Roanoke slabshell, pod lance and Carolina lance were generally found only in deeper troughs with faster flow. Although divers searched for mussels along the banks during descent and ascent, most of their focus was on the deep water habitats, thus species with affinities for shallow habitats may have been under-represented at some sites. However, shallow water habitats are absent at many of the sites where the river slopes sharply to the bottom. At many of the sites with this feature, certain species such as Carolina slabshell and Roanoke slabshell were not detectable or detectable in low numbers.

Both shallow and deep water habitats were present at Sites 32 and 39 in enough quantity to allow for comparison of survey methodologies of comparable effort (time surveyed). As demonstrated in Table 3, the detect ability (CPUE) of many species varies greatly between survey methodology.

Table 3. CPUE of Mussels per survey methodology, Sites 32 and 39

Species	Shallow-32	SCUBA 32	Shallow 39	SCUBA 39
<i>Anodonta couperiana</i>	1.17/hr	0.0/hr	~	~
<i>Elliptio angustata</i>	0.51/hr	0.0/hr	~	~
<i>Elliptio complanata</i>	107.96/hr	94.11/hr	24.13/hr	28.76
<i>Elliptio congaraea</i>	2.35/hr	64.60/hr	1 shell	126.02/hr
<i>Elliptio folliculata</i>	0.0/hr	6.19/hr	0.0/hr	1.36/hr
<i>Elliptio hopetonensis</i>	2.35/hr	0.0/hr	~	~
<i>Elliptio icterina</i>	41.17/hr	22.12/hr	25.86/hr	2.74/hr
<i>Elliptio producta</i>	3.52/hr	6.19/hr	0.0/hr	6.85/hr
<i>Elliptio roanokensis</i>	0.0/hr	4.42/hr	0.0/hr	28.76/hr
<i>Lampsilis splendida</i>	7.05/hr	0.88/hr	10.34/hr	1.37/hr
<i>Pyganodon cataracta</i>	1 shell	0.0/hr	~	~
<i>Unio merus carolinianus</i>	1.17/hr	0.88/hr	~	~
<i>Villosa delumbis</i>	7.05/hr	4.42/hr	~	~

~ indicates not present at site

These differences in CPUE demonstrate that a combination of survey methodology, including the use of SCUBA is necessary to perform adequate inventories of the mussel fauna in this basin.

5.3 Possible presence of Altamaha River endemics in the Savannah River

It has long been believed that the Altamaha River contained seven endemic mussel species; *Alasmidonta arcua*, *Anodonta gibbosa*, *Elliptio dariensis*, *E. hopetonensis*, *E. shepardiana*, *E. spinosa* and *Lampsilis dolabraeformis*. Johnson (1970) suggested that the Altamaha system is very old and was isolated during some of the Pleistocene, which

could have facilitated speciation. Species like *A. arcula* and *L. dolabraeformis* have closely related counterparts in basins to the north (*A. undulata* and *L. cariosa*, respectively). The major conchological differences between these Altamaha endemics and their counterparts to the north are the level of inflation, sharpness of posterior slope and position, or sculpture of the umbos and beaks (see species descriptions Sec. 5.1.1). Similarly, the shell of *E. shepardiana* differs from other lanceolate elliptio species to the north by being more than three times as long as high compared to more than two times as long. Although it has not been challenged in the literature, some researchers have suggested that the Altamaha endemics represent the extremes of clinal variation rather than speciation.

As discussed earlier, based on conchological characteristics, three of the Altamaha endemic species, *A. arcula*, *E. hopetonensis* and *L. dolabraeformis* were identified as occurring in the Savannah River during this study. This is not the first time however that some of these species have been reported in the Savannah River. Patrick, Cairns and Roback (1967) reported *E. hopetonensis* from the Savannah River Site, but this was corrected by Johnson (1970) to *E. complanata*. Simpson (1914) reported *L. dolabraeformis* from the Ogeechee and Savannah River systems; however, Johnson (1970) noted that all of the specimens in the US National Museum “are all *L. cariosa*”. As discussed in the accounts of these species (Sec. 5.1.1), comparison of the DNA sequences of these specimens from the Savannah River with that of topotypic material is needed to confirm the presence of these species in the Savannah River.

6.0 RECOMMENDATIONS

This study provides a current baseline for the distribution and relative abundances of the mussel fauna in the Savannah River from Augusta to Savannah and documents the general area where freshwater mussels are replaced by brackish species (between RM 26.3 and RM 22.8). This information is crucial for the management of these populations and evaluating likely impacts to the freshwater mussel fauna from current and future proposed uses of the river. However, additional critical research needs still exist as noted in Sections 6.1-6.6.

6.1 Genetic Research

As discussed throughout this report, genetic analysis is a major component of this study. Representatives of all species identified were preserved and deposited in the NCMNS. The impending genetics analysis is essential in determining the mussel faunal that occurs in the Savannah River Basin. This work will also allow for a better understanding of ecophenotypic and clinal variations of the freshwater mussel species of the Atlantic Slope.

6.2 Distributional Data

Additional distributional data beyond the 180 river miles covered with this study are needed in the basin. These include:

- the free flowing sections of river above Augusta (between Lake Hartwell and Russell Reservoir
- the sections within the three reservoirs (Hartwell, Richard B. Russell, and J. Strom Thurmond/Clarks Hill), especially tributary arms

- tributaries to Russell and Thurmond Reservoirs
- coastal plain tributaries
- tributaries above Hartwell Reservoir

Examination of historic and recent survey data is needed to prioritize the areas with the most pending needs.

6.3 Long Term Population Monitoring

Various uses of the Savannah River such as water withdrawal, channel dredging, restoration of cut-off bends, etc. are being, or could potentially be proposed in the future. These projects, if constructed, could significantly alter river conditions and may affect mussel populations. Long term qualitative and quantitative monitoring of the mussel populations is needed to adequately manage the mussel resources in this section of the river.

6.4 Habitat Partitioning by Species

As discussed throughout this report, various general observations were made on habitat partitioning by species throughout the study area. Quantifiable understanding of each species use of particular microhabitats is important for the management of individual species with particular conservation concerns.

6.5 Fish Host Identification

The fish hosts for several mussel species occurring in the Savannah River Basin are still unknown. Laboratory and field research is needed in this area, as understanding life cycles is a critical component of species conservation.

6.6 Archeological Research of Mussels in Basin

Much has been learned of mussel faunas in other river basins, by examining archeological material. If archeological freshwater mussel material is available, research comparing current species composition with the archeological material would enhance the understanding of this resource, and thus help facilitate conservation initiatives.

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APPENDIX A: MUSSEL SPECIES PER SITE

SITE	DATE	SAVANNAH RIVER MILE	SCIENTIFIC NAME	#	CPUE (#/ph)
1	8/1/2006	RM 203 33.50757°N, -81.99613°W	<i>Elliptio angustata</i>	2	1.00
			<i>Elliptio complanata</i>	28	14.00
			<i>Elliptio congaraea</i>	7	3.50
			<i>Elliptio fraterna</i>	2	1.00
			<i>Elliptio icterina</i>	42	21.00
2	8/1/2006	RM 202.8 33.50589°N, -81.99642°W	<i>Elliptio angustata</i>	1 shell	0.00
			<i>Elliptio complanata</i>	18	7.20
			<i>Elliptio congaraea</i>	3	1.20
			<i>Elliptio fraterna</i>	1	0.40
			<i>Elliptio icterina</i>	50	20.00
			<i>Fusconaia masoni</i>	1	0.40
3	8/1/2006	RM 202.2 33.49812°N, -81.99153°W	<i>Elliptio complanata</i>	32	24.62
			<i>Elliptio congaraea</i>	65	50.00
			<i>Elliptio hopetonensis</i>	17	13.08
			<i>Elliptio icterina</i>	32	24.62
			<i>Elliptio roanokensis</i>	6	4.62
			<i>Fusconaia masoni</i>	3	2.31
4	8/1/2006	RM 193.2 33.41915°N, -81.92616°W	<i>Elliptio congaraea</i>	1	1.20
			<i>Elliptio icterina</i>	2	2.41
5	8/1/2006	RM 195.8 33.43932°N, -81.91258°W	<i>Elliptio icterina</i>	1 shell	0
6	8/1/2006	RM 196.2 33.45192°N, -81.9205°W	<i>Elliptio congaraea</i>	5	4.17
			<i>Elliptio fisheriana</i>	1	0.83
			<i>Elliptio hopetonensis</i>	2	1.67
			<i>Elliptio icterina</i>	41	34.17
			<i>Elliptio producta</i>	1	0.83
			<i>Leptodea ochracea</i>	1	0.83
			<i>Unio merus carolinianus</i>	1	0.83
7	8/1/2006	RM 201.5 33.48906°N, -81.9899°W	<i>Elliptio angustata</i>	11	14.10
			<i>Elliptio complanata</i>	15	19.23
			<i>Elliptio congaraea</i>	29	37.18
			<i>Elliptio hopetonensis</i>	9	11.54
			<i>Elliptio icterina</i>	34	43.59
			<i>Elliptio lazarus (=arctata)</i>	13	16.67
			<i>Elliptio producta</i>	3	3.85
			<i>Elliptio roanokensis</i>	2	2.56
			<i>Villosa delumbis</i>	2	2.56
8	8/2/2006	RM 122 32.89614°N, -81.4638°W	<i>Elliptio congaraea</i>	71	71.00
			<i>Elliptio folliculata</i>	4	4.00
			<i>Elliptio hopetonensis</i>	16	16.00
			<i>Elliptio icterina</i>	9	9.00
			<i>Elliptio producta</i>	1	1.00
			<i>Elliptio roanokensis</i>	18	18.00
			<i>Lampsilis cariosa</i>	1	1.00
			<i>Unio merus carolinianus</i>	1	1.00
9	8/2/2006	RM 123	<i>Elliptio angustata</i>	10	8.62

SITE	DATE	SAVANNAH RIVER MILE	SCIENTIFIC NAME	#	CPUE (#/ph)
		32.89481°N, -81.4699°W	<i>Elliptio complanata</i>	5	4.31
			<i>Elliptio congrareae</i>	133	114.66
			<i>Elliptio folliculata</i>	5	4.31
			<i>Elliptio hopetonensis</i>	26	22.41
			<i>Elliptio icterina</i>	3	2.59
			<i>Elliptio roanokensis</i>	18	15.52
			<i>Lampsilis cariosa</i>	4	3.45
10	8/2/2006	RM 119.5 32.91551°N, -81.488°W	<i>Lampsilis cariosa</i>	1	2.50
11	8/2/2006	RM 118.9 32.93857°N, -81.5034°W	<i>Elliptio complanata</i>	6	8.96
			<i>Elliptio congrareae</i>	92	137.31
			<i>Elliptio fisheriana</i>	2	2.99
			<i>Elliptio folliculata</i>	7	10.45
			<i>Elliptio hopetonensis</i>	6	8.96
			<i>Elliptio icterina</i>	7	10.45
			<i>Elliptio lazarus (=arctata)</i>	4	5.97
			<i>Elliptio producta</i>	1	1.49
			<i>Elliptio roanokensis</i>	23	34.33
			<i>Lampsilis dolabraeformis</i>	1	1.49
			<i>Villosa delumbis</i>	1	1.49
12	8/2/2006	RM 120.7 (Fat Meat Point Cut) 32.96421°N, -81.5111°W	<i>Alasmidonta arcuata</i>	1	1.18
			<i>Elliptio angustata</i>	1	1.18
			<i>Elliptio complanata</i>	4	4.71
			<i>Elliptio congrareae</i>	44	51.76
			<i>Elliptio fisheriana</i>	1	1.18
			<i>Elliptio folliculata</i>	7	8.24
			<i>Elliptio hopetonensis</i>	1	1.18
			<i>Elliptio icterina</i>	10	11.76
			<i>Elliptio roanokensis</i>	2	2.35
			<i>Lampsilis splendida</i>	2	2.35
			<i>Villosa delumbis</i>	1	1.18
13	8/2/2006	RM 124.2 32.99669°N, -81.4908°W	<i>Elliptio complanata</i>	10	10.87
			<i>Elliptio congrareae</i>	42	45.65
			<i>Elliptio fisheriana</i>	2	2.17
			<i>Elliptio folliculata</i>	1	1.09
			<i>Elliptio hopetonensis</i>	13	14.13
			<i>Elliptio icterina</i>	2	2.17
			<i>Elliptio roanokensis</i>	28	30.43
			<i>Elliptio sp.</i>	6	6.52
			<i>Lampsilis cariosa</i>	1	1.09
			<i>Lampsilis splendida</i>	1	1.09
			<i>Unio merus carolinianus</i>	2	2.17
			<i>Villosa delumbis</i>	1	1.09
14	8/2/2006	RM 124.3 (Johnson's Landing) 32.99712°N, -81.4907°W	<i>Elliptio congrareae</i>	50	100.00
			<i>Elliptio folliculata</i>	5	10.00
			<i>Elliptio producta</i>	2	4.00
			<i>Elliptio roanokensis</i>	28	56.00
			<i>Lampsilis splendida</i>	3	6.00

SITE	DATE	SAVANNAH RIVER MILE	SCIENTIFIC NAME	#	CPUE (#/ph)
			<i>Uniomerus carolinianus</i>		0.00
			<i>Villosa delumbis</i>	4	8.00
15	8/3/2006	RM 68 32.57759°N, -81.3664°W	<i>Elliptio complanata</i>	40	40.00
			<i>Elliptio congaraea</i>	30	30.00
			<i>Elliptio folliculata</i>	6	6.00
			<i>Elliptio hopetonensis</i>	20	20.00
			<i>Elliptio icterina</i>	23	23.00
			<i>Elliptio roanokensis</i>	24	24.00
			<i>Lampsilis cariosa</i>	1	1.00
			<i>Lampsilis splendida</i>	1	1.00
			<i>Villosa delumbis</i>	1	1.00
16	8/3/2006	RM 69.5 32.57065°N, -81.3542°W	<i>Elliptio angustata</i>	2	4.35
			<i>Elliptio complanata</i>	8	17.39
			<i>Elliptio congaraea</i>	40	86.96
			<i>Elliptio hopetonensis</i>	7	15.22
			<i>Elliptio icterina</i>	2	4.35
			<i>Elliptio roanokensis</i>	36	78.26
			<i>Lampsilis cariosa</i>	1	2.17
17	8/3/2006	RM 70 32.57137°N, -81.3563°W	<i>Elliptio angustata</i>	1	2.50
			<i>Elliptio complanata</i>	29	72.50
			<i>Elliptio congaraea</i>	113	282.50
			<i>Elliptio hopetonensis</i>	5	12.50
			<i>Elliptio icterina</i>	3	7.50
			<i>Elliptio roanokensis</i>	39	97.50
18	8/3/2006	RM 64.7 32.55115°N, -81.2879°W	<i>Elliptio complanata</i>	37	29.60
			<i>Elliptio folliculata</i>	1	0.80
			<i>Elliptio icterina</i>	5	4.00
			<i>Lampsilis splendida</i>	2	1.60
			<i>Villosa delumbis</i>	5	4.00
19	8/3/2006	RM 64.1 (Hog Branch) 32.55709°N, -81.2851°W	<i>Elliptio complanata</i>	300	163.93
			<i>Elliptio icterina</i>	6	3.28
			<i>Elliptio roanokensis</i>	1	0.55
			<i>Lampsilis splendida</i>	12	6.56
			<i>Pyganodon cataracta</i>	1 shell	0.00
			<i>Villosa delumbis</i>	6	3.28
20	10/17/2006	RM 185.5 33.35644°N, -81.9342°W	<i>Elliptio congaraea</i>	1	1.33
			<i>Elliptio icterina</i>	1 shell	0.00
21	10/17/2006	RM 183 33.33849°N, -81.9176°W	<i>Elliptio complanata</i>	2	1.60
			<i>Elliptio congaraea</i>	35	28.00
			<i>Elliptio hopetonensis</i>	5	4.00
			<i>Elliptio icterina</i>	5	4.00
22	10/17/2006	RM 181.8 33.32654°N, -81.9056°W	<i>Elliptio congaraea</i>	7	7.00
			<i>Elliptio icterina</i>	1 shell	0.00
23	10/17/2006	RM 178.8 33.31787°N, -81.885°W	<i>Elliptio congaraea</i>	2	2.99
			<i>Elliptio icterina</i>	1	1.49
			<i>Uniomerus carolinianus</i>	1	1.49
24	10/17/2006	RM 173.2 (Lower Silver Bluff Cut)	<i>Anodonta couperiana</i>	1	0.80

SITE	DATE	SAVANNAH RIVER MILE	SCIENTIFIC NAME	#	CPUE (#/ph)
		33.29834°N, -81.852°W	<i>Anodonta implicata</i>	6 1 shell	4.80
			<i>Elliptio angustata</i>	2	1.60
			<i>Elliptio complanata</i>	3	2.40
			<i>Elliptio congaraea</i>	22	17.60
			<i>Elliptio fisheriana</i>	1	0.80
			<i>Elliptio hopetonensis</i>	2	1.60
			<i>Elliptio icterina</i>	9	7.20
			<i>Elliptio producta</i>	2 shells	0.00
			<i>Lampsilis splendida</i>	1	0.80
			<i>Pyganodon cataracta</i>	1	0.80
				2 shells	
			<i>Unio merus carolinianus</i>	13	10.40
			<i>Utterbackia imbecillis</i>	1	0.80
25	10/17/2006	RM 173.3 33.29871°N, -81.5165°W	none		
26	10/17/2006	RM 169.6 (Cut Off # 22)	<i>Anodonta implicata</i>	2 2 shells	1.71
		33.2721°N, -81.8352°W	<i>Elliptio complanata</i>	2	1.71
			<i>Elliptio congaraea</i>	2	1.71
			<i>Elliptio icterina</i>	5	4.27
				1 shell	
			<i>Elliptio producta</i>	1 shell	0.00
			<i>Elliptio roanokensis</i>	3	2.56
				5 shells	
			<i>Lampsilis splendida</i>	4	3.42
			<i>Pyganodon cataracta</i>	1	0.85
			<i>Pyganodon cataracta</i>	4	3.42
				1 shell	
			<i>Toxolasma pullus</i>	1	0.85
			<i>Unio merus carolinianus</i>	3	2.56
				1 shell	
27	10/18/2006	RM 54.1 (Upper End Dyke Field 3) 32.46651°N, -81.1985°W	<i>Alasmidonta undulata</i>	1	0.89
			<i>Anodonta couperiana</i>	1	0.89
			<i>Elliptio complanata</i>	71	63.39
			<i>Elliptio congaraea</i>	108	96.43
			<i>Elliptio fraterna</i>	1	0.89
			<i>Elliptio hopetonensis</i>	9	8.04
			<i>Elliptio icterina</i>	21	18.75
			<i>Elliptio producta</i>	4	3.57
			<i>Elliptio roanokensis</i>	12	10.71
			<i>Lampsilis cariosa</i>	1	0.89
			<i>Lampsilis splendida</i>	1	0.89
			<i>Villosa delumbis</i>	5	4.46
28	10/18/2006	RM 52.1 32.45575°N, -81.1923°W	<i>Anodonta couperiana</i>	6	3.39
			<i>Elliptio complanata</i>	31	17.51
			<i>Elliptio congaraea</i>	1	0.56

SITE	DATE	SAVANNAH RIVER MILE	SCIENTIFIC NAME	#	CPUE (#/ph)
			<i>Elliptio icterina</i>	12	6.78
			<i>Elliptio producta</i>	10	5.65
			<i>Lampsilis cariosa</i>	4	2.26
			<i>Lampsilis splendida</i>	5	2.82
			<i>Unio merus carolinianus</i>	1	0.56
			<i>Villosa delumbis</i>	3	1.69
29	10/18/2006	RM 51.4 (Lagoon at Chair Maker Point) 32.45222°N, -81.2029°W	<i>Elliptio complanata</i>	6	3.59
			<i>Elliptio congaraea</i>	1	0.60
			<i>Elliptio icterina</i>	2 shells	0.00
			<i>Lampsilis splendida</i>	1	0.60
			<i>Pyganodon cataracta</i>	1	0.60
			<i>Utterbackia imbecillis</i>	2	1.20
30	10/18/2006	RM 51.4 35.45222°N, -81.2029°W	<i>Elliptio complanata</i>	58	48.33
			<i>Elliptio icterina</i>	19	15.83
			<i>Elliptio producta</i>	1	0.83
			<i>Lampsilis cariosa</i>	2	1.67
			<i>Lampsilis splendida</i>	6	5.00
			<i>Villosa delumbis</i>	2	1.67
31	10/18/2006	RM 48.3 32.42253°N, -81.2041°W	<i>Elliptio complanata</i>	32	71.11
			<i>Elliptio congaraea</i>	29	64.44
			<i>Elliptio icterina</i>	16	35.56
			<i>Elliptio lazarus (=arctata)</i>	1	2.22
			<i>Elliptio producta</i>	3	6.67
			<i>Elliptio roanokensis</i>	60	133.33
			<i>Lampsilis cariosa</i>	1	2.22
			<i>Unio merus carolinianus</i>	1	2.22
32	10/18/2006	RM 44.8 (Ebenezer Creek) 32.38033°N, -81.1821°W	<i>Anodonta couperiana</i> (T) *	1	1.17
			<i>Anodonta couperiana</i> (S) **	0	0.0
			<i>Elliptio angustata</i> (T)	1	0.51
			<i>Elliptio angustata</i> (S)	0	0.0
			<i>Elliptio complanata</i> (T)	122	107.96
			<i>Elliptio complanata</i> (S)	80	94.11
				5 shells	
			<i>Elliptio congaraea</i> (T)	2	2.35
			<i>Elliptio congaraea</i> (S)	73	64.60
				4 shells	
			<i>Elliptio folliculata</i> (T)	0	0.0
			<i>Elliptio folliculata</i> (S)	7	6.19
			<i>Elliptio hopetonensis</i> (T)	2	2.35
			<i>Elliptio hopetonensis</i> (S)	0	0.0
			<i>Elliptio icterina</i> (T)	35	41.17
			<i>Elliptio icterina</i> (S)	25	22.12
				5 shells	
			<i>Elliptio producta</i> (T)	3	3.52
			<i>Elliptio producta</i> (S)	7	6.19
			<i>Elliptio roanokensis</i> (T)	0	0.0
			<i>Elliptio roanokensis</i> (S)	5	4.42

SITE	DATE	SAVANNAH RIVER MILE	SCIENTIFIC NAME	#	CPUE (#/ph)
			<i>Lampsilis splendida</i> (T)	6	7.05
			<i>Lampsilis splendida</i> (S)	1	0.88
			<i>Pyganodon cataracta</i> (T)	1 shell	0.00
			<i>Pyganodon cataracta</i> (T)	0	0.00
			<i>Unio merus carolinianus</i> (T)	1	1.17
			<i>Unio merus carolinianus</i> (S)	1	0.88
			<i>Villosa delumbis</i> (T)	6	7.05
			<i>Villosa delumbis</i> (S)	5	4.42
33	10/19/2006	RM 27.9 32.23902°N, -81.154°W	<i>Elliptio congraera</i>	1 shell	0.00
			<i>Lampsilis cariosa</i>	1	1.49
34	10/19/2006	RM 27.6 32.23668°N, -81.1544°W	<i>Elliptio complanata</i>	76	60.80
			<i>Elliptio congraera</i>	22	17.60
			<i>Elliptio icterina</i>	15	12.00
			<i>Elliptio producta</i>	12	9.60
			<i>Elliptio roanokensis</i>	10	8.00
			<i>Lampsilis splendida</i>	10	8.00
35	10/19/2006	RM 22.8 (Front River East Bank) 32.18032°N, -81.1565°W	none		
36	10/19/2006	RM 22.8 (Front River West Bank) 32.1795°N, -81.1578°W	none		
37	10/19/2006	RM 26.2 (McCoy's Cut) 32.22108°N, -81.1518°W	<i>Elliptio congraera</i>	1 shell	0.00
38	10/19/2006	RM 26.3 32.2221°N, -81.1503°W	<i>Elliptio complanata</i>	1	2.33
			<i>Elliptio congraera</i>	14	32.56
			<i>Elliptio icterina</i>	2	4.65
			<i>Elliptio roanokensis</i>	22	51.16
39	10/19/2006	RM 29.7 (Big Collis Creek) 32.25414°N, -81.1492°W	<i>Elliptio complanata</i> (T)	14	24.13
			<i>Elliptio complanata</i> (S)	21	28.76
			<i>Elliptio congraera</i> (T)	1 shell	0.0
			<i>Elliptio congraera</i> (S)	92	126.02
			<i>Elliptio folliculata</i> (T)	0	0.0
			<i>Elliptio folliculata</i> (S)	1	1.36
			<i>Elliptio icterina</i> (T)	15	25.86
			<i>Elliptio icterina</i> (S)	2	2.74
			<i>Elliptio producta</i> (T)	0	0.0
			<i>Elliptio producta</i> (S)	5	6.85
			<i>Elliptio roanokensis</i> (T)	0	0.0
			<i>Elliptio roanokensis</i> (S)	21	28.76
			<i>Lampsilis splendida</i> (T)	6	10.34
			<i>Lampsilis splendida</i> (S)	1	1.37

*: (T) - Tactile/shallow water surveys

**: (S) - SCUBA surveys



The
Catena
Group

Survey Area

Freshwater Mussel Surveys
of the Savannah River Basin

For

International Paper and US Fish and Wildlife Service

Date:
October 2007

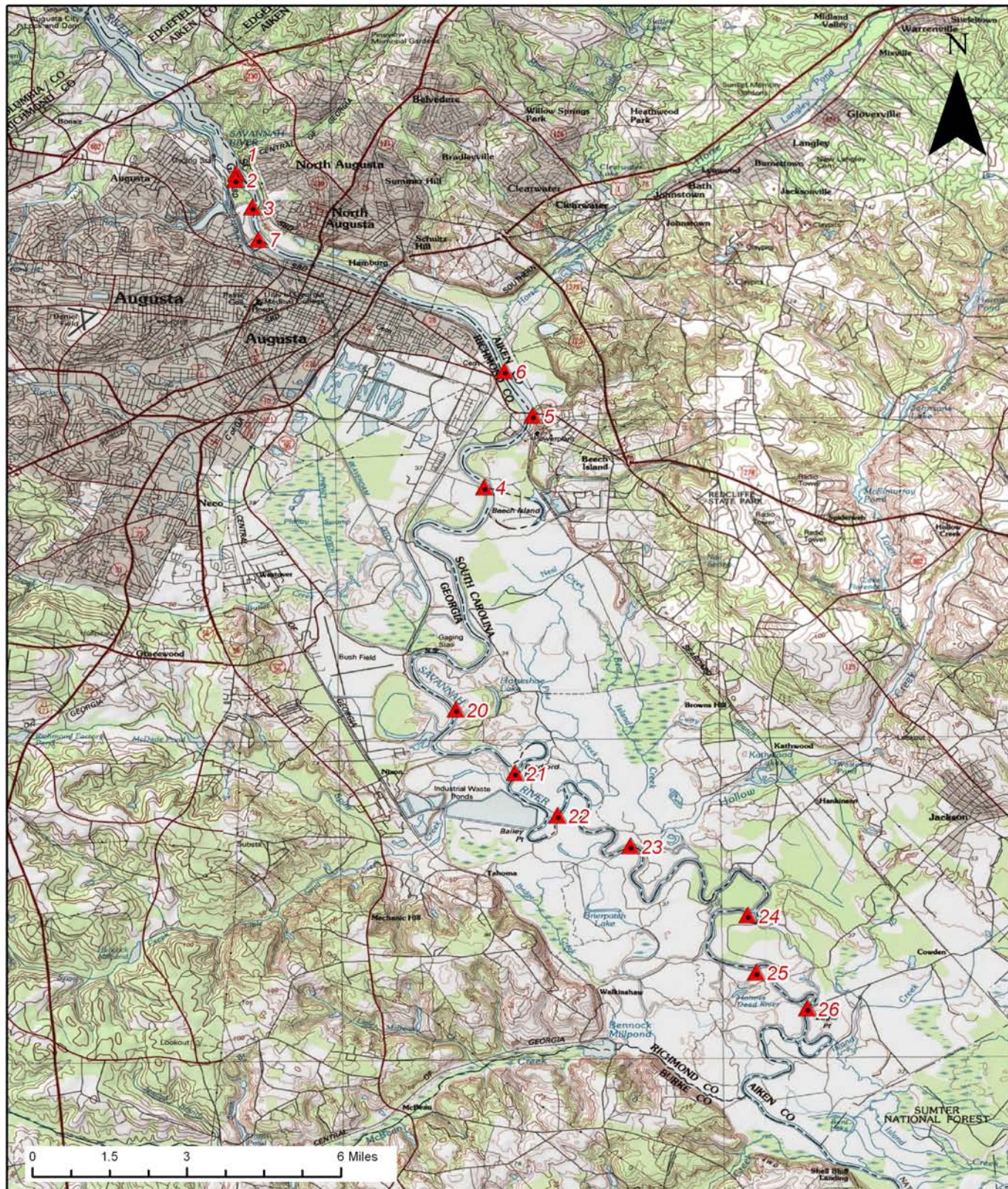
Scale:
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Job No.:
3178

Figure

1





The
Catena
Group

Survey Site Locations

- North Section -

Freshwater Mussel Surveys
of the Savannah River Basin

For
International Paper and US Fish and Wildlife Service

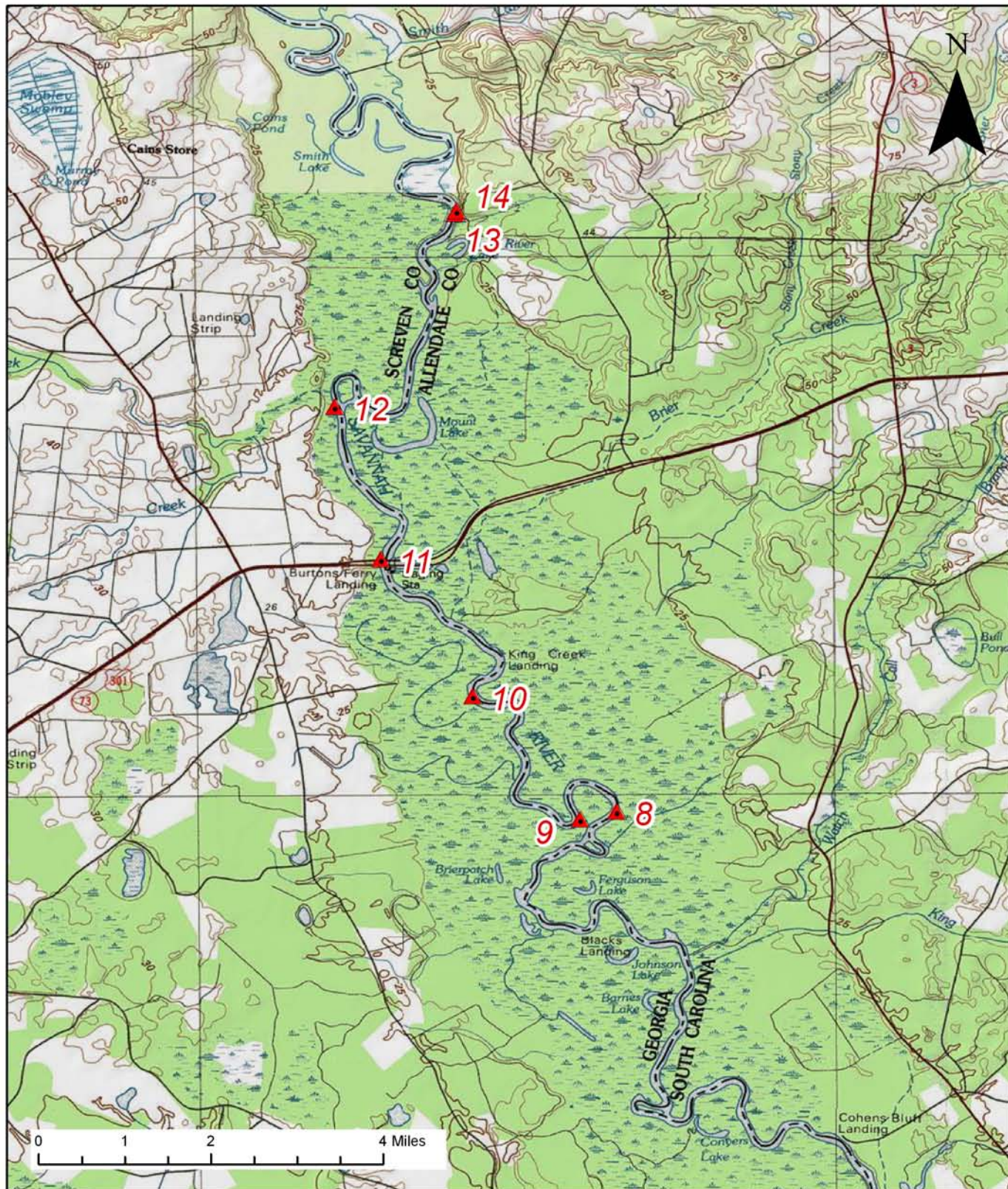
Date: October 2007

Scale: As Shown

Job No.: 3178

Figure

2B



The
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Survey Site Locations

- Central Section -

Freshwater Mussel Surveys
of the Savannah River Basin

for
International Paper and US Fish and Wildlife Service

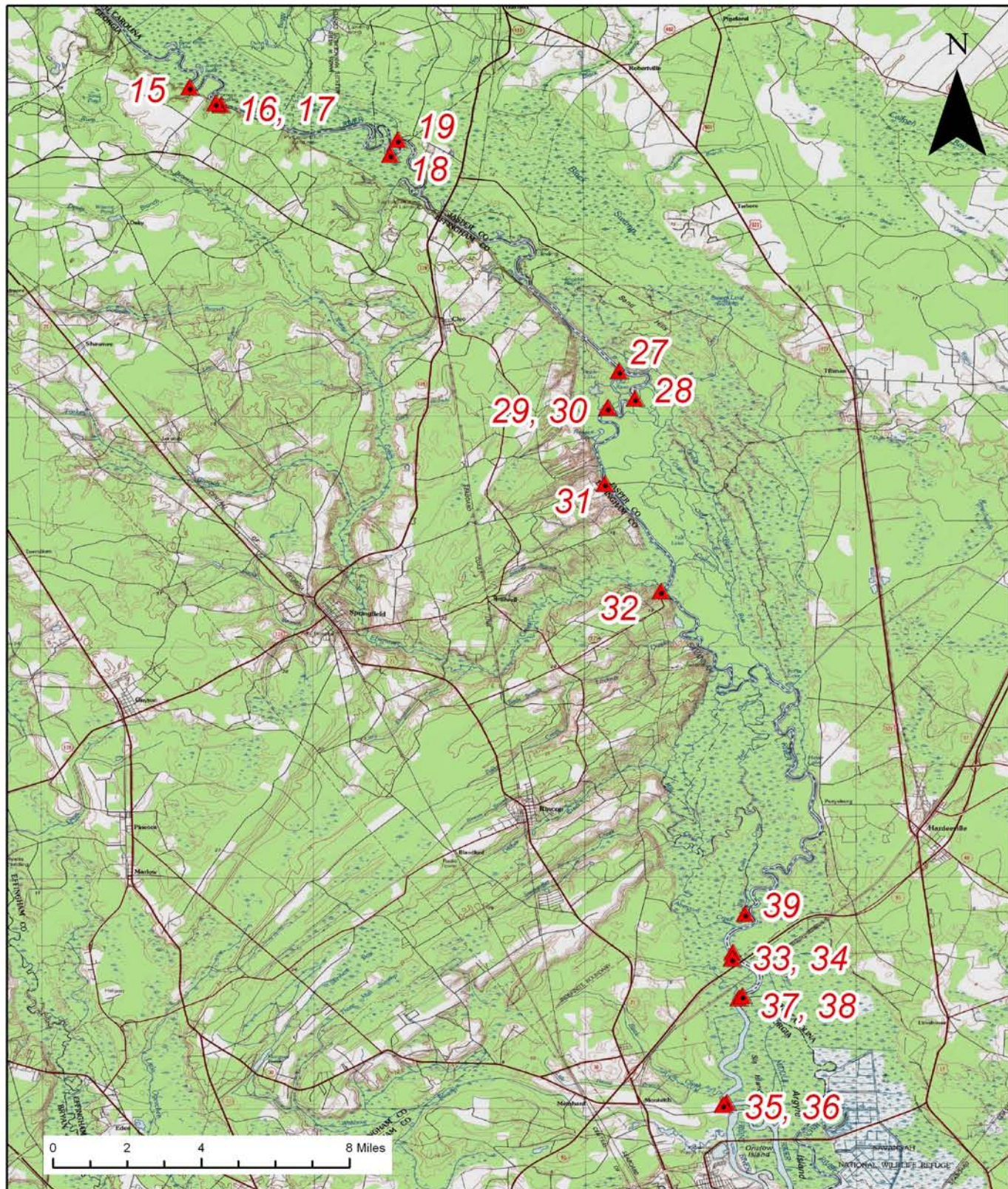
Date:
October 2007

Scale:
As Shown

Job No.:
3178

Figure

2C



The
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Survey Site Locations - South Section -

Freshwater Mussel Surveys
of the Savannah River Basin

For
International Paper and US Fish and Wildlife Service

Date:
October 2007

Scale:
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3178

Figure

2D

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Return-Path: <rebekah.krieg@pnl.gov>
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Thread-Topic: Vogtle
Thread-Index: AChLf6Psy3k7kaBTD+m5mdXMPzTmQAAoDAw
From: "Krieg, Rebekah" <rebekah.krieg@pnl.gov>
To: "Michael Masnik" <MTM2@nrc.gov>,
"Anne Kuntzleman" <ARK2@nrc.gov>
Cc: "Sackschewsky, Michael R" <michael.sackschewsky@pnl.gov>,
"^PNNL NRC Vogtle" <nrc.vogtle@pnl.gov>