Freshwater Mussel Status: Upper North Fork Holston River, Virginia

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Abstract - Previous freshwater mussel surveys (1915–1997) at sites in the upper North Fork Holston River watershed upstream of Saltville, VA, documented 21 species. To assess current status of the fauna, approximately 363 survey hours were spent qualitatively sampling 44 sites in a 77-km reach of the upper river between Saltville and Ceres during 2000–2004. Thirteen species of live freshwater mussels were collected. Species richness appears to have declined only slightly over the last 100 years in this reach of river. However, declines in abundance are now evident in a 6.4-km reach immediately upstream of Saltville. A die-off of federally endangered *Fusconaia cor* (shiny pigtoe) and candidate species *Lexingtonia dolabelloides* (slabside pearlymussel) was documented in the upper river during 1999–2002, but the cause was not identified.

Introduction

Previous freshwater mussel surveys from 1915–1997 at sites in the upper North Fork Holston River watershed upstream of Saltville, VA, documented 21 species (Table 1). However, these surveys were primarily near Saltville, Smyth County, with little survey effort focused on the upstream section of river. The lower section of the river from Saltville (river kilometer [rkm] 128.6) downstream to the Virginia-Tennessee border (rkm 9.8) was extensively surveyed in 1995 by Henley and Neves (1999). Historically, this section supported at least 34 mussel species; however, due to anthropogenic impacts such as mercury contamination, this section has been reduced to 9 extant species. Discharge of large quantities of elemental mercury (Hg) and chloride salts into the river during this century by industries located at Saltville essentially destroyed the mussel fauna (Henley and Neves 1999).

The section of river upstream of Saltville, consisting of 77 rkm, is surrounded by moderate agricultural activity and limited urban development, and contains a relatively intact mussel fauna that has not received obvious anthropogenic impacts. Several endangered mussel species occur in this section, including the federally endangered (FE) *Fusconaia cor* (Conrad) (shiny pigtoe) and *Pegias fabula* (Lea) (little-wing pearlymussel), and the state endangered (SE) *Alasmidonta viridis* (Rafinesque) (slippershell), *Lasmigona holstonia* (Lea) (Tennessee heelsplitter), and *Lexingtonia dolabelloides* (Lea) (slabside pearlymussel). The latter is a federal candidate

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species (FCS), along with *Ptychobranchus subtentum* (Say) (fluted kidneyshell), which also occurs in the upper river. Because mussel populations in the upper river have not been extensively surveyed, this study was initiated in summer of 2000 to determine the status and distribution of mussel populations in the headwaters of the upper North Fork Holston River upstream of Saltville.

Methods

Study area

During the summers of 2000–2004, approximately 77 kilometers of the upper North Fork Holston River (rkm 135.8–212.7) in Smyth and Bland counties, VA, were surveyed for freshwater mussels (Fig. 1). The river flows in a southwest direction and drains the Valley and Ridge Physiographic Province. The stream bottom is mixed substrata underlain primarily with limestone and shale. The upper river is fourth order in size and features moderate-to-high

Table 1. Mussel species collected in the upper North Fork Holston River upstream of Saltville, Smyth, Tazewell, and Bland counties, VA. Collection records by Adams (1915), Ahlstedt and Saylor (1995–1996), Neves and Odom (1989), Neves and Widlak (1988), Ortmann (1918), Stansbery and Clench (1974), and Winston and Neves (1997). The present study (2000–2004) is from North Fork Holston river kilometer (rkm) 135.8 above Saltville, to Ceres, VA, at rkm 212.4.

	Publication date of previous studies							
Species	1915	1918	1974	1995–1988	1989	1996	1997	This study
Actinonaias pectorosa	-	X	X	X	X	X	-	X
Alasmidonta marginata	-	X	-	-	X	-	-	-
Alasmidonta viridis	X	X	X	X	X	X	-	X[A]
Elliptio dilatata	X	-	-	-	-	-	-	-
Fusconaia barnesiana	X	X	X	X	X	X	X	X
*Fusconaia cor**	X	-	X	X	X	X	-	X
Lampsilis fasciola	X	X	X	X	X	X	X	X
Lampsilis ovata	-	X	X	X	X	-	-	X
Lasmigona costata	X	X	-	X	X	-	-	X
Lasmigona holstonia[B]	-	-	-	-	-	-	-	-
Lemiox rimosus	X	-	-	-	-	-	-	-
Lexingtonia dolabelloides	X	X	X	X	X	X	-	X
Medionidus conradicus	X	X	X	X	X	X	X	X
*Pegias fabula**	X	X	-	-	-	X	-	X[B]
Pleurobema oviforme	X	X	X	X	X	X	X	X
Ptychobranchus fasciolaris	-	-	X	X	X	X	-	X
Ptychobranchus subtentum	X	X	X	X	X	X	-	X
Strophitus undulatus	X	X	-	-	-	-	X	-
Toxolasma lividus	X	X	-	X	X	X	-	-
Villosa iris	X	X	X	X	X	X	X	X
Villosa v. vanuxemensis	-	X	X	X	X	X	X	X
Total # of species (21)	15	16	13	15	16	14	7	15

*Federally endangered.

[A]Only shells collected.

[B]Live specimens were collected upstream of Ceres, Bland County, VA in the early 1990s (D. Hubbs, Tennessee Wildlife Resources Agency, Camden, TN, pers. comm.).

gradient riffle-run fluvial geomorphology. The majority of our survey sites were located in the mainstem of the upper North Fork Holston River, from just above Saltville upstream to Ceres. We also surveyed sites in second-order and third-order tributary streams in this section (Laurel and Lick creeks). Topographic maps with locations of collection sites are on file at the Virginia Cooperative Fish and Wildlife Research Unit, Blacksburg, VA.

Qualitative sampling

Freshwater mussels were sampled at 44 sites (Fig. 1), selected by using 7.5-minute US Geological Survey (USGS) topographic maps. Sampling sites were chosen based on accessibility from roads or bridges, remoteness, and habitat types (e.g., mainstem sites vs. tributary sites). The majority of our sampling effort was focused in riffles and runs that contained suitable substrates for freshwater mussels. Sites were surveyed by snorkeling, with 2–4 individuals searching side-by-side and moving upstream. A few sites in tributaries were too shallow for snorkeling; at these sites, we walked in an upstream direction looking for live mussels protruding from the stream bottom. All fresh-dead or relic shell material was also collected. Mussels were identified to species, counted, and immediately returned to the substrate at their collection site. Scientific names of mussels follow those of Turgeon et al. (1998), and the conservation status of each species follows that of Williams et al. (1992).

Simple linear regression analysis was performed using total catch-per-unit effort (CPUE) (number of individuals/hour) data from each site and regressed along river kilometers to derive the parameters of resultant regression equations (SAS Institute 2001). At each site, snorkel distance was measured with a range finder (Bushnell, yardage pro 400) or visually estimated. Additional data and information on mussel, snail, and crayfish abundance and occurrence, qualitative observations on stream habitat, and comments on surrounding land use of each site are reported in Jones and Neves (2005).

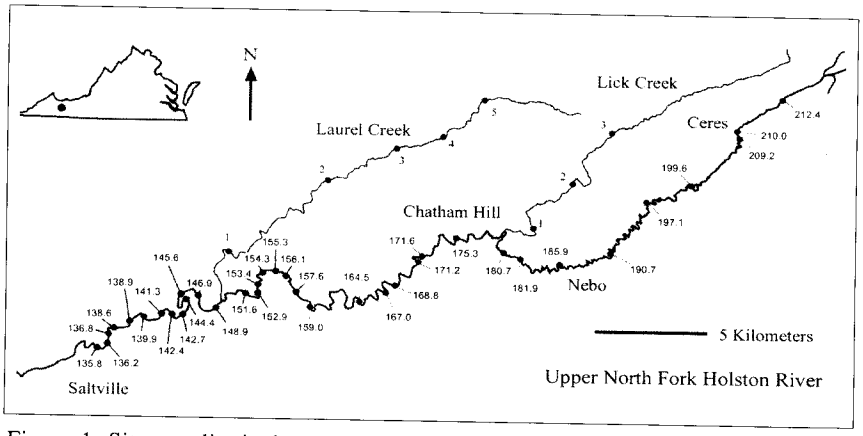

Figure 1. Sites qualitatively surveyed during 2000–2004 for freshwater mussels in the upper North Fork Holston River, VA. Sites are reported as river kilometers or creek sites.

Table 2. Number and CPUE (number of individuals/hour) of mussel species found alive at 36 sampling sites in the upper North Fork Holston River, Smyth and Bland counties, VA.

	River kilometer											
Species	135.8	136.2	136.8	138.6	138.9	139.9	141.3	142.4	142.7	144.4	145.6	146.9
Villosa vanuxemensis	0	0	0	1	0	6	4	6	10	2	1	12
Villosa iris	2	28	26	13	5	5	16	18	35	25	29	70
Lexingtonia dolabelloides	0	2	1	0	3	1	0	6	373	29	19	20
Medionidus conradicus	1	7	13	1	0	5	4	0	4	1	0	4
Ptychobranchus subtentum	0	0	0	0	0	0	0	0	0	0	0	0
Actinonaias pectorosa	1	0	11	1	1	1	5	4	13	4	3	17
Lampsilis fasciola	2	5	6	2	2	2	6	12	36	7	1	28
Pleurobema oviforme	0	0	0	0	0	0	0	0	2	1	0	2
Fusconaia cor	0	3	2	0	5	3	1	8	137	6	11	9
Ptychobranchus fasciolaris	1	1	3	0	4	4	8	15	12	12	11	2
Fusconaia barnesiana	0	0	0	0	0	0	0	0	1	0	0	0
Lasmigona costata	0	0	0	0	0	0	1	0	3	0	0	1
Lampsilis ovata	0	0	1	0	0	0	1	0	3′	0	0	0
Total individuals/site	7	46	63	18	20	27	46	69	629	87	75	165
CPUE	1.2	3.7	6.3	1.0	2.2	3.4	4.6	5.7	21.3	10.9	10.0	9.7

	River kilometer											
Species	148.9	151.6	152.9	153.4	154.3	155.3	156.1	157.6	159.0	164.5	167.0	168.8
Villosa vanuxemensis	51	2	10	23	45	98	122	327	24	120	141	162
Villosa iris	69	14	22	30	37	48	48	235	20	134	145	195
Lexingtonia dolabelloides	44	57	28	96	30	11	1	1	1	3	0	0
Medionidus conradicus	11	0	26	115	70	115	51	123	17	29	57	18
Ptychobranchus subtentum	0	8	66	155	53	89	17	42	18	0	0	0
Actinonaias pectorosa	44	71	26	133	22	19	3	2	1	0	1	0
Lampsilis fasciola	38	27	14	29	7	25	7	28	2	15	16	18

Table 2, continued.

Species	River kilometer											
	148.9	151.6	152.9	153.4	154.3	155.3	156.1	157.6	159.0	164.5	167.0	168.8
Pleurobema oviforme	5	3	11	23	5	12	5	3	2	8	25	15
Fusconaia cor	13	2	0	1	1	0	0	0	0	0	0	0
Ptychobranchus fasciolaris	10	26	17	42	14	12	2	3	1	1	0	0
Fusconaia barnesiana	0	0	0	0	0	0	0	4	0	5	10	2
Lasmigona costata	1	0	0	2	0	0	1	0	0	0	0	0
Lampsilis ovata	2	0	0	0	1	0	0	0	0	0	0	0
Total individuals/site	288	210	220	649	285	429	257	768	86	315	395	410
CPUE	14.4	35.0	22.0	81.1	95.0	30.6	28.5	31.3	5.7	42.0	30.4	39.0

Species	River kilometer											
	171.2	171.6	175.3	180.7	181.9	185.9	190.7	197.1	199.6	209.2	210.0	212.4
Villosa vanuxemensis	27	61	62	40	37	122	97	32	30	92	85	45
Villosa iris	25	76	38	27	47	48	65	26	4	4	0	0
Lexingtonia dolabelloides	0	0	1	0	0	0	0	0	0	0	0	0
Medionidus conradicus	10	22	15	0	1	1	2	0	0	0	0	0
Ptychobranchus subtentum	0	0	0	0	0	0	0	0	0	0	0	0
Actinonaias pectorosa	0	0	0	0	0	0	0	0	0	0	0	0
Lampsilis fasciola	3	15	5	0	1	4	3	1	0	0	0	0
Pleurobema oviforme	4	45	10	1	3	70	40	12	0	0	0	0
Fusconaia cor	0	0	0	0	0	0	0	0	0	0	0	0
Ptychobranchus fasciolaris	0	0	0	0	0	0	0	0	0	0	0	0
Fusconaia barnesiana	1	5	3	0	0	28	14	4	2	0	0	0
Lasmigona costata	0	0	0	0	0	0	0	0	0	0	0	0
Lampsilis ovata	0	0	0	0	0	0	0	0	0	0	0	0
Total individuals/site	70	224	134	68	89	273	221	75	36	96	85	45
CPUE	15.5	24.9	29.8	45.3	9.9	18.2	36.8	12.5	18.0	48.0	28.3	22.5

Results

Approximately 363 survey-hours were expended to sample the upper North Fork Holston River between Saltville and Ceres. At each site in the river, a mean of 10.1 person-hours was spent snorkeling for mussels, covering a mean distance of nearly 395 m per site. Approximately 15.0 survey-hours total were spent sampling two tributaries, Laurel Creek and Lick Creek. At each site in these tributaries, a mean of 1.9 person-hours was spent snorkeling and/or walking, covering a mean distance of nearly 65 m.

We recorded 13 species of live freshwater mussels, totaling 6980 individuals at the 44 sites: 36 sites in the river (Table 2) and 8 sites sampled in Laurel and Lick creeks (Table 3). These species, in order of relative abundance, were as follows (Table 4): *Villosa vanuxemensis* (Lea) (mountain creekshell) (27.1%), *Villosa iris* (Lea) (rainbow mussel) (23.3%), slabside pearlymussel (10.4%), *Medionidus conradicus* (Lea) (Cumberland moccasinshell) (10.3%), fluted kidneyshell (6.4%), *Actinonaias pectorosa* (Conrad) (pheasantshell) (5.5%), *Lampsilis fasciola* (Rafinesque) (wavyrayed lampmussel) (5.3%), *Pleurobema oviforme* (Conrad) (Tennessee clubshell) (4.4%), shiny pigtoe (2.9%), *Ptychobranchus fasciolaris* (Rafinesque) (kidneyshell) (2.9%), *Fusconaia barnesiana* (Lea) (Tennessee pigtoe) (1.1%), *Lasmigona costata* (Rafinesque) (fluted shell) (0.1%), and *Lampsilis ovata* (Say) (pocketbook) (0.1%). Juvenile mussels (individuals <20 mm long) were observed of various species throughout the surveyed reach of river, including juveniles of shiny pigtoe, slabside pearlymussel, and fluted kidneyshell (Jones and Neves 2005). Species richness (≤2) and abundances (≤1/hr.) at tributary sites were low, with the exception of Site 1 in Laurel Creek, which contained 24 individuals of 5 species: mountain creekshell, rainbow mussel, Cumberland moccasinshell, wavyrayed lampmussel, and Tennessee pigtoe (Table 3).

The only federally endangered species found alive during the survey was shiny pigtoe. This species was found at 14 sites between rkm 136.2 and 154.3. Slabside pearlymussel (SE and FCS) was collected alive at 20 sites between rkm 136.2 and 175.3. Fluted kidneyshell (FCS) was collected alive at 8 sites between rkm 151.6 and 159.0. Two additional endangered species

Table 3. Number and CPUE (number of individuals/hour) of mussel species found alive at 8 sampling sites in tributary streams of the upper North Fork Holston River, Smyth, Bland, and Tazewell counties, VA.

	Sites							
	Laurel Creek					Lick Creek		
Species	1	2	3	4	5	1	2	3
Villosa vanuxemensis	5	0	0	0	0	2	1	0
Villosa iris	12	0	0	0	0	0	0	0
Medionidus conradicus	3	0	0	0	0	0	0	0
Lampsilis fasciola	2	2	0	0	0	0	0	0
Fusconaia barnesiana	2	0	0	0	0	0	0	1
Total individuals/site	24	2	0	0	0	2	1	1
CPUE	24	0.7	0	0	0	1	0.5	0.5

were represented by the collection of shells only. One relic shell of little-wing pearlymussel (FE) was collected at rkm 159.0 upstream of Riverside, and several relic shells were collected downstream of the bridge at Nebo, rkm 185.9. One fresh-dead shell of slippershell (SE) was found at rkm 157.6, downstream of the State Route 630 Bridge at Riverside, VA, and one other fresh-dead shell at rkm 154.3.

A plot of catch-per-unit effort (CPUE) regressed on rkm locations shows a downstream pattern of decline in mussel abundance in the surveyed reach of river (Fig. 2). However, mussel abundance based on CPUE at two sites (rkm 153.4 and 154.3) was very high (outliers), which positively affected CPUE in this lower reach downstream of the Route 633 Bridge (Fig. 2). Even with these sites included in the regression analysis, the downstream pattern of decline remains evident; if these two sites are removed from the analysis, the pattern is highly significant ($p < 0.001$).

Discussion

Historical and recent mussel surveys have recorded 21 species in the 77-kilometer reach of river between Saltville and Ceres (Adams 1915; Ahlstedt and Saylor 1995–1996; D. Hubbs, Tennessee Wildlife Resources Agency, Camden, TN, pers. comm.; Neves and Odom 1989; Neves and Widlak 1988; Ortmann 1918; Stansbery and Clench 1974; Winston and Neves 1997). Our study documented the presence of 13 live mussel species and shells of 2 other species in this section, which is comparable to earlier studies (Table 1). Additional specimens of slippershell (3 fresh-dead shells) were collected at rkm 157.6 on 22 July 1999 (B. Beaty, The Nature Conservancy, Abingdon, VA, pers. comm.); therefore, this species is likely extant in the river, but very rare.

Confirmation of an extant population of little-wing pearlymussel in the river is more difficult. A status survey covering the known range of this Cumberlandian species by Ahlstedt and Saylor (1995–1996) reported a

Table 4. Summary of mussel collections in the upper North Fork Holston River, Smyth and Bland counties, VA.

Species	Number collected	Percentage of collection	Sites of occurrence	Distribution range (rkm)
Villosa vanuxemensis	1897	27.1	32	138.6–212.4
Villosa iris	1629	23.3	34	135.8–209.2
Lexingtonia dolabelloides	727	10.4	20	136.2–175.3
Medionidus conradicus	723	10.3	26	135.8–190.7
Ptychobranchus subtentum	448	6.4	8	151.6–159.0
Actinonaias pectorosa	383	5.5	21	135.8–167.0
Lampsilis fasciola	367	5.3	31	135.8–197.1
Pleurobema oviforme	307	4.4	23	142.7–197.1
Fusconaia cor	202	2.9	14	136.2–154.3
Ptychobranchus fasciolaris	201	2.9	21	135.8–164.5
Fusconaia barnesiana	79	1.1	12	142.7–199.6
Lasmigona costata	9	0.1	6	141.3–156.1
Lampsilis ovata	8	0.1	5	136.8–154.3
Total	6980	100.0		

small population in the upper North Fork Holston River. These authors found 3 live, 1 fresh-dead shell, and 2 relict shells downstream of the bridge at Nebo (rkm 185.9). Another live individual was collected in the summer of 1994 across from the USGS gauge station at rkm 136.8 (R.J. Neves, USGS, Blacksburg, VA, unpubl. data). In addition, fresh-dead shells were collected near Nebo in 2004 (S. Hanlon, US Fish and Wildlife Service, Abingdon, VA, pers. comm.). However, the species is difficult to collect because of its small size (adults <20–30 mm) and rare occurrence in the river. Thus, little-wing pearlymussel probably still occurs in the river despite not being collected alive in over 10 years, and should be considered part of the extant mussel fauna.

The SE Tennessee heelsplitter was not found during this survey; however, we only surveyed 3 sites at or upstream of Ceres, VA, where this species was collected in the early 1990s (D. Hubbs, , pers. comm.). A more intensive survey effort is needed in the headwater reaches to determine the occurrence of this rare species in the river.

The last collections of *Elliptio dilatata* (Rafinesque) (spike) and *Lemiox rimosus* (Rafinesque) (birdwing pearlymussel) in the North Fork Holston River are those of C.C. Adams (1915) in the early 1900s; therefore, we consider these 2 species as extirpated. Populations of other species known to occur in the upper river, such as *Alasmidonta marginata* Say (elktoe), *Toxolasma lividus* (Rafinesque) (purple lilliput), and *Strophitus undulatus* (Say) (creeper), also are likely extirpated or extremely rare. These species were recorded sparingly in past collections, and were represented by only 1–3 shells collected in muskrat middens or as relics (Neves and Odom 1989,

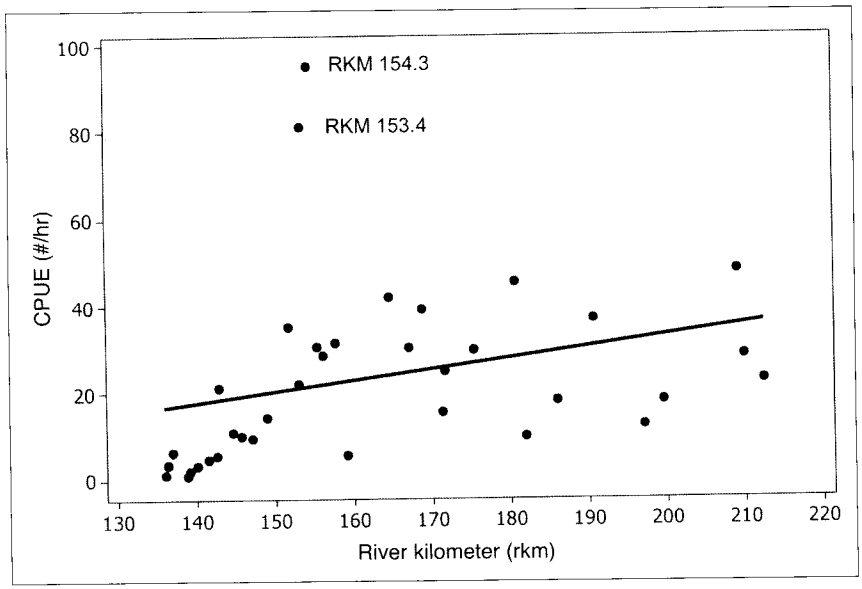

Figure 2. Plot of catch-per-unit effort (CPUE) data at each survey site, regressed on river kilometers (rkm) in the upper North Fork Holston River, VA. The linear regression equation is CPUE = -17.96 + 0.41 (rkm) (R^2 = 7.8%, p = 0.099).

Winston and Neves 1997). Thus, despite the possible loss of a few species that occurred sporadically in the upper river, species richness in the North Fork Holston River upstream of Saltville has declined only slightly in the 20th century. Based on the results of this survey and those conducted in the last 10 years, we believe the extant mussel fauna in the upper North Fork Holston River is comprised of at least 16 species.

Declines in mussel abundance now are evident in sections of the upper river. The reach of river from the State Route 633 Bridge (rkm 142.7) downstream to Saltville (rkm 135.8) shows evidence of population declines. Typically, mussel abundance and richness increase with increasing stream size (Ortmann 1918); however, the opposite trend was observed in this study. The site at rkm 142.7 was one of the best sites in the river for shiny pigtoe and slabside pearlymussel; however, evidence of a die-off primarily of these 2 species at this site was documented beginning in 1999 (Table 5). From 1999–2002, we routinely monitored this site for shells several times each year to determine the extent of the die-off. During this time period, we collected 348 dead slabside pearlymussels and 114 dead shiny pigtoe shells. The majority of collected shells were fresh-dead, and many still contained decaying tissue. The dead mussels appeared to have died in place, and none were collected in muskrat middens. We also observed at that time that some of these dying mussels would first close their shells tightly, and then seemed to waste away until they eventually died and their shells opened again, exposing the decaying soft-parts. The foot of these dying mussels typically appeared emaciated, and approximately 50% of the mantle tissue was separated away from the inside of each valve, creating a pocket of air between the valves and the mantle.

The cause for this die-off currently is unknown and under investigation; the die-off now appears to be recurring from rkm 142.7 upstream to rkm 153.4 (S. Hanlon, pers. comm.). Furthermore, additional sites in this lower reach, such as North Holston Ford (rkm 139.9) and the island at the USGS gauge station (rkm 136.8), contained excellent mussel communities in the late 1980s and early 1990s, but now those communities appear considerably reduced (Neves and Odom 1989; Neves and Widlak 1988; R.J. Neves, USGS, unpubl. data).

Conclusions

Species richness of mussel communities in the North Fork Holston River upstream of Saltville, VA has declined only slightly over the last 100 years. However, a noticeable decline in abundance in the last 10–15 years is now evident in a 6.4-km reach of river immediately upstream of Saltville (rkm

Table 5. Mussels collected fresh-dead in the upper North Fork Holston River immediately upstream (0–200 m) of the State Route 633 Bridge, Smyth County, VA.

Species	Number collected			
	1999	2000	2001	2002
Fusconaia cor	50	10	46	8
Lexingtonia dolabelloides	179	30	119	20

142.7–135.8). Despite this observed decline, juveniles and sub-adults of various species were collected throughout the river, indicating that population recruitment is still occurring for most species. We recommend that the best remaining sites beginning at Rich Valley High School (rkm 156.1) downstream to the Route 633 Bridge (rkm 142.7) be monitored for evidence of further declines or die-offs of mussel populations in the river.

Acknowledgments

We would like to thank Jeff Allen who helped us conduct the survey, and the landowners in Smyth, Bland, and Tazewell counties who granted us permission to access the river through their properties.

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