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CURRENT STATUS OF FRESHWATER MUSSEL POPULATIONS IN THE CLINCH RIVER AT THE APPALACHIA POWER COMPANY'S CLINCH RIVER STEAM PLANT, RUSSELL COUNTY, VIRGINIA (CLINCH RIVER MILES 268.3-264.2)

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ABSTRACT

This study involved assessing the current status of mussel populations in the Clinch River downstream from the Clinch River steam plant located near Carbo, Virginia. Two major catastrophic polluting events occurred here in 1967 (fly ash spill) and 1970 (sulfuric acid spill). Both spills are reported to have severely impacted mollusk, fish, and benthic macro-invertebrate populations downstream a considerable distance below the power plant. Mussel sampling in 1985 documented total elimination of the fauna except in an isolated area previously affected by the spill. Based on the number of mussel species found in 1985 (14) and larger size-classes of mussels measured, it was determined that mussels do not repopulate that quickly and some may have survived. Recent sampling reported 16 mussel species throughout the study area including three federally listed mussels and one fish: *Fusconaia cor* (live), *F. cuneolus* (relic), and *Quadrula cylindrica strigillata* (live); *Noturus flavipinnis* (live). Mussels are actively recruiting based on size-class information and upgrades to the power plant's effluent waste discharge are largely responsible for mussel recovery below the plant.

Key words: Clinch River, fly ash and sulfuric acid spill, mussel recovery, Unionidae, endangered species.

INTRODUCTION

The Clinch River is a headwater tributary of the Tennessee River located in the mountainous ridge and valley region of southwestern Virginia. The river flows south for 148 river miles (238 km) where it enters eastern Tennessee just downstream from Speer's Ferry, Virginia.

The river is nationally recognized for its rich biodiversity of mollusks and fish and at present represents imperiled seed stock that exists for faunal restoration in other streams in the Tennessee and Cumberland River drainages. In terms of the rivers high species diversity and endemism, The Nature Conservancy (TNC) lists the Clinch River as "one of its last great places."

A long list of environmental perturbations (Ahlstedt *et al.,* 2005) and unregulated water pollution have been documented prior to the passage of the Clean Water Act of 1972, which cumulatively has had a major affect on biological communities in the river from the 1870s to the present. From a historical perspective it is perhaps surprising that these biological communities survived the extensive logging of the watershed, agricultural development, coal extraction (surface and deep mining), railroad construction, domestic and industrial waste discharges, habitat loss and habitat fragmentation from impoundment of the lower river in 1937. Studies of the Clinch River from 1964-1969 indicate that the river was considered relatively clean and productive except in localized areas where abundance of fish and invertebrates was negatively impacted by industrial and domestic pollutants below Tazewell and Carbo, Virginia (Wollitz, 1966, 1968). Raleigh *et al.* (1978) also listed major sources of pollution in the upper Clinch

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River, Virginia from industry, mining and domestic wastes. Hence, the continued occurrence and recovery of mollusk and fish populations in certain reaches of the upper Clinch in regards to this study demonstrates that if the water quality is allowed to improve over time and fish hosts are present, mollusk populations will survive and re-colonize previously degraded areas.

At various sampling locations in the Clinch River upstream from St. Paul, Virginia, the occurrence and diversity of freshwater mussels are well known. A total of 44 species are documented in this reach of the river with a sampling time span dating from 1899-1985 (Stansbery *et al.,* 1986). More recent studies of the upper Clinch River upstream from St. Paul include status surveys (Ahlstedt 1991; Church 1991; Winston & Neves, 1997; Watson, 1999; Jones *et al.,* 2001) and site specific monitoring of freshwater mussels at TNC's Cleveland Islands Mussel Preserve (Ahlstedt & Tuberville, 1997; N. Eckert, pers. comm. 2008). At least 25 mussel species are extant at Cleveland Islands (Clinch River Mile CRM 270.9) just upstream from the study area based on monitoring from 2002-2008 (N. Eckert, pers. comm. 2008) and at least 25 species were known to occur in the river (1981-1982) just downstream from St. Paul (CRM 253.5-254.1) (Ahlstedt, 1991).

The objectives of the current study were to: (1) determine the status and abundance of freshwater mussel populations in the Clinch River below the electric power plant near Carbo, Virginia, (2) assess for the presence or absence of mussel recruitment (i.e., small size-classes <30 mm), (3) obtain additional quantitative data to monitor water quality in the upper river, and (4) determine the habitat suitability and availability for restoring mussel populations.

Background

The Appalachian Electric Power Company is a subsidiary of American Electric Power (AEP) based in Columbus, Ohio. As owners of the Clinch River Steam Plant, the plant began producing coal-fired steam-electric power production on the Clinch River in 1958 with its first two generating units. A third unit was added in 1961 and total generating capability of the three units is 705 megawatts (MW). The plant uses several hundred thousand tons of coal annually from surface mining operations that are supplied by a mix of suppliers through long-term contracts and spot purchases. In terms of water usage, the plant withdraws approximately 12 million gallons per day (mg/d) from the Clinch River and approximately 7 mg/d are lost to evaporation from cooling towers, with about 5 mg/d returned to the river (J. Van Hassle, AEP, pers. comm.).

The Clinch River Steam Plant is located in a mountainous region of the river near Carbo in Russell County, Virginia. Large quantities of fly ash are produced as a by-product during the burning of coal for power production and large quantities of water are needed to remove ash from furnace hoppers. The slurry produced is then pumped to settling lagoons where the ash settles and the supernatant is recycled. The power plant was responsible for two catastrophic chemical spills that severely affected biological communities in the river. The first spill occurred on June 10, 1967, when a 75-225 m section of a dike surrounding a fly ash settling lagoon collapsed and within an hour, 198 million m^3 of caustic alkaline slurry fly ash and water (pH 12.0-12.7) flowed into Dump's Creek, a tributary stream on the opposite side of the river across from the power plant (Clinch River Mile CRM 267.9) (Cairns *et al.,* 1971). The slug of caustic water equaled 40% of the daily flow of the river and blocked normal flow for several minutes. The slug raised the normal water levels in the river several meters forcing waste upstream 0.5 miles (CRM 268.4) from the confluence of Dump's Creek. The high pH of alkaline water was composed of 90% hydroxide alkalinity and 10% carbonate alkalinity (Cairns *et al.,* 1971). A

secondary effect which may have contributed to the biological damage was a depression in the dissolved oxygen concentration caused by the decaying organic matter (Anonymous, 1967). The Virginia State Water Control Board assessed damage to benthic fish food organisms ten days after the spill (Anonymous, 1967). Their findings include 1) bottom dwelling fish food organisms appeared to have been completely eliminated for a distance of approximately 3-4 miles (5-7 km) below the spill, 2) the spill affected bottom dwelling fish food organisms in the Clinch River for 75 miles (120 km) below the spill, 3) snails and mussels were eliminated for 11 miles (18 km) below Carbo, and 4) it was predicted that the stream would recover to its former productive capacity within three months after the spill and would include fish stocking (Raleigh *et al.,* 1978). Two years following the spill, benthic organisms had substantially recovered in a linear recovery pattern which included mollusks at sampling stations located l1 miles (18 km) downstream from the spill but sampling stations closest to the site of the spill had not recovered (Cairns *et al.,* 1971). They further reported that the failure for mollusks to re-colonize was due to their inability to reinvade and re-colonize areas as fast as aquatic insects and sampling sites closest to the plant may be affected by the power plant's waste discharge.

A second industrial spill occurred at the power plant on June 19, 1970 involving the release of an undetermined amount of sulfuric acid into the Clinch. The acid spill lowered the pH of the river and killed approximately 5,300 fish. The spill occurred approximately 0.6 miles (1 km) below the plant and extended downstream a distance of 13 miles (21 km) to St. Paul, Virginia. Recovery was apparently rapid for all faunal groups except mollusks (Cairns *et al.,* 1971, Crossman *et al.,* 1973).

The fly ash and sulfuric acid spills of 1967 and 1970 are reported in the literature to have eliminated snails and unionids (freshwater mussels) for 11 miles (18 km) below Carbo (Crossman *et al.,* 1973). In terms of river mile locations where mollusks were eliminated, the spill extended in the Clinch River 0.5 miles upstream from Dump's Creek (CRM 268.4) and downstream to St. Paul (CRM 257.2). The damage to mollusks during the acid spill of 1970 was not considered because it was determined that they had not become re-established there following the 1967 spill.

In 1981 and 1984, seven mussel species were reintroduced by translocations to the Clinch River at three locations (CRM 261.6, 264.1 and 264.8) within the area affected by the spills (Sheehan *et al.,* 1989). The purpose was to assess the feasibility of translocations as a method for re-establishing the mussel fauna to formerly polluted reaches of the river. Sheehan reported high mussel mortalities, especially in 1981, occurring at all sites where reintroductions occurred.

Stansbery *et al.* (1986) under contract to AEP evaluated the mussel fauna in the Clinch River from Carterton Bridge (CRM 264.0) upstream to Cleveland (CRM 270). They reported 23 live and fresh dead mussel species including numerous relicts in their study. However, sampling locations 0.5 mile upstream from Dump's Creek (CRM 268.4) to Cleveland (CRM 270.0) are outside the boundaries of the spill area. Within the immediate boundaries of the spill area during their study (CRM 268.4-264.0), 16 live species and numerous relicts were found in 1985 during qualitative sampling at CRM 267.0-267.4, CRM 267.5-267.7, and CRM 268.2-268.4 including 14 live species present below the confluence of Dump's Creek (CRM 267.0-267.4). With the exception of one live *Fusconaia cor* (Conrad, 1834), no living mussels were found in the river stretch influenced by effluent from the power plant's outfalls 003, 004, and 005 located below the plant on the left descending side of the river. Sheehan *et al.* (1989) later concluded with Stansbery's findings that water quality may still be a problem in the Clinch River affecting mussel re-colonization below the power plant.

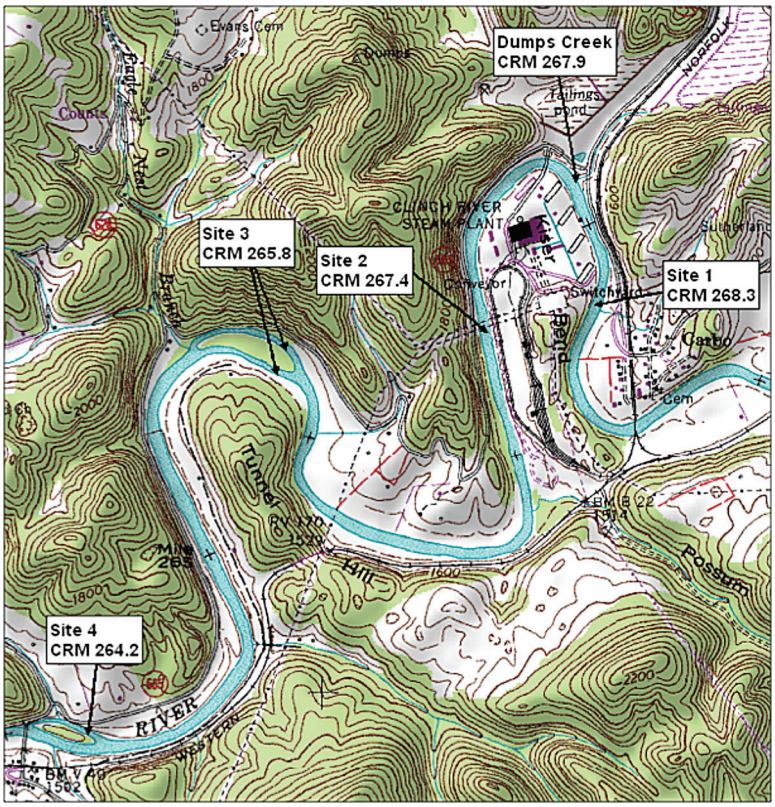

Figure 1— Freshwater mussel monitoring in the Clinch River in the vicinity of the Clinch Steam Plant below Carbo, Russell County, Virginia.

MATERIALS AND METHODS

During June 2008, 4.1 miles (2.6 km) of the upper Clinch River (CRM 264.2-268.3) was surveyed for freshwater mussels at four sites located in the immediate reach of the river affected by the 1967 and 1970 spills both upstream and downstream from the power plant (Fig. 1). Sampling areas were selected based on habitat suitable for mussel colonization and in close proximity to previous 1985 sampling (Stansbery *et al.,* 1986). Sampling did not extend upstream to Cleveland because this was outside the boundary of the spill. Following is a brief description of the four sites sampled:

Site 1 (CRM 268.3) is located immediately upstream of Dump's Creek (CRM 267.9), 0.4 mile from the confluence, directly across the river and upstream from the cooling towers of the plant. This location was in the area impacted by the 1967 caustic slug that was reported to have backed-up river flow 0.5 mile upstream (CRM 268.4). Sampling was done on the right descending bank in riffle and run habitat upstream from the plants cooling towers. GPS Coordinates: 36.5551N-82.1144W.

Site 2 (CRM 267.4) is located in the main channel of the river downstream from plant directly under the power line crossing. This reach consisted of some of the best and most extensive mussel habitat observed. GPS Coordinates: 36.5541N-82.1204W.

Site 3 (CRM 265.8) is an unnamed island upstream from the confluence of Eagle Nest Branch. Sampling was done at the head of the right descending bank side of the island in riffle run habitat. This site also was sampled on the main river side (left descending side of the island) but habitat was considered more embedded. GPS Coordinates: 36.5543N-82.1251W.

Site 4 (CRM 264.2) is an unnamed island that extends downstream on the right descending bank under Carterton Bridge. Sampling was done at the head of the island extending downstream along the right bank to the bridge. GPS Coordinates: 36.5454N-82.1306W.

The sites selected for sampling were based on availability of riffle and run habitat containing suitable substrates for freshwater mussels and all four sampling sites are located in the immediate impact area defined in the 1967 and 1970 chemical spills. Data were collected by systematic 0.25 m^2 quadrat sampling placed along transect lines. Both quadrats and transects were evenly spaced throughout the entire shoal area. Total square area (m^2) of mussel beds was determined by multiplying mean river width, measured at 10 m intervals by total length of the reach sampled. Site dimensions (length and width) were measured using a standard 100 m measuring tape. Upstream and downstream limits of the bed were determined by visually inspecting for substrate composition (e.g., an abrupt change from suitable gravel substrate to unsuitable bedrock or soft sediments), water depth, flow velocity, and absence of mussels. All 0.25 m^2 quadrats were excavated to hardpan or to approximately 20 cm in depth. Both quantitative and qualitative (timed search) were done by snorkel equipped divers. Quantitative mussel sampling and data analysis followed procedures established by Jones & Neves (2008). Qualitative sampling consisted of timed searches where spatial coverage was needed for finding mussels in areas of the river that have low population densities, low diversity or rare species.

All live mussels (no fresh dead observed) were measured in millimeters (mm) with a dial caliper for total shell length (anterior-posterior). The presence of smaller sized individuals (<30 mm) is indicative of successful reproduction and recruitment within the last couple of years. All live individuals were returned back to the approximate location from where they were collected.

Sampling sites were identified by latitude and longitude (degrees, minutes, seconds) using a hand-help Global Positioning System (GPS) unit. Locations also were identified by roads, bridges, islands, and towns using U.S. Geological Survey (USGS) 7.5 minute topographic maps.

RESULTS AND DISCUSSION

Freshwater mussels were sampled in 2008 at four sites in the Clinch River in the vicinity of the Carbo power plant (Fig. 1). Sampling began approximately 25 m downstream from Carterton Bridge (site 4) and no sampling was done at sites farther downstream due to access and non-availability of suitable habitat which consisted of long pools and bedrock. A total of 510 (0.25 m^2) quadrat samples were collected including timed qualitative snorkel searches. Sixteen mussel species were found in the study area including three federally listed mussels, *Fusconaia cor* (live), *F. cuneolus* (Lea, 1840) (relict), and *Quadrula cylindrica strigillata* (Wright, 1898) (live) found at sites 1 and 2. One live *F. cor* (age 5 years) and *Lasmigona costata* (Rafinesque, 1820) also was reported in 2007 at site 4 during qualitative sampling but none found during the 2008 study. Three individuals of the federally threatened yellowfin madtom, *Noturus flavipinnis* (Taylor, 1969) were observed at site 2, including a male guarding an egg clutch. Spiny riversnails, *Io fluvialis* (Say, 1825), also were observed at this site.

Summary statistics for each sampling site are presented in Tables 1-4 including shell length measurement data. A comparison of sampling results from 1985 (Stansbery *et al.,* 1986) with the current study are presented in Table 5. Table 6 is a listing of mussel records dating from 1899-1985 reported by Stansbery as occurring in the upper Clinch upstream from St. Paul, Virginia and includes mussels documented in the river at St. Paul 1979, 1981-1982 (Ahlstedt, 1991) and Cleveland (1985-present) (Ahlstedt, 1991; Ahlstedt & Tuberville, 1997; N. Eckert, pers. comm.).

Concerning this study, mussel populations are currently re-colonizing this reach of the Clinch River below the power plant based on quantitative and qualitative sampling, size-class measurement data, and comparison with previous 1985 sampling (Tables 1-5). Mussel habitat appears restricted to the sides of the river or back-side of islands except at site 2 where some of the best habitat exists across the width of the river channel located immediately downstream from the power plant. This is the same general location where Stansbery *et al.* (1986) reported 14 live and fresh dead mussels along the right descending bank downstream from Dump's Creek. Comparisons were made with Stansbery's survey and recent 2008 sampling locations in the immediate area affected by the spills (CRM 268.4-264.0). No sampling was done during 2008 farther upstream outside the perceived spill area.

Table 1— Summary of 100 (0.25 m^2) quantitative quadrat samples and qualitative sampling for freshwater mussels and shell length measurement data in the Clinch River (Site 1, CRM 268.3) upstream from AEP, Russell County, Virginia (2008).

				Shell length (mm)	
	Quant.	Qual.	Total	(range)	(mean)
Actinonaias pectorosa	10	15	25	75-114	(91.6)
Elliptio dilatata	8	15	23	41-92	(68.9)
Fusconaia barnesiana	3	1	4	35-55	(46.8)
Medionidus conradicus	7	5	12	31-50	(39.3)
Ptychobranchus fasciolaris	3	1	4	52-90	(75.0)
Ptychobranchus subtentum	-	1	1	80	(80.0)
Quadrula c. strigillata	2	-	2	70	(70.0)
Villosa iris	-	3	3	46-66	(56.7)
Villosa vanuxemensis	1	-	1	22	(22.0)
TOTAL 34	41	75			

SUMMARY STATISTICS FOR 100 QUADRAT SAMPLES COLLECTED RIGHT DESCENDING HALF OF RIVER: Site dimensions 100 m length x 15 m width. MD: mean density (per 0.25 m^2 and 1.0 m^2), SD: standard deviation, SE: standard error, CV: coefficient of varation, CI: confidence interval; lower and upper 95% CI apply to MD per 0.25 m^2.

	MD 0.25 m^2	MD m^2	SD	SE	CV of SE (Precision)	lower 95% CI	upper 95% CI
A. pectorosa	0.10	0.40	0.30	0.030	0.30	0.041	0.16
E. dilatata	0.08	0.32	0.27	0.027	0.34	0.027	0.13
F. barnesiana	0.03	0.12	0.17	0.017	0.57	-0.004	0.06
M. conradicus	0.07	0.28	0.38	0.038	0.54	-0.005	0.15
P. fasciolaris	0.03	0.12	0.17	0.017	0.57	-0.004	0.06
Q. c. strigillata	0.02	0.08	0.14	0.014	0.70	-0.008	0.05
V. vanuxemensis	0.01	0.04	0.10	0.010	1.00	-0.010	0.03
	0.34	1.36	0.65	0.065	0.19	0.21	0.47

Recent sampling produced 16 live mussel species; Stansbery in 1985 reported 17. Five, reported by Stansbery were not found during the present study: *Alasmidonta marginata* Say, 1818, *Lampsilis cardium* Rafinesque, 1820, *Leptodea fragilis* (Rafinesque, 1820), *Potamilus alatus* (Say, 1817), and *Strophitus undulatus* (Say, 1817); and four were not found by Stansbery: *Lampsilis ovata* (Say, 1817), *Pleurobema oviforme* (Conrad, 1834), *Ptychobranchus subtentum* (Say, 1825), and *Q. c. strigillata*. Both quantitatively and qualitatively mussels exist at all four 2008 sampling sites including eight species present at CRM 264.2 and 11 at CRM 265.8 but none were reported by Stansbery at these locations in 1985. Most of Stansbery's mussels were found during qualitative sampling at CRM 267.0-267.4, CRM 267.5-267.7, and CRM 268.2-268.4 and only two found in quantitative sampling at CRM 267.0: *Potamilus alatus* (1 live) and *Villosa iris* (Lea, 1829) (2 live). With the exception of one live *F. cor* reported by Stansbery, no living mussels were found in the river influenced by effluent from the power plant's outfalls 003, 004, and 005 located along the power plant's left descending side of the river. Only one sampling site (CRM 267.4) was comparable between the two surveys that contained good species diversity and relatively high numbers present but present diversity and total numbers found are significantly different (Table 5).

Based on our review of Stansbery's 1985 survey results which included size data on the live mussels found, it appears unlikely that all freshwater mussels were eliminated during the

Table 2— Summary of 170 (0.25 m^2) quantitative quadrat samples and qualitative sampling for freshwater mussels and shell length measurement data in the Clinch River (Site 2, CRM 267.4) immediately downstream from AEP, Russell County, Virginia (2008).

	Quant.	Qual.	Total	Shell length (mm) (range)	(mean)
Actinonaias pectorosa	2	5	7	77-110	96
Amblema plicata	-	1	1	78	78
Elliptio dilatata	9	15	24	41-82	59
Fusconaia barnesiana	-	1	1	48	48
Fusconaia cor	1	1	2	21-63	42
Fusconaia subrotunda	-	2	2	55-67	61
Lampsilis ovata	-	1	1	84	84
Medionidus conradicus	30	50	80	22-51	36
Pleurobema oviforme	-	1	1	58	58
Ptychobranchus fasciolaris	3	3	6	45-88	66
Quadrula c. strigillata	-	1	1	82	82
Villosa iris	11	10	21	28-60	41
Villosa vanuxemensis	-	1	1	54	54
TOTAL	56	92	148		

SUMMARY STATISTICS FOR 100 QUADRAT SAMPLES COLLECTED LEFT DESCENDING HALF OF RIVER: Site dimensions 200 m length x 20 m width. Abbreviations as in Table 1.

	MD 0.25 m^2	MD m^2	SD	SE	CV of SE (Precision)	lower 95% CI	upper 95% CI
E. dilatata	0.02	0.08	0.14	0.014	0.7	-0.008	0.05
F. cor	0.01	0.04	0.10	0.010	1.0	-0.010	0.03
M. conradicus	0.10	0.40	0.30	0.030	0.3	0.041	0.16
P. fasciolaris	0.01	0.04	0.10	0.010	1.0	-0.010	0.03
V. iris	0.05	0.20	0.22	0.022	0.4	0.007	0.09
	0.19	0.76	0.42	0.042	0.2	0.110	0.27

SUMMARY STATISTICS FOR 70 QUADRAT SAMPLES COLLECTED RIGHT DESCENDING HALF OF RIVER: Site dimensions 130m length x 20m width. Abbreviations as in Table 1.

	MD 0.25 m^2	MD m^2	SD	SE	CV of SE (Precision)	lower 95% CI	upper 95% CI
A. pectorosa	0.02	0.11	0.24	0.029	1.00	-0.03	0.08
E. dilatata	0.10	0.40	0.35	0.041	0.41	0.02	0.18
M. conradicus	0.28	1.14	0.62	0.074	0.26	0.14	0.43
P. fasciolaris	0.02	0.11	0.17	0.020	0.70	-0.01	0.07
V. iris	0.08	0.34	0.33	0.039	0.46	0.01	0.16
	0.52	2.11	1.05	0.125	0.24	0.28	0.77

spills of 1967 and 1970. The presence of 14 mussel species (152 live individuals of which some were adults based on Stansbery's size-class data) found in 1985 (Table 5) in the immediate impact zone along the right descending bank downstream from Dump's Creek suggests species survived. It appears doubtful that mussels could re-establish themselves that quickly and only be limited to this location in the river. The kill was reported to extend downstream to St. Paul,

Table 3— Summary of 120 (0.25 m^2) quantitative quadrat samples and qualitative sampling for freshwater mussels and shell length measurement data in the Clinch River (Site 3, CRM 265.8) at island upstream from Eagle Nest Branch, Russell County, Virginia (2008).

	Quant.	Qual.	Total	Shell length (mm) (range)	(mean)
Actinonaias pectorosa	3	1	4	63-88	76
Amblema plicata	-	2	2	92-110	101
Elliptio dilatata	16	5	21	41-86	61
Fusconaia barnesiana	1	-	1	-	-
Fusconaia subrotunda	1	3	4	36-62	47
Lampsilis fasciola	2	-	2	45-58	51
Lampsilis ovata	2	-	2	79-86	82
Medionidus conradicus	8	3	11	19-45	38
Ptychobranchus fasciolaris	3	3	6	45-82	62
Villosa iris	8	1	9	47-57	48
Villosa vanuxemensis	1	-	1	31	31
TOTAL	45	18	63		

SUMMARY STATISTICS FOR 60 QUADRAT SAMPLES COLLECTED LEFT DESCENDING MAIN RIVER SIDE OF THE ISLAND: Site dimensions 60 m length x 30 m width. Abbreviations as in Table 1.

	MD 0.25 m^2	MD m^2	SD	SE	CV of SE (Precision)	lower 95% CI	upper 95% CI
A. pectorosa	0.01	0.06	0.13	0.017	1.00	-0.016	0.049
M. conradicus	0.01	0.06	0.13	0.017	1.00	-0.016	0.049
	0.03	0.13	0.18	0.023	0.70	-0.012	0.079

SUMMARY STATISTICS FOR 60 QUADRAT SAMPLES COLLECTED UPPER RIGHT DESCENDING SIDE OF ISLAND: Site dimensions 40 m length x 20 m width. Abbreviations as in Table 1.

	MD 0.25 m^2	MD m^2	SD	SE	CV of SE (Precision)	lower 95% CI	upper 95% CI
A. pectorosa	0.03	0.13	0.18	0.023	0.70	-0.012	0.079
E. dilatata	0.26	1.06	0.55	0.071	0.26	0.128	0.405
F. barnesiana	0.01	0.06	0.13	0.017	1.00	-0.016	0.049
F. subrotunda	0.01	0.06	0.13	0.017	1.00	-0.016	0.049
L. fasciola	0.03	0.13	0.18	0.023	0.70	-0.012	0.079
L. ovata	0.03	0.13	0.18	0.023	0.70	-0.012	0.079
M. conradicus	0.11	0.46	0.37	0.048	0.41	0.022	0.211
P. fasciolaris	0.05	0.2	0.22	0.028	0.57	-0.006	0.106
V. iris	0.13	0.53	0.47	0.060	0.45	0.015	0.252
V. vanuxemensis	0.01	0.06	0.13	0.017	1.00	-0.016	0.049
	0.71	2.86	1.04	0.134	0.19	0.453	0.980

Table 4— Summary of 120 (0.25 m^2) quantitative quadrat samples and qualitative sampling for freshwater mussels and shell length measurement data in the Clinch River (Site 4, CRM 264.2) at Carterton Island Bridge, Russell County, Virginia (2008).

	Quant.	Qual.	Total	Shell length (mm) (range)	(mean)
Actinonaias pectorosa	7	3	10	61-89	76
Elliptio dilatata	11	2	13	41-86	57
Fusconaia barnesiana	1	-	1	48	-
Lampsilis fasciola	3	-	3	59-66	62
Medionidus conradicus	37	4	41	21-52	37
Ptychobranchus fasciolaris	6	-	6	36-91	70
Villosa iris	14	9	23	23-57	35
Villosa vanuxemensis	1	-	1	61	61
TOTAL	80	18	98		

SUMMARY STATISTICS FOR 120 QUADRAT SAMPLES COLLECTED UPPER RIGHT DESCENDING SIDE OF ISLAND: Site dimensions 100 m length x 12 m width. Abbreviations as in Table 1.

	MD 0.25m^2	MD m^2	SD	SE	CV of SE (Precision)	lower 95% CI	upper 95% CI
A. pectorosa	0.05	0.23	0.24	0.241	0.37	0.016	0.100
E. dilatata	0.09	0.36	0.34	0.031	0.34	0.030	0.153
F. barnesiana	0.01	0.03	0.09	0.008	1.00	-0.008	0.025
L. fasciola	0.03	0.10	0.16	0.014	0.57	-0.003	0.053
M. conradicus	0.30	1.23	0.58	0.052	0.17	0.205	0.412
P. fasciolaris	0.05	0.20	0.22	0.020	0.40	0.011	0.089
V. iris	0.11	0.46	0.32	0.029	0.25	0.059	0.174
V. vanuxemensis	0.01	0.03	0.09	0.008	1.00	-0.008	0.025
	0.66	2.66	0.84	0.077	0.12	0.516	0.818

but immediately below St. Paul 25 mussel species (2,243 live individuals) were present during a mussel removal project in 1981 and 1982 (Ahlstedt, 1991). Apparently, the caustic slug was neutralized enough to allow for the survival of mussels just below St. Paul. Given the absence of mussels in 1985 throughout the rest of the river sampled downstream from the power plant to Carterton Bridge, there is no doubt this reach also was heavily impacted by the spills but also by ongoing chronic water quality problems originating from plant outfalls 003, 004, and 005 (Stansbery *et al.,* 1986; Sheehan *et al.,* 1989). However, a few individuals of *P. alatus* and *V. iris* either survived or re-colonized this reach post-1970 (Stansbery *et al.,* 1986). Likely sources for the present re-colonization of this reach includes the 14 species and/or other mussels that may have survived the spill including mussels extant in 1981 and 1982 downstream from St. Paul (25 species, current status unknown) and upstream at the TNC's Cleveland Island's Mussel Preserve (25 species, currently extant).

An advanced wastewater treatment plant was completed at the Clinch River Steam Plant in June 1993 at a cost of approximately 12 million dollars. This new facility was designed to remove trace metals to very low levels including copper which was a contaminant of major concern from a toxicity standpoint to mollusks. Copper levels were reduced from >100 parts per billion (ppb) in the discharge prior to the treatment plant upgrade, to <10 ppb currently (J. Van

Table 5— Quantitative and qualitative freshwater mussel sampling in the Clinch River (CRM 264.0-268.3) in the vicinity of the Clinch River steam plant Russell County, Virginia. [**S**-Stansbery, 1985; **A**-Ahlstedt *et al.,* 2008]

	264.0 **S**-quant.	264.0 **A**-quant.	**A**-qual.	264.0-264.1 **S**-qual.	264.1-264.2 **S**-qual.	264.9-265.0 **S**-qual.	265.0 **S**-quant.	265.7-266.2 **S**-qual.	265.8 **A**-quant.	**A**-qual.	266.0 **S**-quant.	267.0 **S**-quant.
Actinonaias pectorosa	-	7	3	-	-	-	-	-	3	1	-	-
Alasmidonta marginata	-	-	-	-	-	-	-	-	-	-	-	-
Amblema plicata	-	-	-	-	-	-	-	-	-	2	-	-
Elliptio dilatata	-	11	2	-	-	-	-	-	16	5	-	-
Fusconaia barnesiana	-	1	-	-	-	-	-	-	1	-	-	-
Fusconaia cor	-	-	-	-	-	-	-	-	-	-	-	-
Fusconaia subrotunda	-	-	-	-	-	-	-	-	1	3	-	-
Lampsilis cardium	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis fasciola	-	3	-	-	-	-	-	-	2	-	-	-
Lampsilis ovata	-	-	-	-	-	-	-	-	2	-	-	-
Lasmigona costata	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	-	-	-	-	-	-	-	-	-	-	-	-
Medionidus conradicus	-	37	4	-	-	-	-	-	8	3	-	-
Pleurobema oviforme	-	-	-	-	-	-	-	-	-	-	-	-
Potamilus alatus	-	-	-	-	1	-	-	-	-	-	-	1
Ptychobranchus fasciolaris	-	6	-	-	-	-	-	-	3	3	-	-
Ptychobranchus subtentum	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula c. strigillata	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus undulatus	-	-	-	-	-	-	-	-	-	-	-	-
Villosa iris	-	14	9	-	-	-	-	-	8	1	-	2
Villosa vanuxemensis	-	1	-	-	-	-	-	-	1	-	-	-
TOTAL	-	8	18	-	1	-	-	-	45	18	-	3

Table 5— continued.

	267.0-267.4 **S**-qual.	267.4 **A**-quant.	**A**-qual.	267.2 S-qual.	267.5-267.7 S-qual.	267.8 S-qual.	267.9 S-qual.	268.0 S-qual.	267.8-268.2 S-qual.	268.3 A-quant.	A-qual.	268.2-268.4 S-qual.
Actinonaias pectorosa	6	2	5	-	-	-	-	-	-	10	15	
Alasmidonta marginata	1	-	-	-	-	-	-	-	-	-	-	-
Amblema plicata	2	-	1	-	-	-	-	-	-	-	-	-
Elliptio dilatata	6	9	15	-	-	-	-	-	-	8	15	-
Fusconaia barnesiana	2	-	1	-	-	-	-	-	-	3	1	-
Fusconaia cor	-	1	1	-	-	1	-	-	-	-	-	-
Fusconaia subrotunda	-	-	2	-	-	-	-	-	-	-	-	3
Lampsilis cardium	6	-	-	-	1	-	-	-	-	-	-	-
Lampsilis fasciola	2	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata	-	-	1	-	-	-	-	-	-	-	-	-
Lasmigona costata	37	-	-	-	15	-	-	-	-	-	-	32
Leptodea fragilis	-	-	-	1	-	-	-	-	-	-	-	-
Medionidus conradicus	4	30	50	-	-	-	-	-	-	7	5	2
Pleurobema oviforme	-	-	1	-	-	-	-	-	-	-	-	-
Potamilus alatus	4	-	-	1	-	-	-	-	-	-	-	-
Ptychobranchus fasciolaris	4	3	3	-	1	-	-	-	-	3	1	2
Ptychobranchus subtentum	-	-	-	-	-	-	-	-	-	-	1	-
Strophitus undulatus	1	-	-	-	-	-	-	-	-	-	-	-
Quadrula c. strigillata	-	-	1	-	-	-	-	-	-	2	-	-
Villosa iris	29	11	10	-	4	-	-	-	-	-	3	-
Villosa vanuxemensis	48	-	1	1	2	-	-	-	-	1	-	-
TOTAL	152	56	92	3	23	1	-	-	-	34	41	42

Hassel, AEP, pers. comm.). Completing this treatment plant upgrade represents a commitment by AEP to improve the quality of the AEP discharge, resulting in improvements to the Clinch River water quality at the power plant.

CONCLUSION

The mussel fauna in this reach of the Clinch River was severely affected by the caustic spills of 1967 and 1970, respectively. Mussels were eliminated within the immediate impact area of the spill, but Stansbery's (1986) data indicates some mussel species may have survived in a localized area of the river. Post-spill sampling of the river suggested that water quality was still a problem below the waste outfalls of the power plant prior to 1993 upgrades, but the occurrence in 2008 of 16 mussel species of varying size-classes and the presence of three federally listed species (two mussels, one fish) is strong evidence that recovery is occurring. Mussel habitat is restricted to small segments of the study area, but where suitable habitat was found along the backsides of islands and especially in the main river channel downstream from the power plant, conditions for further recovery are excellent.

During our survey we focused on a reach of the Clinch River in the influence of the power plant operations and concentrated our sampling effort in areas sampled by Stansbery in 1985. The population sources for mussel re-colonization of this reach post-1970 existed in the upper reaches of the river at Cleveland and downstream below St. Paul. Mussels obviously were surviving just below St. Paul in 1981 and 1982, but the current status of mussels immediately upstream and downstream from St. Paul as a potential source for infected host fish migration is currently unknown and warrants a separate survey.

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