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Freshwater Mussel Declines in the Upper South Fork Holston River, Virginia

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ABSTRACT

The Holston River originates in southwestern Virginia from three tributaries: South, Middle, and North forks. A freshwater mussel survey conducted between 1968 and 1974 at 16 sites in the South Fork Holston River, Virginia documented only nine species. To determine changes in the mussel assemblage, we resurveyed these sites and found a significant decrease in the number of species per site and number of sites containing mussels. Little recruitment was present in the mainly senescent mussel community. Many industrial and land-use practices in the early 20th Century could have initially contributed to these declines. As many impacts ended, the Tennessee Valley Authority completed construction of the South Fork Holston Reservoir near the Virginia/Tennessee border, which has since restricted mussel recovery in the watershed.

Key words: Virginia, Holston River, mussels, declines, impoundments.

INTRODUCTION

The South Fork of the Holston River is one of three headwater tributaries originating in southwestern Virginia. The South Fork Holston River (SFHR) is joined by the Middle Fork Holston River directly above the South Fork Holston Reservoir in Washington County, Virginia (Fig. 1). During a survey of the pre-impounded SFHR in 1901, C. C. Adams (1915) failed to locate his target organism, the spiny riversnail (*Io fluvialis* Say, 1825), but did record the presence of 10 freshwater mussel species at two Virginia sites (Ortmann, 1918). Ortmann (1918) surveyed one site in 1913 and found eight species, three of which were additions to the known mollusk fauna. Collectively, these surveys documented 13 species, including the pheasantshell, *Actinonaias pectorosa* (Conrad 1834), elktoe, *Alasmidonta marginata* Say 1818, slippershell, *A. viridis* (Rafinesque 1820), spike, *Elliptio dilatata* (Rafinesque 1820), tan riffleshell, *Epioblasma florentina walkeri* (Wilson and Clark 1914), Tennessee pigtoe, *Fusconaia barnesiana* (Lea 1838), wavyrayed lampmussel, *Lampsilis fasciola* Rafinesque 1820, flutedshell, *Lasmigona costata* (Rafinesque 1820), Cumberland moccasinshell, *Medionidus conradicus* (Lea 1834), Tennessee clubshell, *Pleurobema oviforme* (Conrad 1834), fluted kidneyshell, *Ptychobranchus subtentum* (Say 1825), rainbow mussel, *Villosa iris* (Lea 1838), and mountain creekshell, *V. vanuxemensis* (Lea 1838).

Over a 6-year period (1968-1974), Stansbery & Clench (1977) conducted the first comprehensive freshwater mussel survey above the impounded section of the SFHR, Virginia. They sampled 16 mainstem sites and identified nine species, but did not record *A. marginata*, *A. viridis*, *E. dilatata*, *P. subtentum*, or *E. f. walkeri*, all of which were known from earlier surveys. However, Stansbery & Clench (1977) found a single specimen of littlewing pearlymussel, *Pegias fabula* (Lea 1838), which was not previously recorded from SFHR. They speculated that because the SFHR has minimal contact with calcium-bearing substrates, calcium may be a limiting factor for mollusks that have a high calcium requirement.

Similar to Virginia, the Tennessee section of the SFHR has shown dramatic declines in its once diverse unionid fauna. Collections from two prehistoric aboriginal sites and four localities surveyed by Ortmann (1918) in the lower to middle sections yielded 35 species (Parmalee & Polhemus, 2004), including all species known from Virginia SFHR except slippershell (*A. viridis*) and Tennessee clubshell (*P. oviforme*). All native riverine mussels have disappeared from the SFHR in Tennessee. In impounded reaches, the giant floater (*Pyganodon grandis*) and paper pondshell (*Utterbackia imbecillis*) have become established (Parmalee & Polhemus, 2004).

The purpose of our study was to determine changes and trends of freshwater mussel populations in the SFHR in Virginia by resurveying sites sampled by Stansbery & Clench (1977). In addition, we review historic threats in the drainage as potential causal factors for mussel declines.

MATERIALS AND METHODS

Study area

The SFHR originates near Sugar Grove, Smyth County, Virginia and flows southwestward 215 river km (RKm) before emptying into the South Fork Holston Reservoir in Washington County, Virginia (Fig. 1). Completed in 1950, the 18,730 ha reservoir extends 38.6 km to the confluence of the South Fork and Middle Fork Holston rivers in Washington County, Virginia. Land-use in the watershed is 76% forested, 21% agricultural, and 3% residential (USGS, 2003). Geology consists primarily of sedimentary and metamorphic rocks (VDMR, 2003). The SFHR headwaters and Laurel Creek are classified as trout waters by the Virginia Department of Game and Inland Fisheries (VDGIF).

Mussel sampling

Our survey was conducted from July 2000 to September 2003 and included all 16 mainstem sites (Table 1) sampled by Stansbery & Clench (1977). We spent a total of 146 survey hours with field crews ranging from 2 to 6 individuals, averaging 9 person-hours per site. Sampling was conducted during summer months to take advantage of low flow and clear water conditions. Sampling distance was calculated as 20 times average bankfull width, which allows for a series of pool, riffle, and run habitat units to be included in the sample section (Leopold et al., 1964). We selected 150 m and 500 m as the minimum and maximum distance of the sampling boundaries. A Garmin etrex unit was used to obtain geographic (Universal Transverse Mercator) coordinates.

All habitats were sampled by snorkeling by moving upstream, scanning substrate, and hand-picking mussels from the stream bottom. When possible, boulders, logs, and other large items were overturned during the search. Live mussels and shells were held underwater in mesh bags. All live mussels were identified and shell length measured to the nearest mm using dial calipers. They were then checked for gravidity, sexed, photographed, and returned to their original position. Common and scientific nomenclature follows Turgeon et al. (1998) and conservation status follows Williams et al. (1993). We used a nonparametric Wilcoxon Signed Rank test ($\alpha = 0.05$) to detect changes in species richness and abundance at each site and the number of sites inhabited by each species between the 1968-1974 and 2000-2003 surveys (Pilarczyk et al., 2006). Because $N < 20$, we used the Wilcoxon Signed Rank statistic of W+ to test for differences.

RESULTS

We collected a total of 66 live mussels of seven species at nine (56%) mainstem sites (Table 2). The most widely distributed species, *Villosa vanuxemensis*, was found at eight sites, whereas the most numerous species, *V. iris*, comprised 44% of total abundance and was the second most widely distributed species (present at 6 sites). Three species, *A. pectorosa*, *L. costata*, and *M. conradicus*, were each represented only by a single live specimen. *Fusconaia barnesiana* was represented by the collection of relic shells at two sites. We observed the greatest mussel abundance at site 12, where 21 individuals were collected, and the highest species richness ($n = 5$) at site 7.

In comparing our findings to those of Stansbery & Clench (1977), we found a significant decrease (W+ = -25, $p = 0.0098$) in the number of species per site between the two surveys. Nine sites had fewer species (mean = -2.3 species/site) during our survey, two sites contained more species (mean = +1.5 species/site) than during the previous survey, and five sites had an equal number of species during both surveys.

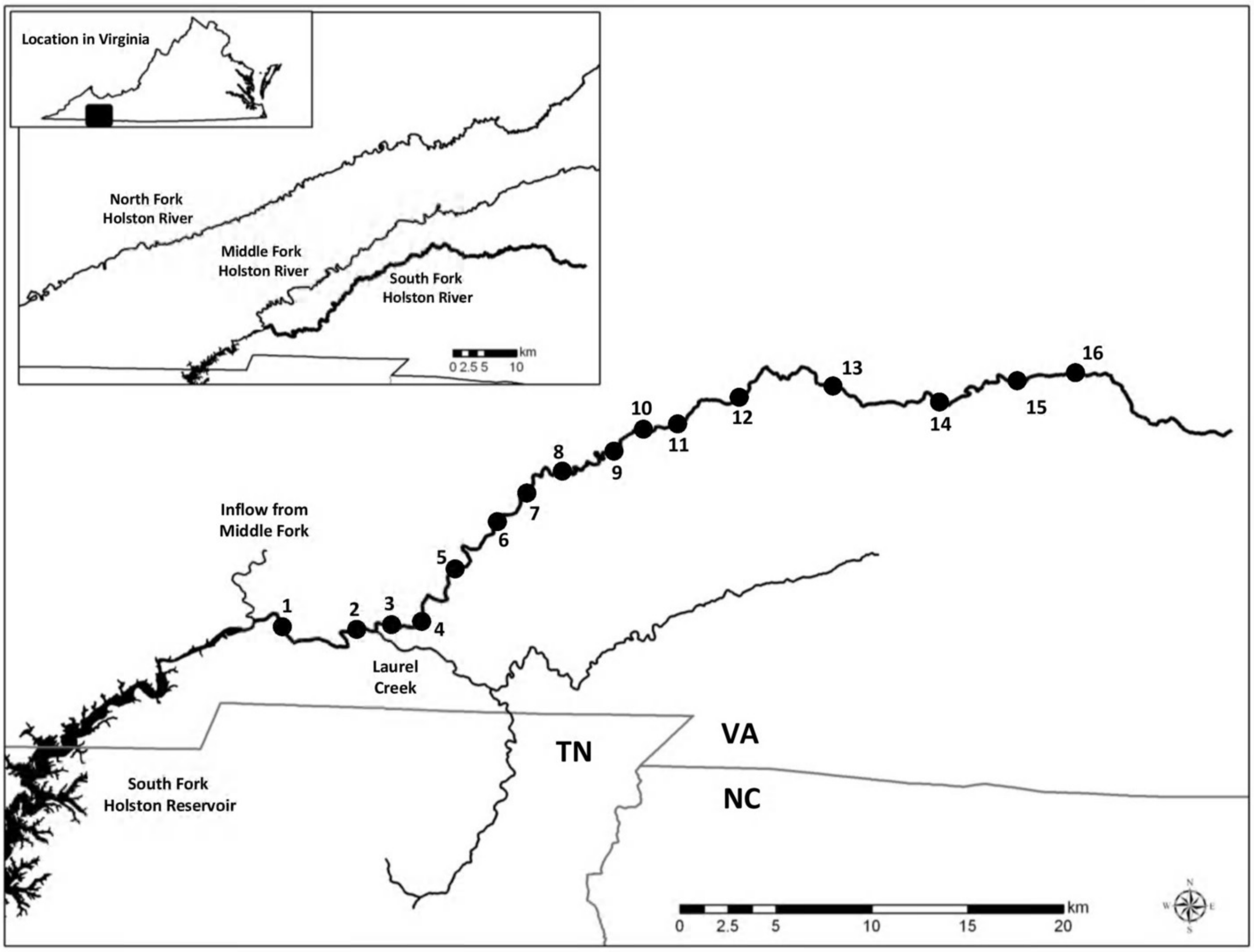

Fig. 1. Mussel survey sites on the South Fork Holston River, Washington and Smyth counties, Virginia.

Table 1. South Fork Holston River site locations surveyed between 2000 and 2003.

Site	RKm	UTM X	UTM Y	Location
1	118.4	420794	4056642	Alvarado (Barrow)
2	124.2	424498	4056335	Drowning Ford (Hwy 58)
3	127.5	427338	4056650	Rambeaux Bridge
4	128.9	428195	4057255	Wright Bridge (Hwy 91)
5	133.7	430070	4059620	Mast Bridge
6	138.2	432113	4062233	Buck Bridge
7	140.2	433286	4063734	1.6 km SSW Friendship
8	143.2	435152	4064715	Little Rock Church Ford
9	149.7	438333	4066174	4.8 km ENE Friendship
10	150.8	439114	4067052	Love's Mill
11	152.7	440655	4067120	2.2 km SW St. Clair Bottom
12	158.2	445078	4069246	4.3 km W Thomas Bridge
13	166.5	450874	4068480	1.1 km above Thomas Bridge
14	171.4	455186	4068515	Quebec
15	178.6	459708	4069793	Teas
16	180.4	461442	4069919	Roberts Mill

Site 4 demonstrated the sharpest decrease, with a loss of six species.

We observed a significant decrease ($W+ = -18$, $p = 0.0078$) in the number of sites containing live mussels compared to the 1968-1974 surveys (Fig. 2). All species with the exception of *L. fasciola* demonstrated a decline in the number of sites of occurrence between the two studies, with *L. costata* demonstrating the largest decrease (five sites in 1968-1974 versus one in 2000-2003). Neither *P. fabula* nor *F. barnesiana* were collected during our survey.

Stansbery & Clench (1977) did not report species abundance by site but noted abundance by species over the entire survey. While abundance was not significantly different ($W+ = -.500$, $p = 0.984$) between the two surveys, we observed greater abundance of *V. vanuxemensis*, *V. iris*, *P. oviforme*, and *L. fasciola*, and declines in abundance in *A. pectorosa*, *L. costata*, *M. conradicus*, *P. fabula*, and *F. barnesiana*.

Table 2. The number of live freshwater mussels collected during sampling of mainstem sites of the South Fork Holston River, Virginia between 2000 and 2003 (R = Relict, x = species collected by Stansbery and Clench between 1968 and 1974).

Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
Rkm	118.4	124.2	127.5	128.9	144.7	138.2	140.2	143.2	149.7	150.8	152.7	158.2	166.5	171.4	178.6	180.4		
Mussel species																	**# of sites**	**Total live**
Actinonaias pectorosa	Rx		1x	Rx	R	R	Rx										1	1
Fusconaia barnesiana			Rx	x		R											0	0
Lampsilis fasciola	2		1x	Rx	2x	x	1										4	6
Lasmigona costata	x		x	x	x	1	x										1	1
Medionidus conradicus				x		x	1x										1	1
Pegias fabula				x													0	0
Pleurobema oviforme	R		Rx	1x	4x	Rx	4x	1									4	10
Villosa iris	x		3x	2x	Rx	3x	3x	1x	R	1	x	16x					7	29
V. vanuxemensis	x	x	3x	4x	1x	1x	2x	1x		1	x	5x		x			8	18
Total live mussel species (2000-03)	1	0	4	3	3	3	5	3	0	2	0	2	0	0	0	0	9	-
Total live mussels	2	0	8	7	7	5	11	3	0	2	0	21	0	0	0	0	-	66
Total species (1968-74)	4	1	7	9	5	5	6	2	0	0	2	2	0	1	0	0		
Change in number of mussel species (1968-74 vs. 2000-03)	-3	-1	-3	-6	-2	-2	-1	+1	0	+2	-2	0	0	-1	0	0		

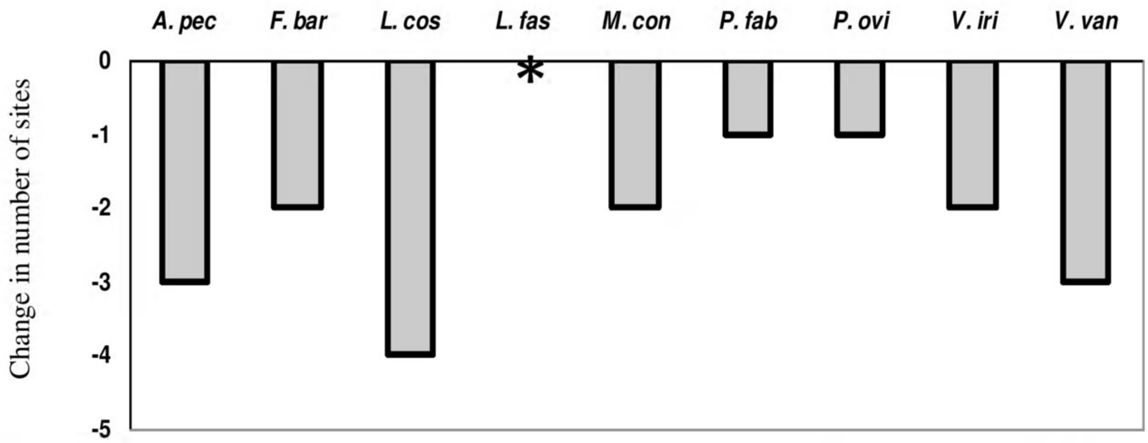

Fig. 2. Change in number of sites containing mussel species reported from 1968 to 2003 in the South Fork Holston River, Virginia. *A. pec* = *Actinonaias pectorosa*, *F. bar* = *Fusconaia barnesiana*, *L. cos* = *Lasmigona costata*, *L. fas* = *Lampsilis fasciola*, *M. con* = *Medionidus conradicus*, *P. fab* = *Pegias fabula*, *P. ovi* = *Pleurobema oviforme*, *V. iri* = *Villosa iris*, *V. van* = *Villosa vanuxemensis*, * = no change

With the exception of *V. iris* and *V. vanuxemensis*, the majority of specimens that we collected were old individuals with highly-eroded valves. Mean shell lengths for the three most abundant species were 81.49 mm (±1.89 SE) *P. oviforme*, 55.31 mm (±1.90 SE) *V. iris*, and 52.52 mm (±1.59 SE) *V. vanuxemensis*. Gravid individuals of *L. fasciola*, *P. oviforme*, and *V. iris* were found during the survey, but only *V. iris* showed evidence of recruitment (two specimens ≤ 30 mm shell length).

DISCUSSION

Our findings are similar to other studies that demonstrate a continual decline in species presence in the SFHR (Ortmann, 1918; Stansbery & Clench, 1977; Parmalee & Polhemus, 2004). Since the beginning of the 20th Century, the freshwater mussel assemblage has declined from 14 to 7 species with only one (*V. iris*) demonstrating recruitment.

Two federally endangered mussels, *E. f. walkeri* and *P. fabula*, were collected during previous surveys of the SFHR. Both are sparsely-distributed in a few cool, headwater tributaries of the Tennessee and Cumberland River systems (Parmalee & Bogan, 1998). Recent collections of *P. fabula* in Virginia include three individuals in the upper North Fork Holston River (Ahlstedt & Saylor, 1995-1996) and one in the upper Clinch River (Jones et al., 2001). In Virginia, one *E. f. walkeri* specimen was found in the Middle Fork Holston River in 1997 (Henley et al., 1999), while a reproducing population remains in the upper Clinch River watershed in Indian Creek, Tazewell County (Winston & Neves, 1997). The absence of both species during our surveys indicates that they may be extirpated from the SFHR system.

Our sampling techniques had several advantages over those of Stansbery & Clench (1977). Their sampling method was a visual search by wading (D. Stansbery, pers. comm.). We sampled by snorkeling, which is typically more effective than wading, and is more amenable to detecting small, cryptic species (Strayer & Smith, 2003). Also, the previous survey sampled a small area with less search effort (D. Stansbery, pers. comm.). Our average sampling distance was over 424 m, which allowed us to sample multiple pool/riffle/run habitat sequences. Although our sampling methods were rigorous, we were unable to match species richness or abundances compared to those of earlier efforts, thus an indication that mussel population declines are likely more severe than previously reported.

The precipitous decline of freshwater mussels in the drainage is perplexing. Stansbery & Clench (1977) claimed that stream temperature and available calcium, among other factors, may limit certain mussel species in the SFHR. Indeed, we did not find mussels in the most upstream sites typical of these conditions. In lower mainstem sections where water quality, temperature, and physical habitat were suitable, mussels were still absent or diminished indicating that the current condition of the mussel fauna could be a legacy of past disturbances from reservoirs, industrial pollution, and land-use practices in the watershed.

The impoundment of free-flowing reaches has eliminated 35 mussel species from the middle to lower SFHR, Tennessee (Parmalee & Polhemus, 2004). Within the impounded reach, freshwater mussels and obligate riverine fish species essential for their reproductive life-cycle are negatively affected by increased sedimentation and depth, altered flows and thermal regimes, and anoxia (Neves et al., 1997). Below impoundments, mussels are affected by coldwater releases during summer months, low dissolved oxygen, disruption of seasonal flows, sediment scour, and changes in fish-host availability (Vaughn & Taylor, 1999). To overcome these stressors, a considerable distance is required below the reservoir to restore the mussel assemblage to pre-impoundment abundance and richness (Vaughn & Taylor, 1999). Because dams and impoundments occur throughout the SFHR in Tennessee, it is unlikely that any mussel assemblage can be restored to pre-impoundment levels.

Fragmentation of rivers by reservoirs can isolate aquatic species and lead to reduction in genetic flow and variation (Pringle, 1997). Because mussels are long-lived invertebrates with low rates of recruitment, the lag between the perturbation and population decline can take decades (Neves et al., 1997). Since Stansbery & Clench (1977) observed significant species losses only 18 years after the South Fork Holston dam was created, it is unlikely that the reservoir, although a factor, could alone account for the dramatic decline in mussel diversity.

Other potential causes that may have contributed to mussel declines in the SFHR include past industrial land-use practices. The upper SFHR watershed was historically mined for manganese, lead, barite, zinc, and iron (Miller, 1944). Of these, manganese mining is the most destructive because it requires the washing of clay and soil from hard ore. Ore washers were located at several sites along streams and creeks in the upper watershed, resulting in heavy sedimentation. Manganese mines left large barren pits that were a constant source of sediment. Most manganese mining occurred prior to 1919 and after 1937 due to World War I and II, which halted the import of foreign ore. No mineral mining currently occurs in the upper watershed and many sites have been restored as part of efforts by the U.S. Forest Service (USFS), Tennessee Valley Authority, and the Virginia Department of Game and Inland Fisheries (C. Thomas, USFS retired, pers. comm.).

In addition to mining, several other industries may have contributed to declines of the SFHR mussel populations. Extensive logging occurred throughout the SFHR watershed from 1900-1930 (Wilson, 1932). No best management practices to reduce sediment runoff were employed during this time. A wood tannin extract facility, reported to be the second largest of its kind in the world, operated at Teas (RKm 178.7) between 1910 and 1925 (Wilson, 1932). During this period, the facility processed 200 cords of wood per day to produce an estimated 1,137 liters (300 gallons) of concentrated liquid wood tannin extract. A textile dye plant was present at Damascus on Beaverdam Creek (a tributary of Laurel Creek), from 1918-1985. The operation specialized in sulfur dyes which use aromatic hydrocarbon intermediates such as benzene, naphthalene, diphenylamine, and azobenzene as starting materials (Colorants Industry History, 2005). Although no water quality records exist for these industries, they undoubtedly had a negative and lasting impact on the SFHR biota many miles downstream.

Even with the documented declines of the mussel fauna in the SFHR, there are some positive signs for its recovery. Since 1998, the VDGIF has operated a mussel cultivation facility (Aquatic Wildlife Conservation Center) at RKm 168.2. The facility holds over 32 mussel species primarily from the upper Clinch River. Using SFHR water, the operation has demonstrated high mussel growth and survival. Between 2005 and 2010, VDGIF has translocated 275 adults of five species from the Middle Fork Holston River to the SFHR at Rkm 140.2. At the same SFHR location, 12,316 one-week to five-month old propagated *V. vanuxemensis* were released. Unfortunately, no concerted effort has been attempted to monitor these releases. Future monitoring will be necessary to determine if translocation and propagation are successful strategies in restoring the freshwater mussels of the SFHR.

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LITERATURE CITED

Adams, C. C. 1915. The variations and ecological distribution of snails of the genus *Io*. Memoirs of the National Academy of Science 12(2): 1-92.

Ahlstedt, S. A., & C. F. Saylor. 1995-1996. Status survey of the little-wing pearlymussel, *Pegias fibula* (Lea 1838). Walkerana 8: 81-105.

Colorants Industry History. 2005. Beaver Chemical Works, Damascus, Virginia. http://www.colorants history.org/BeaverChemicalWorks.html

Cummins, K. W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. American Midland Naturalist 76: 477-504.

Henley, W. F., R. J. Neves, L. L. Zimmerman, & R. Winterringer. 1999. A survey of freshwater mussels in the Middle Fork Holston River, Virginia. Banisteria 14: 15-24.

Jones, J. W., R. J. Neves, M. A. Patterson, C. R. Good, & M. A. Patterson. 2001. A status survey of freshwater mussel populations in the upper Clinch River, Tazewell County, Virginia. Banisteria 17: 20-30.

Leopold, L. B., M. G. Wolman, & J. P. Miller. 1964. Fluvial Processes in Geomorphology. Freeman, San Francisco, CA. 522 pp.

Miller, R. L. 1944. Geology and Manganese Deposits of the Glade Mountain District, Virginia. Virginia Geological Survey Bulletin 61. 150 pp.

Neves, R. J., A. E. Bogan, J. D. Williams, S. A. Ahlstedt, & P. W. Hartfield. 1997. Pp. 43-85 *in* G. W. Benz & D. E. Collins (eds.), Aquatic Fauna in Peril: the Southeastern Perspective. Special Publication 1, Southeast Aquatic Research Institute. Lenz Design and Communications, Decatur, GA.

Ortmann, A. E. 1918. The nayades (freshwater mussels) of the upper Tennessee Drainage with notes on synonymy and distribution. Proceedings of the American Philosophical Society 57: 521-626.

Parmalee, P. W., & A. E. Bogan. 1998. The Freshwater Mussels of Tennessee. The University of Tennessee Press, Knoxville, TN. 328 pp.

Parmalee, P. W., & R. R. Polhemus. 2004. Prehistoric and pre-impoundment populations of freshwater mussels (Bivalvia: Unionidae) in the South Fork Holston River, Tennessee. Southeastern Naturalist 3: 231-240.

Pilarczyk, M. M., P. M. Stewart, D. N. Shelton, H. N Blalock-Herod, & J. D. Williams. 2006. Current and recent historical freshwater mussel assemblages in the Gulf Coast Plains. Southeastern Naturalist 5: 205-226.

Platts, W. S., W. F. Megahan, & G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. U.S. Forest Service General Technical Report INT-138. Ogden, UT. 70 pp.

Pringle, C. M. 1997. Exploring how disturbance is transmitted upstream: going against the flow. Journal of the North American Benthological Society 16: 425-438.

Stansbery, D. H., & W. J. Clench. 1977. The Pleuroceridae and Unionidae of the upper South Fork Holston River in Virginia. Bulletin of the American Malacological Union, Inc. for 1977: 75-79.

Strayer, D. L., & D. R. Smith. 2003. A guide to sampling freshwater mussel populations. American Fisheries Society Monograph 8: 1-103.

Turgeon, D. D., J. F. Quinn, Jr., A. E. Bogan, E. V. Coan, F. G. Hochberg, W. G. Lyons, P. M. Mikkelsen, R. J. Neves, C. F. E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F. G. Thompson, M. Vecchione, & J. D. Williams. 1998. Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Mollusks, 2nd Edition. American Fisheries Society, Special Publication 26, Bethesda, MD. 509 pp.

U. S. Geological Survey. 2003. National Land Cover Database Zone 59 Land Cover Layer. Ver. 1.0. 1 Sept. 2003. http://www.fgdc.gov/metadata/fgdc-std-001-1998.dtd (Accessed 8 April 2010)

Vaughn, C. C., & C. M. Taylor. 1999. Impoundments and the decline of freshwater mussels: a case study of an extinction gradient. Conservation Biology 13: 912-920.

Virginia Division of Mineral Resources. 2003. Digital representation of the 1993 geologic map of Virginia. Virginia Division of Mineral Resources Publication 174, compact disc.

Williams, J. M., M. L. Warren, Jr., K. S. Cummings, J. L. Harris, & R. J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18: 6-22.

Wilson, G. 1932. Smyth County History and Traditions. Higginson Book Company, Salem, MA. 397 pp.

Winston, M. R., & R. J. Neves. 1997. Survey of the freshwater mussel fauna of unsurveyed streams of the Tennessee River drainage, Virginia. Banisteria 10: 3-8.