

**Freshwater Mussel Survey of Three Sites at Cedar Bluff, Clinch River, Virginia:
Augmentation Monitoring Sites - 2007**



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Introduction

Over the last 100 years, freshwater mussel populations have experienced dramatic declines. Among the 297 species historically known from the U.S., nearly 70 % are presently classified as threatened, endangered or extinct (Neves 1999). Similarly, of the 81 freshwater mussel species recognized in Virginia, 37 (46%) are listed as threatened or endangered, with 32 occurring in the Clinch, Powell, and Holston river watersheds of Virginia's upper Tennessee River drainage.

Recent advancements in propagation techniques have led to a vast boom in attempts to restore declining or extirpated populations by releasing cultured juvenile mussels or by translocating adult mussels. Many of these attempts have been made with little or no scientific control with regards to determining success or failure. Before implementing species recovery, it is important to develop baseline information at the release point that includes habitat suitability, mussel assemblage, mussel density, mussel age class structure, host fish presence, and presence or absence of target species (Strayer and Smith 2003). All of these factors must be considered when determining the effectiveness of long-term mussel restoration activities.

In 2002, the Virginia Department of Game and Inland Fisheries (DGIF) developed a strategy to restore freshwater mussels in six reaches within the upper Tennessee River drainage. These reaches include four on the Clinch River, and one site each on the Powell and North Fork Holston rivers (Figure 1). The main restoration technique, termed augmentation, was to release translocated adults or propagated juveniles into reaches where valid species records exist since 1980. Within each

augmentation reach, a site was selected to develop a baseline to gauge success of mussel restoration activities.

In previous years, sample sites have included the Clinch River at Clinchport (Clinch River Mile [CRM] 213.2), Scott Co., (2001 & 2006, Eckert et. al 2008a); Slant (CRM 223.6), Scott Co., (2005, Eckert et. al 2008b); and Cleveland Island (CRM 270.8), Russell Co., (2002). During 2004, two sites; the State Route 833 Bridge crossing (Powell River Mile [PRM] 120.3) and Fletcher Ford (PRM 117.3), were sampled in the Powell River, Lee County, Virginia (2004, Eckert et. al 2007). The present study (2007) sampled three sites on the Clinch River at Cedar Bluff (CRM 322.7) in Tazewell Co.

Objective

At Cedar Bluff, Clinch River, specific objectives of this study were:

1. To map mussel distribution, richness, and relative abundance at available suitable habitat.
2. To quantify mussel aggregations at high density sections at all sites.
3. To identify ideal mussel habitat at each site for mussel augmentation.
4. Determine the effectiveness of previous restoration activities at the Lindsey Property.

Study Area

Three sites on the Clinch River in Tazewell Co., Virginia were sampled during the present study. They will be referred to as Old Mill Road, the Lindsey Property and Davis Property (Figure 2). These three sites are located at Clinch River Mile (CRM) 324.0, 322.7 and 321.6 respectively. These sites were selected as a representative of Virginia Freshwater Mussel Restoration Plan reach 5 which is defined as Pounding Mill downstream to Richlands, including the lower two miles of Indian Creek, a distance of

approximately twelve river miles. This area has been sampled several times previously (Table 1). Records of species presence from these samples can be compared to the current study.

On August 27, 1998 a tanker truck overturned on U.S. Route 460 in Tazewell County, Virginia. The truck released approximately 1,350 gallons of Octocure 554-revised, a rubber accelerant, into an unnamed tributary about 530 feet from its confluence with the Clinch River (U.S. Fish & Wildlife Service 2004). The spill turned the river a snowy white color and caused a significant fish kill. The spill also killed most aquatic benthic macroinvertebrates for about seven miles downstream. It is estimated that over 18,000 freshwater mussels were killed by the spill including over 750 individuals of three endangered species (*Epioblasma florentina walkeri*, *Quadrula cylindrica strigillata* and *Villosa perpurpurea*). Prior to the spill the Clinch River had been described as having one of the most diverse mussel and fish faunas of any comparable sized stream in North America (Neves 1991). Two of the sites for the present study fall within the stream reach affected by the spill (Lindsey Property and Davis Property) while the uppermost site (Old Mill Road) falls above the spill zone (Figure 2).

Methods

Several factors should be considered when selecting a survey design. They include survey goals, target populations, available resources, site characteristics and general knowledge of mussel populations (Strayer and Smith 2003). When conducting a survey it is important to plan sampling techniques that will provide the most useful information possible. To ensure that the current mussel assemblage was accurately characterized, multiple sampling techniques were employed. The use of multiple

sampling techniques increases confidence in the validity of observed results (Strayer and Smith 2003).

Initial site reconnaissance

Prior to the initiation of a large scale quantitative mussel sample an initial site analysis is necessary. Early reconnaissance of a potential survey site includes snorkeling prospective areas to search for suitable habitat and the presence of live mussels. In the case of the present study, two of the selected sites had been impacted by the chemical spill, one of which had been the target of restoration activities. These sites were chosen to determine the progress of mussel stockings thus far. The third site was above the impacted zone and had also been the site of juvenile mussel stockings.

Semi-Quantitative

The semi-quantitative portion of this survey included a systematic sample of the entire site length using 1-m² quadrats. The site was marked every 20 m with stakes and every 40 m with ropes. Ropes were marked every 5 m across the stream with flagging tape to provide lanes and a visual guide while sampling (Figure 3).

Each 20 m section was divided into lanes 5 m wide. Lanes were selected based on the average width of each section, starting with the center of the stream and moving 5 m left and right. One sampler was assigned to each lane, and the longitudinal position of the sampler within the lane was determined randomly. Sampling each lane begins by staggering the starting position of every other sampler, one starts at 1 m then the next at 3 m, while the third sampler begins at 1 m again. From the staggered starting point, a 1-m² quadrat was sampled every 4 m for a total of five quadrats sampled per sampler within

each lane. By this design, 5 m² are sampled in an area that measures 100 m²; a total of 5% of the overall habitat within each lane (Figure 4).

At every quadrat, depth, habitat type, visibility and dominant substrate class were recorded. Mussels on the surface were collected and then the large substrate was removed with the remaining substrate gently fanned to reveal additional mussels near the surface. Every mussel was identified, counted and measured.

By beginning the survey with this method, it is possible to delineate the areas of highest mussel density within the site. After determining the areas of highest density, quantitative sampling was conducted to assess the density of mussels within the mussel bed. Data from the semi-quantitative sample was graphed using spatial analysis in ArcMap 9.2 (ESRI) to visually highlight areas of higher density.

Quantitative

Because of the sensitive species potentially present in the study area only the Lindsey Property was selected for quantitative sampling. An area at the Lindsey Property that had previously been the focus of various mussel stockings (Table 2) was selected for quantitative sampling. Quantitative sampling was used to estimate population size and age structure for monitoring purposes. The quantitative sampling approach involves random sampling within the selected area using 0.25-m² quadrats. A small grid was constructed using an x,y coordinate system. Within the small grid, 50-0.25-m² quadrats were randomly selected. Each quadrat was excavated using a Ferraro streambed sampler; these samplers are built with perforated aluminum, which allows flow through the sampler, while maintaining enough rigidity to handle a large volume of substrate (Figure 5). First, the mussels on the surface are removed, identified and measured, and then the

substrate was excavated into the sampler; typical excavation depth was approximately 20 cm. Substrate from the quadrat was then placed in a set of nested sieves (2.54 cm, 1.27 cm, 0.64 cm) and washed to reveal subsurface mussels. All substrate was returned to the original quadrat after sieving. The purpose of sieving substrate was to collect and identify juvenile mussels which are usually not collected in sampling without excavation; any mussel less than 30 mm was considered a juvenile. All subsurface mussels were identified and measured, and then the data were compiled to determine mean density and precision, target of which was 25%. The Dunn equation for precision, a modified Downing and Downing equation, $[N = ((2*SD)/(P*X))^2]$ was used because it is easy to manipulate and can provide both the precision of the mean and the number of samples needed to obtain the desired precision level (Dunn 2000). Upon completion of quadrat sampling the final precision was calculated. Due to the sensitive nature of the endangered species present in the study area the number of samplers given access to the stream was limited and the total number of quadrats sampled was reduced to decrease the potential impact of sampling activities.

Qualitative

Upon completion of the quantitative sampling, a qualitative sample was taken to determine additional species not found using earlier sampling methods. A qualitative sample is often more effective in detecting the presence of rare species than a quantitative sample (Strayer and Smith 2003). The qualitative sample was conducted systematically in 20 m sections in a similar fashion to the semi-quantitative sample. Samplers either snorkeled or used a view bucket and kept record of live and relic mussels during a 20 minute sample of each section. Observations were recorded at the end of each 20 m

section and the total sample was compiled into an overall list of live and relic species observed.

Results

Davis Property

Semi-Quantitative

The semi-quantitative sample at the Davis Property consisted of 93-1-m² quadrats. The sample area was 70 m long, approximately 24 m wide for a total sample area of 1,650 m² (Figure 6). Present study was conducted during extreme drought conditions; average depth of the site was 12.8 cm, ranging from 0 cm to 26 cm (Figure 7). Visibility was generally greater than one meter. Substrate was predominantly pebble (68%), and gravel (26%) with much lower percentages of cobble, sand, and woody debris.

A total of 3 mussels were collected to yield a mean density of 0.032/m² (Figure 8; Table 3). Only one species was collected live and it showed signs of recent recruitment (*Villosa iris* length < 30 mm; 33.0% of individuals collected).

Qualitative

A 4.0 person-hour visual search was conducted systematically from the downstream to upstream end of the survey site. This search yielded 0 species live and 12 represented by relic shell only for a total of 12 species (Table 4). This sampling added eleven species to our species list, all relic only. *Actinonaias pectorosa*, *E. f. walkeri*, *Fusconaia barnesiana*, *Lampsilis fasciola*, *Lampsilis ovata*, *Medionidus conradicus*, *Pleurobema oviforme*, *Ptychobranhus fasciolaris*, *Ptychobranhus subtentum*, *Q. c.*

strigillata and *V. perpurpurea* were all found as relic shell material during the qualitative sample but had not been collected during the earlier quadrat sample.

Lindsey Property

Semi-Quantitative

The semi-quantitative sample at the Lindsey Property consisted of 160-1-m² quadrats. The sample area was 120 m long, approximately 23 m wide for a total sample area of 2,760 m² (Figure 9). Present study was conducted during extreme drought conditions nearly 10 percent of the sample quadrats were taken on dry substrate; average depth of the site was 23.7 cm, ranging from 0 cm to 78 cm (Figure 10). Visibility was generally less than one meter. Substrate was predominantly pebble (44%), and gravel (15%) with lower percentages of cobble, sand, mud and woody debris.

A total of 17 mussels were collected to yield a mean density of 0.106/m² (Figure 11; Table 5). Four species were collected live, including a federally endangered *V. perpurpurea*, with only one showing signs of recent recruitment (*V. iris* length < 30 mm; 17.6% of individuals collected).

Quantitative

The grid for the quantitative sample was 10 m by 15 m and was located from transects 55-70 in lanes 5-15. This area was chosen because both translocated adults and hatchery reared juvenile mussels had been released there between 2004 and 2006 (Table 2). Average depth in this quantitative sample area was 18.7 cm. In 51-0.25-m² quadrats, 15 mussels were collected for a density of 0.29/0.25 m² (Table 6) with a precision of 49.0%. Recent recruitment was seen in one species, *V. iris* (33.3% of individuals

collected). Of the mussels collected, 33% (5) were visible at the surface, 67% (10) were collected subsurface.

Qualitative

A 6.0 person-hour visual search was conducted systematically from the downstream to upstream end of the survey site. This search yielded 5 species live and 3 represented by relic shell only for a total of 8 species (Table 4). This sampling added five species to our species list (3 live and 2 relic only). *A. pectorosa*, *L. fasciola* and *P. oviforme* were found live during the qualitative sample but had not been collected during the earlier quadrat sample.

Old Mill Road

Semi-Quantitative

The semi-quantitative sample at Old Mill Road consisted of 72-1-m² quadrats. The sample area was 71 m long, approximately 19 m wide for a total sample area of 1,349 m² (Figure 12). Average depth of the site was 31.1 cm, ranging from 0 cm to 59 cm (Figure 13). Visibility was generally less than one meter due to rainstorm activity in the area. Substrate was predominantly sand (28%) and bedrock (28%) with pebble (14%), and gravel (12%) and lower percentages of cobble, mud and woody debris.

A total of 15 mussels were collected to yield a mean density of 0.208/m² (Figure 14; Table 7). Two species were collected live each showing signs of recent recruitment (*V. iris* & *M. conradicus* length < 30 mm; 20.0% of individuals collected).

Qualitative

A 3.5 person-hour visual search was conducted systematically from the downstream to upstream end of the survey site. This sample was conducted during the semi-quantitative sampling, a fact that increased turbidity and may have decreased efficiency of the sample. This search yielded 2 species live and 1 represented by relic shell only for a total of 3 species (Table 4). This sampling added only *P. oviforme* to the species list for this site as relic only.

Discussion

Previous surveys in the present study area recorded 24 species live and 1 by relic shells only (Table 1). The present study found 9 species live and 4 as relic shell only for a total of 13 species. *Actinonaias ligamentina*, *Alasmidonta marginata*, *Alasmidonta viridus*, *Elliptio dilatata*, *Fusconaia cor*, *Fusconaia cuneolus*, *Lasmigona costata*, *Lasmigona holstonia*, *Lexingtonia dolabellloides*, *Pegias fabula*, *Strophitus undulatus* and *Villosa vanuxemensis* were not recorded either live or as relic shells during the present study. While some of these species were lost in the reach prior to the spill, the decline in overall density was certainly brought about by the spill in which a complete kill of 16 species was observed. The three sample approach proved effective in completing an overall species list, 6 species were added by conducting the qualitative surveys (Table 8).

Davis Property

One species was recovered live at this site and 12 others were represented by relic shell material. This indicates a mussel assemblage that was recently eradicated and is in the early stages of recovery. This site is further from a source population to aid in

recruitment than the Lindsey Property and thus will be slower to show natural recruitment. Recently this site has been the focus of cultured juvenile mussel releases. Future studies may document the presence of increased numbers of *A. pectorosa*, *E. dilatata*, *E. f. walkeri*, *L. fasciola*, *L. ovata*, *V. iris* and *V. vanuxemensis*. Recovery of these species in the near future would be an indication that stocking events have been successful. In the future we recommend continued stocking of both cultured juveniles and adult mussels at this site until a suitable population size and structure can be established.

Lindsey Property

Eight species were recorded live at this site, including a single *V. perpurpurea*. Of the species recovered live 5 are believed to be the result of adult mussel translocation activities while only 3 (*F. barnesiana*, *P. oviforme* and *V. iris*) are believed to be the result of natural recruitment or possibly cultured juvenile releases (*V. iris*). Over 300 tagged adult mussels have been released at this site from 2004 to 2006. The present study recovered very few of these individuals prompting us to believe that conditions at this site are presently unsuitable for restoration activities (Table 9). Further study is required to assess the full extent of habitat degradation at this site and it is recommended that restoration activities cease until conditions are better understood.

Old Mill Road

Two species were recorded live at this site and a third by relic shell only. This is the only site in the present study that was unaffected by the 1998 chemical spill. Semi-quantitative sampling data supports that the mussel density at this site is twice as high as the re-built population at the Lindsey Property (0.208/m² vs. 0.106/m²). This site

previously served as our source population for *V. iris* and *M. conradicus* that were translocated to the Lindsey Property from 2004 to 2006. We believe that this may have decreased the number of animals observed at this site. One other reason for lower mussel density at this site is that 28% of the recorded substrate was bedrock or boulder providing little usable mussel habitat. It may be that natural mussel density at this location is relatively low due to habitat constraints.

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Literature Cited

- Ahlstedt, S.A., and J. Tuberville. 1997. Quantitative reassessment of the freshwater mussel fauna in the Clinch and Powell Rivers, Tennessee and Virginia. A national strategy for the conservation of native freshwater mussels. Pp. 72-97 in K.S. Cummings, A.C. Buchanan, C.A. Mayer, & T.J. Naimo, eds. Conservation and management of freshwater mussels II: Initiatives for the future. Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, MO, Upper Mississippi River Conservation Committee, Rock Island, IL.
- Dunn, H.L. 2000. Development of strategies for sampling freshwater mussels (Bivalvia: Unionidae). Pages 161-167. In Tankersley, R.A., D.I. Warmolts, G.T. Watters, B.J. Armitage, P.D. Johnson, and R.S. Butler (editors). 2000. Freshwater Mollusk Symposia Proceedings. Ohio Biological Survey, Columbus, Ohio. xxi + 274p.
- Eckert, N. L., J. J. Ferraro, M. J. Pinder, and B. T. Watson. 2007. Freshwater Mussel and Spiny Riversnail Survey of SR 833 Bridge and Fletcher Ford, Powell River, Virginia: Augmentation Monitoring Sites – 2004. Final Report: Virginia Department of Game and Inland Fisheries, Richmond. 43p.

- Eckert, N. L., J. J. Ferraro, M. J. Pinder, and B. T. Watson. 2008a. Freshwater Mussel and Spiny Riversnail Survey of Clinchport, Clinch River, Virginia: Augmentation Monitoring Site – 2006. Final Report: Virginia Department of Game and Inland Fisheries, Richmond. 39p.
- Eckert, N. L., J. J. Ferraro, M. J. Pinder, and B. T. Watson. 2008b. Freshwater Mussel and Spiny Riversnail Survey of Slant, Clinch River, Virginia: Augmentation Monitoring Site – 2005. Final Report: Virginia Department of Game and Inland Fisheries, Richmond. 36p.
- Jones, J.W., R.J. Neves, M.A. Patterson, C.R. Good and A. DiVittorio. 2001. A status survey of freshwater mussel populations in the Upper Clinch River, Tazewell County, Virginia. *Banisteria* 17:20-30.
- Jones, J.W. and R.J. Neves. 2004. Survey of freshwater mussel populations in Indian Creek, Tazewell County, Virginia. Final Report: U.S. Fish and Wildlife Service, Abingdon, Virginia. 33p.
- Neves, R.J. 1991. Mollusks. In: *Virginia's Endangered Species*. K. Terwilliger, ed. McDonald and Woodward Publishing Co., Blacksburg, Virginia. Pp. 251-320.
- Neves, R.J. 1999. Conservation and commerce: Management of freshwater mussel (*Bivalvia: Unionoidea*) resources in the United States. *Malacologia* 40(1-2):461-474.
- 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.
- Stansbery, D.H., C.B. Stein, and G.T. Watters. 1986. The distribution and relative abundance of unionid mollusks in the Clinch River in the vicinity of Appalachian Power Company's Clinch River Plant at Carbo, Virginia (Clinch River miles 264-270). The Ohio State University Research Foundation, Columbus, OH. 184p.
- Strayer, D.L., and D.R. Smith. 2003. A Guide to Sampling Freshwater Mussel Populations. American Fisheries Society, Monograph 8, Bethesda, Maryland.
- U.S. Fish & Wildlife Service. 2004. Final restoration plan and environmental assessment for the Certus chemical spill natural resource damage assessment. U.S. Fish & Wildlife Service. Virginia Field Office. July 2004. 45p.
- Winston, M.R., and R.J. Neves. 1997. Survey of the freshwater mussel fauna of unsurveyed streams of the Tennessee River drainage, Virginia. *Banisteria* 10:3-8.

Table 1. Previous mussel collections in the Clinch River at or near Cedar Bluff. Records include only collections within 5 river miles of the present survey sites.

Species	1912 ¹	1981 ²	1979 ³	1988 ³	1994 ³	1996 ⁴	1999 ⁵	2004 ⁶	2007 ⁷
<i>A. ligamentina</i>							R		
<i>A. pectorosa</i>		L	L			L	R		
<i>A. marginata</i>	L								
<i>A. viridus</i>	L	L					R		
<i>E. dilatata</i>	L								
<i>E. f. walkeri</i>	L	L			L	L		L	
<i>F. barnesiana</i>	L	L	L		L	L	L	L	
<i>F. cor</i>						L			
<i>F. cuneolus</i>			L						
<i>F. subrotunda</i>	L	L	L				R		
<i>L. fasciola</i>	L	L	L			L	L	L	
<i>L. ovata</i>	L					L			
<i>L. costata</i>	L	L				L	R		
<i>L. holstonia</i>	L	L							
<i>L. dolabelloides</i>	L	L				L			
<i>M. conradicus</i>	L	L			L	L	L	L	
<i>P. fabula</i>		L							
<i>P. oviforme</i>	L	L	L			L	L	L	
<i>P. fasciolaris</i>		L	L			L	L	L	
<i>P. subtentum</i>	L	L	L			L	R		
<i>Q. c. strigillata</i>	L	L				L		L	
<i>S. undulatus</i>	L								
<i>V. iris</i>	L	L	L	L	L	L	L	L	
<i>V. perpurpurea</i>	L	L			L	L		L	
<i>V. vanuxemensis</i>						L	R	L	
Live	19	17	9	1	5	16	6	10	
Relic	--	--	--	--	--	--	7	--	
Total	19	17	9	1	5	16	13	10	

¹Records from Ortmann (1918)

²Records from Stansbery et. al (1986)

³Records from Ahlstedt & Tuberville (1997)

⁴Records from Winston & Neves (1997)

⁵Records from Jones et. al (2001)

⁶Records from Jones & Neves (2004)

⁷Present study conducted at Cedar Bluff from August 7th-9th, 2007.

Table 2. Lab cultured juvenile and translocated adult freshwater mussels released at the Linsey property between 2004 and 2007.

Species	Method	Date	Age	Number
<i>Actinonaias pectorosa</i>	Lab cultured	6/17/05	1 week	1,081
	Translocation	6/17/05	Adult	32
	Lab cultured	10/20/05	1 wk	19,640
<i>Epioblasma f. walkeri</i>	Streamside Infestation	4/20/05	1 day	2,300
	Translocation	4/20/05	Adult	6
	Lab cultured	5/12/05	5 day	754
	Translocation	11/10/05	Adult	7
	Streamside Infestation	3/28/07	1 day	625
	Streamside Infestation	4/12/07	1 day	625
	Streamside Infestation	5/7/07	1 day	625
<i>Fusconaia barnesiana</i>	Lab cultured	8/29/05	3 wks	58
	Translocation	11/2/05	Adult	5
<i>Lampsilis fasciola</i>	Lab cultured	10/22/04	6 yrs	50
	Lab cultured	6/17/05	7 yrs	50
	Lab cultured	6/17/05	1 week	2,692
	Lab cultured	7/12/05	1 week	4,646
	Lab cultured	7/28/05	2 wks	1,622
	Lab cultured	8/10/05	2 day	2,052
	Lab cultured	8/26/05	3 wks	1,095
	Lab cultured	8/29/05	2 wks	6,812
	Lab cultured	8/29/05	8 wks	243
	Lab cultured	9/15/05	3 days	5,817
	Lab cultured	9/29/05	3 wks	2,737
	Lab cultured	10/12/05	12 wks	208
	Lab cultured	10/12/05	2 wks	934
	Lab cultured	10/20/05	3 wks	8,056
	Lab cultured	10/20/05	8 wks	1,426
	Lab cultured	10/12/04	3 days	2,006
	Lab cultured	10/20/04	1 week	2,856
	Lab cultured	6/17/05	2 wks	650
	Lab cultured	7/29/05	3 wks	3,806
	Lab cultured	8/29/05	8 wks	2,187
<i>Lampsilis ovata</i>	Lab cultured	10/12/05	2 wks	642
	Lab cultured	6/13/07	4 days	4,996
	Lab cultured	6/27/07	2 wks	4,354
	Lab cultured	9/15/05	1 week	445
	Translocation	11/2/05	Adult	8
<i>Medionidus conradicus</i>	Translocation	6/17/05	Adult	30
<i>Ptychobranhus fasciolaris</i>	Translocation	6/17/05	Adult	30

Table 2 (Continued). Lab cultured juvenile and translocated adult freshwater mussels released at the Linsey property between 2004 and 2007.

Species	Method	Date	Age	Number
<i>Ptychobranchnus subtentum</i>	Lab cultured	6/17/05	6 wks	100
	Translocation	6/17/05	Adult	22
<i>Quadrula c. strigillata</i>	Lab cultured	6/17/05	4 wks	1,397
	Translocation	6/17/05	Adult	12
<i>Villosa iris</i>	Lab cultured	10/22/04	7 wks	214
	Lab cultured	10/22/04	2 yrs	2
<i>Villosa perpurpurea</i>	Lab cultured	6/17/05	1 week	4,891
	Lab cultured	6/17/05	8 months	200
	Lab cultured	6/17/05	2 wks	3,211
	Lab cultured	7/12/05	1 week	1,485
	Lab cultured	7/28/05	1 week	2,150
	Lab cultured	8/10/05	2 days	1,598
	Lab cultured	8/26/05	2 days	1,041
	Lab cultured	8/29/05	12 wks	211
	Lab cultured	9/15/05	2 wks	709
	Translocation	9/29/05	Adult	40
	Lab cultured	10/12/05	2 wks	4,810
	Lab cultured	10/20/05	12 wks	194
	Translocation	11/2/05	Adult	58
	Lab cultured	10/22/04	6 months	66
	Lab cultured	5/12/05	3 wks	455
	Translocation	6/17/05	Adult	4
<i>Villosa vanuxemensis</i>	Lab cultured	6/17/05	2 wks	3,279
Total (12 Species)				112,327

Table 3. Total number and density of mussel species collected during semi-quantitative sampling of the Clinch River at the Davis Property. Individuals measuring less than 30 mm were considered juveniles.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per m ²)
<i>Villosa iris</i>	3	1	100	0.03
<i>Actinonaias pectorosa</i>	0	0	0	0
<i>Elliptio dilatata</i>	0	0	0	0
<i>Epioblasma f. walkeri</i>	0	0	0	0
<i>Fusconaia barnesiana</i>	0	0	0	0
<i>Fusconaia cor</i>	0	0	0	0
<i>Fusconaia cuneolus</i>	0	0	0	0
<i>Fusconaia subrotunda</i>	0	0	0	0
<i>Lampsilis fasciola</i>	0	0	0	0
<i>Lampsilis ovata</i>	0	0	0	0
<i>Lasmigona costata</i>	0	0	0	0
<i>Lexingtonia dolabelloides</i>	0	0	0	0
<i>Medionidus conradicus</i>	0	0	0	0
<i>Pleurobema oviforme</i>	0	0	0	0
<i>Ptychobranhus fasciolaris</i>	0	0	0	0
<i>Ptychobranhus subtentum</i>	0	0	0	0
<i>Quadrula c. strigillata</i>	0	0	0	0
<i>Villosa perpurpurea</i>	0	0	0	0
<i>Villosa vanuxemensis</i>	0	0	0	0
Total	3	1	100	0.03

Table 4. Live and relic mussels collected in the present study during qualitative sampling, August 2007.

Species	Davis Property	Lindsey Property	Old Mill Road	Overall
<i>Actinonaias pectorosa</i>	R	L		L
<i>Elliptio dilatata</i>				
<i>Epioblasma f. walkeri</i>	R			R
<i>Fusconaia barnesiana</i>	R	R		R
<i>Fusconaia cor</i>				
<i>Fusconaia cuneolus</i>				
<i>Fusconaia subrotunda</i>	R			R
<i>Lampsilis fasciola</i>	R	L		L
<i>Lampsilis ovata</i>	R			R
<i>Lasmigona costata</i>				
<i>Lexingtonia dolabelloides</i>				
<i>Medionidus conradicus</i>	R	R	L	L
<i>Pleurobema oviforme</i>	R	L	R	L
<i>Ptychobranhus fasciolaris</i>	R			R
<i>Ptychobranhus subtentum</i>	R	L		L
<i>Quadrula c. strigillata</i>	R			R
<i>Villosa iris</i>	R	L	L	L
<i>Villosa perpurpurea</i>	R			R
<i>Villosa vanuxemensis</i>				
Live	--	5	2	6
Relic	13	2	1	7
Total	13	7	3	13

Table 5. Total number and density of mussel species collected during semi-quantitative sampling of the Clinch River at the Lindsey Property. Individuals measuring less than 30 mm were considered juveniles.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per m ²)
<i>Villosa iris</i>	14	3	82.3	0.088
<i>Ptychobranhus fasciolaris</i>	1	0	5.9	0.006
<i>Ptychobranhus subtentum</i>	1	0	5.9	0.006
<i>Villosa perpurpurea</i>	1	0	5.9	0.006
<i>Actinonaias pectorosa</i>	0	0	0	0
<i>Elliptio dilatata</i>	0	0	0	0
<i>Epioblasma f. walkeri</i>	0	0	0	0
<i>Fusconaia barnesiana</i>	0	0	0	0
<i>Fusconaia cor</i>	0	0	0	0
<i>Fusconaia cuneolus</i>	0	0	0	0
<i>Fusconaia subrotunda</i>	0	0	0	0
<i>Lampsilis fasciola</i>	0	0	0	0
<i>Lampsilis ovata</i>	0	0	0	0
<i>Lasmigona costata</i>	0	0	0	0
<i>Lexingtonia dolabelloides</i>	0	0	0	0
<i>Medionidus conradicus</i>	0	0	0	0
<i>Pleurobema oviforme</i>	0	0	0	0
<i>Quadrula c. strigillata</i>	0	0	0	0
<i>Villosa vanuxemensis</i>	0	0	0	0
Total	17	3	100	0.106

Table 6. Total number and density of mussel species collected in the Clinch River at the Lindsey Property in quantitative sampling. Individuals measuring less than 30 mm were considered juveniles.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per 0.25m ²)
<i>Villosa iris</i>	11	5	0	0.216
<i>Actinonaias pectorosa</i>	2	0	0	0.039
<i>Fusconaia barnesiana</i>	1	0	0	0.019
<i>Ptychobranhus fasciolaris</i>	1	0	0	0.019
<i>Elliptio dilatata</i>	0	0	0	0
<i>Epioblasma f. walkeri</i>	0	0	0	0
<i>Fusconaia cor</i>	0	0	0	0
<i>Fusconaia cuneolus</i>	0	0	0	0
<i>Fusconaia subrotunda</i>	0	0	0	0
<i>Lampsilis fasciola</i>	0	0	0	0
<i>Lampsilis ovata</i>	0	0	0	0
<i>Lasmigona costata</i>	0	0	0	0
<i>Lexingtonia dolabelloides</i>	0	0	0	0
<i>Medionidus conradicus</i>	0	0	0	0
<i>Pleurobema oviforme</i>	0	0	0	0
<i>Ptychobranhus subtentum</i>	0	0	0	0
<i>Quadrula c. strigillata</i>	0	0	0	0
<i>Villosa perpurpurea</i>	0	0	0	0
<i>Villosa vanuxemensis</i>	0	0	0	0
Total	15	5	100	0.294

Table 7. Total number and density of mussel species collected during semi-quantitative sampling of the Clinch River at Old Mill Road. Individuals measuring less than 30 mm were considered juveniles.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per m ²)
<i>Villosa iris</i>	12	2	80	0.167
<i>Medionidus conradicus</i>	3	1	20	0.041
<i>Actinonaias pectorosa</i>	0	0	0	0
<i>Elliptio dilatata</i>	0	0	0	0
<i>Epioblasma f. walkeri</i>	0	0	0	0
<i>Fusconaia barnesiana</i>	0	0	0	0
<i>Fusconaia cor</i>	0	0	0	0
<i>Fusconaia cuneolus</i>	0	0	0	0
<i>Fusconaia subrotunda</i>	0	0	0	0
<i>Lampsilis fasciola</i>	0	0	0	0
<i>Lampsilis ovata</i>	0	0	0	0
<i>Lasmigona costata</i>	0	0	0	0
<i>Lexingtonia dolabelloides</i>	0	0	0	0
<i>Pleurobema oviforme</i>	0	0	0	0
<i>Ptychobranhus fasciolaris</i>	0	0	0	0
<i>Ptychobranhus subtentum</i>	0	0	0	0
<i>Quadrula c. strigillata</i>	0	0	0	0
<i>Villosa perpurpurea</i>	0	0	0	0
<i>Villosa vanuxemensis</i>	0	0	0	0
Total	15	3	100	0.208

Table 8. Mussel species collected in the Clinch River at Cedar Bluff based on type of sampling employed. Qualitative reflect all species collected live, fresh dead or relic; other samples are live collections only.

Species	Semi-Quantitative	Quantitative	Qualitative	Overall
<i>Actinonaias pectorosa</i>		X	X	X
<i>Elliptio dilatata</i>				
<i>Epioblasma f. walkeri</i>			X	X
<i>Fusconaia barnesiana</i>		X	X	X
<i>Fusconaia cor</i>				
<i>Fusconaia cuneolus</i>				
<i>Fusconaia subrotunda</i>			X	X
<i>Lampsilis fasciola</i>			X	X
<i>Lampsilis ovata</i>			X	X
<i>Lasmigona costata</i>				
<i>Lexingtonia dolabelloides</i>				
<i>Medionidus conradicus</i>	X		X	X
<i>Pleurobema oviforme</i>			X	X
<i>Ptychobranhus fasciolaris</i>	X	X	X	X
<i>Ptychobranhus subtentum</i>	X		X	X
<i>Quadrula c. strigillata</i>			X	X
<i>Villosa iris</i>	X	X	X	X
<i>Villosa perpurpurea</i>	X		X	X
<i>Villosa vanuxemensis</i>				
Totals	5	4	13	13

Table 9. Tagged adult mussels recovered during the present study of the Clinch River near Cedar Bluff.

Species	Site	Tag Number	Status	Survey Type
<i>A. pectorosa</i>	Lindsey	L533	Live	Quantitative
<i>A. pectorosa</i>	Lindsey	D201	Live	Quantitative
<i>A. pectorosa</i>	Lindsey	A124	Live	Quantitative
<i>A. pectorosa</i>	Lindsey	L524	Live	Quantitative
<i>A. pectorosa</i>	Lindsey	L514	Live	Quantitative
<i>E. f. walkeri</i>	Davis	D038	Relic	Qualitative
<i>L. fasciola</i>	Lindsey	D247	Relic	Semi-quantitative
<i>L. fasciola</i>	Lindsey	X	Live	Qualitative
<i>L. fasciola</i>	Lindsey	D472	Relic	Qualitative
<i>L. fasciola</i>	Lindsey	D450	Relic	Qualitative
<i>L. fasciola</i>	Lindsey	D091	Relic	Quantitative
<i>P. fasciolaris</i>	Lindsey	L555	Live	Quantitative
<i>P. fasciolaris</i>	Lindsey	D215	Live	Quantitative
<i>P. fasciolaris</i>	Lindsey	A042	Relic	Quantitative
<i>P. fasciolaris</i>	Lindsey	D210	Live	Semi-quantitative
<i>P. fasciolaris</i>	Lindsey	L553	Live	Semi-quantitative
<i>P. subtentum</i>	Lindsey	D124	Live	Semi-quantitative
<i>P. subtentum</i>	Lindsey	L547	Live	Qualitative
<i>V. iris</i>	Lindsey	D485	Live	Semi-quantitative
<i>V. iris</i>	Lindsey	D446	Relic	Semi-quantitative
<i>V. iris</i>	Lindsey	D392	Live	Semi-quantitative
<i>V. iris</i>	Lindsey	D461	Live	Qualitative
<i>V. iris</i>	Lindsey	D461	Live	Semi-quantitative

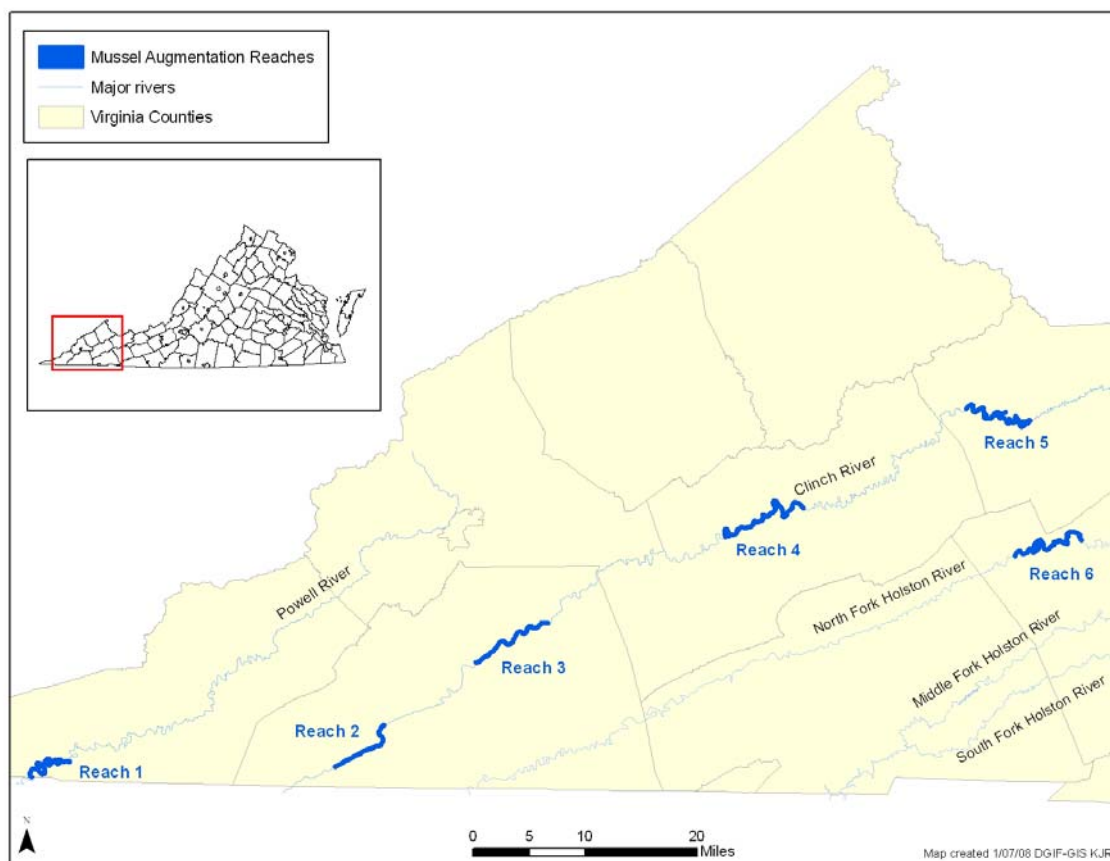


Figure 1. Stream reaches designated as augmentation reaches by the Virginia Department of Game and Inland Fisheries mussel restoration plan. Six reaches are divided between the Powell River (1), Clinch River (4) and North Fork Holston River (1).

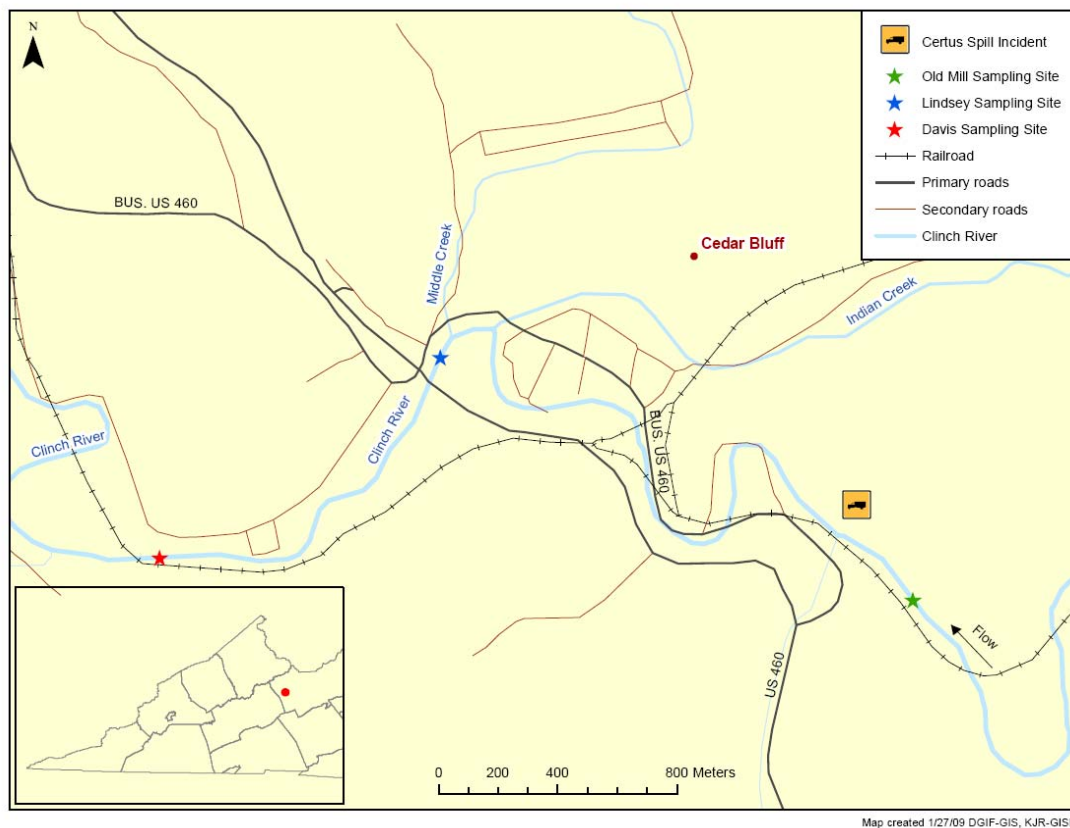


Figure 2. Location of present study sites within Tazewell County, Virginia.



Figure 3. Elevated view of the Lindsey Property. Ropes are stretched every 40 meters with flags every 5 meters to delineate lanes and serve as a visual guide.

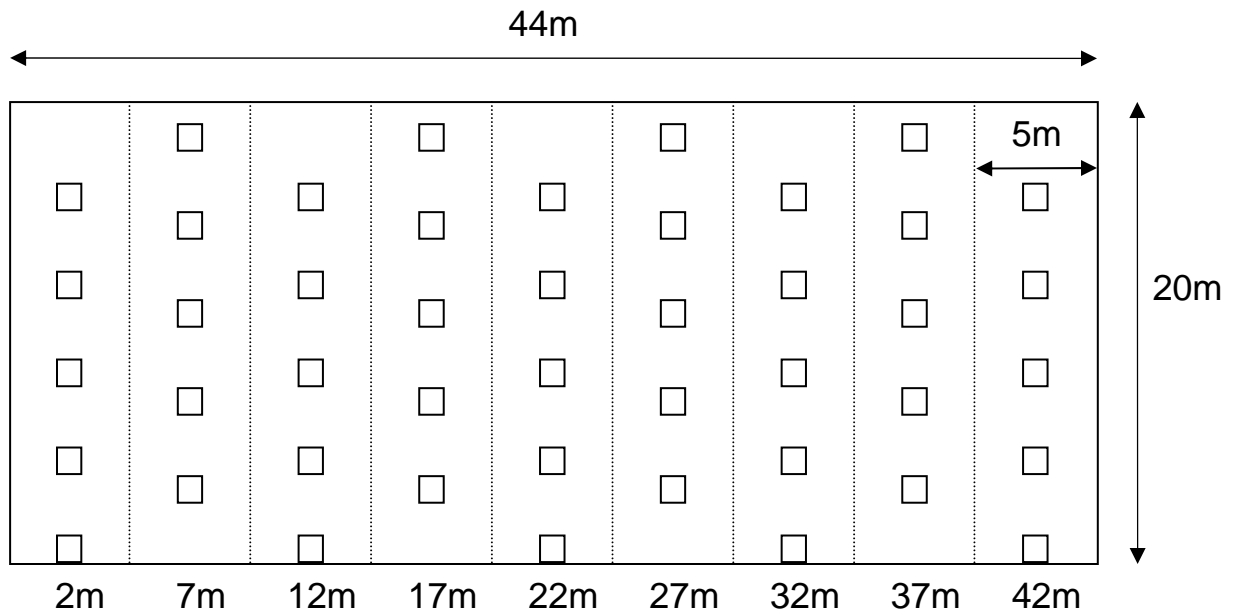


Figure 4. Representation of semi-quantitative sampling method at a site 44m wide. Squares indicate sampling location and lines show lane boundaries. Each lane is 5m wide and 20m long. Five samples are taken representing 5% of overall habitat. Starting position of samplers alternates between 1m and 3m.



Figure 5. The Ferraro streambed sampler. This sampler is made with perforated aluminum and was designed to hold all substrate excavated from a 0.25 m² quadrat.

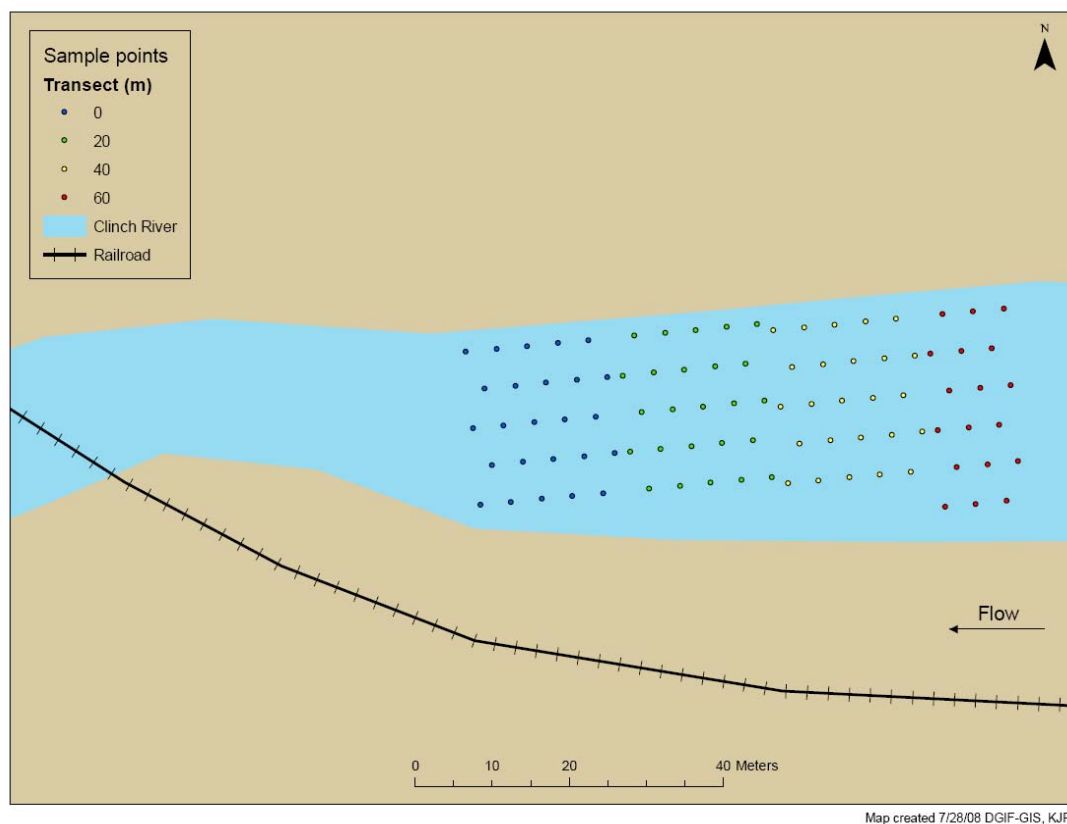


Figure 6. Location of 1m quadrats sampled during semi-quantitative sampling on the Clinch River at the Davis Property.

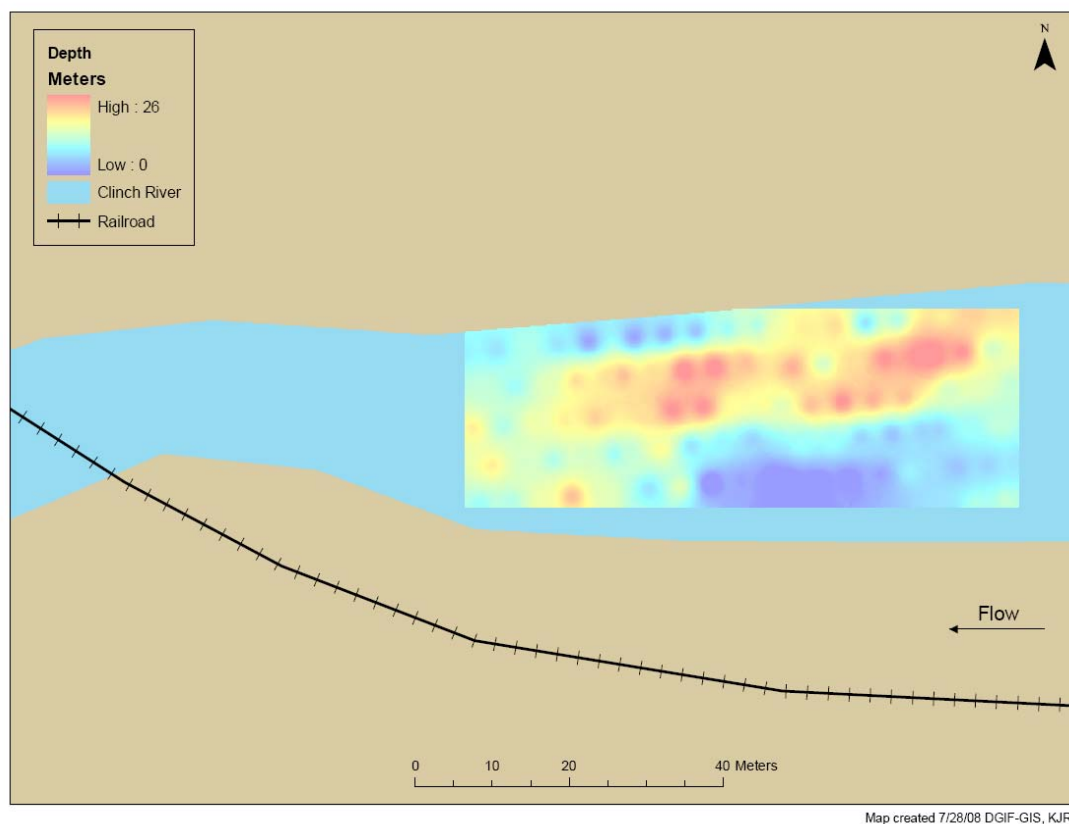


Figure 7. Depth profile of the Clinch River at the Davis Property, August 2007.

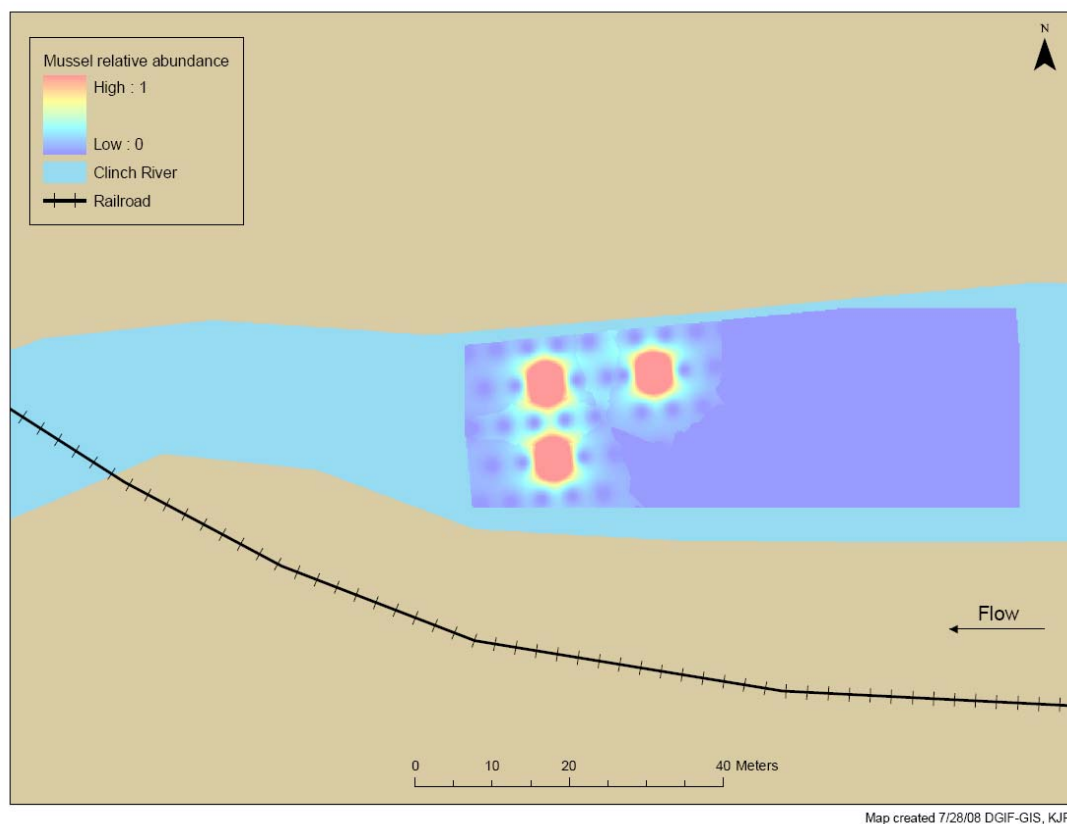


Figure 8. Relative abundance and location of mussels collected at the Davis Property during the present study.

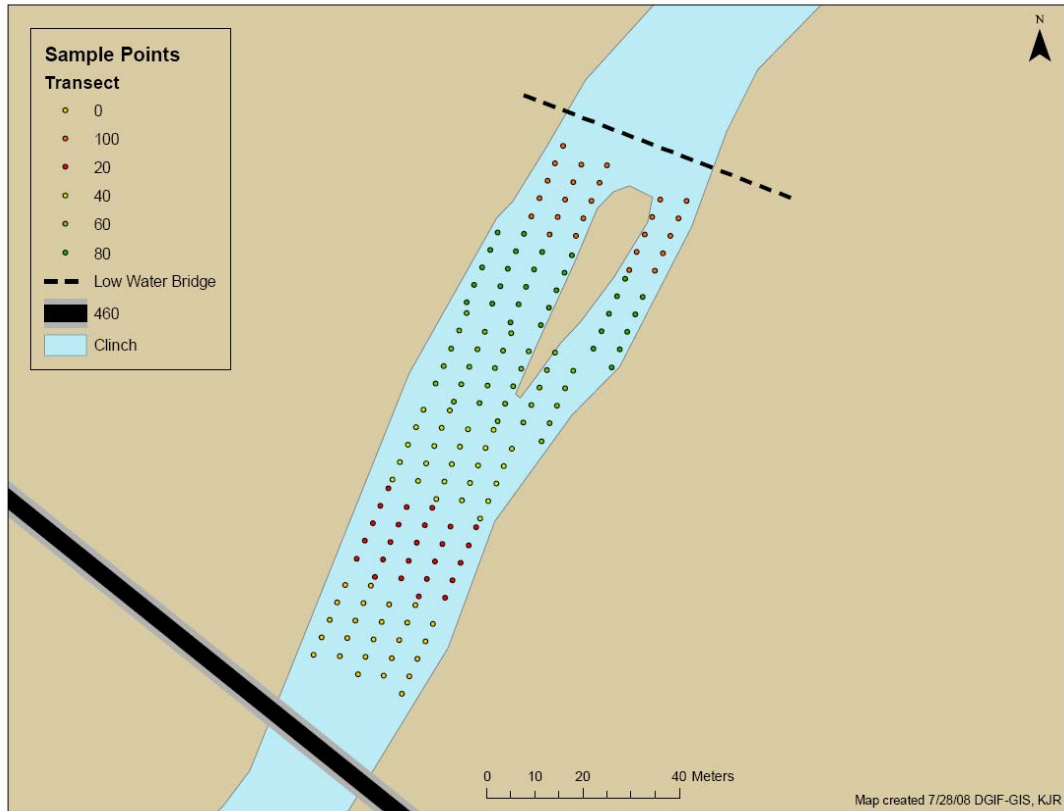


Figure 9. Location of 1m quadrats sampled during semi-quantitative sampling on the Clinch River at the Lindsey Property.

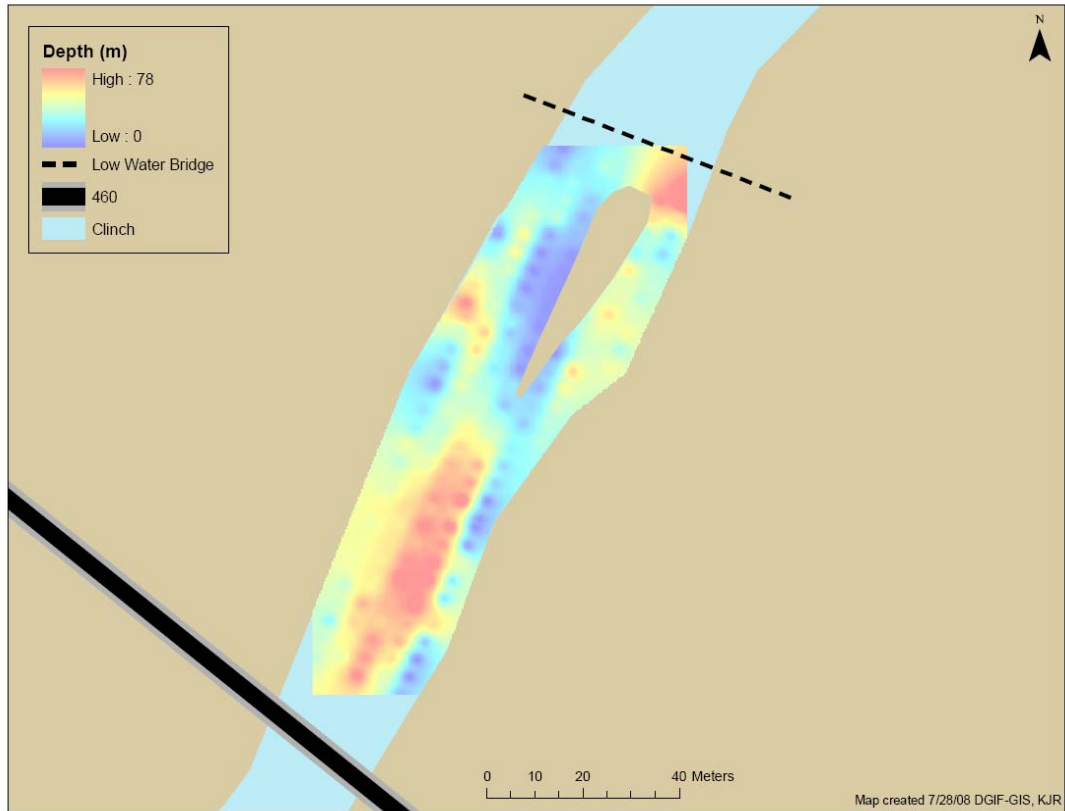


Figure 10. Depth profile of the Clinch River at the Lindsey Property, August 2007.

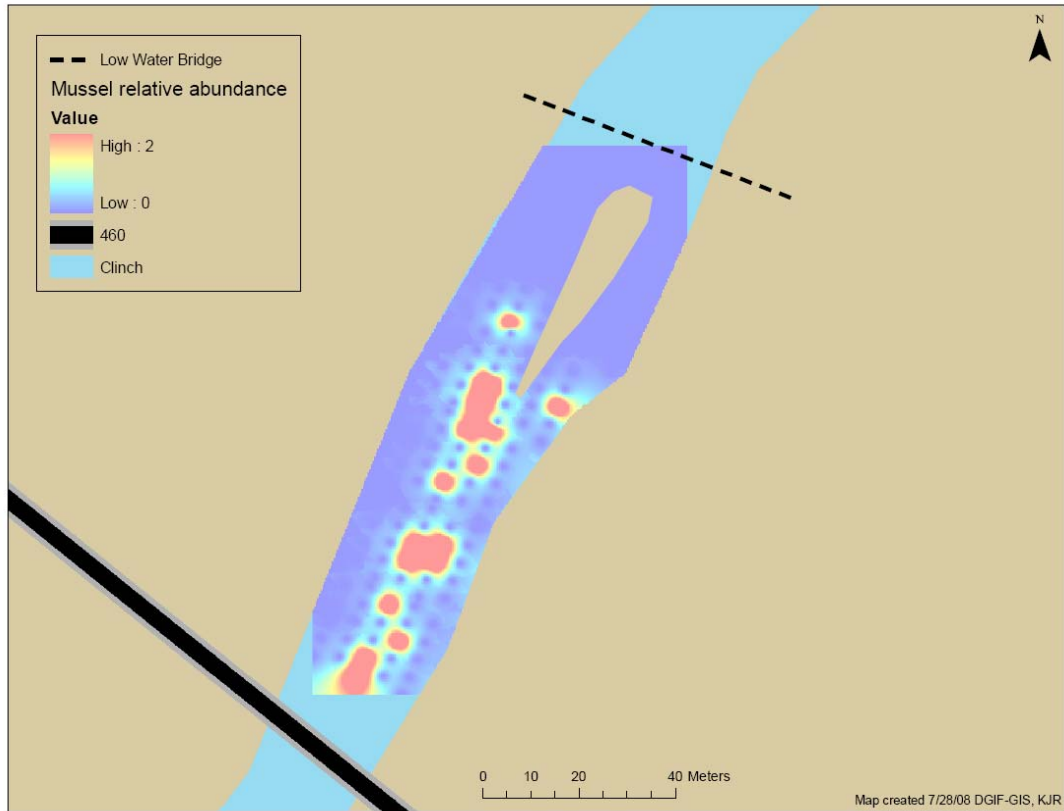


Figure 11. Relative abundance and location of mussels collected at the Lindsey Property during the present study.

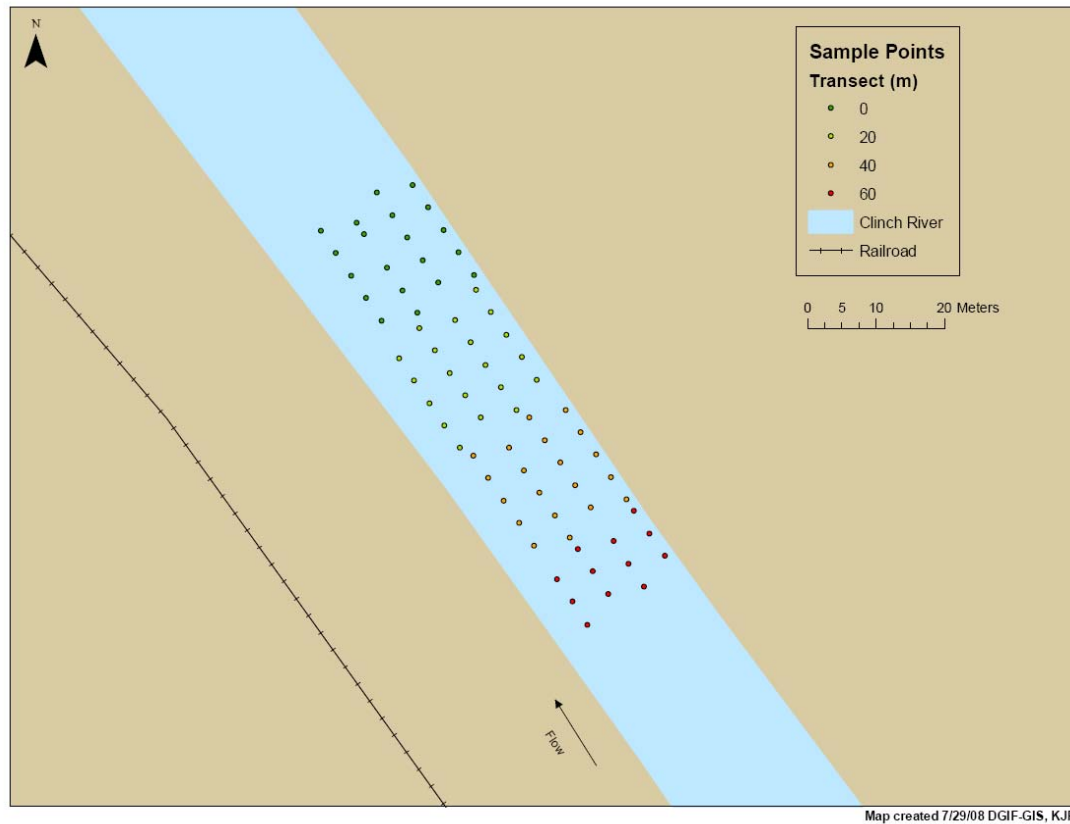


Figure 12. Location of 1m quadrats sampled during semi-quantitative sampling on the Clinch River on Old Mill road.

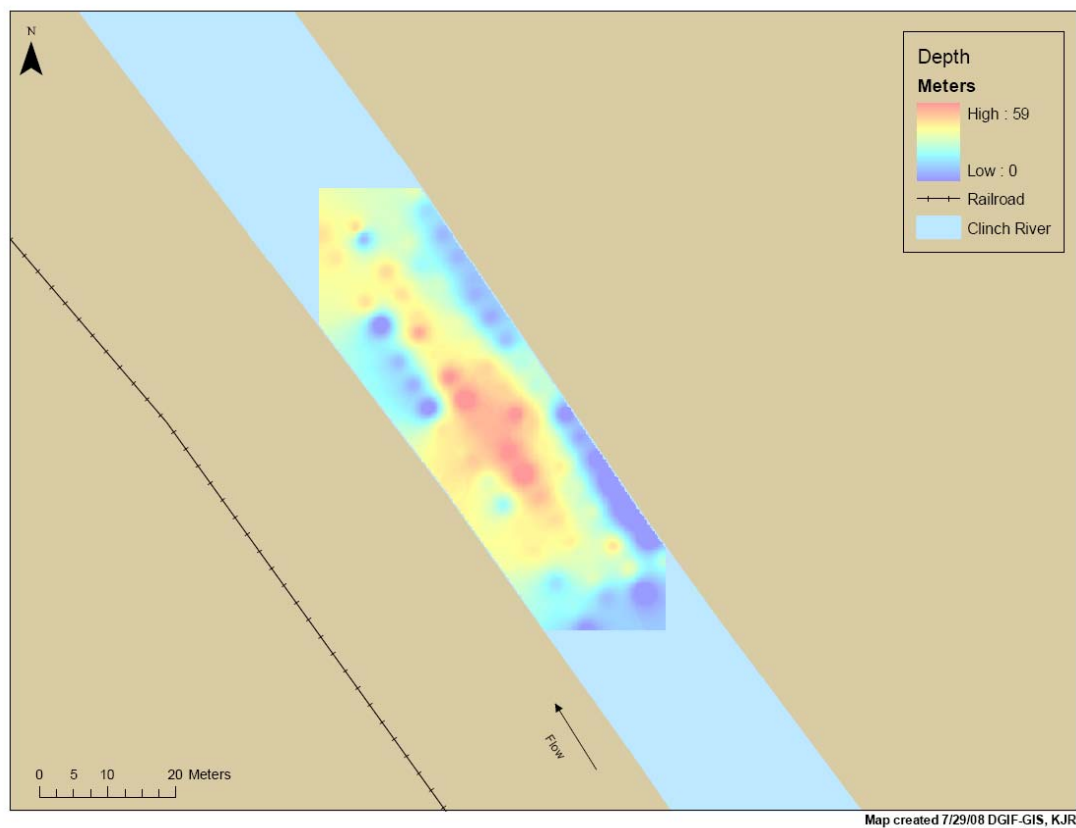


Figure 13. Depth profile of the Clinch River at Old Mill road, August 2007.

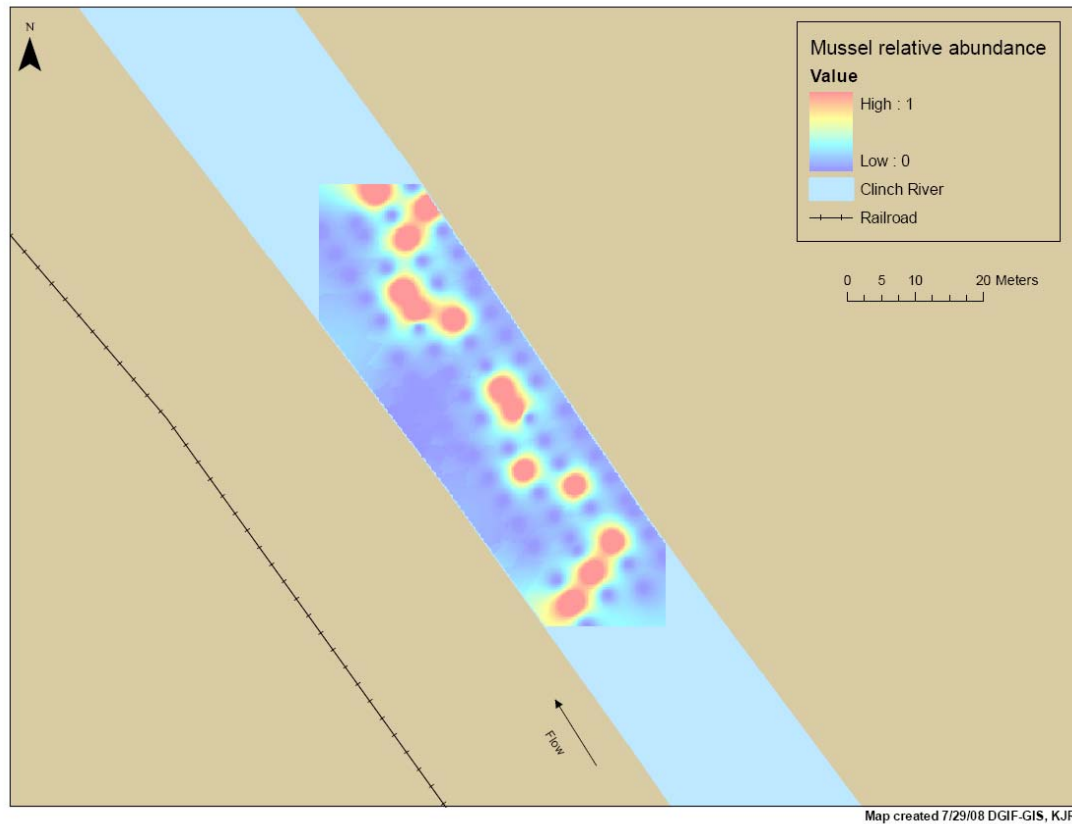


Figure 14. Relative abundance and location of mussels collected at Old Mill road during the present study.

Appendix 1. Scientific name, common name, Virginia wildlife action plan tier, state and

federal status of species mentioned in this report.

Species Name	Common Name	WAP Tier	State*	Federal*
<i>Actinonaias ligamentina</i>	mucket	---	----	----
<i>Actinonaias pectorosa</i>	pheasantshell	---	----	----
<i>Alasmidonta marginata</i>	elktoe	III	SSC	SOC
<i>Alasmidonta viridus</i>	slippershell	II	SE	----
<i>Elliptio dilatata</i>	spike	---	----	----
<i>Epioblasma f. walkeri</i>	tan riffleshell	I	SE	FE
<i>Fusconaia barnesiana</i>	Tennessee pigtoe	II	SSC	----
<i>Fusconaia cor</i>	shiny pigtoe	I	SE	FE
<i>Fusconaia cuneolus</i>	finerayed pigtoe	I	SE	FE
<i>Fusconaia subrotunda</i>	longsolid	III	----	SOC
<i>Lampsilis fasciola</i>	wavyrayed lampmussel	---	----	----
<i>Lampsilis ovata</i>	pocketbook	IV	----	----
<i>Lasmigona costata</i>	flutedshell	---	----	----
<i>Lasmigona holstonia</i>	Tennessee heelsplitter	II	SE	SOC
<i>Lexingtonia dolabelloides</i>	slabside pearlymussel	II	ST	FC
<i>Medionidus conradicus</i>	moccasinshell	---	----	----
<i>Pegias fabula</i>	little-wing pearlymussel	I	SE	FE
<i>Pleurobema oviforme</i>	Tennessee clubshell	III	----	SOC
<i>Ptychobranhus fasciolaris</i>	kidneyshell	---	----	----
<i>Ptychobranhus subtentum</i>	fluted kidneyshell	II	----	FC
<i>Quadrula c. strigillata</i>	rough rabbitsfoot	I	SE	FE
<i>Strophitus undulatus</i>	creeper	IV	----	----
<i>Villosa iris</i>	rainbow	---	----	----
<i>Villosa perpurpurea</i>	purple bean	I	SE	FE
<i>Villosa vanuxemensis</i>	mountain creekshell	IV	----	----

* FE=Federally Endangered, SOC=Federal Species of Concern, FC=Federal Candidate, SE=State Endangered, ST=State Threatened, SSC=State Species of Concern.