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A Survey of Freshwater Mussels in the Middle Fork Holston River, Virginia

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INTRODUCTION

The Middle Fork Holston River (MFHR) in southwestern Virginia flows in a southwesterly direction through Wythe, Smyth, and Washington counties to its confluence with the South Fork Holston River at South Holston Lake (Fig. 1). The river's watershed is primarily limestone bedrock with dissolved $CaCO_3$ concentrations from 52 mg/l to 350 mg/l, with a mean of 134 mg/l (Virginia Department of Environmental Quality [VDEQ] 1998). Average discharge for the period between 1931 and 1996 was estimated at 245 cfs, with an estimated mean peak flow of 4534 cfs at the USGS gauging station at Meadowview, Virginia. The 1997 annual 7-day minimum discharge recorded at this gauging station was 63 cfs, and the average monthly summer flow (July through September) for the period 1931 to 1996 was 129 cfs. Watershed use is characterized by mostly agriculture and moderate urban development.

Historically, 21 species of freshwater mussels have been collected in the MFHR during this century (Table 1). These species included the elktoe, *Alasmidonta marginata* Say, 1818; slippershell mussel, *A. viridis* (Rafinesque, 1820); littlewing pearlymussel, *Pegias fabula* (Lea, 1838); flutedshell, *Lasmigona costata* (Rafinesque, 1820); Tennessee heelsplitter, *L. holstonia* (Lea, 1838); Tennessee pigtoe, *Fusconaia barnesiana* (Lea, 1838), shiny pigtoe, *F. cor* (Conrad, 1834); slabside pearlymussel, *Lexingtonia dolabelloides* (Lea, 1840); Tennessee clubshell, *Pleurobema oviforme* (Conrad, 1834); spike, *Elliptio dilatata* (Rafinesque, 1820); kidneyshell, *Ptychobranchus fasciolaris* (Rafinesque, 1820); fluted kidneyshell, *P. subtentum* (Say, 1825); pheasantshell, *Actinonaias pectorosa* (Conrad, 1834); mucket, *A. ligamentina* (Lamarck,1819); purple wartyback, *Cyclonaias tuberculata* (Rafinesque, 1820); Cumberland moccasinshell, *Medionidus conradicus* (Lea, 1834); rainbow mussel, *Villosa iris* (Lea, 1829); mountain creekshell, *V. vanuxemensis* (Lea, 1838); pocketbook, *Lampsilis ovata* (Say, 1817); wavyrayed lampmussel, *L. fasciola* Rafinesque, 1820; tan riffleshell, *Epioblasma florentina walkeri* (Wilson and Clark, 1914); and black sandshell, *Ligumia recta* (Lamarck, 1819). There were no abundance data included in past survey reports (Ortmann 1918; Stansbery & Clench 1974; Neves et al. 1980; VDCR 1996), and the majority of the species reported

[1] The Unit is supported jointly by the U. S. Geological Survey, the Virginia Department of Game and Inland Fisheries, Virginia Polytechnic Institute and State University, and the Wildlife Management Institute.

were found between MFHRM 4.7 and MFHRM 35.5 (Table 1).

The objectives of our survey were to record species composition and abundance of freshwater mussels and their reproductive success at selected sites, and to compare the historic and present species composition of freshwater mussels in the river.

METHODS

Selected sites were surveyed for unionid mussels to determine species diversity, abundance, and the presence of young mussels in the MFHR. Based on known locations of live mussels and recent qualitative snorkeling surveys, appropriate sites were designated for survey (Fig. 1). The level of survey effort expended at a site was defined by catch-per-unit-effort (CPUE) values. The river bottom at each of 25 sites was first surveyed using a random CPUE (RCPUE) snorkeling technique that consisted of surveyors swimming the site with mask and snorkel to locate mussel aggregations. Because of differences in ability and experience of snorkelers in locating mussels, the RCPUE of the principal investigator (Henley) was used to trigger subsequent sampling. The 6 sites with the highest RCPUE values received further survey effort that consisted of CPUE and quadrat surveys along transects (Table 2). Mussel surveys were conducted between June 1997 and July 1998.

At each site, a RCPUE survey was conducted by a crew of 2 to 5 people to confirm the presence of mussels, their relative abundance, and the position of mussel aggregations. During a RCPUE survey, only visible mussels were counted; few rocks were overturned. Observed mussels were left in position, and their locations were marked with fluorescent flags. After a site survey was completed, mussels were examined to record species, sex and gravidity, and returned to the exact location of collection. RCPUE values were calculated by dividing the number of mussels observed by total effort in hours.

The TCPUE sampling was conducted along transects that were not randomly selected, but were positioned to include mussel aggregations discovered during the

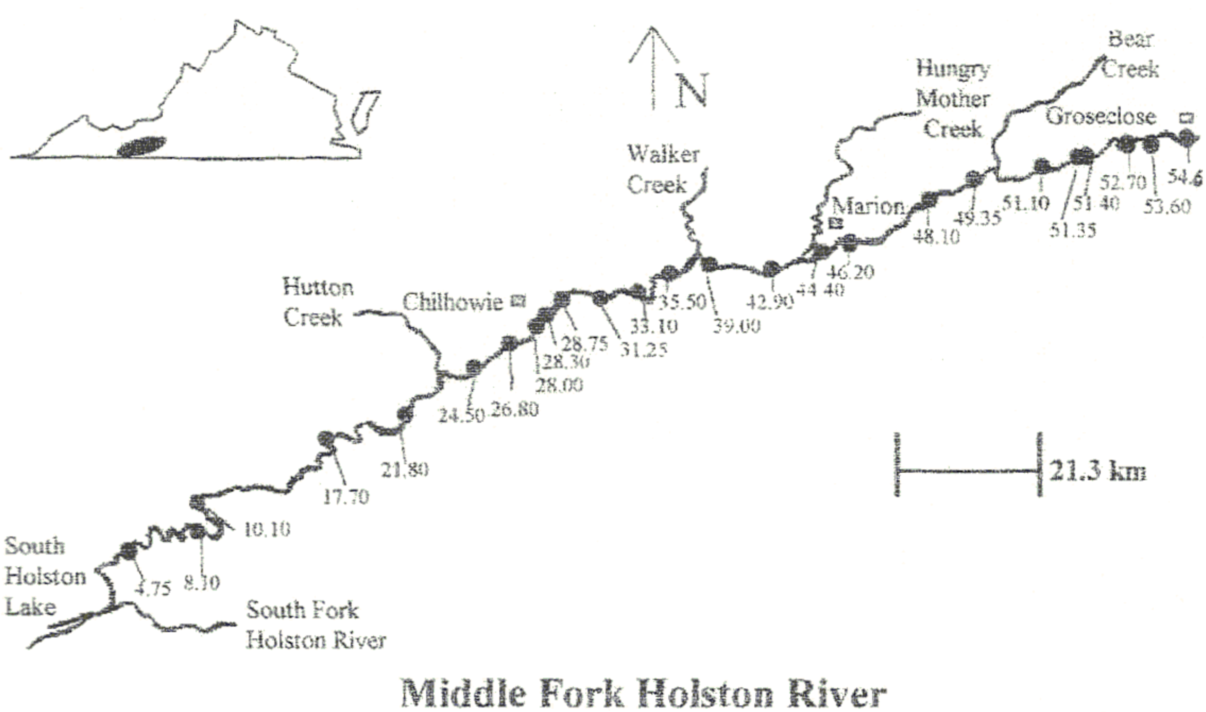


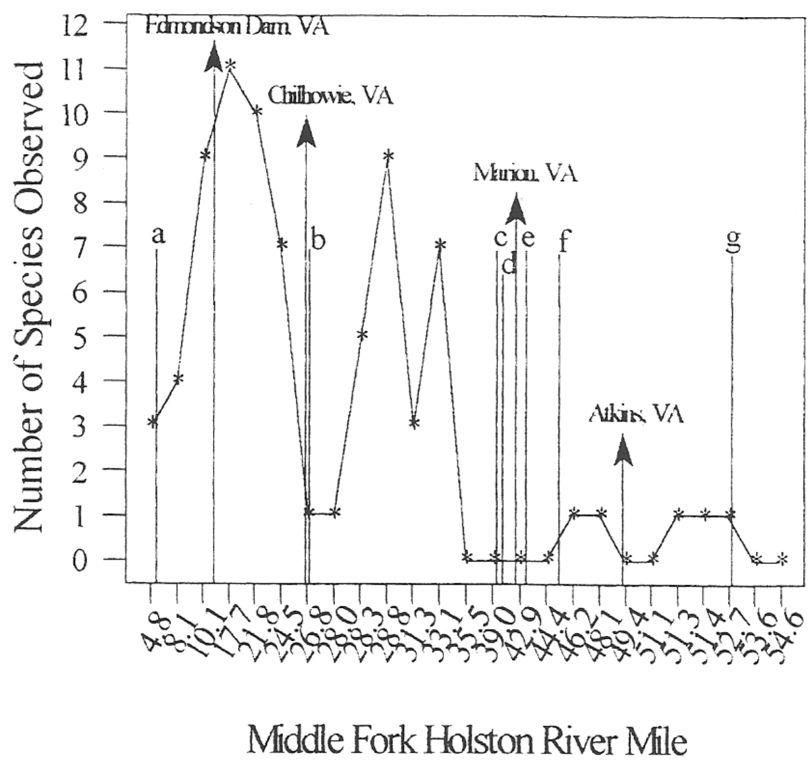
Fig. 1. Locations of freshwater mussel survey sites in the MFHR, Virginia.

Table 1. Species of freshwater mussels recorded for the Middle Fork Holston River in the twentieth century. Sources include Ortmann (1918)(O), Stansbery & Clench (1974)(S), Neves et al. (1980)(N), and the Virginia Department of Conservation and Recreation (1996)(V). Historic river mile locations are approximate.

Species	Middle Fork Holston River Survey Sites (MFHRM)																				
	53.6	52.7	51.4	48.1	46.2	44.4	42.9	35.5	33.1	31.2	29.1	28.0	21.8	19.5	18.4	17.7	13.0	11.5	10.8	8.1	4.7
Alasmidonta marginata Say, 1818												O					N	S	N		S N
Alasmidonta viridis (Rafinesque, 1820)												O									
Pegias fibula (Lea, 1838)								S				S									
Lasmigona costata (Rafinesque, 1820)								S				O S			N	S	N	S	N	S	S
Lasmigona holstonia (Lea, 1838)	S N	S	S																		
Fusconaia barnesiana (Lea, 1838)									S N	S N	S N	O S N	S N		N	S	N	S	N	S	N
Lexingtonia dolabelloides (Lea, 1840)																S	N		N	S	S N
Pleurobema oviforme (Conrad, 1834)									S	S N	S N	O S	S			S		S	N	S	S
Elliptio dilatata (Rafinesque, 1820)									S N	S N	S N	O S N	S N		N	S	N	S	N	S	
Ptychobranchus fasciolaris (Rafinesque, 1820)											N		S		N		N	S	N	S	N
Ptychobranchus subtentum (Say, 1825)									N		S	O S N	S N		N		N	S	N	S	N
Medionidus conradicus (Lea, 1834)									S	S N	S N	O S N			N	S	N	S	N	S	
Actinonaias pectorosa (Conrad, 1834)													S		N	S	N	S	N	S	S N
Actinonaias ligamentina (Lamarck, 1819)															N						
Villosa iris (Lea, 1829)		S			S	S	O	S	S N	S N	S N	O S N	S N		N	S	N	S	N	S	N
Villosa vanuxemensis (Lea, 1838)					S	S	O S	S	S N	S N	S N	O S N	S N		N	S	N		N	S	N
Lampsilis ovata (Say, 1817)																	N		N	S	
Lampsilis fasciola Rafinesque, 1820									S	S N	S N	O S	S N		N	S	N	S	N	S	N
Epioblasma f. walkeri (Wilson & Clark, 1914)											S	O S			N	S					
Cyclonaias tuberculata (Rafinesque, 1820)																			N		
Fusconaia cor (Conrad, 1834)																V					
Ligumia recta[a] (Lamarck, 1819)														V							

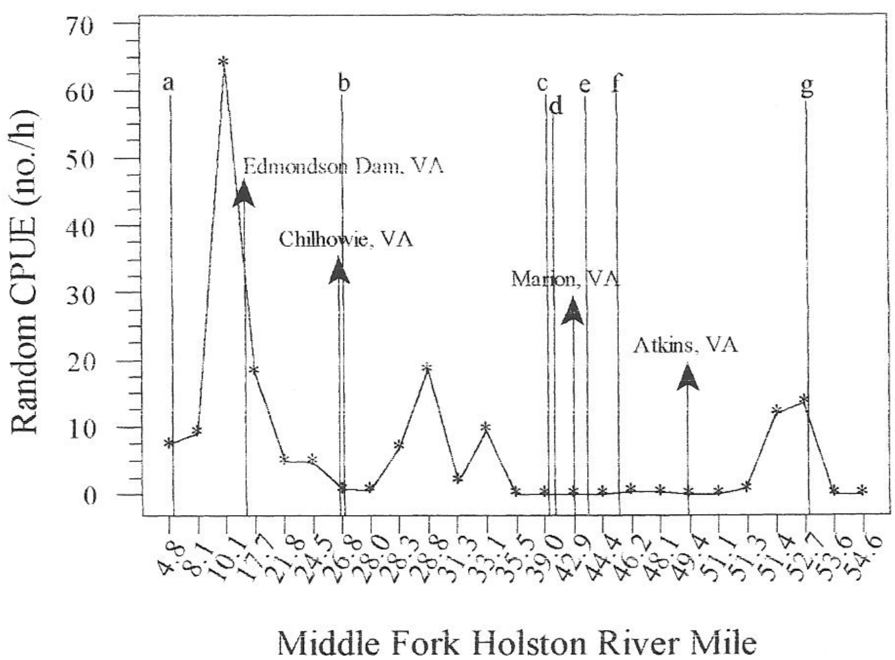
[a] Recently dead male collected in 1988.

RCPUE survey. The number of transects and distances between transects varied between survey sites to include mussel aggregations. The first upstream transect was randomly positioned using a random number table. A global positioning system (GPS) reading was obtained at this first transect for each survey site. Lengths of survey sites were 40 m (MFHRM 33.1 and 10.1), 45 m (MFHRM 8.1), 50 m (MFHRM 28.75), 60 m (MFHRM 51.4), and 150 m (MFHRM 17.7). Transects were placed 5 m apart at each survey site except MFHRM 17.7, where transects were 10 m apart. Sampling at the latter site was more extensive because of the collection of the federally endangered tan riffleshell, *E. florentina walkeri*. TCPUE surveys were conducted to include 1 m on either side of transect lines. A 2 m length of metal rebar with a painted center-line was used during surveys to aid surveyors in remaining within transect width limits. Thus, TCPUE surveys provided an estimate of species composition and relative abundance. During these surveys, most cobbles larger than 25 cm were overturned (and replaced) to determine the presence of mussels. Mussel positions were flagged to allow exact replacement after species, sex, gravidity, length, and width measurements (mm) were recorded. Survey crews consisted of 2 to 6 people, but at least two of the same individuals were always present during all sampling conducted. Catch-per-unit-effort was



[a] MFHRM 5.02, Washington County Wastewater Treatment Plant, Municipal, Minor classification.
[b] MFHRM 26.92, Chilhowie Wastewater Treatment Plant, Municipal, Minor classification.
[c] MFHRM 39.58, Marion Wastewater Treatment Plant, Municipal, Major classification.
[d] MFHRM 40.50, Marion Automatic Car Wash, Industrial, Minor classification.
[e] MFHRM 43.25 – 43.75, Brunswick Corp. and other industrial plants, Industrial, Minor classification.
[f] MFHRM 45.67, Marion Wastewater Treatment Plant, Municipal, Minor classification.
[g] MFHRM 52.78, Smyth County I-81 Rest Area, Municipal, Minor classification.

Fig. 2. Distribution of species richness in the MFHR. The figure includes MFHRM locations of major towns and VDEQ discharge permits issued for the river (VDEQ 1998).



[a] MFHRM 5.02, Washington County Wastewater Treatment Plant, Municipal, Minor classification.
[b] MFHRM 26.92, Chilhowie Wastewater Treatment Plant, Municipal, Minor classification.
[c] MFHRM 39.58, Marion Wastewater Treatment Plant, Municipal, Major classification.
[d] MFHRM 40.50, Marion Automatic Car Wash, Industrial, Minor classification.
[e] MFHRM 43.25 – 43.75, Brunswick Corp. and other industrial plants, Industrial, Minor classification.
[f] MFHRM 45.67, Marion Wastewater Treatment Plant, Municipal, Minor classification.
[g] MFHRM 52.78, Smyth County I-81 Rest Area, Municipal, Minor classification.

Fig. 3. Random CPUE (no./h) of MFHR survey sites. The figure includes MFHRM locations of major towns and VDEQ discharge permits issued for the river (VDEQ 1998).

calculated as previously described.

For subsequent quantification of mussel assemblages, 0.25 m^2 quadrats were randomly positioned on existing transect lines using a random numbers table. The number of quadrats employed for each survey site, and the number of quadrats per transect, varied for each site because the level of survey precision and the number of transects per site varied. Sites where the state threatened *L. holstonia* and the federally endangered *E. f. walkeri* had been observed were surveyed with sufficient quadrats to achieve a 15% precision, while all other quadrat sites were surveyed with a 20% precision. The following sample size formula was used to determine the number of quadrats required to achieve the desired levels of precision at survey sites (Downing & Downing 1992):

$$n = 1 \cdot \left(\frac{\text{\# mussels estimated per m}^2}{10{,}000 / A}\right)^{-0.5} \cdot D^{-2},$$

where: A = cm^2 covered by each replicate sample (in this case 2500 cm^2),

and: D = SE/m = the desired accuracy of density estimates.

Using this formula, sample sizes to allow density estimate precisions of 15% and 20% were calculated. Quadrats were excavated to hardpan, or to approximately 25 cm, and substratum was later replaced. Mussels were examined for species, sex and gravidity, then measured for length and width, and replaced at the position of collection.

In addition to random and transect CPUE (no./h) and density estimations (no./m^2), results obtained by these survey techniques provided species composition and estimates of reproductive success, as defined by small size classes, within the mussel aggregations at the sites. The presence of juveniles (< 20 mm) at a site indicated recent reproduction. Since CPUE, density, and species composition were recorded at surveyed sites, these values were regressed on MFHR mile location. The results of the various survey techniques used during this study were compared to identify the survey method(s) most appropriate for attaining survey objectives. All statistical analyses and graphics were conducted and generated using Minitab 10.5[2] (Minitab, Inc., College Station, Pennsylvania).

RESULTS AND DISCUSSION

During this survey, 15 species of freshwater mussels were observed in the MFHR (Table 3). These species included the rainbow mussel, *V. iris*; mountain creekshell, *V. vanuxemensis;* wavyrayed lampmussel, *L. fasciola*; Tennessee clubshell, *P. oviforme*; slabside pearlymussel, *L. dolabelloides*; Tennessee pigtoe, *F. barnesiana*; spike, *E. dilatata*; fluted kidneyshell, *P. subtentum*; kidneyshell, *P. fasciolaris*; Cumberland moccasinshell, *M. conradicus*; pheasantshell, *A. pectorosa*; purple wartyback, *C. tuberculata*; flutedshell, *L. costata*; Tennessee heelsplitter, *L. holstonia*; and tan riffleshell, *E. f. walkeri*.

Table 2. Site locations and relative abundances per survey methods used at sites in the MFHR, Virginia from June 1997 to July 1998. For TCPUE and quadrat survey sites, latitude and longitude are for position of first downstream transect; otherwise, for center of site mussel aggregation. CPUE = no./h and density = no./0.25 m^2.

MFHRM	Site Location		Relative Abundances		
	Latitude	Longitude	Random CPUE	Transect CPUE	Quadrat Density
4.8	36°49'13.78"	81°37'06.90"	7.39	-	-
8.1	36°41'32.28"	81°51'53.85"	9.07	37.92	3.40
10.1	36°44'23.98"	81°46'53.46"	64.00	51.56	5.22
17.7	36°50'06.38"	81°35'43.79"	18.17	26.84	1.12
21.8	36°46'23.15"	81°42'47.81"	5.03	-	-
24.5	36°47'55.63"	81°40'40.70"	4.89	-	-
26.8	36°50'38.50"	81°29'29.90"	0.77	-	-
28.0	36°48'29.01"	81°40'19.41"	0.67	-	-
28.3	36°42'15.67"	81°51'39.79"	7.00	-	-
28.8	36°50'14.36"	81°30'30.16"	18.46	9.89	0.80
31.2	36°41'18.71"	81°53'38.23"	2.00	-	-
33.1	36°49'12.04"	81°37'08.08"	9.57	16.62	2.00
35.5	36°48'22.05"	81°37'39.31"	0.00	-	-
39.0	36°47'15.90"	81°41'13.52"	0.00	-	-
42.9	36°52'28.48"	81°23'57.95"	0.00	-	-
44.4	36°51'28.65"	81°28'21.15"	0.00	-	-
46.2	36°48'29.15"	81°40'16.64"	0.50	-	-
48.1	36°52'28.48"	81°23'57.95"	0.33	-	-
49.4	36°52'02.58"	81°25'38.83"	0.00	-	-
51.1	36°41'33.76"	81°51'52.45"	0.00	-	-
51.3	36°53'09.99"	81°22'30.60"	0.77	-	-
51.4	36°53'19.08"	81°20'48.79"	11.52	3.17	1.23
52.7	36°53'20.37"	81°20'48.98"	13.50	-	-
53.6	36°53'23.27"	81°20'37.20"	0.00	-	-
54.6	36°53'46.06"	81°19'15.54"	0.00	-	-
MFHR Mean			6.95	24.00	2.30
MFHR Range			0.00 - 64.00	3.17 – 51.56	0.80 – 5.22

[2] Use does not imply endorsement by the U. S. government.

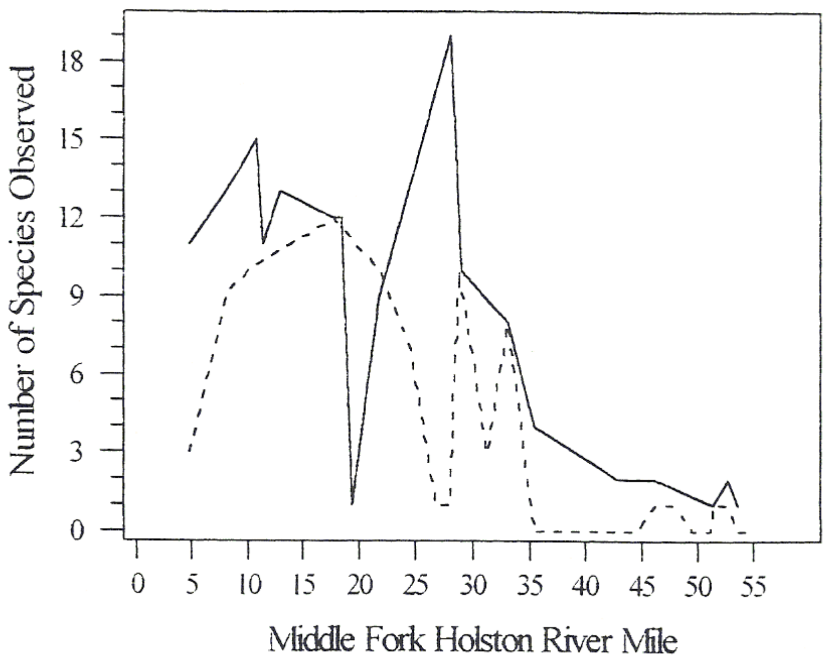


Fig. 4. Distribution of species richness in the Middle Fork Holston River from Ortmann (1918), Stansbery & Clench (1974), Neves et al. (1980), and the Virginia Department of Conservation and Recreation (1996) surveys (combined total; solid line) and this survey (dashed line).

The federally endangered tan riffleshell and the state threatened Tennessee heelsplitter are rare and of localized occurrence in the river. The only other known location of the tan riffleshell in Virginia is in Tazewell County. A toxic spill that occurred in August of 1998 into the Clinch River at Cedar Bluff essentially eliminated the population of tan riffleshells in the mainstem Clinch River, Tazewell County (Watson 1999). Isolated populations of the Tennessee heelsplitter also are known to occur in the Clinch River and upper Middle Fork Holston River (Winston & Neves 1997). Species that were historically found in the MFHR, but were not observed during this survey, are the slippershell mussel, *A. viridis*; littlewing pearlymussel, *P. fabula*; pocketbook, *L. ovata*; shiny pigtoe, *F. cor*; mucket, *A. ligamentina*; and black sandshell, *L. recta* (Ortmann 1918; Stansbery & Clench 1974; Neves et al. 1980; VDCR 1996)(Tables 1 and 3). Thus, the federally endangered littlewing pearlymussel and shiny pigtoe, as well as the state endangered slippershell and state threatened black sandshell, may be extirpated from the river.

At the 25 sites surveyed with the RCPUE method, abundance estimates ranged from 0.0 to 64.0 mussels/h, with a mean of 6.9 mussels/h (Table 3). Abundance estimates for the 6 sites surveyed with the TCPUE technique ranged from 3.2 to 51.6, with a mean of 24.0 mussels/h (Table 3). At these same 6 sites, quadrat density estimates ranged from 0.8 to 5.2 mussels/m^2, with a mean of 2.3 (Table 3). The species diversity in the river generally increased proceeding downstream, but river mile location was not highly predictive of the number of species observed at each of the RCPUE sites surveyed (r^2=50.1, $p<0.0001$). Also, river mile location was not predictive of the RCPUE (no./h) values for these sites (r^2=19.2, $p<0.02$). At the six sites also surveyed on transects, the TCPUE (no./h) values were inversely related to river mile location (r^2=73.4, $p<0.02$); however, density estimates (mussels/m^2) for these transect sites were not statistically related to river mile location (r^2=26.6, $p<0.17$).

There was an obvious association between low measures of mussel abundance, number of species observed, and survey site positions in downstream proximity to the towns of Atkins, Marion, and Chilhowie (Fig. 2 and 3). The RCPUE values and number of species at survey sites downstream of these towns dropped markedly from upstream values. At MFHRM 17.7, the RCPUE value was 65 mussels/h with 11 species collected,

Table 3. Species relative abundances (no./h) and densities (no./0.25m^2) for MFHR survey sites. Values within table cells are: top = RCPUE, middle = TCPUE, and bottom = quadrat density. Dashes indicate that survey types were not conducted.

Species	Middle Fork Holston River Survey Sites (MFHRM)																								
	54.6	53.6	52.7	51.4	51.3	51.1	49.4	48.1	46.2	44.4	42.9	39.0	35.5	33.1	31.3	28.8	28.3	28.0	26.8	24.5	21.8	17.7	10.1	8.1	4.8
Villosa vanuxemensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.50	0.00	0.00	0.00	0.00	2.14	0.50	1.50	0.50	0.00	0.50	1.56	1.78	1.00	0.00	0.00	0.00
(Lea, 1838)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	2.46	-	0.97	-	-	-	-	-	2.21	0.00	0.00	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.14	-	0.03	-	-	-	-	-	0.04	0.00	0.00	-
Villosa iris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	1.00	0.50	0.00	0.00	0.00	0.22	0.49	1.17	0.25	0.00	0.00
(Lea 1829)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	1.32	-	0.11	-	-	-	-	-	4.65	0.00	0.00	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.02	-	-	-	-	-	0.05	0.00	0.00	-
Lasmigona holstonia	0.00	0.00	13.2	10.3	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(Lea, 1838)	-	-	-	29.5	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.00	0.00	0.00	-
	-	-	-	0.31	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.00	0.00	0.00	-
Lasmigona costata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00
(Rafinesque, 1820)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.00	0.07	0.00	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.00	0.00	0.00	-
Pleurobema oviforme	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.29	0.50	6.00	1.50	0.00	0.00	1.11	0.49	8.50	1.47	2.11	0.00
(Conrad, 1834)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	3.21	-	4.41	-	-	-	-	-	10.8	1.49	0.85	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.11	-	0.07	-	-	-	-	-	0.10	0.06	0.00	-
Lexingtonia dolabelloides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.50	0.00	0.00	0.00	0.00	0.16	1.00	5.66	11.5	3.86
(Lea, 1840)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.19	-	0.11	-	-	-	-	-	0.22	9.70	21.1	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.00	0.44	0.78	-
Elliptio dilatata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	1.00	0.50	0.67	0.00	0.44	0.16	0.17	0.00	0.00	0.00
(Rafinesque, 1820)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	6.52	-	2.15	-	-	-	-	-	0.28	0.00	0.42	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.22	-	0.02	-	-	-	-	-	0.00	0.00	0.00	-
Ptychobranchus subtentum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	1.14	0.00	0.25	0.00	0.00
(Say, 1825)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.10	-	0.54	-	-	-	-	-	0.11	0.07	0.09	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.03	-	-	-	-	-	0.00	0.00	0.00	-
Ptychobranchus fasciolaris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.83	0.00	0.24	0.43
(Rafinesque, 1820)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.11	-	-	-	-	-	3.04	1.90	1.44	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.03	0.06	0.00	-
Lampsilis fasciola	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.50	0.00	0.00	0.00	0.67	0.16	1.17	0.25	0.00	0.00
Rafinesque, 1820	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.43	-	-	-	-	-	0.55	0.48	0.34	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.00	0.00	0.00	-
Fusconaia barnesiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.50	1.50	0.00	0.00	0.67	0.49	1.50	0.98	0.00	0.00
(Lea, 1838)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	1.42	-	1.56	-	-	-	-	-	2.32	0.14	2.79	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.03	-	0.03	-	-	-	-	-	0.03	0.03	0.00	-
Medionidus conradicus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.16	2.00	0.00	0.00	0.00
(Lea, 1834)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.09	-	0.00	-	-	-	-	-	1.16	0.00	0.00	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.02	0.00	0.00	-
Actinonaias pectorosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	48.4	3.53	3.00
(Conrad, 1834)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.55	37.9	4.99	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.00	0.72	0.05	-
Cyclonaias tuberculata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.94	0.00
(Rafinesque, 1820)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.00	0.07	0.93	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.00	0.00	0.03	-
Epioblasma florentina walkeri	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00
(Wilson & Clark, 1914)	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.00	0.00	0.00	-
	-	-	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	0.00	-	-	-	-	-	0.00	0.00	0.00	-

whereas at survey sites in Chilhowie, no mussels were observed. Upstream of Marion (MFHRM 31.1), the RCPUE estimate was 10 mussels/h of 7 species, but at and downstream of Marion no mussels were collected. Also, no species were found at Atkins. Downstream of these towns, there are recovering reaches of the river where the number of species and relative abundances gradually increase, and aggregations reoccur (Fig. 2 and 3). No juvenile mussels were collected in downstream proximity to these towns. The decreases in species richness and abundance downstream of these towns may be the result of past or present discharges to the river. The locations of permitted discharges (Figs. 2 and 3), authorized by the Virginia Department of Environmental Quality (VDEQ 1998) provide evidence that decreases in species richness and abundance are strongly associated with the presence of towns.

Although the greatest species richness is still found between MFHRM 35.0 and MFHRM 4.8, a comparison of our findings with those of other surveys conducted in the twentieth century shows a distinct decrease in the number of species collected in this river reach (Fig. 4). This decline is particularly evident for the area in and immediately downstream of Chilhowie. From this vicinity of the river, Ortmann (1918) and Stansbery & Clench (1974) reported 11 species of freshwater mussels, whereas Neves et al. (1980) collected 5 species (Table 1). We collected only one species (*V. vanuxemensis*). Also, between MFHRM 42.9 and 53.6 there was a gradual decrease in the number of species to the headwaters, where only *L. holstonia* was collected (Fig. 4). In this river reach and immediately downstream of Atkins, Stansbery & Clench (1974) collected 3 species of mussels, including *V. iris*, *V. vanuxemensis*, and *L. holstonia*. Neves et al. (1980) and our survey recorded only *L. holstonia* in this reach of the river. Thus, the gradual transition to headwater species that existed historically near Atkins has been effectively eliminated since 1974 (Fig. 4). The survey effort expended by the Virginia Department of Conservation and Recreation (VDCR) at MFHRM 19.5 is undocumented, therefore the collection of no live mussels at this survey site (only one recently dead *L. recta* was collected) may be the result of insufficient survey effort (VDCR 1996) (Fig. 4).

Sedimentation and turbidity may be affecting species richness and abundance of freshwater mussels in the river. During our surveys, approximately 50% of all planned survey trips were cancelled due to low visibility from turbid conditions. Weeks after moderate rain events, visibility remained unsuitable for snorkeling. We found that when the discharge measured at the USGS gauging station at Meadowview, VA exceeded 130 cfs, the river downstream of that station was too turbid for surveying. We surveyed from the headwaters of the river (MFHRM 54.6) to downstream of Chilhowie (MFHRM 4.8), and noted that this entire length of river was heavily sedimented and silted. Sedimentation was evident in all areas surveyed except high velocity riffles. Throughout the entire length of the river surveyed, we observed widespread problems of bank erosion and agricultural sediment input, with livestock access to the river as the primary problem.

Although our results show that survey sites immediately downstream of Atkins, Marion, and Chilhowie are nearly devoid of freshwater mussels, they also show that mussel populations at most other survey sites lack recruitment of young mussels. The exception to this was at MFHRM 51.4, a site occupied only by *L. holstonia*. At this site, numerous juveniles were collected and multiple age classes were present. Eleven juvenile *L. holstonia* were sampled at MFHRM 51.4 in our quadrat survey.

No juveniles were observed at survey sites using the CPUE survey method, whereas 9 juveniles were collected using TCPUE. At all sites other than MFHRM 51.4, there was a notable absence of numerous age classes. Mussels at these sites were mostly large old individuals. Although 10.3% of all mussels collected during TCPUE surveys were gravid, no recruitment of juvenile mussels was evident. Because of the absence of recruitment at most sites in the river, we recognize a possible crisis regarding the potential extirpation of uncommon freshwater mussels in most of the MFHR. If conditions that inhibit recruitment and reproduction of mussels in the river do not improve before most individuals in the older age classes die, then several additional species of freshwater mussels may be eliminated from the river.

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