Mayo Creek Aquatic Survey

V.C. Summer Units 2 and 3
Combined Construction/Operating License Project

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1.0 INTRODUCTION

In February 2006, SCE&G and Santee Cooper announced that they had selected a preferred site and a preferred reactor design for two new nuclear units. The new units would be built on the existing V.C. Summer Nuclear Station site near Jenkinsville, South Carolina. By mid-2006, SCE&G made the determination that new nuclear units 2 and 3 and important support facilities (e.g., cooling towers) would be placed approximately one mile south of existing Unit 1, in an area dominated by young planted pines and older mixed pine-hardwood stands. Because land clearing and earth moving associated with construction of new facilities could potentially degrade water quality in the Mayo Creek watershed, SCE&G commissioned Tetra Tech NUS to conduct studies of fish and mussels in Mayo Creek and its tributaries. The goal of the studies was to establish baseline conditions in Mayo Creek for purposes of impact assessment and to identify any special-status aquatic species that might be present.

2.0 THE SITE AND VICINITY

Mayo Creek (Figure 1) is the only stream in the project area that offers substantial year-round flow and habitat adequate to support reasonably diverse assemblages of benthic organisms and fish. Several other unnamed drainages that appear on U.S. Geological Survey (USGS) topographic maps as streams flowing into Parr Reservoir immediately north and south of the project site are either intermittent streams (known locally as "wet weather" streams) or small perennial streams that may be only inches wide in late summer.

In some places, these small streams are dammed by snags and leafpack, creating pools that may be 6-8 feet wide after heavy rains. Based on a July 2006 reconnaissance conducted by SCE&G and Tetra Tech NUS biologists, these pools serve as refuges for fish, crayfish, and aquatic insects during droughts and low-water periods. The importance of these "pool refugia" to fish and aquatic insects in intermittent streams is well known (Labbe and Fausch 2000; Magoulick 2000). Pools with relatively stable hydrology (water levels) in intermittent streams are associated with successful reproduction, population growth, and immigration of fish, whereas pools with more variable hydrology (drying completely or nearly so) tend to be characterized by population declines and emigration (Magoulick and Kobza 2003; Love 2004).

Mayo Creek is approximately three miles long and drains an area of about four square miles (Figure 1). It rises a half-mile southeast of the VCSNS Unit 1 generating facilities, flows south for approximately one mile then curves to the southwest before emptying into the Broad River at Hampton Island, just below the Parr Shoals dam. For much of its length, it flows through a mixed hardwood forest, and is almost completed shaded by a well-developed tree canopy. The tree canopy (shade) apparently moderates water temperatures in summer, which ranged from 23 to 25°C (74 to 76°F) on July 20, 2006 when stream levels were relatively low and ambient temperatures approached 100°F. Fish are found in all stream reaches, but are most numerous in

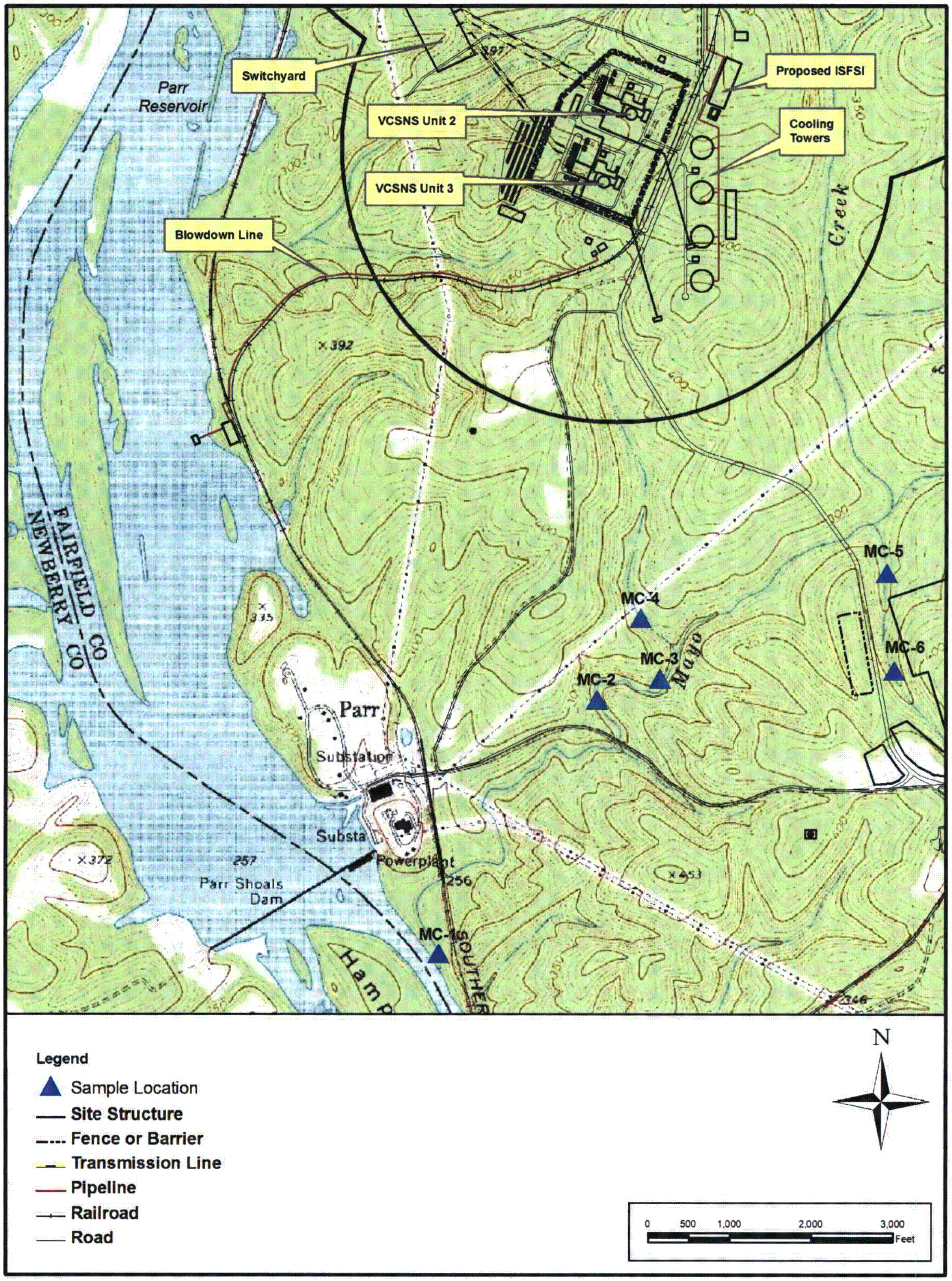

Figure 1. Fish Survey Sampling Locations

middle reaches that contain a mix of substrate and habitat types. The lower portion of Mayo Creek, immediately above its confluence with the Broad River, is noticeably wider and deeper than the rest of the stream, because of back-flow from the Broad River. The stream bottom here has a thick covering of silt, and habitat for fish and invertebrates is marginal at best.

Although the Mayo Creek drainage is almost completely undeveloped and there has been no logging in its floodplain, there has been significant logging activity in the watershed. Some sediment is presumed to have entered the stream with stormwater runoff from logging areas. For reasons that are unclear and are apparently related to characteristics of the watershed and the stream's morphology, it is subject to flash floods after heavy rains. These floods have eroded and undercut the stream's banks along much of its length and covered the stream bottom in many places with a heavy layer of silt.

Surveys of Mayo Creek fish and mussels were conducted in July and November 2006. Supplemental fish sampling was conducted in April 2007 to collect baseline information on a Mayo Creek tributary that could be affected by construction of an access road. The Mayo Creek aquatic surveys were designed to gather baseline information on the stream's biotic communities, supporting the assessment of construction impacts in the COL Environmental Report. The surveys were also intended to identify any special-status species that might be present, so that protection of any such species could be factored into project planning. Mayo Creek was selected for surveys because it is the only substantial stream in the project area, and the only one likely to contain significant numbers of fish and macrobenthos. Other streams in the project area are assumed to support smaller, less diverse benthic and fish communities that are a subset of the Mayo Creek communities, with species predominating that are able to tolerate high levels of turbidity and high summer water temperatures.

3.0 METHODS

Sampling Locations

Tetra Tech NUS and SCE&G biologists conducted a reconnaissance of project area streams and drainages in early July 2006. The goal of the reconnaissance was to identify sampling locations downstream of proposed construction sites that would yield representative baseline data on aquatic biota. This reconnaissance suggested that the small streams draining areas immediately north, west, and south of the proposed construction area were too small to effectively sample in summer: none was more than 2 feet wide or more than a few inches deep. The decision was made to focus sampling efforts on the middle reaches of Mayo Creek, downstream of the point where the west branch of the creek joins the mainstem. This portion of the stream appeared to offer year-round flows that would make electrofishing, the preferred sampling method, possible. Portions of Mayo Creek above this confluence had substantially less flow and were less accessible.

Three sampling transects (MC-1, MC-2, and MC-3) were initially established on the mainstem of Mayo Creek and sampled in July 2006 (see Figure 1). Transect MC-1, intended to serve as an indicator of fish movement between Mayo Creek and the Broad River, was abandoned after the July sampling round because so few fish were present and because its soft, silt-laden bottom made sampling difficult. In November 2006, an additional sampling station (MC-4) was established on an upstream tributary of Mayo Creek to validate the assumption that tributary fish assemblages represent a subset of mainstem fish assemblages. SCE&G determined in early 2007 that it would be necessary to build an access road from the existing Parr Road to the proposed site of Units 2 and 3. Because the construction of this road appeared to have potential for impacting a small, north-flowing tributary of Mayo Creek, this tributary was sampled in April 2007 with minnow traps, at new sampling stations designated MC-5 and MC-6. Sampling sites are described in Table 1.

Table 1. Descriptions of Mayo Creek Sampling Sites

Transect	Length (ft)	Average Width	Average Depth	Substrate	Notes
Transect MC-1	189	19 ft. 2 in.	1.5 ft.	Silty	Well-developed canopy; fully shaded; undercut banks, heavy silt load (turbid)
Transect MC-2	205	8 ft. 6 in.	8 inches	Boulder, rubble, cobble, gravel, or sand, depending on stream gradient/location	Well-developed canopy, almost completely shaded; alternating riffle-run-pool habitats.
Transect MC-3	166	6 ft.	6 inches	Boulder, rubble, cobble, gravel, sand, or silt, depending on stream gradient/location	Well-developed canopy, almost completely shaded; alternating riffle-run-pool habitats.
Station MC-4	N/A	3 ft.	1.0 ft.	Sand, leaves, litter	Pool in small tributary
Station MC-5	N/A	6 ft.	12 in.	Sand, litter	Pool in small tributary
Station MC-6	N/A	6 ft.	16 in	Sand, litter	Pool in small tributary

Biologist retrieves minnow trap at Station MC-5.

Water Quality

Water quality measurements were taken at each transect/station on the first day of each sampling round. In July, temperature, dissolved oxygen, conductivity, turbidity, and pH measurements were taken with a Horiba Model U-10 water quality instrument. Although the instrument was calibrated in advance of fieldwork, all field turbidity readings in July were zero, suggesting a probe malfunction. In November, temperature, dissolved oxygen, and conductivity measurements were taken with a YSI Model 85 water quality instrument. An Orion portable pH meter was used in November.

Fish Sampling and Handling

Transects MC-1, MC-2, and MC-3 were sampled using a Smith-Root Model LR-24 backpack electrofisher with settings intended to produce maximum amperage, as conductivity was relatively low. Current strength varied little, and was generally around 0.15-0.2 amp. Two netters followed the operator of the backpack unit as he moved upstream, collecting stunned fish. Standard galvanized minnow traps were set up- and downstream of the three electrofishing transects after the completion of electrofishing and retrieved approximately 24 hours later. Tributary streams (Sampling Stations MC-4, MC-5, and MC-6) were sampled using wire minnow traps exclusively; these streams were either too small or too steep-sided to effectively and safely electrofish. Table 2 shows how the various transects and stations were sampled.

All fish collected, regardless of sampling method, were placed in a 10 percent buffered formalin solution and returned to the Aiken Office of Tetra Tech NUS to be measured, weighed, and identified to species. Although field identification and processing of fish would have been preferable, and would not have required sacrificing fish, concerns about possible mis-identification of small specimens and potentially rare species argued against it.

Fish were identified by an experienced Tetra Tech NUS fishery biologist, but identities of more obscure species and small (< 75 mm TL) catastomids were confirmed by either Dean Fletcher or Fred C. Rohde. Dean Fletcher is Research Coordinator of the Fish Ecology Program at the Savannah River Ecology Laboratory and co-author of *Fishes of the Middle Savannah River Basin*. Fred Rohde, a Fisheries Scientist with North Carolina Division of Marine Resources, is senior author of *Freshwater Fishes of the Carolinas, Virginia, Maryland, and Delaware*, and co-author of *Freshwater Fishes of South Carolina* (in preparation).

Table 2. Sampling Locations and Sampling Methods.

	July 2006		**November 2006**		**April 2007**
	Electrofishing	**Minnow Traps**	**Electrofishing**	**Minnow Traps**	**Minnow Traps**
MC-1	√	√			
MC-2	√	√	√	√	
MC-3	√	√	√	√	
MC-4				√	
MC-5					√
MC-6					√

Although quantitative surveys of freshwater mussels were not conducted, field personnel were instructed to be alert to the presence of bivalves, whether mussels or (Asiatic) clams. No live clams or mussels and no dead shells were observed in any of the stream reaches. No dead shells or midden piles were observed on stream banks. Mussels are common in portions of the Broad River (Bettinger, Crane, and Bulak 2003), but conditions in Mayo Creek appear to be unsuitable for these organisms. Because Mayo Creek is shallow and the bottom is visible in most locations and because representative segments (gravel bottom, sandy bottom, silty bottom) of the stream were searched and no mussels were found, there is no reason to believe that freshwater mussels are present in deeper pools or less-accessible areas of the creek.

4.0 RESULTS AND DISCUSSION

Water Quality

Water temperatures in Mayo Creek ranged from 23.6°C to 24.6°C (74°F to 76°F) in July and 12.5°C to 13.0°C (54°F to 55°F) in November. Temperatures in late summer appear to be moderated by the well-developed tree canopy, which shades most portions of the stream. Temperature and dissolved oxygen showed the expected inverse relationship, with dissolved oxygen concentrations at all stations higher in fall than summer. In July 2006, when air temperatures exceeded 36°C/97°F and stream temperatures reached almost 25°C/77°F, dissolved oxygen concentrations in all three mainstem reaches were higher than 5.0 mg/L. Most southeastern states use 5.0 mg/L (daily average) and 4.0 mg/L (instantaneous minimum) as criteria in establishing water quality standards for protection of aquatic life in warmwater streams (EPA 2007). In November, dissolved oxygen concentrations were somewhat higher, 8.5 to 8.8 mg/L. Mayo Creek's conductivity, which ranged from 110 to 117 millisiemens/cm, would place the stream in the lowest quartile (< 180 millisiemens/cm) of U.S. rivers (Potapova and Charles 2003) but was slightly higher than other streams in the Broad River drainage (Cooney et al. 2006). Measurements of pH in Mayo Creek generally ranged between 6.0 and 6.6, whereas pH measurements at other streams in the Broad River drainage in water year 2005 (last year for which USGS data are available) ranged between 6.6 – 7.6 (Tyger River) and 6.3 -7.7 (Enoree River) (Cooney et al. 2006).

Fish Populations

A total of 495 fish representing 14 species were collected during the 2006 Mayo Creek study (Table 3). Collections were dominated by Cyprinids (minnows) and Lepomids (sunfish); 92.2 percent of all fish collected were members of these two families. Bluehead chub (37.2 percent of total), yellowfin shiner (18.2 percent of total), sandbar shiner (16.4 percent), redbreast (9.7 percent), and creek chub (8.1 percent) were the species most often collected. Cyprinids (5 species) made up 80.7 percent of all fish collected.

Table 3. Summary of 2006 Mayo Creek Fish Collections

Common Name	Scientific Name	Total Number[a]	Relative Abundance (%)
Bluehead Chub	*Nocomis leptocephalus*	184	37.2
Yellowfin Shiner	*Notropis lutipinnis*	90	18.2
Sandbar Shiner	*Notropis scepticus*	81	16.4
Redbreast sunfish	*Lepomis auritus*	48	9.7
Creek Chub	*Semotilus atromaculatus*	40	8.1
Brassy jumprock	*Scartomyzon sp.*	19	3.8

Table 3. Summary of 2006 Mayo Creek Fish Collections (continued)

Common Name	Scientific Name	Total Number[a]	Relative Abundance (%)
Tesselated Darter	*Etheostoma olmstedi*	9	1.8
Seagreen Darter	*Etheostoma thalassinum*	8	1.6
Bluegill	*Lepomis machrochirus*	7	1.4
Greenfin Shiner	*Cyprinella chloristia*	4	0.8
Largemouth Bass	*Micropterus salmoides*	2	0.4
Margined Madtom	*Noturus insignis*	1	0.2
Piedmont Darter	*Percina crassa*	1	0.2
Flat Bullhead	*Ameirus platycephalus*	1	0.2
		495	100

a. includes electrofishing and minnow trap collections

Measures of abundance and species richness (Table 4) were markedly higher at Transects 2 and 3, a portion of the stream with a well-developed canopy, good water quality, a mix of aquatic habitats, and substantial year-round flow. Other transects/stations tended to be characterized by heavier silt, sediment, and debris loads, less optimal water quality, and/or extreme low flows in summer and early fall. Transects MC-2 and MC-3 had lower water temperatures and higher concentrations of dissolved oxygen than Transect MC-1 in July 2006, presumably reflecting a better-developed canopy (more completely shaded) and lower levels of solids, which absorb solar energy and raise water temperatures. There may also be cool seeps and springs in this stretch of the creek that buffer the stream's water temperatures. Stations MC-4, MC-5, and MC-6 were established on small tributaries of Mayo Creek. These small tributaries are subject to sudden changes in temperature and flow, and may turn from tiny (several inches wide) rills into debris-filled torrents after heavy rains.

Table 4. Number of Fish Collected in 2006-2007 by Sampling Location

	MC-1[a]	MC-2[b]	MC-3[b]	MC-4[c]	MC-5[d]	MC-6[d]
Bluegill	1	1	5			
Bluehead chub		92	88	4		
Brassy jumprock		12	7			
Creek chub		9	20	11	3	14
Flat bullhead			1			
Greenfin shiner		4				
Largemouth bass		1	1			

Table 4. Number of Fish Collected in 2006-2007 by Sampling Location (continued)

	MC-1[a]	MC-2[b]	MC-3[b]	MC-4[c]	MC-5[d]	MC-6[d]
Margined madtom		1				
Piedmont darter			1			
Redbreast sunfish	13	11	10	14		
Sandbar shiner		45	36			
Seagreen darter		5	3			
Tesselated darter		5	4			
Yellowfin shiner		54	36			
Number of Fish	14	240	212	29	3	14
Number of Species	2	12	12	3	1	1

a. July 2006 only

b. July and November 2006

c. November 2006 only

d. April 2007 only

All fish sampling gear are selective to some degree; however, electrofishing has proven to be the least selective and most effective single method for collecting stream fishes (EPA 1999). Pulsed DC (direct current) electrofishing is the method of choice to obtain a representative sample of the fish in wadeable streams, and was the method employed at V.C. Summer Nuclear Station. Because the goal of the sampling was to develop a list of species present and their relative abundance, rather than population estimates, "single-pass" sampling was employed rather than multiple-pass sampling.

Electrofishing success was dramatically higher at MC-2 and MC-3 than MC-1, reflecting substantially higher abundance of fish in these stream reaches (Table 5). Catch-per-unit effort was higher in the fall than in the summer, but statistical tests were not applied to the data to determine if differences were significant. These differences could have been the result of fish being more evenly distributed in the fall, fish being less active (water temperatures ranged from 12.5 to 13.0°C in November), or even netting efficiency (there were changes in field personnel between July and November).

Table 5. Electrofishing Catch-Per-Unit-Effort (CPUE) in 2006.

Sampling Location	July 2006 Total Number of Fish	July 2006 CPUE (fish/min)	July 2006 CPUE (fish/hour)	November 2006 Total Number of Fish	November 2006 CPUE (fish/min)	November 2006 CPUE (fish/hour)
MC-1	2	0.204	12.2	Not Sampled	N/A	N/A
MC-2	83	6.975	418.5	145	12.29	737.3
MC-3	66	5.789	347.4	92	8.364	501.8

Only two fish were collected at MC-1 in July 2006, which was the primary reason this transect was abandoned. A handful of species dominated electrofishing collections at MC-2 and MC-3, bluehead chub, yellowfin shiner, and sandbar shiner being the species with highest CPUE (Tables 6 and 7). Bluehead chub are found in a variety of habitats across the southeastern U.S. They were found at 42 of the 45 sites in the Broad River drainage sampled by SCDNR in 2003-2004 (Bettinger, Crane, and Bulak 2006). Yellowfin shiners have more restrictive habitat requirements, typically being found in clear-water streams in forested areas, but were also common in collections. Yellowfin shiners were found at 39 of 45 Broad River drainage sites sampled by SCDNR in 2003-2004 (Bettinger, Crane, and Bulak 2006). Sandbar shiners, which are often associated with clear, sandy-bottomed streams, were also numerous at both MC-2 and MC-3. They were found at 27 of 45 sites in the Broad River drainage sampled by SCDNR (Bettinger, Crane, and Bulak 2006).

Table 6. Electrofishing Catch by Species in July 2006.

	Total Number of Fish			Catch-Per-Unit-Effort		
	MC-1	MC-2	MC-3	MC-1	MC-2	MC-3
Bluehead Chub	0	36	15	---	181.5	78.9
Yellowfin Shiner	0	17	8	---	85.7	42.1
Sandbar Shiner	0	17	28	---	85.7	147.4
Redbreast sunfish	1	1	3	6.1	5.0	15.8
Creek Chub	0	1	2	---	5.0	10.5
Brassy jumprock	0	3	3	---	15.1	15.8
Tesselated Darter	0	4	3	---	20.2	15.8
Seagreen Darter	0	3	1	---	15.1	5.3
Bluegill	1	0	2	6.1	---	10.5
Largemouth Bass	0	0	1	---	---	5.3
Margined Madtom	0	1	0	---	5.0	---

Table 7. Electrofishing Catch by Species in November 2006.

	Total Number of Fish		Catch-Per-Unit-Effort	
	MC-2	MC-3	MC-2	MC-3
Bluehead Chub	50	49	254.2	267.3
Yellowfin Shiner	37	27	188.1	147.3
Sandbar Shiner	28	5	142.4	27.3
Redbreast sunfish	8	2	40.7	10.9
Creek Chub	5	1	25.4	5.5
Brassy jumprock	9	4	45.8	21.8
Tesselated Darter	1	1	5.1	5.5
Seagreen Darter	2	0	10.2	---
Greenfin shiner	4	2	20.3	10.9
Largemouth Bass	1	0	5.1	---
Piedmont darter	0	1	---	5.5

Three species were collected in minnow traps at sampling station MC-4: creek chub (11 fish), bluehead chub (4 fish), and redbreast sunfish (14 fish). The number and relative abundance of redbreast at this station were surprisingly high, given that the stream was only 2-3 feet wide when sampled and clogged with fallen leaves. All of the redbreast collected were small (49-90 mm TL) and probably moved into this small tributary when stream levels were higher and were trapped when waters receded.

Only one species (17 individuals), the creek chub, was found in the unnamed, north-flowing Mayo Creek tributary sampled (Stations MC-5 and MC-6) with minnow traps in April 2007. When sampling was conducted, there was a modest flow in some portions of this tributary, and no water (see photograph that follows) in others, making it difficult to sample. Minnow traps were placed in the four deepest pools available, and retrieved the following day. Two of the four pools contained traps with fish; these pools were designated sampling stations MC-5 and MC-6 and marked with day-glo plastic flagging, should additional sampling be conducted.

Unnamed Mayo Creek tributary stream sampled in April 2007, showing dry streambed.

The fish community structure of Mayo Creek bears a striking resemblance to those of other small Piedmont streams in Georgia and South Carolina. Yellowfin shiners (35.7 percent of total) and bluehead chubs (24.3 percent of total) dominated collections from four of five habitat types in Moore Creek, a third-order lower Piedmont stream in central Georgia (Parmley and Gaddis 2001). Cyprinids comprised 70 percent of all fish collected from Moore Creek. Three Cyprinids (bluehead chub, yellowfin shiner, creek chub) were numerically dominant in samples from two (Newberry County) South Carolina Piedmont streams in both dry (2000) and wet years (2003), but creek chubs were relatively more abundant in the wet ("post-drought") year (Keaton et al. 2005). Keaton et al. hypothesized that turbidity associated with higher rainfall and higher streamflows in 2003 drove bluehead chubs and yellowfin shiners upstream into less-turbid tributaries. They also hypothesized that deeper water created conditions more favorable to the creek chub, a large (up to 12 inches long), "aggressive," omnivorous minnow species that can feed on smaller minnows.

Most of the fish species collected in Mayo Creek and its tributaries are common species that are typically associated with streams and rivers in the Piedmont of the Carolinas and Georgia. Appendix **A** contains life history information on each of the species collected. Most fish species collected are common-to-abundant in the Broad River drainage (Bettinger, Crane, and Bulak 2006). No fish species listed by the state of South Carolina or the United States Fish & Wildlife

Service (SCDNR 2006; USFWS 2006) was collected. No fish species designated a "species of concern" by the state of South Carolina or USFWS (SCDNR 2006; USFWS 2006) was collected. Species of concern are not protected by law, but are considered by state and federal agencies in conservation planning and during project reviews.

The South Carolina Department of Natural Resources (SCDNR) has been engaged in a state-wide assessment of fisheries resources since 2002, part of a larger effort (termed the "Comprehensive Wildlife Conservation Strategy") intended to benefit the state's fish and wildlife. As part of this effort, fishes of wadeable streams in the Broad River drainage were inventoried in 2003 and 2004 (Bettinger, Crane, and Bulak 2006). Forty-five sites were sampled, yielding more than 20,000 fish specimens that represented 8 families and 45 species. Eleven of these species were assigned moderate, high, or highest "conservation priorities," meaning these species, although not protected by law, are given special attention in agency conservation planning and project reviews. Three of the species collected from Mayo Creek have been designated species of conservation concern by SCDNR: greenfin shiner (Moderate), flat bullhead (Moderate), and Piedmont darter (High).

5.0 SUMMARY

Surveys of Mayo Creek and two of its tributaries revealed a surprisingly diverse assemblage of fishes (14 species) dominated numerically by Cyprinids (minnows). Five minnow species comprised almost 81 percent of all fish collected. Three centrarchid (sunfish) species and three percid (darter) species were also present, but tended to be less abundant. Smaller numbers of catastomids (suckers; one species) and ictalurids (catfish; two species) were also present. No state- or federally-listed fish species were collected. No species designated "species of concern" by the state of South Carolina or USFWS were collected. Several uncommon fish species were collected, but none has been afforded state or federal protection.

Several species of freshwater mussel and the non-native clam *Corbicula* are found in the lower Broad River (Bettinger, Crane, and Bulak 2003) into which Mayo Creek flows. However, it appears that conditions in Mayo Creek and its tributaries are not conducive to survival and/or propagation of bivalves. Although systematic surveys of mussels and clams were not conducted, biologists were instructed to note their presence and collect specimens if any were discovered. No live specimens and no shells were observed in any of the streams surveyed

REFERENCES

Barbour, M.T., J. Gerritson, B.D. Snyder, and J. B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Macroinvertebrates, and Fish. Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Bettinger, J., J. Crane, and J. Bulak. 2003. Broad River Aquatic Resources Inventory Completion Report (Draft). Prepared by SCDNR as part of the Broad River Comprehensive Entrainment Mitigation and Fisheries Resource Enhancement Program. January 28.

Bettinger, J., J. Crane, and J. Bulak. 2006. Piedmont Stream Survey – Broad River Basin. South Carolina Department of Natural Resources, Columbia, SC.

Cooney, T.W., P.A. Drewes, S.W. Ellisor, T.H. Lanier, and F. Melendez. 2006. Water Resources Data, South Carolina. Water Year 2005. Water-Data Report SC-05-01. Publication of S.C. Water Science Center, U.S. Geological Survey, Columbia, SC.

EPA. 2007. "Water Quality Standards: State, Tribal, and Territorial Standards." Available online at http://www.epa.gov/waterscience/standards/wqslibrary/.

Hayes, G. and J. Bettinger. undated. "High Conservation Priority – Other Species." South Carolina Dept. of Natural Resources, Columbia, SC. Available on line at http://www.dnr.sc.gov/cwcs/pdfhigh/Other.pdf.

Jenkins, R.E. and N.M. Burkhead. 1994. *Freshwater Fishes of Virginia.* American Fisheries Society, Bethesda, MD.

Keaton, M., D. Haney, and C.B. Anderson. 2005. Impact of drought upon fish assemblage structure in two South Carolina Piedmont streams. Hydrobiologia 545: 209-223.

Labbe, T.R. and K. D. Fausch. 2000. Dynamics of intermittent stream habitat regulate persistence of a threatened fish at multiple scales, Ecological Applications 10(6): 1774-1791.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J. R. Stauffer. 1980. *Atlas of North American Freshwater Fishes*. North Carolina State Museum of Natural History, Raleigh, NC.

Love, J. W. 2004. Ecological and Genetic Consequences of Seasonal Drought on Stream Communities Inhabiting Pool Refugia, Doctoral Dissertation, Mississippi State University.

Magoulick, D. D. 2000. Spatial and temporal variation in fish assemblages of drying stream pools: the role of abiotic and biotic factors. Aquatic Ecology 34(1): 29-41.

Magoulick, D.D. and R. M. Kozba. 2003. The role of refugia for fishes during drought; a review and synthesis, Freshwater Biology 48(7): 1186-1198.

Marcy, B.C., D. E. Fletcher, F. D. Martin, M. H. Paller, and M.J.M. Reichert. 2005. *Fishes of the Middle Savannah River Basin*. The University of Georgia Press, Athens.

NCDWQ (North Carolina Division of Water Quality). 1999. Stream Fish Community Structure Assessment. North Carolina Department of Environment and Natural Resources, Division of Water Quality, Raleigh. Available on line at http://www.esb.enr.state.nc.us/BAUwww/IBI%20Methods%202.pdf.

Parmley, D. and G. Gaddis. 2001. A survey of the Moore Creek fish fauna, Baldwin County, Georgia. Georgia Journal of Science 59: 137-146.

Potapova, M. and D. F. Charles. 2003. Distribution of benthic diatoms in U.S. rivers in relation to conductivity and ionic composition. Freshwater biology 48(8): 1311-1328.

Rohde, F. 1998. 1998 Report of Region–Northeast. Southeastern Fishes Council. Available on line at http://www.flmnh.ufl.edu/fish/organizations/sfc/RegionalReports/R1NE1998.htm.

South Carolina Department of Natural Resources. 2006. South Carolina Rare, Threatened, and Endangered Species Inventory: all species found in South Carolina. Available on line at https://www.dnr.sc.gov/pls/heritage/county_species.list?pcounty=all.

USFWS (United States Fish and Wildlife Service). 2006. South Carolina Distribution Records of Endangered, Threatened, Candidate and Species of Concern. Prepared by Ecological Services office of USFWS, Last updated March 2006.

APPENDIX A

SPECIES DESCRIPTIONS

Cyprinidae (carps and minnows)

Greenfin shiner. Medium-sized (to 72 mm SL) minnow found above Fall Line in Upper Piedmont of South Carolina and North Carolina (Lee et al. 1980; Bettinger undated). Endemic to Santee Drainage, which includes three major river systems in South Carolina --- the Wateree, the Broad, and the Saluda. Greenfin shiners are found in creeks and small rivers with cool, clear water (Bettinger undated). In these habitats, prefers the slower areas and margins of pools and runs with clean sand and rocky substrates. North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the species as an insectivore and rates its pollution tolerance as "intermediate" (NCDWQ 1999).

Bluehead chub. Common, thick-bodied (up to 214 mm SL) minnow found in Piedmont and mountain streams from South Branch of Potomac River in Virginia to Altamaha River, Georgia (Lee et al. 1980). Found in a variety of habitats from cool, high-gradient and clear streams to warm, lower-gradient, turbid streams. Substrates in these streams can range from bedrock to silt. North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the species as an omnivore and rates its pollution tolerance as "intermediate" (NCDWQ 1999).

Yellowfin shiner. Small to medium-sized (60 mm SL max) minnow found in Santee River drainage (SC), Savannah River drainage (SC-Ga), and Altamaha River drainage (Ga) (Lee et al 1980). Generally found in small, clear headwater streams; where found, often abundant. North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the species as a "specialized insectivore" and rates its pollution tolerance as "intermediate" (NCDWQ 1999).

Sandbar shiner. Medium-sized (50-75 mm SL) minnow found in Blue Ridge foothill and Piedmont streams, from Cape Fear drainage (N.C.) to Savannah drainage (S.C. and Georgia) (Lee et al. 1980). Typically inhabits pools of small-to-medium size streams with sandy substrates. North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the species as a "specialized insectivore" and rates its pollution tolerance as "intermediate" (NCDWQ 1999).

Creek chub. Large (to 305 mm TL) minnow found in ponds, creeks, and rivers throughout the eastern and Midwestern U.S. and, less commonly, in Great Plains and Prairie Provinces of Canada (Lee et al. 1980). Found in streams and river across the Piedmont of North and South

Carolina. Most abundant in small streams and brooks; less abundant in shallows of lakes and impoundments. North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the species as an insectivore and rates it as "tolerant" of pollution (NCDWQ 1999). Lee et al. (1980) and most other authorities describe it as a sight-feeding omnivore that eats algae, insects, and even small fish.

Catastomidae (suckers)

Brassy jumprock. This as yet-undescribed species was created when the taxonomy of the genus *Moxostoma* was re-examined by Dr. Robert Jenkins in 1990s (Rohde 1998). Formerly known as the "smallfin redhorse" (*Moxostoma robustum*), this species was placed in the genus *Scartomyzon,* while the newly-named robust redhorse inherited the Latin name *Moxostoma robustum*. Found from the Cape Fear River drainage in North Carolina to the Altamaha River drainage in Georgia in medium-sized streams to large rivers with varied substrates ((Marcy et al. 2005). North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the brassy jumprock as an insectivore and rates its pollution tolerance as "intermediate" (NCDWQ 1999).

Ictaluridae (freshwater catfishes)

Margined madtom. Small catfish (47-90 mm SL) that ranges from New Hampshire to Georgia. Found chiefly in clearwater streams with moderate current. More abundant in riffle areas with gravel-rubble substrates. North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the species as an insectivore and rates its pollution tolerance as "intermediate" (NCDWQ 1999).

Flat bullhead. Medium-sized catfish (179-286 mm TL) found in Piedmont and Coastal Plain streams from southern Virginia to Georgia (Lee et al. 1980). Within these streams, adults occur mostly in low-flow areas with silty, muddy, or sandy bottoms while young tend to inhabit areas with higher flow and clearer water. North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the species as an insectivore and rates it as "tolerant" of pollution (NCDWQ 1999).

Centrarchidae (sunfishes)

Redbreast sunfish. Common sunfish that is found in Coastal Plain and Piedmont streams and rivers from Canada to Florida (Lee et al. 1980; Jenkins and Burkhead 1994). Found most often in pools and backwaters of these streams and rivers in water that may be clear to turbid. Also found in ponds, oxbow lakes, and large impoundments. North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the species as an insectivore and rates it as "tolerant" of pollution (NCDWQ 1999).

Bluegill. Common sunfish that is found in streams, rivers, ponds, lakes, and impoundments across the eastern and midwestern U.S. Found in all southeastern waters except high-gradient trout streams in Appalachians (Jenkins and Burkhead 1994; Marcy et al. 2005). North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the bluegill as an insectivore and rates its pollution tolerance as "intermediate" (NCDWQ 1999).

Largemouth bass. Popular sport fish that is found throughout the U.S. and has been introduced to Central America, South America, and parts of Europe. Inhabits streams, rivers, ponds, and impoundments throughout its range, but is most often associated with the weedy shallows of ponds and impoundments. More tolerant of turbidity than other black basses and less tied to flowing water (Marcy et al. 2005). North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies this aggressive predator as a piscivore and rates its pollution tolerance as "intermediate" (NCDWQ 1999). Although largely piscivorous, largemouth bass also eat insects, crayfish, frogs, snakes, mice, baby birds and "almost any other animal of appropriate size that has fallen in or is swimming in the water" (Marcy et al. 2005).

Percidae (perches/darters)

Tesselated darter. One of the most widely-distributed North American darters, found from Quebec to Georgia (Lee et al. 1980). Common in streams and larger, low-gradient rivers under a variety of temperature and water-clarity conditions (Jenkins and Burkhead 1994). Also found in brackish water in estuaries. Typically found in pools and calmer areas; avoids riffles. Found on substrates ranging from mud to clean gravel to rubble (Jenkins and Burkhead 1994). North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the species as a "specialized insectivore" and rates its pollution tolerance as "intermediate" (NCDWQ 1999).

Seagreen darter. Restricted to the Santee Drainage of North and South Carolina (Lee et al. 1980). Within the Santee Drainage it is found in all the major river systems --- Saluda, Broad, Catawba, Congaree, and Wateree (Lee et al. 1980; Hayes and Bettinger undated). More common in Blue Ridge foothills and upper Piedmont streams over rubble, cobble and bedrock; less common in lower Piedmont and upper Coastal Plain. North Carolina Department of Environment and Natural Resources' Division of Water Quality classifies the species as a "specialized insectivore" and rates it as "intolerant" of pollution (NCDWQ 1999).

Piedmont darter. The Piedmont darter is found primarily in North and South Carolina in the Cape Fear, Pee Dee, and Santee drainages (Lee et al. 1980). There are a few populations in south-central Virginia, just north of the North Carolina state line (Jenkins and Burkhead 1994). The species prefers moderate-gradient creeks, streams, and rivers. It is commonly associated with rubble and gravel riffles and runs. North Carolina Department of Environment and Natural

Resources' Division of Water Quality classifies the species as a "specialized insectivore" and rates it as "intolerant" of pollution (NCDWQ 1999).