Freshwater Mussel and Spiny Riversnail Survey of Slant, Clinch River, Virginia: Augmentation Monitoring Site: 2005

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Introduction

Freshwater mussel populations have experienced dramatic declines across the country when comparing the current assemblages to historical accounts. 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 at 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 at least 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 (CRM 213.2), Scott Co., (2001) and the Clinch River at Cleveland Island (CRM 270.8), Russell Co., (2002). During 2004, two sites; the State Route 833 Bridge crossing (PRM 120.3) and Fletcher Ford (PRM 117.3), were sampled in the Powell River, Lee County, Virginia (Eckert et. al 2007). The present study (2005) sampled the Clinch River at Slant (CRM 223.6) in Scott Co.

Objective

At Slant, Clinch River, specific objectives of this study were:

1. To map mussel distribution, richness, and relative abundance at available suitable habitat including the state endangered spiny riversnail (*Io fluvialis*).
2. To quantify sections of high density mussel aggregations at the site.
3. To identify ideal mussel habitat at the site for mussel augmentation.

Study Area

The site known as Slant is 6.7 km south of Fort Blackmore in Scott, Co Virginia and located at Clinch River Mile 223.6 (Figures 2 & 3). A swinging bridge that was built in 1977 (VDOT structure #9009) SR 662 crosses the Clinch River just downstream of the site. This site was selected as a representative of Virginia Freshwater Mussel Restoration Plan reach 3 which is defined as Pendleton, Grays and Simones islands. This site was selected because of its' close proximity to Pendleton Island (approximately 1.5 RM downstream) and that it was more accessible to a large survey crew. This area has been

sampled several times over the last 30 years (Table 1), records from these samples can be compared to the current study.

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 measured, 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. During these early site visits factors such as site accessibility and ease of sampling are considered. In addition, notes are taken about rare species collections in the event that they are not collected during quantitative sampling.

Semi-Quantitative

The semi-quantitative portion of this survey included a systematic sample of the entire site length using 1-m^2 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 4).

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-m^2 quadrat was sampled every 4 m for a total of five quadrats sampled per sampler within each lane. By this design, 5 m^2 are sampled in an area that measures 100 m^2; a total of 5% of the overall habitat within each lane (Figure 5).

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. In addition, presence of the spiny riversnail was recorded.

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. Upon completion of the entire survey (semi-quantitative, quantitative, and qualitative), the semi-quantitative data was statistically analyzed to verify the location selection for quantitative sampling. Analysis of Variance was conducted (with multiple comparisons, $P < 0.05$) to find significant differences between sections sampled. Any significant difference indicates an area of higher mussel density which may be sampled

quantitatively. Data from the semi-quantitative sample was graphed using spatial analysis in ArcMap 9.1 (ESRI) to visually highlight areas of higher density.

Quantitative

The area of highest mussel density during semi-quantitative sampling 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-m^2 quadrats. A small grid was constructed using an x,y coordinate system. Within the small grid, 100-0.25-m^2 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 6). First, the mussels on the surface are removed, identified, counted, 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 and juvenile mussels. All subsurface and juvenile mussels were identified, counted, and measured, and then the data were compiled to determine mean density and precision, target of which was 25%. The Dunn equation, a modified Downing and Downing equation, for precision [$N = ((2*SD)/ (P*X))^2$] 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 any additional quadrats to achieve the desired precision level, the final precision was calculated.

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.

Incidental

During any intensive multi-layered quantitative survey there are ample opportunities for samplers to encounter mussels outside of structured sampling. This includes mussels observed during preliminary site surveys, site preparation and mussels that are found near but outside of sampling quadrats. Species found live in this manner that are not otherwise collected in structured sampling will be recorded as incidental finds.

Results

Semi-Quantitative

The semi-quantitative sample at Slant included 435-1-m^2 quadrats. The sample area was 200-m long and approximately 45-m wide for a total sample area of 9,000 m^2 (Figure 7). Average depth of the site was 47.1 cm, ranging from 2 cm to 110 cm (Figure

8). Visibility was generally greater than one meter. Flow rate was approximately 350 CFS during the three days of sampling. Substrate was predominantly cobble (31%), boulder (31%) and gravel (22%) along with much lower percentages of pebbles, sand and mud.

A total of 605 mussels were collected to yield a mean density of 1.39/m^2 (Table 2). Twenty-two species were collected alive with only *Villosa iris* showing signs of recent recruitment (length < 30 mm; 0.2% of individuals collected). Two distinct mussel aggregations were identified within the sample area near mid-channel between 60 m and 120 m and also from 140 m upstream to 200 m (Figure 9). The most abundant species were *Actinonaias ligamentina* (263), *Actinonaias pectorosa* (106) and *Ptychobranchus fasciolaris* (40).

Density of *Io fluvialis* was 1.11 snails/m^2 equaling 482 collected individuals. Spiny riversnail distribution showed that their highest density was found from markers 40-120 m along the left ascending side of midstream (Figure 10).

Quantitative

During the Slant survey, two quantitative samples were taken. For reporting purposes, they will be referred to as the upper and lower quantitative sample because the upper sample was nearly directly upstream of the lower sample (Figure 11).

Lower quantitative

The grid for the lower quantitative sample was 60 m by 15 m and was located from transects 60-120 in lanes 15-30. Average depth in this quantitative sample area was 52.7cm. In 101 0.25-m^2 quadrats, 96 mussels were collected for a density of 0.95/0.25 m^2 (Table 3) with a precision of 21.4%. Recent recruitment was seen in three species,

Elliptio dilatata, Medionidus conradicus and *P. fasciolaris* (3.1% of individuals collected). Of the mussels collected, 59% (57) were visible at the surface, 41% (39) were collected subsurface. The most common species (*A. ligamentina*; 43 collected) showed no significant difference in length of individuals collected surface vs. subsurface (P=0.511). A length frequency analysis of this species showed the majority of individuals collected to be larger than 90 mm with no individuals smaller than 50 mm (Figure 12).

Upper quantitative

The grid for the upper quantitative sample was 60 m by 15 m and was located from transects 140-200 in lanes 20-35. Average depth in this quantitative sample area was 62.2 cm. In 100 0.25-m^2 quadrats, 93 mussels were collected for a density of 0.93/0.25 m^2 (Table 4) with a precision of 28.3%. Recent recruitment was seen in two species, *P. fasciolaris* and *V. iris* (2.1% of individuals collected). Of the mussels collected, 72% (67) were visible at the surface, 28% (26) were collected subsurface. The most common species (*A. ligamentina*; 35 collected) showed no significant difference in length of individuals collected surface vs. subsurface (P=0.072). A length frequency analysis of this species showed the majority of individuals collected to be larger than 100 mm with no individuals smaller than 80 mm (Figure 12).

Qualitative

A 31-person hour visual search was conducted systematically from the downstream to upstream end of the survey site. This search yielded 21 species live and 8 represented by relic shell only for a total of 29 species (Table 5). This sampling added six species to our species list (3 live and 3 relic only). *Ligumia recta, Fusconaia*

cuneolus and *Quadrula pustulosa* were all found live during the qualitative sample but had not been collected during the earlier quadrat samples.

Incidental

During preliminary site preparation, a live *Epioblasma brevidens* and *Dromus dromas* were found along with two *Ligumia recta.* These species were scarcely represented in the quadrat sampling but should be considered extant at this time.

Depth correlation

The Slant survey was conducted on consecutive days with no fluctuations in stream level. The lack of variation in stream depth allows for comparisons of mussel presence versus stream depth. Average depth in quadrats containing mussels was significantly greater than that of quadrats with no mussels (50.1 cm vs. 44.0 cm; P <0.001). Correlation analysis did not reveal a relationship between depth and mussel presence (P=0.263) and a regression analysis gave an r^2 value of 0.069. A graph of mussels collected versus depth did show a slight visual trend towards higher mussel density with increasing depth (Figure 13); however this trend was not statistically supported as density did not significantly increase with stream depth.

Average depth of quadrats containing *Io fluvialis* was significantly different from quadrats with no *Io fluvialis* (42.3 cm vs. 51.0 cm; P = 0.02). Correlation analysis showed a weak negative relationship between depth and *Io fluvialis* collection (P= -0.21), and a regression analysis gave an r^2 value of 0.046. A graph of *Io fluvialis* collected versus depth shows the majority of individuals (75%) were collected between 20 cm and 50 cm (Figure 14).

Discussion

Past collections at this site have yielded 36 species live while the current study found 27 live with 3 represented by relic shell only. Of previously known species from this location *Alasmidonta marginata, Epioblasma capsaeformis, Epioblasma triquetra, Leptodea fragilis, Lexingtonia dolabelloides, Pleurobema rubrum* and *Villosa perpurpurea* were not recorded in the present study. Relic valves of one species, *Epioblasma torulosa gubernaculum* were collected having not been previously noted at this site. While interesting, this note only strengthens the current assumption that this species is extinct.

In two quantitative samples at Slant, 34.4% of all mussels were collected sub-surface. This confirms the need for a sampling approach that will collect not only surface, but subsurface mussels also. The semi-quantitative and quantitative portion of the survey collected 24 of the 30 total species, while qualitative sampling added six species to the site total (Table 6).

No extensive quantitative sampling has previously been conducted at the Slant site. Most records from this site are either qualitative records or inferred records from the Pendleton Island site nearby upstream. As such it is not possible to exactly compare previous collections or site densities. With that said, collections by Ahlstedt upstream at Pendleton Island have shown a decline from 24.60 to 4.60 over the course of 25 years (Ahlstedt et. al 2005). This trend can not be ignored and seems to be typical of mussel communities the entire length of the Clinch River as well as surrounding drainages.

Several mussel species may be collected from Slant in sufficient numbers for propagation. Short term brooders such as *Fusconaia cor, F. subrotunda* and *Plethobasus*

cyphyus along with long term brooders such as *A. ligamentina, A. pectorosa, Lampsilis fasciola, P. fasciolaris, P. subtentum* and *V. iris* can be found in numbers suitable for propagation. Three increasingly rare species, *Cumberlandia monodonta, L. recta* and *Potamilus alatus* can be found at this site in low numbers. This site may be a suitable source location to collect these individuals for captive breeding.

Currently, Slant has a low overall mussel density, and very little evidence of juvenile mussel recruitment or balanced population demographics. All size curves for this site point to large remnant populations with few young individuals. These factors lead us to believe that this site has been impacted and that it is not a suitable location for the release of propagated juvenile mussels. Larger juveniles, or sub-adult mussels may be released at this site, but stocking of microscopic juveniles is not recommended at this time.

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Table 1. Present and historical records of mussel collections in the Clinch River at Slant.

Species	1979[1]	1980's[2]	1989[3]	1994[1]	1999[1]	2004[1]	Present Study[4]
Actinonaias ligamentina	L	L		L	L	L	L
Actinonaias pectorosa	L	L		L	L	L	L
Alasmidonta marginata		L	L				
Amblema plicata	L	L		L	L	L	L
Cumberlandia monodonta		L	L				L
Cyclonaias tuberculata	L	L		L	L	L	L
Cyprogenia stegaria		L	L				R
Dromus dromas		L					L
Elliptio crassidens							
Elliptio dilatata	L	L		L	L	L	L
Epioblasma brevidens		L	L				L
Epioblasma capsaeformis	L	L					
Epioblasma t. gubernaculum							R
Epioblasma triquetra		L	L				
Fusconaia barnesiana	L	L	L				L
Fusconaia cor	L	L	L	L		L	L
Fusconaia cuneolus	L	L	L	L	L		L
Fusconaia subrotunda	L	L		L	L	L	L
Hemistena lata			L				
Lampsilis fasciola	L	L		L	L		L
Lampsilis ovata	L	L				L	L
Lasmigona costata	L	L		L	L		L
Lemiox rimosus		L	L				L
Leptodea fragilis	L						
Lexingtonia dolabelloides		L	L				
Ligumia recta	L	L	L				L
Medionidus conradicus	L	L			L		L
Plethobasus cyphyus		L	L				L
Pleurobema oviforme		L	L				L
Pleurobema rubrum		R	L	L			
Potamilus alatus	L	L					L
Ptychobranchus fasciolaris	L	L		L	L	L	L
Ptychobranchus subtentum	L	L		L	L		L
Quadrula c. strigillata	L	L	L				L
Quadrula pustulosa		L					L
Strophitus undulatus			L				
Truncilla truncata		L	L				R
Villosa iris		L			L	L	L
Villosa perpurpurea	L		L				
Villosa vanuxemensis		L					L
Live	**21**	**33**	**19**	**13**	**13**	**10**	**27**
Relic	**--**	**1**	**--**	**--**	**--**	**--**	**3**
Total	**21**	**34**	**19**	**13**	**13**	**10**	**30**

[1]Records courtesy of Steve Ahlstedt, USGS. (Collection site Pendleton Island)
[2] Records courtesy of Dr. Richard Neves Virginia Cooperative Research Unit (Collections made from 1984-1994 consisting of midden shell observations.)
[3] Records courtesy of The Nature Conservancy (Collection site Pendleton Island)
[4] Present study conducted at Slant from September 7th-9th, 2005.

Table 2. Total number and density of mussel species collected during semi-quantitative sampling of the Clinch River at Slant. Mussels measuring less than 30 mm were considered juveniles.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per m^2)
Actinonaias ligamentina	263	0	43.5	0.605
Actinonaias pectorosa	106	0	17.5	0.244
Ptychobranchus fasciolaris	40	0	6.6	0.092
Villosa iris	39	1	6.4	0.090
Cyclonaias tuberculata	33	0	5.4	0.076
Amblema plicata	23	0	3.8	0.053
Elliptio dilatata	22	0	3.6	0.051
Fusconaia subrotunda	14	0	2.3	0.032
Ptychobranchus subtentum	14	0	2.3	0.032
Lampsilis fasciola	12	0	1.9	0.027
Plethobasus cyphyus	9	0	1.5	0.021
Fusconaia cor	6	0	1.0	0.014
Lasmigona costata	6	0	1.0	0.014
Medionidus conradicus	3	0	0.5	0.007
Potamilus alatus	3	0	0.5	0.007
Cumberlandia monodonta	2	0	0.4	0.005
Lampsilis ovata	2	0	0.4	0.005
Quadrula c. strigillata	2	0	0.4	0.005
Villosa vanuxemensis	2	0	0.4	0.005
Dromus dromas	1	0	0.2	0.002
Epioblasma brevidens	1	0	0.2	0.002
Pleurobema oviforme	1	0	0.2	0.002
Cyprogenia stegaria	0	0	0	0
Elliptio crassidens	0	0	0	0
Epioblasma capsaeformis	0	0	0	0
Epioblasma t. gubernaculum	0	0	0	0
Epioblasma triquetra	0	0	0	0
Fusconaia barnesiana	0	0	0	0
Fusconaia cuneolus	0	0	0	0
Lemiox rimosus	0	0	0	0
Ligumia recta	0	0	0	0
Quadrula pustulosa	0	0	0	0
Total	**605**	**1**	**100**	**1.391**

Table 3. Total number and density of mussel species collected in the Clinch River at Slant in the lower quantitative sample. Mussels measuring less than 30 mm were considered juveniles.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per 0.25m^2)
Actinonaias ligamentina	43	0	44.8	0.43
Actinonaias pectorosa	18	0	18.8	0.18
Ptychobranchus fasciolaris	10	1	10.4	0.10
Cyclonaias tuberculata	6	0	6.3	0.06
Villosa iris	5	0	5.2	0.05
Elliptio dilatata	4	1	4.2	0.04
Fusconaia barnesiana	2	0	2.1	0.02
Fusconaia cor	2	0	2.1	0.02
Fusconaia subrotunda	1	0	1.0	0.01
Lampsilis fasciola	1	0	1.0	0.01
Medionidus conradicus	1	1	1.0	0.01
Ptychobranchus subtentum	1	0	1.0	0.01
Quadrula c. strigillata	1	0	1.0	0.01
Villosa vanuxemensis	1	0	1.0	0.01
Amblema plicata	0	0	0	0
Cumberlandia monodonta	0	0	0	0
Cyprogenia stegaria	0	0	0	0
Dromus dromas	0	0	0	0
Elliptio crassidens	0	0	0	0
Epioblasma brevidens	0	0	0	0
Epioblasma capsaeformis	0	0	0	0
Epioblasma t. gubernaculum	0	0	0	0
Epioblasma triquetra	0	0	0	0
Fusconaia cuneolus	0	0	0	0
Lampsilis ovata	0	0	0	0
Lasmigona costata	0	0	0	0
Lemiox rimosus	0	0	0	0
Ligumia recta	0	0	0	0
Plethobasus cyphyus	0	0	0	0
Pleurobema oviforme	0	0	0	0
Potamilus alatus	0	0	0	0
Quadrula pustulosa	0	0	0	0
Total	**96**	**3**	**100**	**0.95**

Table 4. Total number and density of mussel species collected in the Clinch River at Slant in the upper quantitative sample. Mussels measuring less than 30 mm were considered juveniles.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per 0.25m^2)
Actinonaias ligamentina	35	0	37.6	0.35
Actinonaias pectorosa	19	0	20.4	0.19
Cyclonaias tuberculata	8	0	8.6	0.08
Fusconaia subrotunda	6	0	6.4	0.06
Ptychobranchus fasciolaris	5	1	5.4	0.05
Amblema plicata	4	0	4.3	0.04
Elliptio dilatata	4	0	4.3	0.04
Lampsilis fasciola	3	0	3.2	0.03
Villosa iris	3	1	3.2	0.03
Cumberlandia monodonta	1	0	1.1	0.01
Lasmigona costata	1	0	1.1	0.01
Lemiox rimosus	1	0	1.1	0.01
Medionidus conradicus	1	0	1.1	0.01
Plethobasus cyphyus	1	0	1.1	0.01
Villosa vanuxemensis	1	0	1.1	0.01
Cyprogenia stegaria	0	0	0	0
Dromus dromas	0	0	0	0
Elliptio crassidens	0	0	0	0
Epioblasma brevidens	0	0	0	0
Epioblasma capsaeformis	0	0	0	0
Epioblasma t. gubernaculum	0	0	0	0
Epioblasma triquetra	0	0	0	0
Fusconaia barnesiana	0	0	0	0
Fusconaia cor	0	0	0	0
Fusconaia cuneolus	0	0	0	0
Lampsilis ovata	0	0	0	0
Ligumia recta	0	0	0	0
Pleurobema oviforme	0	0	0	0
Potamilus alatus	0	0	0	0
Ptychobranchus subtentum	0	0	0	0
Quadrula c. strigillata	0	0	0	0
Quadrula pustulosa	0	0	0	0
Total	**93**	**2**	**100**	**0.93**

Table 5. Live and relic mussel species collected in the Clinch River at Slant during qualitative sampling, September 2005.

Species	0	20	40	60	80	100	120	140	160	180	Present Overall
Actinonaias ligamentina	L	L	L	L	L	L	L	L	L	L	L
Actinonaias pectorosa	L	L	L	L	L	L	L	L	L	L	L
Amblema plicata	L	L	L	L		L	L	L	L	L	L
Cumberlandia monodonta	R	R		R	L	R	L	L	L	L	L
Cyclonaias tuberculata	L	L	L	L	L	L	L	L	L	L	L
Cyprogenia stegaria										R	R
Dromus dromas											
Elliptio dilatata	L	L	L	L		L	L	L	L	L	L
Elliptio crassidens											
Epioblasma brevidens	R			R							R
Epioblasma capsaeformis											
E. t. gubernaculum						R					R
Epioblasma triquetra											
Fusconaia barnesiana							R				R
Fusconaia cor	L	R	L	L	R	L	R	R	L	L	L
Fusconaia cuneolus	L	R		R				R	R	R	L
Fusconaia subrotunda	L	L	L	L	L	L	L	L	L	L	L
Lampsilis fasciola		L	L	L	L		R	L		R	L
Lampsilis ovata				R	L		R	R		R	L
Lasmigona costata				L	L	R	L	L	R	R	L
Lemiox rimosus				R	R				R	R	R
Ligumia recta	R			R	R		R	R	L	R	L
Medionidus conradicus	R		L	L							L
Plethobasus cyphyus			L	L	L		R	L	L	R	L
Pleurobema oviforme			R	R							R
Potamilus alatus				R					L	L	L
Ptychobranchus fasciolaris	L	R	L	L	L	L	L	L	L	L	L
Ptychobranchus subtentum	L	L	L	L	L	L	R	L	L	R	L
Quadrula c. strigillata	L			L	R	R	R	L		R	L
Quadrula pustulosa	R	R			L		R			R	L
Truncilla truncata	R							R		R	R
Villosa iris				L	L	L	L	L	L	L	L
Villosa vanuxemensis							R	R		R	R
Live	**11**	**8**	**12**	**15**	**13**	**10**	**10**	**14**	**14**	**11**	**21**
Relic	**6**	**5**	**1**	**8**	**4**	**4**	**10**	**6**	**3**	**13**	**8**
Total	**17**	**13**	**13**	**23**	**17**	**14**	**20**	**20**	**17**	**24**	**29**

Table 6. Mussel species collected in the Clinch River at Slant based on type of sampling employed. Records reflect all species collected live, fresh dead or relic.

Species	Semi-Quantitative	Quantitative	Qualitative	Incidental*	Overall
Actinonaias ligamentina	X	X	X		X
Actinonaias pectorosa	X	X	X		X
Amblema plicata	X	X	X		X
Cumberlandia monodonta	X	X	X		X
Cyclonaias tuberculata	X	X	X		X
Cyprogenia stegaria			X		X
Dromus dromas	X			X	X
Elliptio dilatata	X	X	X		X
Elliptio crassidens					
Epioblasma brevidens	X		X	X	X
Epioblasma capsaeformis					
Epioblasma t. gubernaculum			X		X
Epioblasma triquetra					
Fusconaia barnesiana		X	X		X
Fusconaia cor	X	X	X		X
Fusconaia cuneolus			X		X
Fusconaia subrotunda	X	X	X		X
Lampsilis fasciola	X	X	X		X
Lampsilis ovata	X		X		X
Lasmigona costata	X	X	X		X
Lemiox rimosus		X	X		X
Ligumia recta			X	X	X
Medionidus conradicus	X	X	X		X
Plethobasus cyphyus	X	X	X		X
Pleurobema oviforme	X		X		X
Potamilus alatus	X		X		X
Ptychobranchus fasciolaris	X	X	X		X
Ptychobranchus subtentum	X	X	X		X
Quadrula c. strigillata	X	X	X		X
Quadrula pustulosa			X		X
Truncilla truncata			X		X
Villosa iris	X	X	X		X
Villosa vanuxemensis	X	X	X		X
Totals	**22**	**19**	**29**	**3**	**30**

* Incidental records are reserved for rare and endangered species that were found live coincidentally.

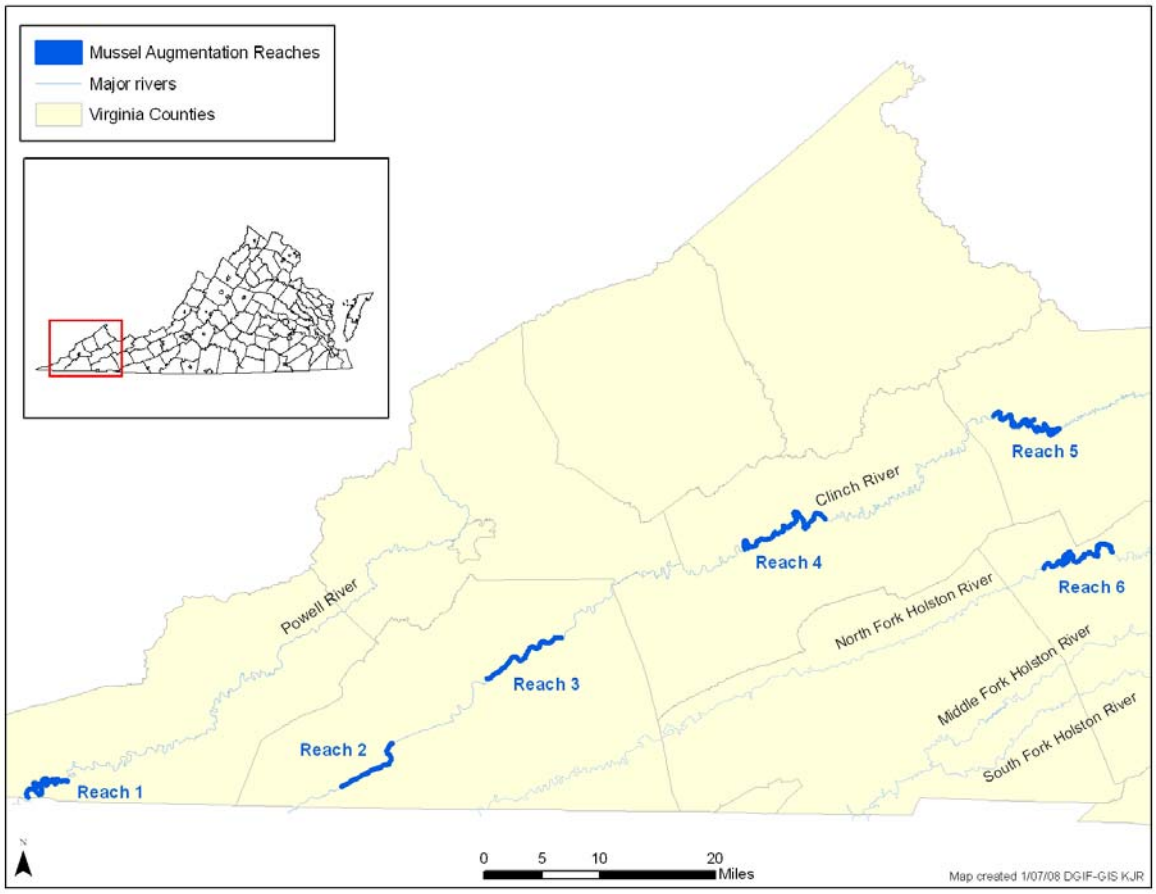


Figure 1. Stream reaches designated as augmentation reaches by the Virginia Department of Game and Inland Fisheries mussel restoration plan. Six reaches are divided between the Powell River (1), Clinch River (4) and North Fork Holston River (1).

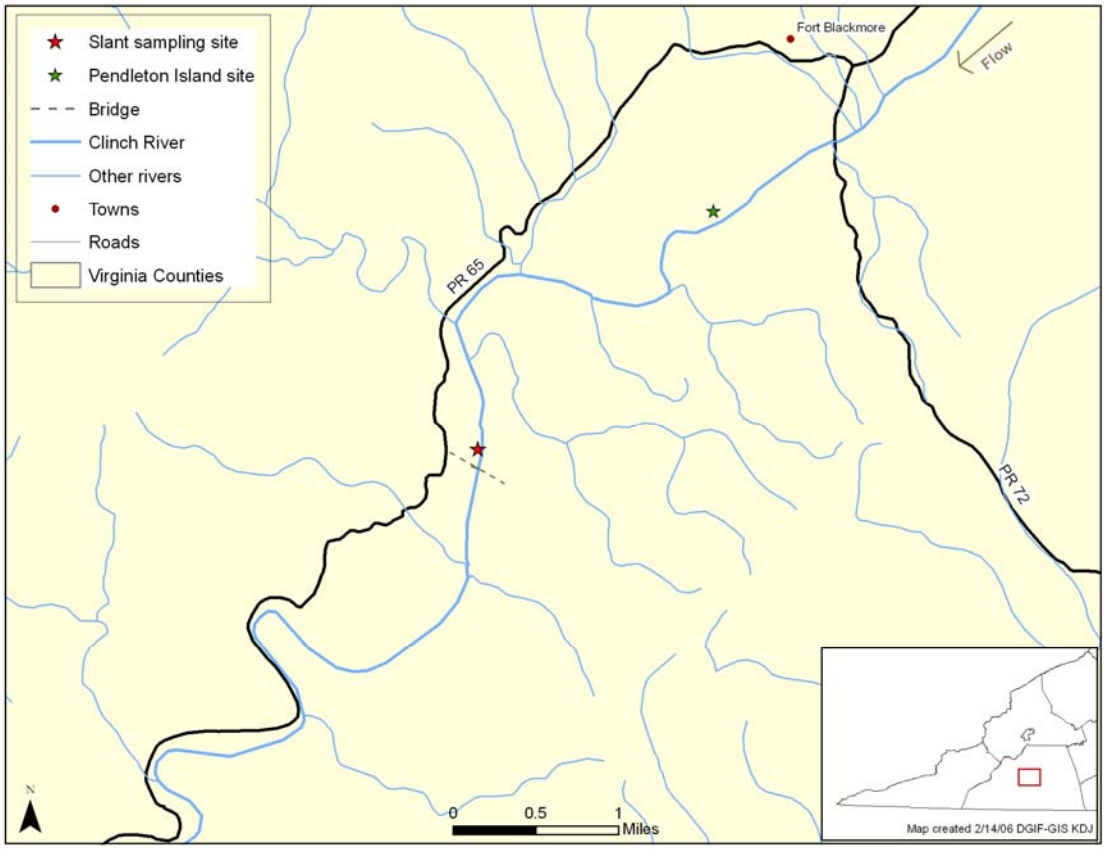


Figure 2. The Clinch River in Scott Co. Virginia. The current study was conducted at the Slant site near Fort Blackmore.

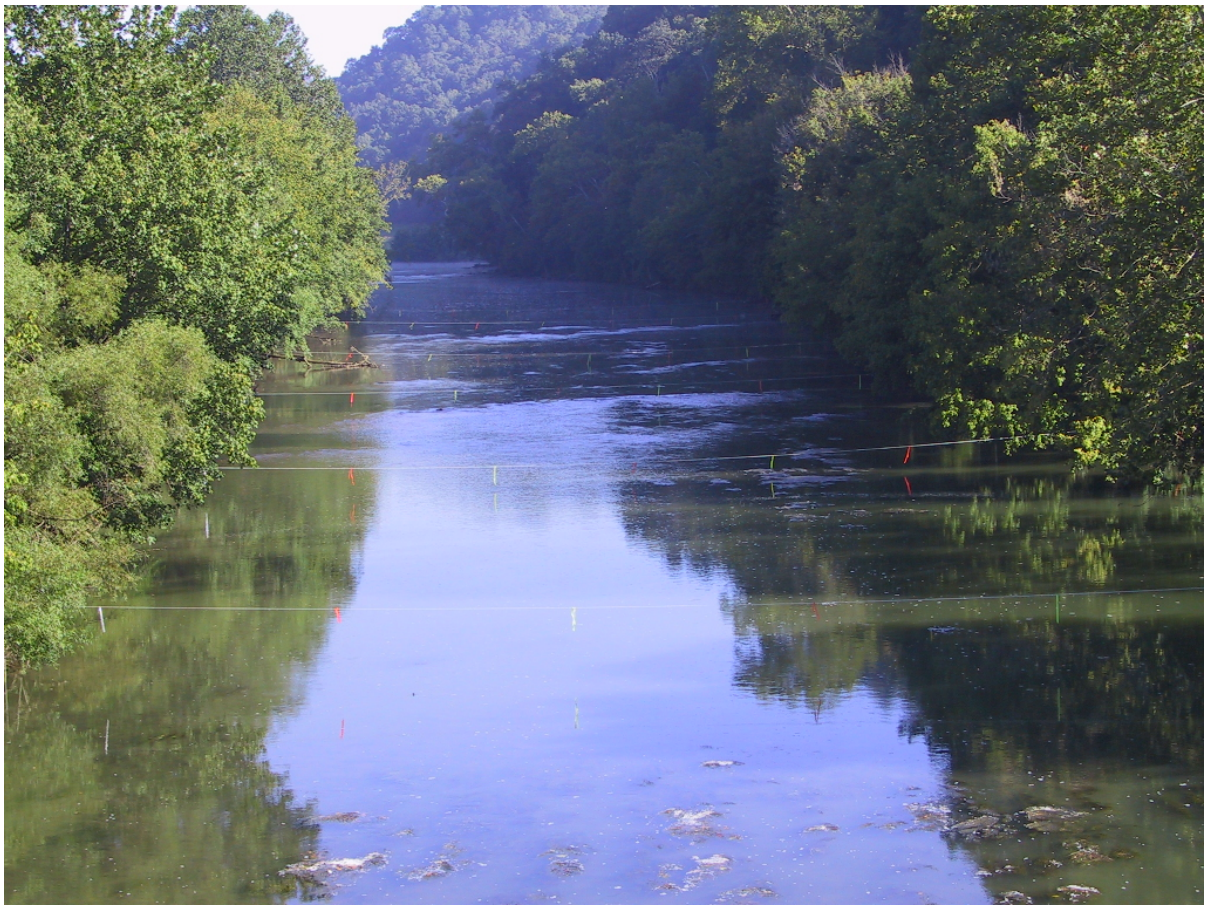


Figure 3. Elevated view of the Clinch River at Slant. Ropes with flagging can be seen delineating lanes within the stream.

Figure 4. Overhead view of a survey site. Ropes are stretched every 40 meters with flags to delineate lanes and serve as a visual guide. Black lines show one lane.

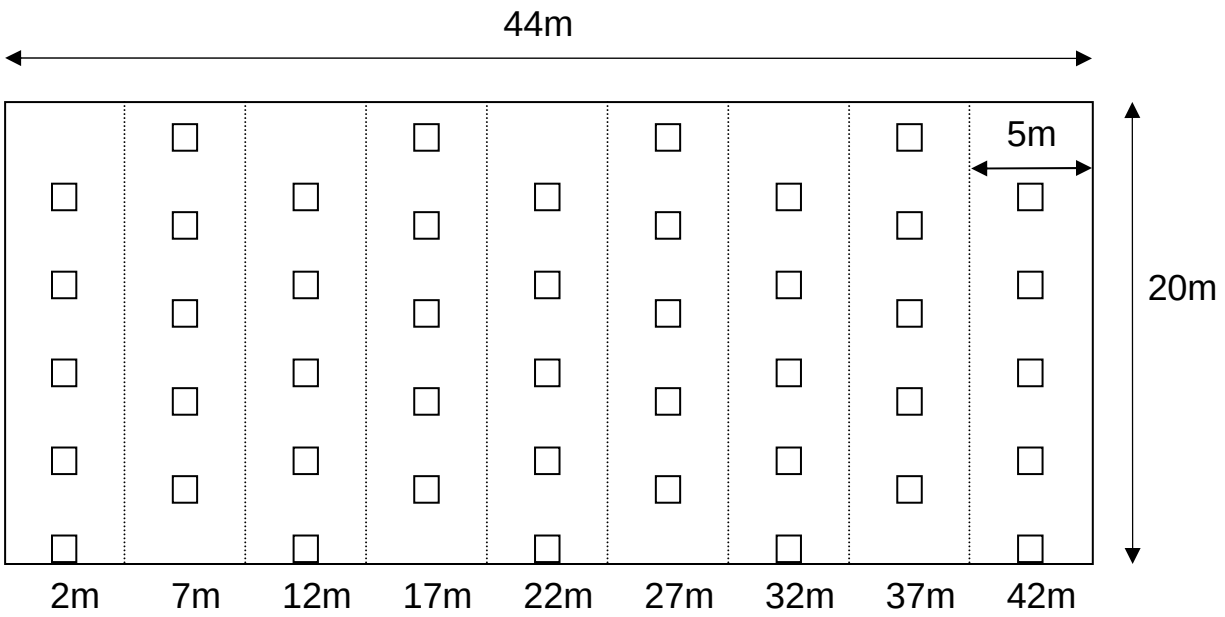


Figure 5. Graphic representation of semi-quantitative sampling method. Squares indicate sampling location and dashed lines show lane boundaries. Each lane is 5m wide and 20m long. Five samples are taken representing 5% of overall habitat. Starting position of samplers alternates between 1m and 3m.

Figure 6. The Ferraro streambed sampler. This sampler is made with perforated aluminum and was designed to hold all substrate excavated from a 0.25 m^2 quadrat.

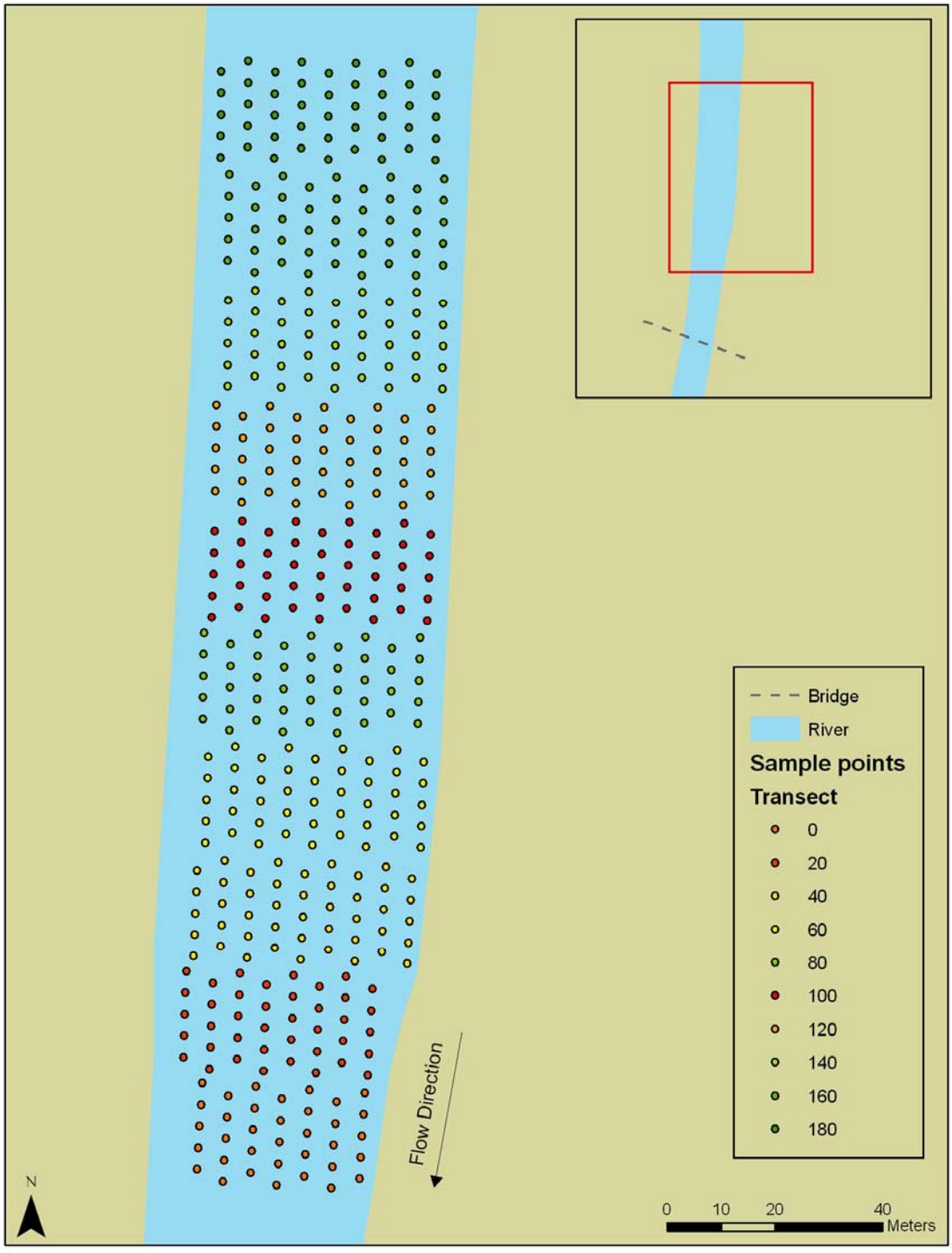


Figure 7. Overhead map of Slant, Clinch River, showing sample area and location of quadrats sampled during semi-quantitative sampling during September 2005.

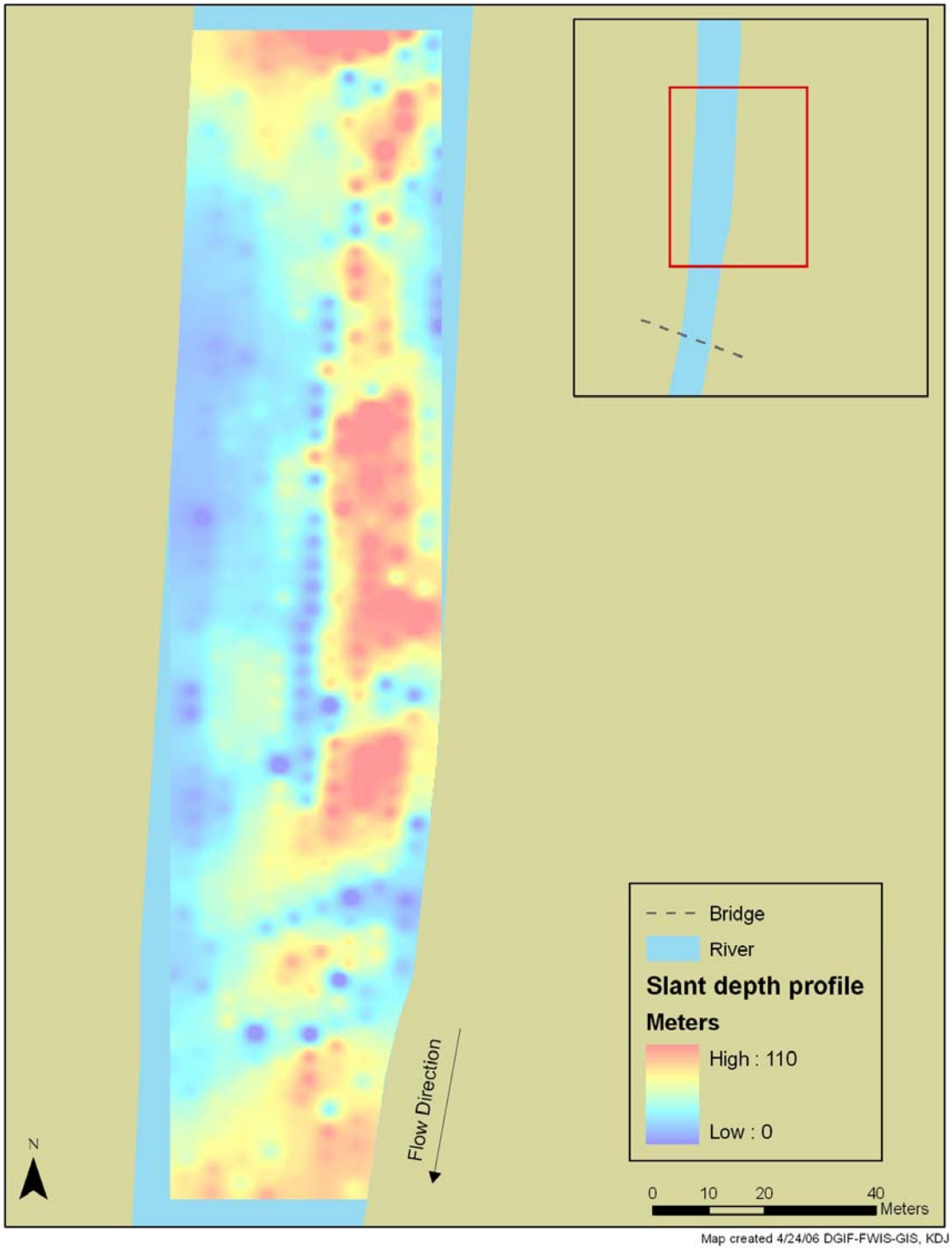


Figure 8. Overhead map of Slant, Clinch River, showing the depth profile of the site during the present study. Present study was conducted on consecutive days in September, 2005 with no variation in stream discharge.

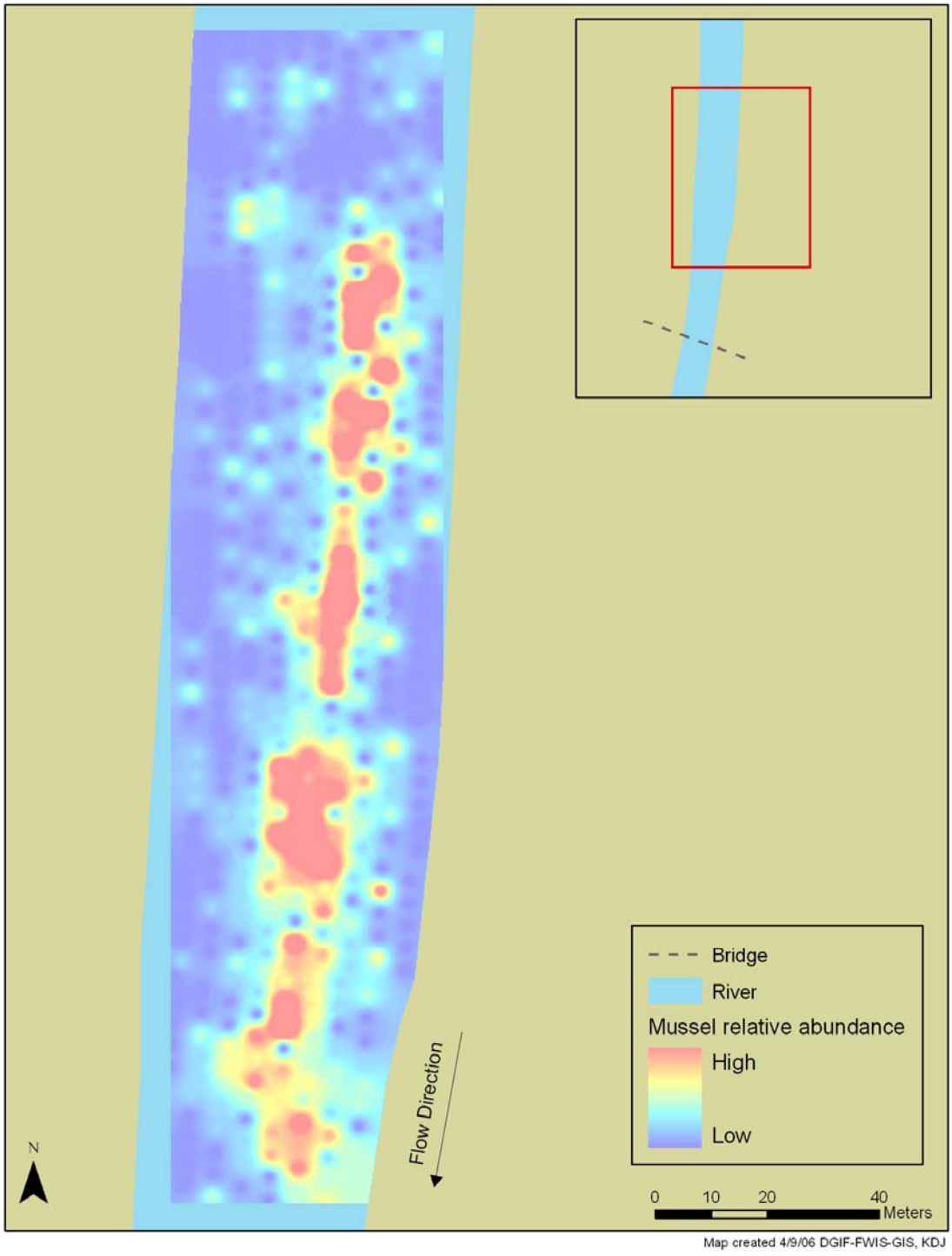


Figure 9. Overhead map showing distribution of mussels found during semi-quantitative sampling of the Slant site on the Clinch River.

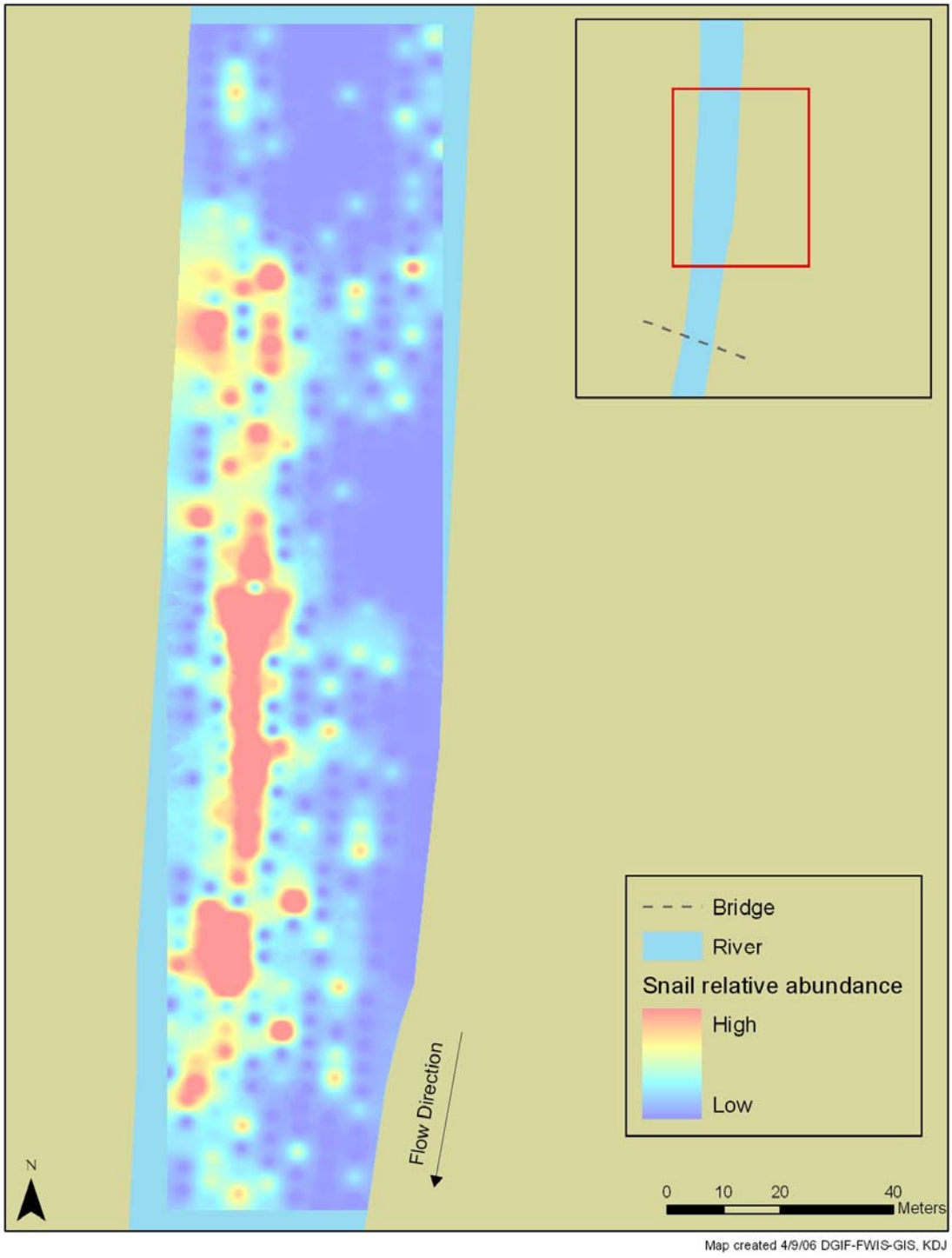


Figure 10. Overhead map showing distribution of spiny riversnail, *Io fluvialis*, collected during semi-quantitative sampling of the Slant site on the Clinch River.

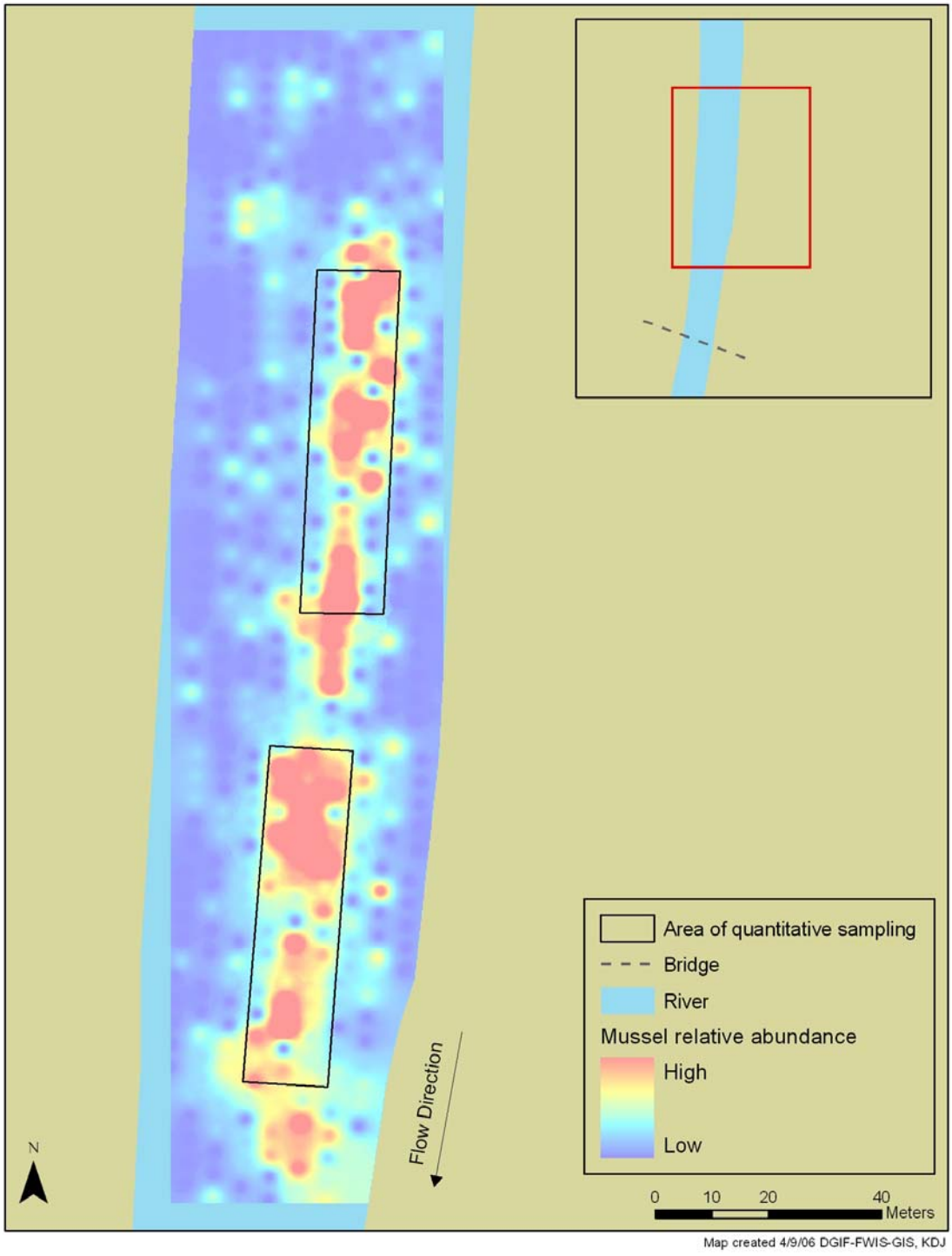
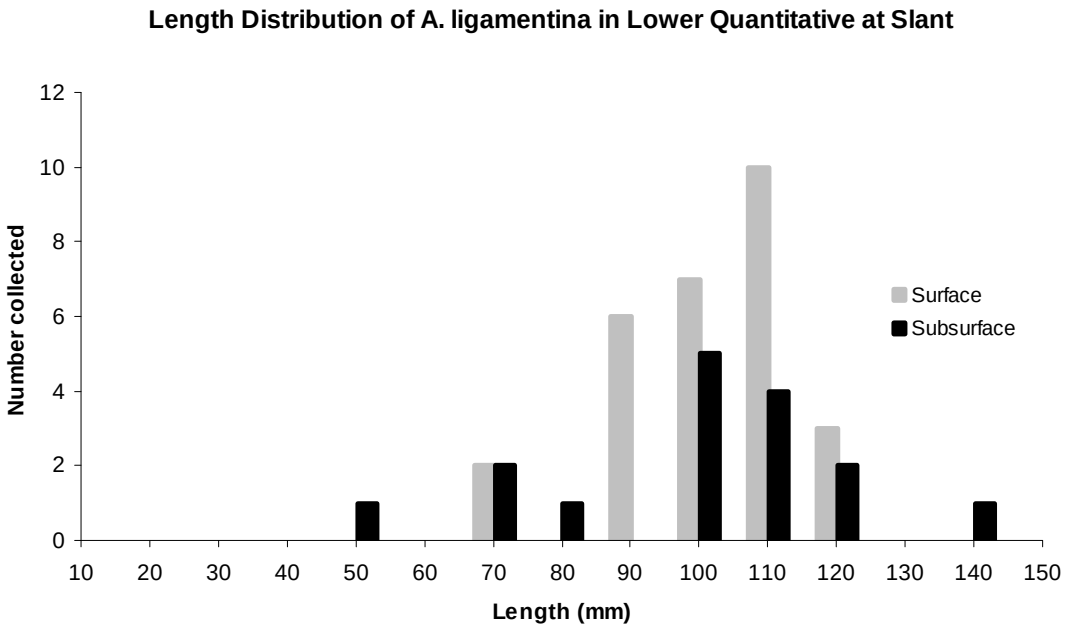


Figure 11. Relative abundance of mussels collected during the semi-quantitative sample at Slant. Boxes indicate the two sites selected for further quantitative sampling. The lower sample is downstream of the upper sample.



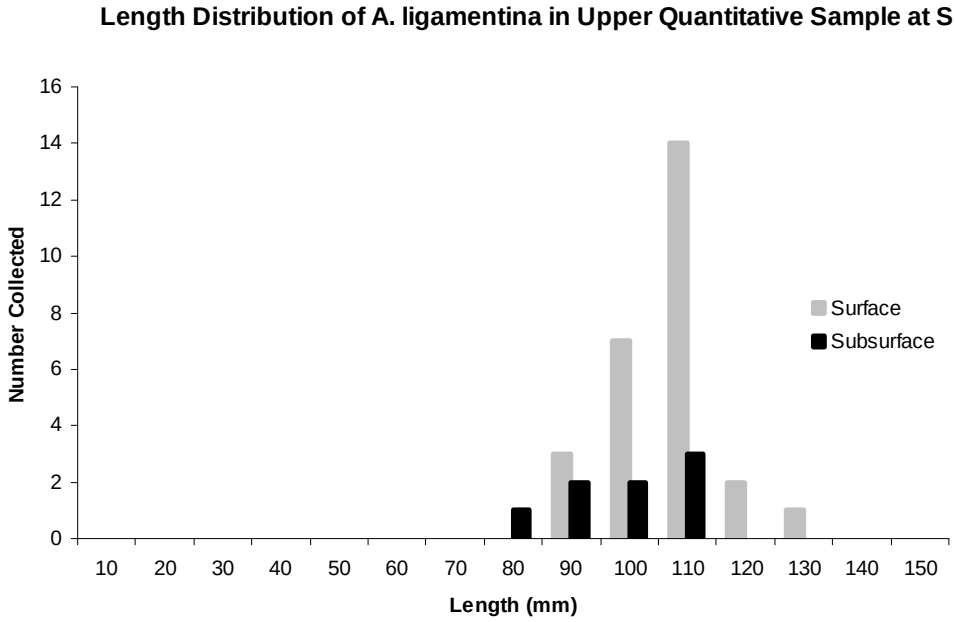


Figure 12. Length distribution of *A. ligamentina* collected during the lower and upper quantitative sample. Individuals were measured separately based on surface or subsurface collection.

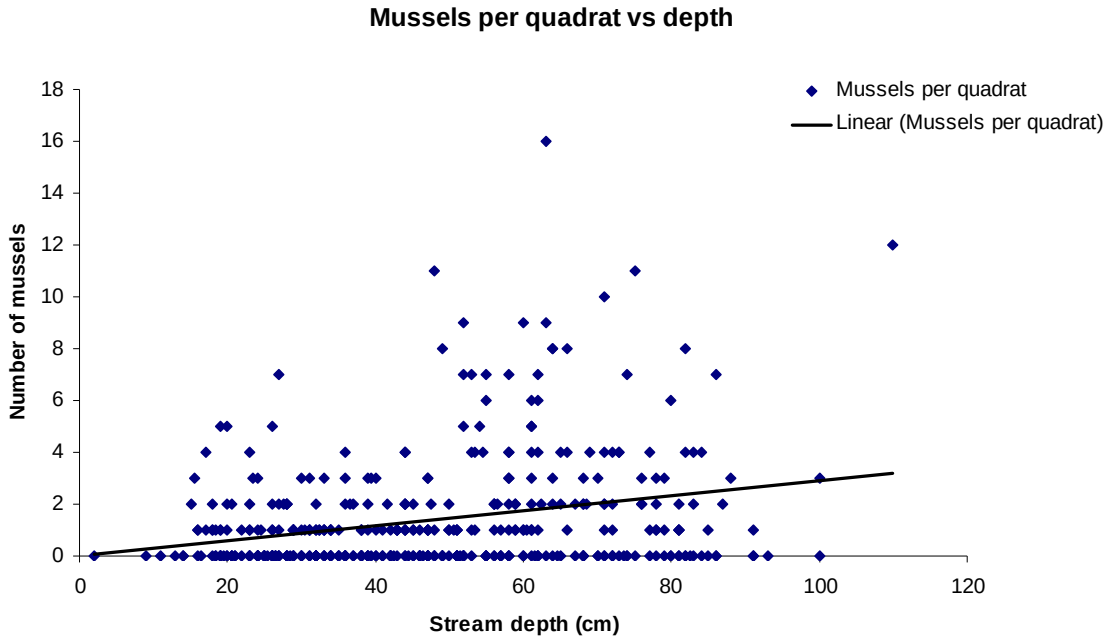


Figure 13. Presence of mussels in semi-quantitative sampling at Slant versus depth of quadrat. A trend line shows the relationship between depth and presence of mussels at this site. R^2 value = 0.069

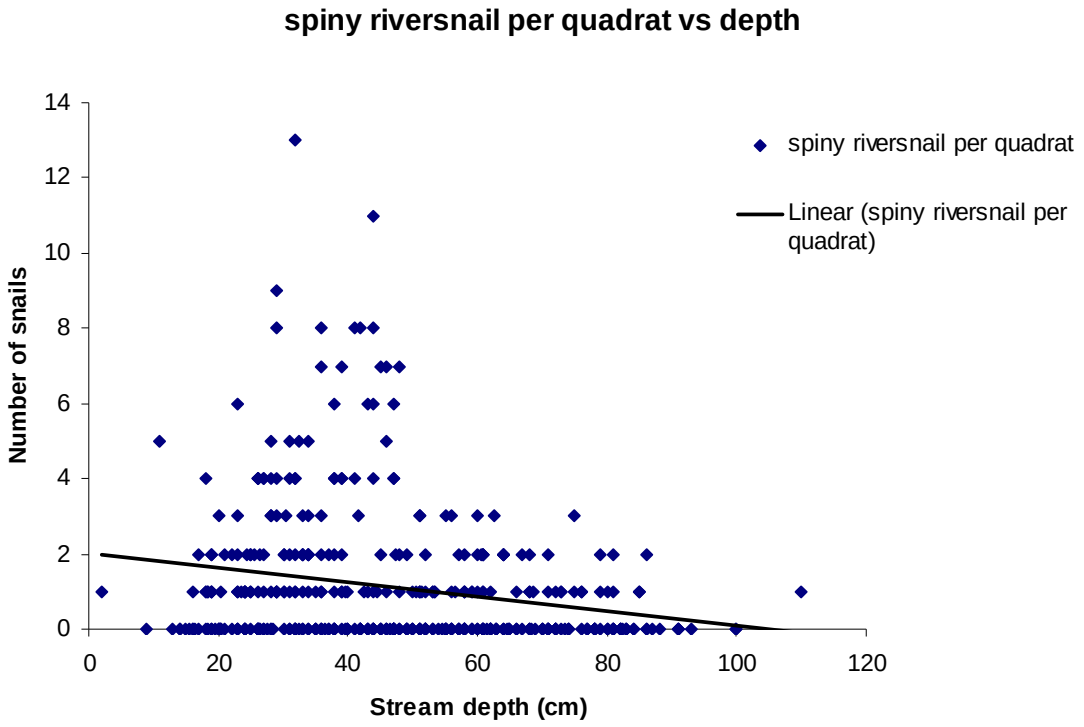


Figure 14. Presence of spiny riversnail, *Io fluvialis*, in semi-quantitative sampling at Slant versus depth of quadrat. A trend line shows the relationship between depth and presence of mussels at this site. R^2 value = 0.046

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*
Actinonaias ligamentina	mucket	---	-----	-----
Actinonaias pectorosa	pheasantshell	---	-----	-----
Amblema plicata	threeridge	---	-----	-----
Cumberlandia monodonta	spectaclecase	**II**	**SE**	**FC**
Cyclonaias tuberculata	purple wartyback	---	-----	-----
Cyprogenia stegaria	fanshell	**I**	**SE**	**FE**
Dromus dromas	dromedary pearlymussel	**I**	**SE**	**FE**
Elliptio crassidens	elephantear	**IV**	**SE**	-----
Elliptio dilatata	spike	---	-----	-----
Epioblasma brevidens	Cumberland combshell	**I**	**SE**	**FE**
Epioblasma capsaeformis	oystermussel	**I**	**SE**	**FE**
Epioblasma t. gubernaculum	green blossom	**I**	**SE**	**FE**
Epioblasma triquetra	snuffbox	**II**	**SE**	**SOC**
Fusconaia barnesiana	Tennessee pigtoe	**II**	**SSC**	-----
Fusconaia cor	shiny pigtoe	**I**	**SE**	**FE**
Fusconaia cuneolus	finerayed pigtoe	**I**	**SE**	**FE**
Fusconaia subrotunda	longsolid	**III**	-----	**SOC**
Hemistena lata	crackling pearlymussel	**I**	**SE**	**FE**
Io fluvialis	spiny riversnail	**III**	**ST**	**SOC**
Lampsilis fasciola	wavyrayed lampmussel	---	-----	-----
Lampsilis ovata	pocketbook	**IV**	-----	-----
Lemiox rimosus	birdwing pearlymussel	**I**	**SE**	**FE**
Leptodea fragilis	fragile papershell	**IV**	**ST**	-----
Lexingtonia dolabelloides	Slabside pearlymussel	**II**	**ST**	**FC**
Ligumia recta	black sandshell	**III**	**ST**	-----
Medionidus conradicus	moccasinshell	---	-----	-----
Plethobasus cyphyus	sheepnose	**II**	**ST**	**FC**
Pleurobema oviforme	Tennessee clubshell	**III**	-----	**SOC**
Pleurobema rubrum	Pyramid pigtoe	**II**	**SOC**	**SE**
Potamilus alatus	pink heelsplitter	---	-----	-----
Ptychobranchus fasciolaris	kidneyshell	---	-----	-----
Ptychobranchus subtentum	fluted kidneyshell	**II**	-----	**FC**
Quadrula c. strigillata	rough rabbitsfoot	**I**	**SE**	**FE**
Quadrula pustulosa	pimpleback	**IV**	**ST**	-----
Truncilla truncata	deertoe	**IV**	**SE**	-----
Villosa iris	rainbow	---	-----	-----
Villosa vanuxemensis	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.