Freshwater Mussel and Spiny Riversnail Survey of SR 833 Bridge and Fletcher Ford, Powell River, Virginia: Augmentation Monitoring Sites - 2004

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January 4, 2007

Table of Contents

List of Tables

List of Figures

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 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 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. Many surveyors have sampled these sites over the years using either quantitative or qualitative sampling techniques (Ortmann 1918; Dennis 1981; Ahlstedt and Tuberville 1997; S. Ahlstedt 1999 & 2004 pers. comm.; Wolcott & Neves 1994;

Tables 1 & 2). These records have shown a declining trend in the number of species, as well as overall density.

At SR 833 Bridge and Fletcher Ford, Powell 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 mussel aggregations at high density sections at both sites.
3. To identify ideal mussel habitat at each site for mussel augmentation.

Study Area:

The Powell River is a tributary of the Clinch River within the Upper Tennessee River System. The Powell River flows southwest approximately 145 km in Virginia, from central Wise County to the Tennessee border and drains an area of approximately 143,226 ha. The major land uses in this area are forest (61.3%), agricultural (29.5%) and other (9.2%), including uses such as coal mining, industrial and urban.

The Powell River historically contained 41 mussel species (Ortmann 1918). Recently, an overall decline in freshwater mussel density and species richness has been documented (Wolcott and Neves 1994, Ahlstedt and Tuberville 1997, Ahlstedt 1999 & 2004 pers. comm.). These declines have been linked to agricultural and urban land uses (Diamond et al. 2002) and coal mining activities (Terwilliger et al. 1995).

On October 24, 1996, a coal slurry impoundment associated with a coal processing plant owned by Lone Mountain Processing, Inc. in Lee County, Virginia, failed, resulting in the release of 6,000,000 gal of coal slurry to the Powell River watershed. A mix of water, coal fines, clay, and associated contaminants (blackwater) extended downstream 104.6 km, ultimately to Norris Reservoir. The coal slurry spill impacted fish, freshwater mussels, other benthic organisms, supporting aquatic habitat, and designated critical habitat for two federally listed fish (USFWS 2003). While this

event was clearly documented, it appears that many other blackwater events have occurred in the Powell River as evidenced by the large amounts of coal fines in the stream bed and deposited along the stream banks.

Both sites for the present study can be found approximately 16 – 19 kilometers southwest of Jonesville, Virginia (Figure 2). The two sites are found at Powell River mile 120.3 (SR 833 Bridge) and 117.3 (Fletcher Ford).

The SR 833 Bridge (VDOT structure #6498) was built in 1966**,** on property owned by the Tennessee Valley Authority. Land surrounding this site is used primarily for agriculture, with adjacent patches of forested land. Preliminary scouting of the SR 833 Bridge revealed suitable mussel habitat that could easily be sampled extending from just upstream of the bridge downstream for a total length of 153 m.

The site known as Fletcher Ford was purchased by The Nature Conservancy in 1991. Adjacent land is primarily forested with some agriculture. Preliminary scouting at Fletcher Ford revealed a large island creating two large channels directly downstream of a large deep pool. It was decided that the right ascending channel would be surveyed along with the lower end of the large pool, which measured 133 m in length.

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).

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 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 one 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 4).

At every quadrat depth, flow regime, visibility and dominant substrate type 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 sampled using a Ferraro streambed sampler (Figure 5). The Ferraro streambed samplers are built with perforated aluminum which allows flow through the sampler, while maintaining enough rigidity to handle a large volume of substrate. 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 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.

Results:

833 Bridge:

Semi-Quantitative

During semi-quantitative sampling of the SR 833 Bridge site, 257-1-m^2 quadrats were sampled in an area 153 m long and approximately 35 m wide equaling 5,355 m^2 (Figure 6). Moving upstream, the site transitions from a broad riffle into a run ending in a pool. The sampling occurred during low water with the average depth across the site being 29 cm, with a range of 4.5 cm - 70 cm. Substrate size ranged from sand to boulder with the vast majority being pebble (70%) and gravel (21%). Visibility in the water was greater than 1 m horizontal distance at each quadrat sampled.

A total of 368 mussels were collected for a mean density of 1.43/m^2 (Table 3). A total of 14 species were collected live, with two with two species (*Medionidus*

conradicus and *Villosa iris*,) showing signs of recruitment (length < 30 mm; 2.2% of individuals collected). Mussels were distributed predominantly from the 80 m to 130 m transect with the largest aggregation along the left ascending bank (Figure 7). The vast majority of specimens collected were *Actinonaias pectorosa* (255), followed by *Actinonaias ligamentina* (41), and *Elliptio dilatata* (29).

A total of 665 spiny riversnail were collected for a mean density of 2.59 snails/m^2. Spiny riversnail distribution showed that their highest density was found from markers 80-130 m midstream and along the left ascending bank (Figure 8).

Quantitative

Visual and statistical analysis of semi-quantitative collection data indicated that the highest mussel density occurred from the 80 m to 130 m transect along the left ascending bank (Figure 7). One hundred 0.25-m^2 quadrats were sampled within an area measuring 50 m x 30 m. We collected 77 mussels, representing 9 species, for a mean density of 0.77 mussels/0.25 m^2 (Table 4), with a precision level of 26.6%. Two of the 9 species collected (*A. pectorosa and M. conradicus*) showed signs of recent recruitment (6.5% of individuals collected). Of the 77 individuals collected, 55.8% (44) were collected subsurface. The most common species (*A. pectorosa*; 53 collected) showed no significant difference in length of individuals collected surface vs. subsurface (P=0.172). A length frequency analysis of this species showed the majority of individuals collected to be larger than 90 mm (Figure 9).

Qualitative

Twenty-four mussel species were collected during a 12 person-hour timed search, including 18 live species and six species represented by relic shells only (Table 5). Qualitative sampling added 10 species (five by live specimen and five by relic shell) to the species list generated by semi-quantitative and quantitative sampling. A live *Villosa*

vanuxemensis was the only live species not collected in the qualitative sampling (present in relic material) but noted in the quantitative sampling methods. Two notable finds during qualitative sampling were a live *Fusconaia cuneolus,* and relic *Epioblasma triquetra*.

Fletcher Ford:

Semi-Quantitative

The Fletcher Ford site was broken into three sections referred to as FF1, FF2 and FF3 moving upstream from the lower end of the small island. During semi-quantitative sampling, 147-1–m^2 quadrats were surveyed in an area approximately 133 m long ranging from 20 to 46 m wide with a total area of 3,721 m^2 (Figure 10). The stream habitat at this site transitioned from a riffle/run in FF1 to run in FF2, while FF3 transitions from run to pool. The average depth at the site is 38 cm with a range of 1 cm - 120 cm. Substrate size ranged from silt to boulder with an equal distribution of gravel (42%) and pebble (42%). Visibility in the water was greater than 1 m horizontal distance at each quadrat sampled.

A total of 305 mussels were collected for a mean density of 1.75 mussels/m^2 (Table 6). Fifteen species were collected with 3 (*A. pectorosa, E. dilatata* and *M. conradicus*) showing signs of recent recruitment (3.9% of individuals collected). Mussels were most highly distributed in the upper 20 m of the FF1 section and mid-channel in the upper end of the FF2 section (Figure 11). Within the three sections, the individual mean densities were 2.27/m^2, 2.65/m^2, and 0.65/m^2 respectively. The most common species collected were *A. pectorosa* (161)*,* followed by *A. ligamentina* (41), and *M. conradicus* (40).

The mean overall density of spiny riversnail was 4.17/m^2, with a total of 726 collected. In similar fashion, mean density of spiny riversnail in the three sections were 4.30/m^2, 6.51/m^2 and 1.93/m^2 respectively. The area of highest snail density was found in the FF2 section along the left ascending bank (Figure 12).

Quantitative

Visual and statistical analysis of semi-quantitative sampling data supported quantitatively sampling the FF2 reach of this site along the right ascending bank (Figure 10). One hundred 0.25-m^2 quadrats were excavated within a section measuring 50 m x 20 m. A total of 90 mussels were collected, representing 13 species, for a mean density of 0.90 mussels/0.25m^2 (Table 7), with a precision level of 24.6%. Three of the 13 species collected (*A. pectorosa, V. iris* and *Lampsilis fasciola*) in this sampling showed signs of recent recruitment (8.9% of individuals collected). Of the 90 mussels collected, 51.1% (46) were collected subsurface. Individuals of the most common species (*A. pectorosa*; 53 collected) were significantly larger in total length when collected on the surface vs. subsurface (P=0.020). A length frequency analysis of this species revealed 9.4% (5 of 53) of individuals collected were considered to be recent recruitment (Length < 30mm; Figure 13).

Qualitative

Twenty-three mussel species were collected during a 9.4 person-hour timed search, including 17 live species and six species represented by relic shells only (Table 8). Qualitative sampling added eight species (four by live specimen and four by relic shell) to the species list generated by semi-quantitative and quantitative sampling. Three species were not collected live in the qualitative sampling (or present in relic material) but were noted by single, live specimens in the quantitative sampling methods: *Ligumia recta*, *Pleurobema oviforme* and *V. vanuxemensis*. The most interesting find during

qualitative sampling was a relic *Cyprogenia stegaria,* a species that has not previously been recorded in the Powell River.

Incidental

During any systematic mussel survey, samplers are bound to notice animals during site preparation and cleanup, as well as individuals that fall outside of set quadrats during sampling. During site preparation at Fletcher ford a single *Quadrula sparsa* was collected, observed and released. All other species found in an incidental manner were also found during systematic sampling of the site.

Discussion

The results of this survey confirm the need for a multi-faceted sampling approach. Over 50 % (51.6% and 58.8% respectively) of mussels collected during quantitative sampling were collected subsurface. In addition, several juvenile mussels were recorded as a result of our focus on sampling subsurface. This fact cannot be overlooked when designing a survey to determine the total density and age class structure of mussels at a site. Another piece of evidence for the multi-faceted approach was found in the qualitative sampling results of this study. At SR 833 Bridge and Fletcher Ford, several species (5 and 3, respectively) were recorded live during qualitative sampling that had not fallen within quadrats during either quantitative or semi-quantitative sampling (Tables 9 & 10). In addition, one species (*Quadrula sparsa*) was found at Fletcher Ford incidentally outside of the three structured sampling techniques.

SR 833 Bridge

A total of 24 species were collected at SR 833 Bridge, including 19 live and 5 represented by relic shells only (Table 1). This includes four federally endangered species and two species of concern. Historically, 30 species have been collected at this site (Ortmann 1918, Dennis 1981, Ahlstedt and Tuberville 1997, Ahlstedt 2004 pers.

comm., Wolcott & Neves 1994), ranging from 24 to 6 species live depending on sampling intensity. The following species were collected live by previous surveys, yet were not collected live or relic during the present study; *Elliptio crassidens*, *Epioblasma capsaeformis*, *Fusconaia cor*, *Lemiox rimosus*, *Leptodea fragilis*, *P. oviforme* and *Toxolasma lividus*. Species previously collected currently represented by relic shell only include; *Epioblasma brevidens*, *E. triquetra*, *Lampsilis ovata*, *L. recta* and *Potamilus alatus*. *Fusconaia cuneolus* was the only species collected that had not previously been recorded live at this site.

The present study found an overall mean density of 1.43/m^2 at this site. Wolcott and Neves (1994) collected 5.1/m^2 in 20 quadrats in 1988. Ahlstedt collected 2.6/m^2 in 20 quadrats in 2004 (unpublished, pers. comm.). The present study found a density of 3.08/m^2 (0.77/ 0.25 m^2) during quantitative sampling within the mussel bed. We believe this number to be a better representation of the current mussel population at this site because it is based on 100 quadrats with a precision of 26.6%. In addition, areas of low mussel density were identified during semi-quantitative sampling and then excluded during quantitative sampling to avoid misrepresenting the density of the mussel bed.

Semi-quantitative data showed the highest density linearly to fall between the markers for 80 and 130 meters. Juvenile mussels representing three species were collected in the quantitative sample area leading us to believe it to be suitable habitat for future juvenile mussel releases. To be fair, we were employing a sampling technique designed to collect juvenile mussels and thus areas outside the quantitative sample should not be considered altogether unsuitable.

The SR 833 Bridge site has a lower overall density and total number of species than Fletcher Ford. While this is the case, the SR 833 Bridge site did have a higher density of *V. iris,* a species of interest for the Lone Mountain restoration project. In the

future, species such as *A. ligamentina, A. pectorosa, V. iris* and *Io fluvialis* may be readily collected from this site for propagation.

Fletcher Ford

Compared with SR 833 Bridge, many more surveys have been conducted at Fletcher Ford (Ortmann 1918; Dennis 1981; Ahlstedt and Tuberville 1997; Ahlstedt 1999 & 2004 pers. comm.; Wolcott & Neves 1991; Beaty 2001, 2002; pers. comm.). A total of 33 species have been collected at this site during previous studies. During the present survey, 22 species were collected live and 4 were represented by relic shell material (Table 10), including six federally endangered species and three state threatened species. Of species previously collected, no evidence was found for the following: *Alasmidonta marginata*, *E. capsaeformis*, *E. triquetra*, *Fusconaia barnesiana*, *F. cor*, *F. cuneolus*, *Hemistena lata*, *L. fragilis* and *Ptychobranchus subtentum*. Additional species represented by relic shells only included *C. stegaria*, *E. crassidens*, *Lasmigona costata* and *P. alatus*. Notable finds included a relic *C. stegaria* and a live *Q. pustulosa*, neither species has been recorded at this site previously. No previous record could be found of *C. stegaria* in the Powell River.

The present study found an overall mean density of 1.75/m^2 at this site. Ahlstedt has monitored this site since 1979 on a 5-year cycle showing a decline from 11.14/m^2 (Ahlstedt and Tuberville 1997) to 1.24/m^2 (Ahlstedt 2004 pers. comm.) using 42 quadrats per sample. Wolcott and Neves (1994) collected 6.5/m^2 in 20 quadrats in 1988. The present study found a density of 3.6/m^2 (0.90/ 0.25 m^2) using 100 quadrats. It is not known exactly where at the site Wolcott and Neves (1994) sampled. However, Ahlstedt collected his 2004 quadrats in the FF3 reach of this site, a section with significantly fewer mussels than the downstream reaches. Because the sampling effort differed, these two studies may not be directly compared. However, there is no doubt that a sharp decline

has occurred at this location. In the future, using our techniques we will be able to track the location of mussel assemblages within the site.

The FF2 section of the Fletcher Ford site was determined to hold the most dense mussel assemblage. Combined sampling techniques revealed a total of five species showing signs of recent recruitment, which confirms this area as a target for restoration activities. While only the FF2 section was quantitatively sampled, the FF1 section held a higher density mussel population (2.27/m^2) compared to FF3 (0.65/m^2). We believe the FF1 and FF2 sections to be better target areas for restoration than FF3.

The Fletcher Ford site had better overall mussel density and several species of interest were found there that were not recorded at SR 833 Bridge. Three federally endangered species *E. brevidens, L. rimosus* and *Q. sparsa* were found live only at this site. In addition, species of interest for the Lone Mountain project *L. recta* and *L. ovata* were found at this site, but not SR 833 Bridge.

A more balanced age class structure was seen at Fletcher Ford, evidenced by the higher percentage of overall juveniles recorded and the size distribution curves for the most common species (Figures 9 & 13). For these reasons Fletcher Ford may be a better target for mussel restoration activities. Propagation stock of available species may come from both sites, and both should receive propagated juveniles and translocated adults in the future. However, the site with the best potential for observed success appears to be Fletcher Ford.

Acknowledgements

We would like to thank the Tennessee Valley Authority (833 Bridge) and The Nature Conservancy (Fletcher Ford) for granting access to their property. This survey would not have been possible without the help of the following individuals who provided

assistance: John Alderman, Braven Beaty, Terri Brown, Tom Dickinson, Maureen Dougherty, Brian Evans, Stacy Fowler, Teresa Frazier, Dave Garst, Shane Hanlon, Charles Horton, Stefanie Huffer, Chris Isaac, Travis Lowe, Rachel Mair, Amy Martin, Scott Sanders, Clinton Tolliver, Ronnie Vicars, Jenny Wampler, and Amanda Wood.

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Table 1. Present and historical records of mussel species collected in the Powell River at SR 833 bridge crossing.

Species	1918[1]	1978[2]	1979[3,4]	1989[5]	2004[3]	Present Study[6]
Actinonaias ligamentina		L	L	L		L
Actinonaias pectorosa		L	L	L	L	L
Amblema plicata		L	L	L		L
Cyclonaias tuberculata		L	L	L		L
Cyprogenia stegaria						
Dromus dromas		L		L		L
Elliptio crassidens	L					
Elliptio dilatata		L	L	L		L
Epioblasma brevidens		L	L	L		R
Epioblasma capsaeformis		L		L		
Epioblasma triquetra		L				R
Fusconaia barnesiana		L	L	L		L
Fusconaia cor		L	L			
Fusconaia cuneolus						L
Fusconaia subrotunda	L	L	L	L	L	L
Lampsilis fasciola		L	L	L		L
Lampsilis ovata		L	L	L		R
Lasmigona costata		L	L	L		L
Lemiox rimosus	L		L			
Leptodea fragilis		L	L			
Ligumia recta				L		R
Medionidus conradicus		L	L	L	L	L
Plethobasus cyphyus		L				L
Pleurobema oviforme	L					
Potamilus alatus		L	L			R
Ptychobranchus fasciolaris		L	L	L	L	L
Ptychobranchus subtentum	L	L				L
Quadrula c. strigillata		L		L		L
Quadrula intermedia				L		L
Quadrula pustulosa						
Quadrula sparsa						
Toxolasma lividus	L					
Villosa iris		L	L		L	L
Villosa vanuxemensis		L			L	L
Live	**6**	**24**	**18**	**18**	**6**	**19**
Relic	**---**	**---**	**---**		**---**	**5**
Total	**6**	**24**	**18**	**18**	**6**	**24**

[1] Collections of A.E. Ortmann, 1918; Locality is listed as Powell River at Jonesville, Va.
[2] Collected by S.D. Dennis from 1973-1978.
[3] Records courtesy of Steve Ahlstedt, USGS.
[4] This sample was taken approximately 0.4 mile upstream from current study site.
[5] Collected by L.T. Wolcott from 1988-1989.
[6] Present study conducted from August 23rd, 2004 to September 25th, 2004.

Table 2. Present and historical records of mussel species collected in the Powell River at Fletcher Ford.

Species	1918[1]	1978[2]	1979[3]	1983[3]	1988[3]	1989[4]	1994[3]	1999[3]	2001[5]	2002[5]	2004[3]	Present Study[6]
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	L
Alasmidonta marginata	L											
Amblema plicata		L	L		L		L		L	L		L
Cyclonaias tuberculata		L	L		L	L	L	L	L	L	L	L
Cyprogenia stegaria												R
Dromus dromas		L				L		L	L	L		L
Elliptio crassidens		L		L								R
Elliptio dilatata	L	L	L	L	L	L	L	L	L	L	L	L
Epioblasma brevidens	L	L	L			L	L		L	L	L	L
Epioblasma capsaeformis		L	L	L								
Epioblasma triquetra		L	L	L	L	L		L				
Fusconaia barnesiana	L	L	L	L		L						
Fusconaia cor	L	L										
Fusconaia cuneolus									R			
Fusconaia subrotunda	L	L	L	L	L	L	L		R			L
Hemistena lata		L										
Lampsilis fasciola	L	L	L	L		L		L	L	L		L
Lampsilis ovata		L		L					L	L		L
Lasmigona costata		L		L		L			R			R
Lemiox rimosus	L					L						L
Leptodea fragilis		L	L									
Ligumia recta		L				L						L
Medionidus conradicus	L	L	L	L	L	L	L	L	L	L	L	L
Plethobasus cyphyus		L				L	L			L		L

Pleurobema oviforme	L		L		L				R			L
Potamilus alatus		L				L			R			R
Ptychobranchus fasciolaris	L	L	L	L	L	L	L		L	L	L	L
Ptychobranchus subtentum		L		L								
Quadrula c. strigillata		L							R			L
Quadrula intermedia		L	L			L			L	L		L
Quadrula pustulosa												L
Quadrula sparsa					L	L			L			L
Villosa iris	L	L							L			L
Villosa vanuxemensis		L										L
Live	**13**	**28**	**16**	**14**	**11**	**19**	**10**	**8**	**14**	**13**	**7**	**22**
Relic	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**6**	**---**	**---**	**4**
Total	**13**	**28**	**16**	**14**	**11**	**19**	**10**	**8**	**20**	**13**	**7**	**26**

[1] Collections of A.E. Ortmann 1918. Locality is listed as Powell River near Rose Hill, Va.
[2] Collections of S.D. Dennis from 1973 to 1978.
[3] Records courtesy of Steve Ahlstedt, USGS.
[4] Collections made by L.T. Wolcott during 1988-1989.
[5] Records courtesy of Braven Beaty, TNC. 2001 collections occurred between august 8, 2001 and November 11, 2001.
[6] Present study conducted from August 24th to September 24th, 2004.

Table 3. Total number and density of mussel species collected during semi-quantitative sampling of the Powell River at SR 833 Bridge.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per m^2)
Actinonaias pectorosa	255	0	69.29	0.992
Actinonaias ligamentina	41	0	11.14	0.159
Elliptio dilatata	29	0	7.88	0.113
Medionidus conradicus	20	3	5.43	0.078
Lampsilis fasciola	5	0	1.36	0.019
Villosa iris	5	2	1.36	0.019
Fusconaia subrotunda	3	0	0.82	0.012
Plethobasus cyphyus	3	0	0.82	0.012
Ptychobranchus fasciolaris	2	0	0.54	0.008
Cyclonaias tuberculata	1	0	0.26	0.004
Lasmigona costata	1	0	0.26	0.004
Ptychobranchus subtentum	1	0	0.26	0.004
Quadrula intermedia	1	0	0.26	0.004
Villosa vanuxemensis	1	0	0.26	0.004
Amblema plicata	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 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
Lemiox rimosus	0	0	0	0
Ligumia recta	0	0	0	0
Pleurobema oviforme	0	0	0	0
Potamilus alatus	0	0	0	0
Quadrula c. strigillata	0	0	0	0
Quadrula pustulosa	0	0	0	0
Quadrula sparsa	0	0	0	0
Total	**368**	**5**	**100**	**1.43**

Table 4. Total number and density of mussel species collected during quantitative sampling of the Powell River at SR 833 Bridge.

Species	Total Collecte	Number of juveniles	Percent of Collection	Density (per 1/4 m^2)
Actinonaias pectorosa	53	3	68.8	0.53
Elliptio dilatata	7	0	9.1	0.07
Medionidus conradicus	7	2	9.1	0.07
Actinonaias ligamentina	5	0	6.5	0.05
Cyclonaias tuberculata	1	0	1.3	0.01
Fusconaia subrotunda	1	0	1.3	0.01
Lampsilis fasciola	1	0	1.3	0.01
Ptychobranchus fasciolaris	1	0	1.3	0.01
Villosa iris	1	0	1.3	0.01
Amblema plicata	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 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
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
Ptychobranchus subtentum	0	0	0	0
Quadrula c. strigillata	0	0	0	0
Quadrula intermedia	0	0	0	0
Quadrula pustulosa	0	0	0	0
Quadrula sparsa	0	0	0	0
Villosa vanuxemensis	0	0	0	0
Total	**77**	**5**	**100**	**0.77**

Table 5. Live and relic mussel species collected in the Powell River at SR 833 Bridge during qualitative sampling. Sampling conducted August 27th, 2004.

Species	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	Present Overall
Actinonaias ligamentina	L	L	L	L	L	L	L	L	L
Actinonaias pectorosa	L	L	L	L	L	L	L	L	L
Amblema plicata			L					L	L
Cyclonaias tuberculata		L					L	R	L
Cyprogenia stegaria									
Dromus dromas					L				L
Elliptio dilatata	L	L	L	L	L	L	L	L	L
Elliptio crassidens									
Epioblasma brevidens							R		R
Epioblasma capsaeformis									
Epioblasma triquetra	R		R						R
Fusconaia barnesiana							L		L
Fusconaia cor									
Fusconaia cuneolus						L			L
Fusconaia subrotunda	L	L			L		L	L	L
Lampsilis fasciola		R	R			R	L		L
Lampsilis ovata	R		R					R	R
Lasmigona costata						L		R	L
Lemiox rimosus									
Ligumia recta						R	R	R	R
Medionidus conradicus		L	L	L	L	L	L	L	L
Plethobasus cyphyus		L							L
Pleurobema oviforme									
Potamilus alatus				R	R		R	R	R
Ptychobranchus fasciolaris	L	L				L	L	R	L
Ptychobranchus subtentum					L				L
Quadrula c. strigillata				R			L		L
Quadrula intermedia							L		L
Quadrula pustulosa									
Quadrula sparsa									
Villosa iris				L	R	R		L	L
Villosa vanuxemensis						R		R	R
Live	**5**	**8**	**5**	**5**	**7**	**7**	**11**	**7**	**18**
Relic	**2**	**1**	**3**	**2**	**2**	**4**	**3**	**7**	**6**
Total	**7**	**9**	**8**	**7**	**9**	**11**	**14**	**14**	**24**

Table 6. Total number and density of mussel species collected during semi-quantitative sampling of the Powell River at Fletcher Ford.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per m^2)
Actinonaias pectorosa	161	1	52.79	0.925
Actinonaias ligamentina	41	0	13.44	0.235
Medionidus conradicus	40	7	13.11	0.229
Elliptio dilatata	22	2	7.21	0.126
Amblema plicata	7	0	2.29	0.040
Ptychobranchus fasciolaris	7	0	2.29	0.040
Cyclonaias tuberculata	5	0	1.63	0.028
Lampsilis fasciola	5	0	1.63	0.028
Lampsilis ovata	4	0	1.31	0.022
Plethobasus cyphyus	3	0	0.99	0.017
Quadrula intermedia	3	0	0.99	0.017
Epioblasma brevidens	2	0	0.66	0.011
Lemiox rimosus	2	0	0.66	0.011
Villosa iris	2	0	0.66	0.011
Villosa vanuxemensis	1	0	0.33	0.006
Cyprogenia stegaria	0	0	0	0
Dromus dromas	0	0	0	0
Elliptio crassidens	0	0	0	0
Epioblasma capsaeformis	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
Fusconaia subrotunda	0	0	0	0
Lasmigona costata	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
Quadrula sparsa	0	0	0	0
Total	**305**	**10**	**100**	**1.75**

Table 7. Total number and density of mussel species collected during quantitative sampling of the Powell River at Fletcher Ford.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per 1/4m^2)
Actinonaias pectorosa	53	5	58.9	0.53
Actinonaias ligamentina	14	0	15.6	0.14
Elliptio dilatata	6	0	6.7	0.06
Medionidus conradicus	6	0	6.7	0.06
Lampsilis ovata	2	0	2.2	0.02
Villosa iris	2	2	2.2	0.02
Amblema plicata	1	0	1.1	0.01
Cyclonaias tuberculata	1	0	1.1	0.01
Epioblasma brevidens	1	0	1.1	0.01
Lampsilis fasciola	1	1	1.1	0.01
Ligumia recta	1	0	1.1	0.01
Plethobasus cyphyus	1	0	1.1	0.01
Pleurobema oviforme	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 capsaeformis	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
Fusconaia subrotunda	0	0	0	0
Lasmigona costata	0	0	0	0
Lemiox rimosus	0	0	0	0
Potamilus alatus	0	0	0	0
Ptychobranchus fasciolaris	0	0	0	0
Ptychobranchus subtentum	0	0	0	0
Quadrula c. strigillata	0	0	0	0
Quadrula intermedia	0	0	0	0
Quadrula pustulosa	0	0	0	0
Quadrula sparsa	0	0	0	0
Villosa vanuxemensis	0	0	0	0
Total	**90**	**8**	**100**	**0.90**

Table 8. Live and relic mussel species collected in the Powell River at Fletcher Ford during qualitative sampling. Sampling conducted September 24th, 2004.

Species	FF1	FF2	FF3	Present Live or Relic
Actinonaias ligamentina	L	L	L	L
Actinonaias pectorosa	L	L	L	L
Amblema plicata	L	L	L	L
Cyclonaias tuberculata	R	L		L
Cyprogenia stegaria	R			R
Dromus dromas	L	L	L	L
Elliptio dilatata	L	L	L	L
Elliptio crassidens	R			R
Epioblasma brevidens	L	L	L	L
Epioblasma capsaeformis				
Epioblasma triquetra				
Fusconaia barnesiana				
Fusconaia cor				
Fusconaia cuneolus				
Fusconaia subrotunda	R	L		L
Lampsilis fasciola		R		R
Lampsilis ovata		L	L	L
Lasmigona costata	R		R	R
Lemiox rimosus		L		L
Ligumia recta			R	R
Medionidus conradicus	L	L	L	L
Plethobasus cyphyus	R		L	L
Pleurobema oviforme				
Potamilus alatus	R	R		R
Ptychobranchus fasciolaris	R	L	R	L
Ptychobranchus subtentum				
Quadrula c. strigillata	R	L	R	L
Quadrula intermedia	R	L		L
Quadrula pustulosa			L	L
Quadrula sparsa				
Villosa iris	L	L		L
Villosa vanuxemensis				
Live	**8**	**15**	**10**	**17**
Relic	**10**	**7**	**4**	**6**
Total	**18**	**22**	**14**	**23**

Table 9. Mussel species collected in the Powell River at the SR 833 bridge site based on type of sampling employed. Records reflect all species collected live, fresh dead and relic.

Species	Semi-Quantitative	Quantitative	Qualitative	Incidental*	Overall
Actinonaias ligamentina	X	X	X		X
Actinonaias pectorosa	X	X	X		X
Amblema plicata			X		X
Cyclonaias tuberculata	X	X	X		X
Cyprogenia stegaria					
Dromus dromas			X		X
Elliptio dilatata	X	X	X		X
Elliptio crassidens					
Epioblasma brevidens			X		X
Epioblasma capsaeformis					
Epioblasma triquetra			X		X
Fusconaia barnesiana			X		X
Fusconaia cor					
Fusconaia cuneolus			X		X
Fusconaia subrotunda	X	X	X		X
Lampsilis fasciola	X	X	X		X
Lampsilis ovata			X		X
Lasmigona costata	X		X		X
Lemiox rimosus					
Ligumia recta			X		X
Medionidus conradicus	X	X	X		X
Plethobasus cyphyus	X		X		X
Pleurobema oviforme					
Potamilus alatus			X		X
Ptychobranchus fasciolaris	X	X	X		X
Ptychobranchus subtentum	X		X		X
Quadrula c. strigillata			X		X
Quadrula intermedia	X		X		X
Quadrula pustulosa					
Quadrula sparsa					
Villosa iris	X	X	X		X
Villosa vanuxemensis	X		X		X
Totals	**14**	**9**	**24**	**0**	**24**

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

Table 10. Mussel species collected in the Powell River at Fletcher Ford 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
Cyclonaias tuberculata	X	X	X		X
Cyprogenia stegaria			X		X
Dromus dromas	X		X		X
Elliptio dilatata	X	X	X		X
Elliptio crassidens			X		X
Epioblasma brevidens	X	X	X		X
Epioblasma capsaeformis					
Epioblasma triquetra					
Fusconaia barnesiana					
Fusconaia cor					
Fusconaia cuneolus					
Fusconaia subrotunda			X		X
Lampsilis fasciola	X	X	X		X
Lampsilis ovata	X	X	X		X
Lasmigona costata			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
Potamilus alatus			X		X
Ptychobranchus fasciolaris	X		X		X
Ptychobranchus subtentum					
Quadrula c. strigillata			X		X
Quadrula intermedia	X		X		X
Quadrula pustulosa			X		X
Quadrula sparsa				X	X
Villosa iris	X	X	X		X
Villosa vanuxemensis	X				X
Totals	**16**	**13**	**23**	**1**	**26**

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

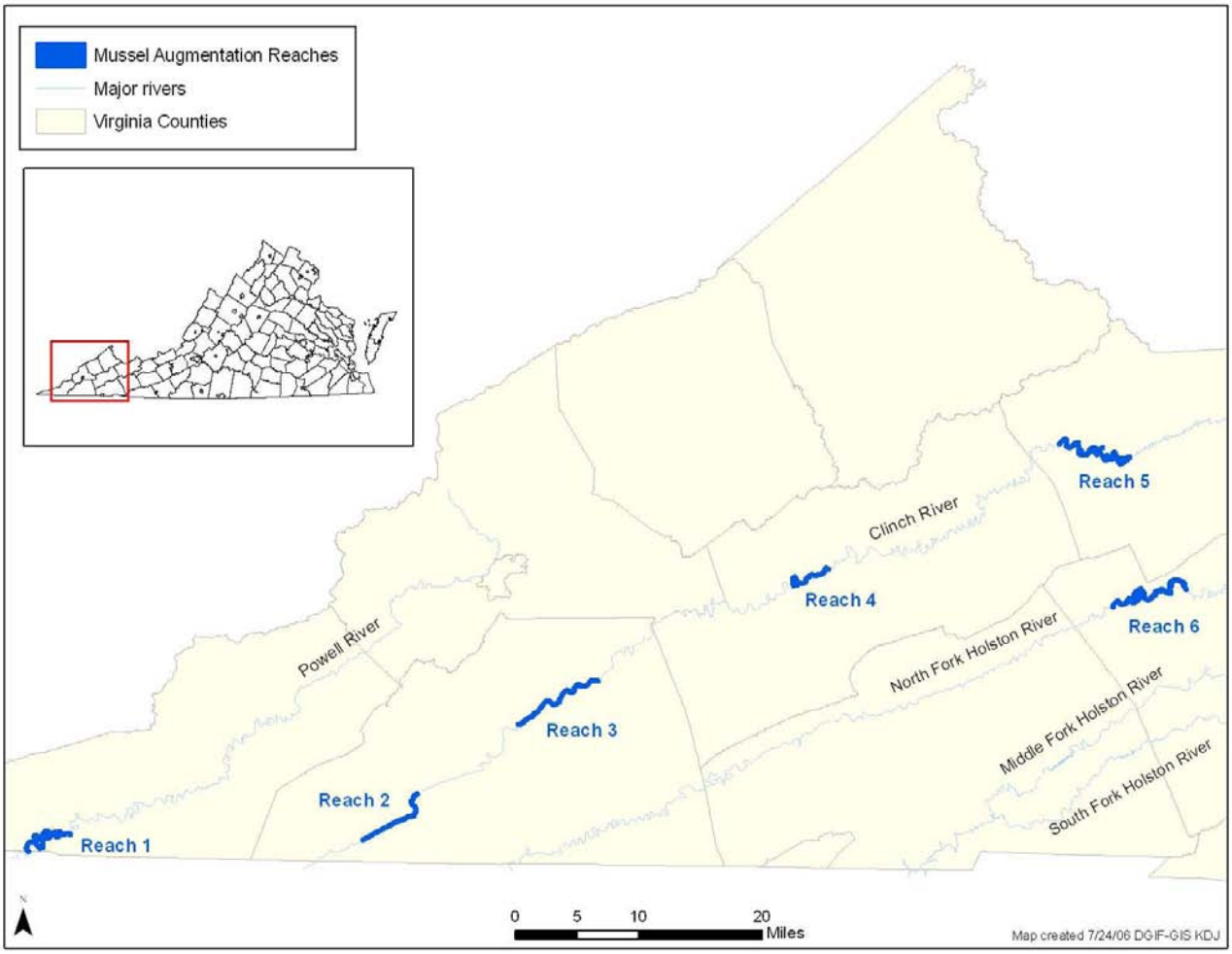

Figure 1. Stream reaches designated as augmentation reaches by the Virginia Department of Game and Inland Fisheries mussel restoration plan. Six reaches are divided between the Powell River (1), Clinch River (4) and North Fork Holston River (1).

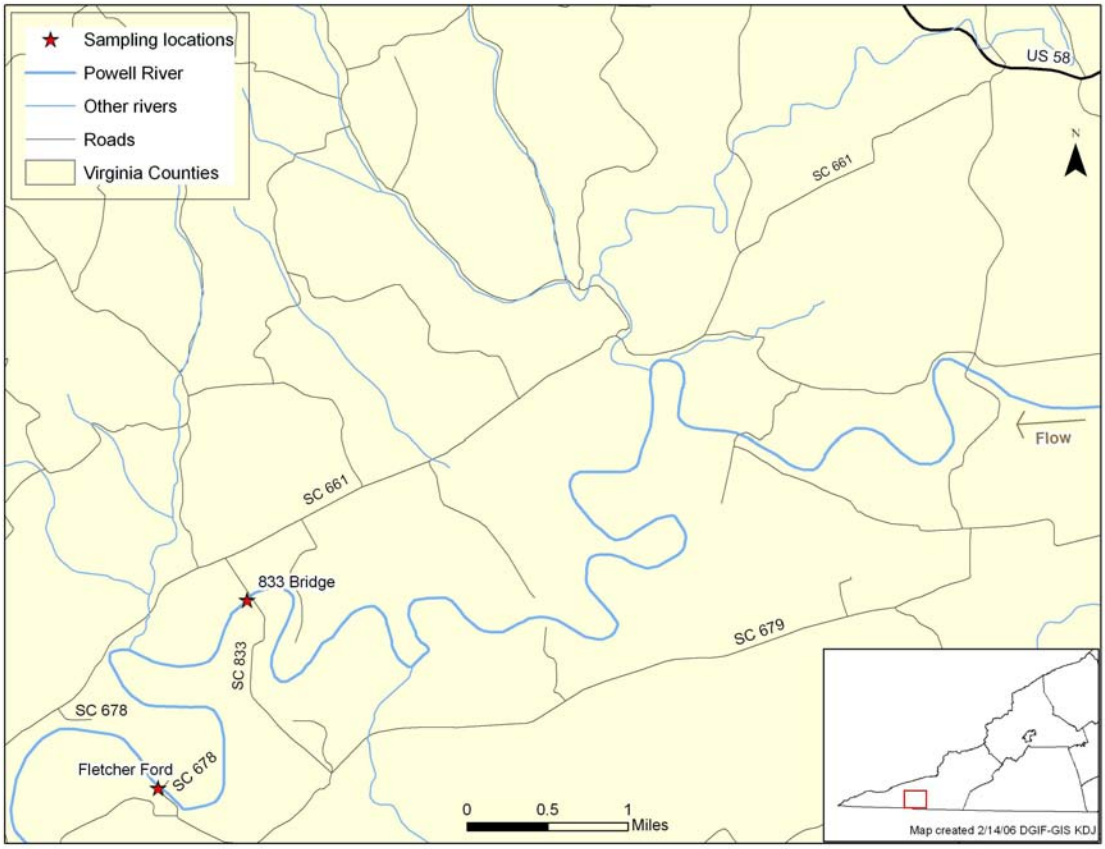

Figure 2. The Powell River in Lee County, Virginia. Musselrama 2004 included a survey of both SR 833 bridge and Fletcher Ford.

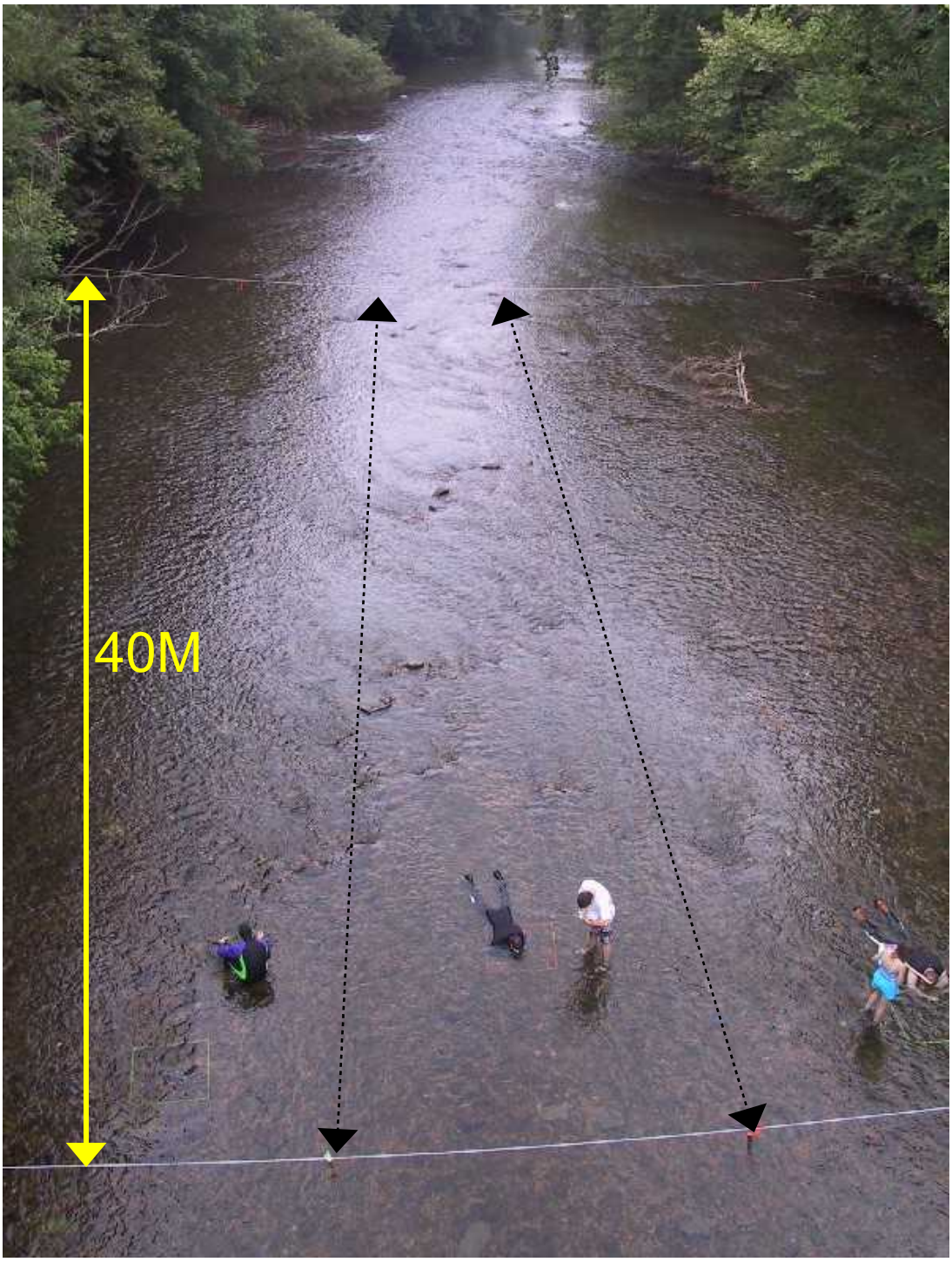

Figure 3. Overhead view of the 833 bridge site. Ropes are stretched every 40 meters with flags to delineate lanes and serve as a visual guide. Black lines show one lane.

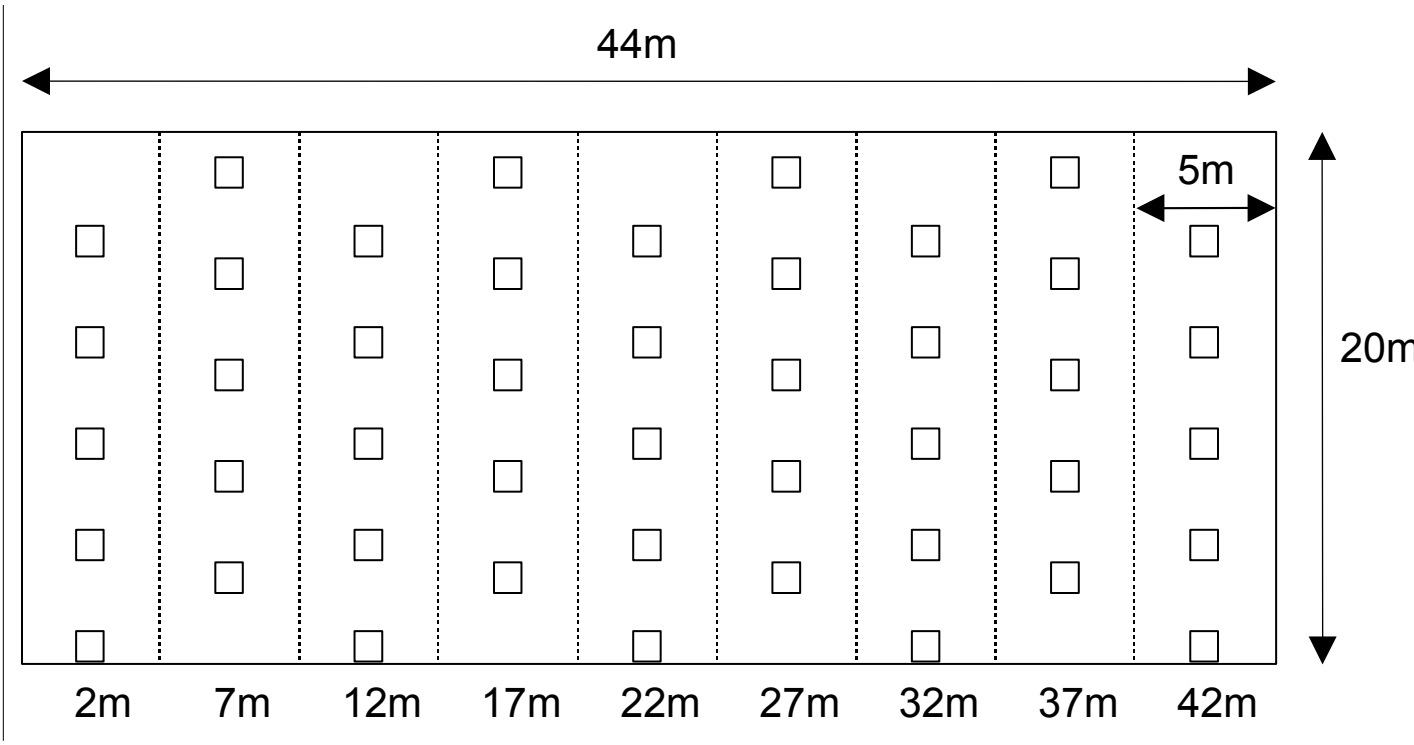

Figure 4. Graphic representation of semi-quantitative sampling method. Squares indicate sampling location and dashed lines show lane boundaries. Each lane is 5m wide and 20m long. Five samples are taken representing 5% of overall habitat. Starting position of samplers alternates between 1m and 3m.

Figure 5. 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.

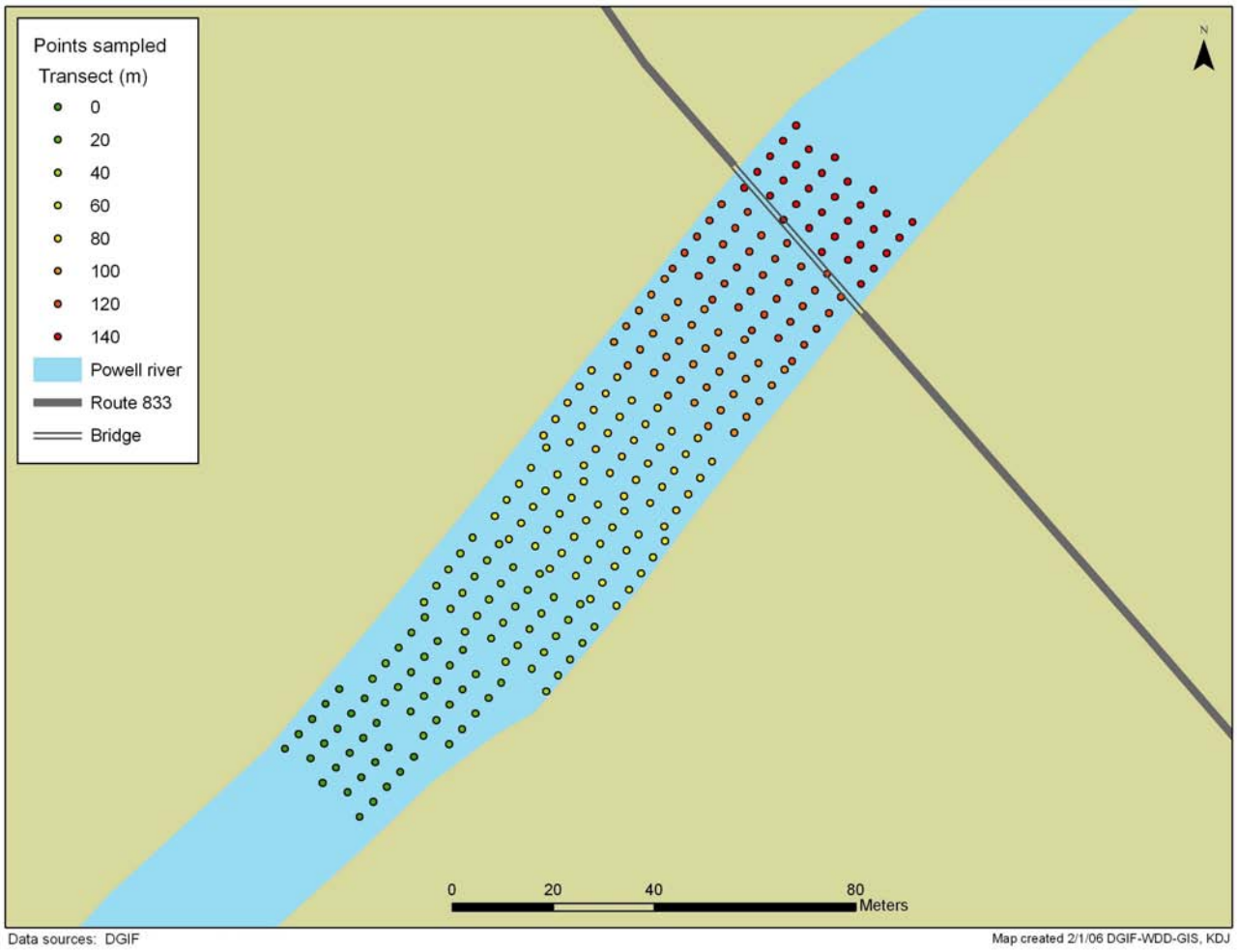

Figure 6. Overhead map of SR 833 bridge showing sample area and location of quadrats sampled during semi-quantitative sampling during August 2004.

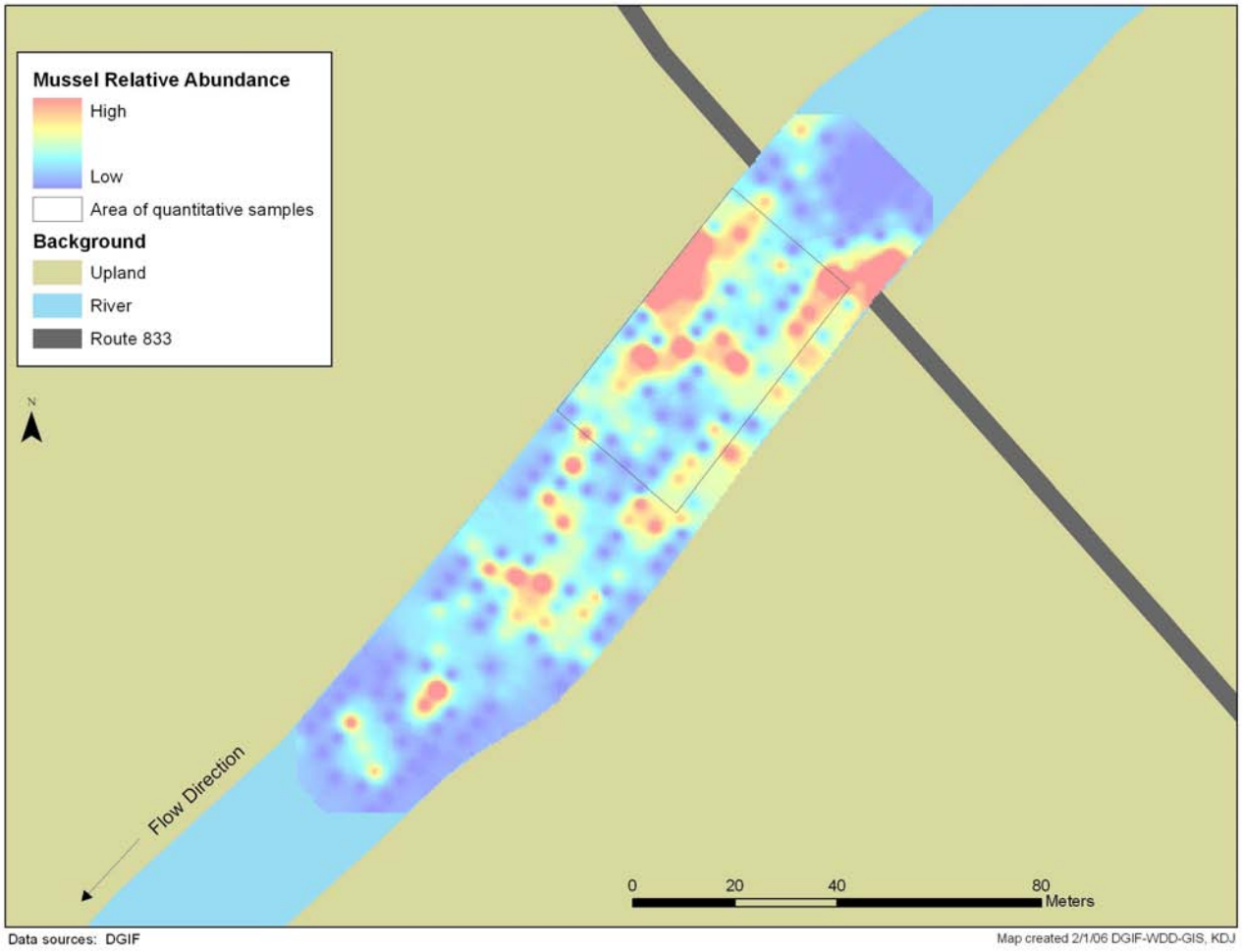

Figure 7. Relative abundance of mussels found during semi-quantitative sampling at SR 833 Bridge. The red areas indicate regions of higher mussel density within the sample. The square denotes the area that was selected for quantitative sampling.

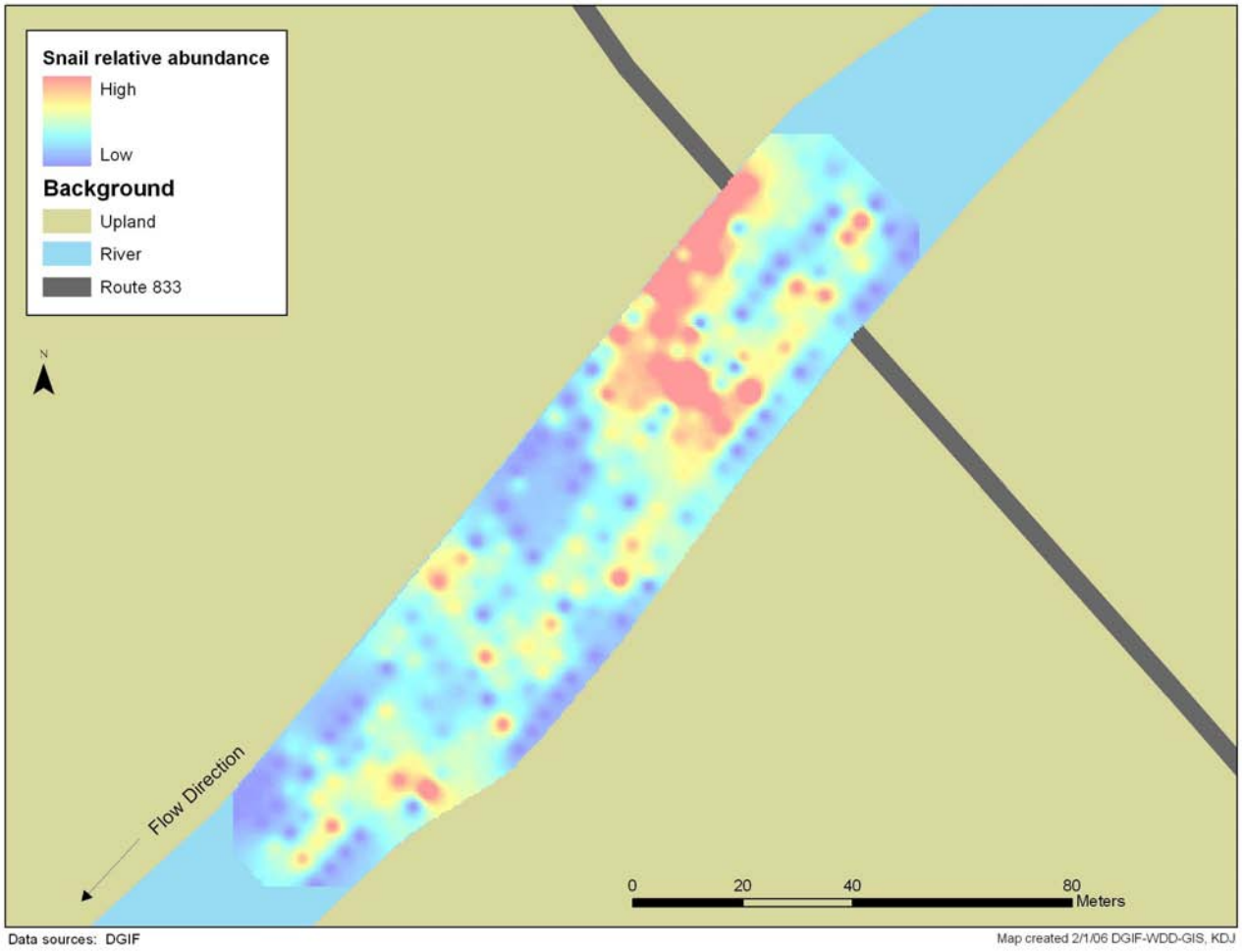

Figure 8. Relative abundance of spiny riversnail, *Io fluvialis,* collected during semi-quantitative sampling at SR 833 Bridge. This map shows areas of higher density of spiny riversnail.

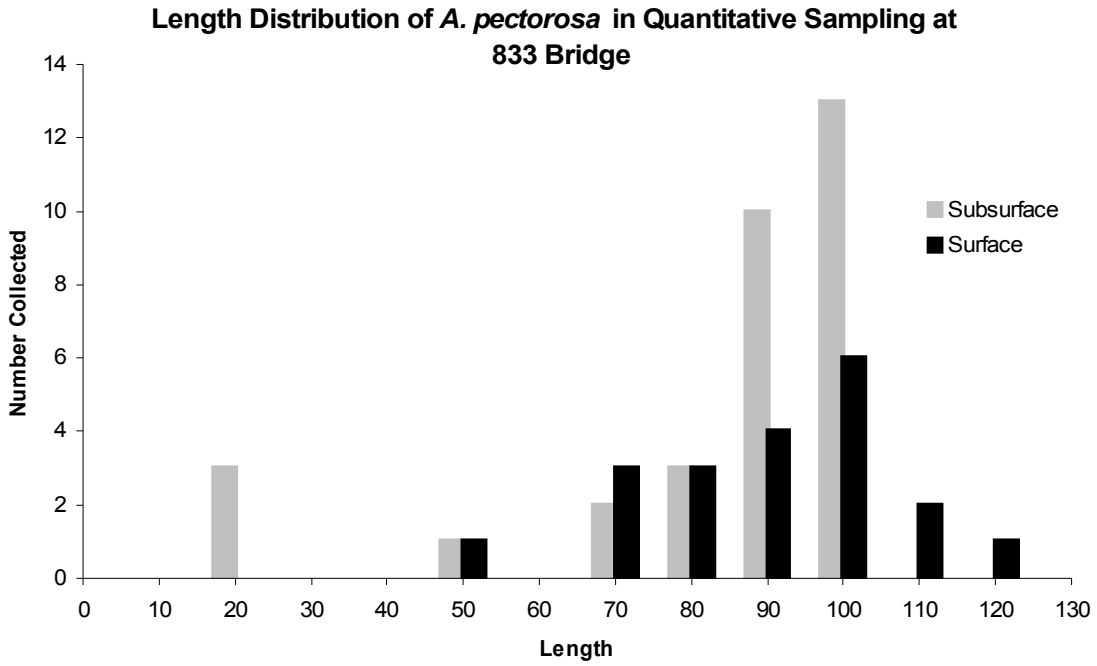

Figure 9. Length distribution of *Actinonaias pectorosa* collected during quantitative sampling in the Powell River at SR 833 Bridge. Individuals were measured separately based on surface or subsurface collection. Individuals below 30 mm are considered evidence of recent recruitment.

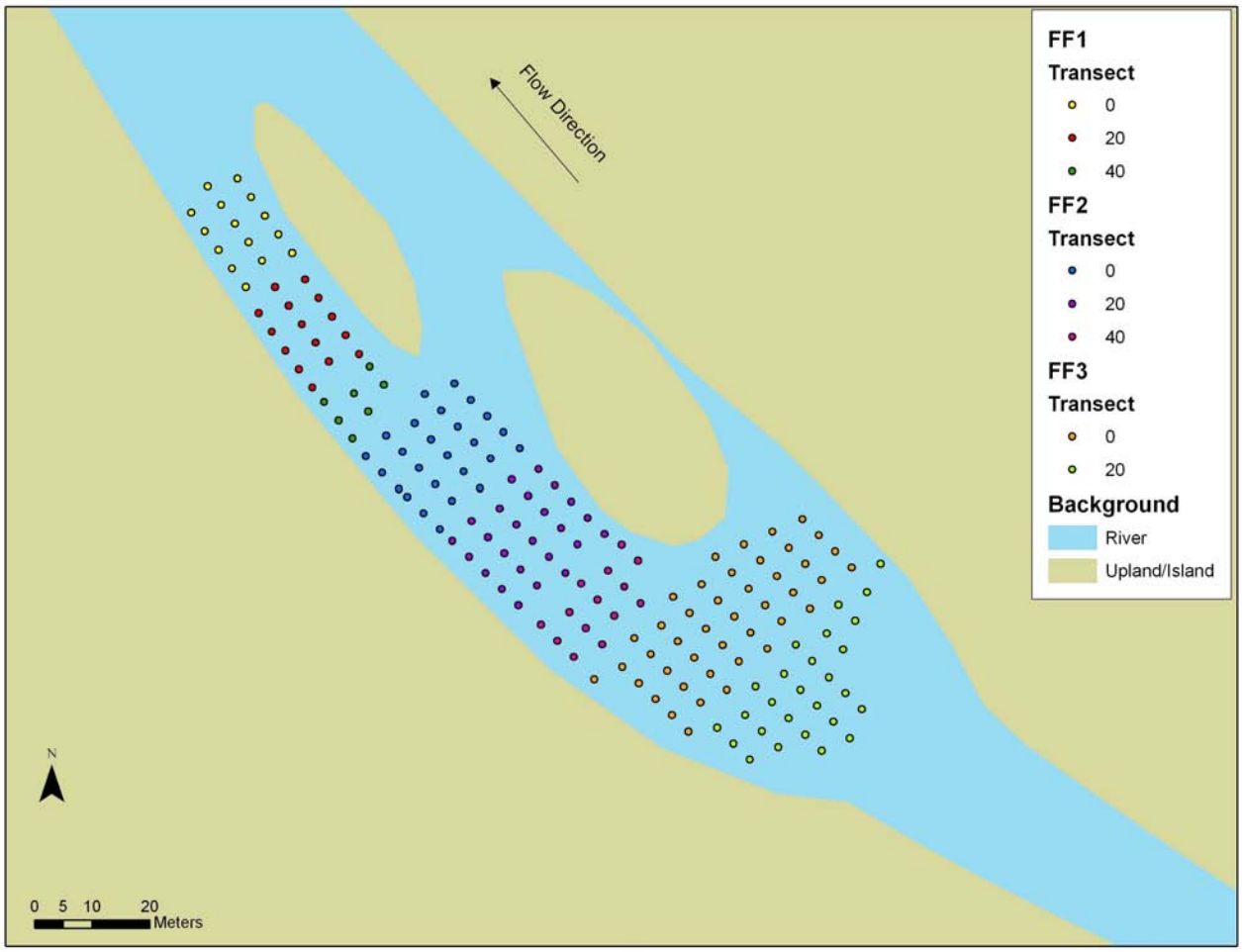

Figure 10. Overhead map of Fletcher Ford showing sample area and location of quadrats sampled during semi-quantitative sampling during August 2004.

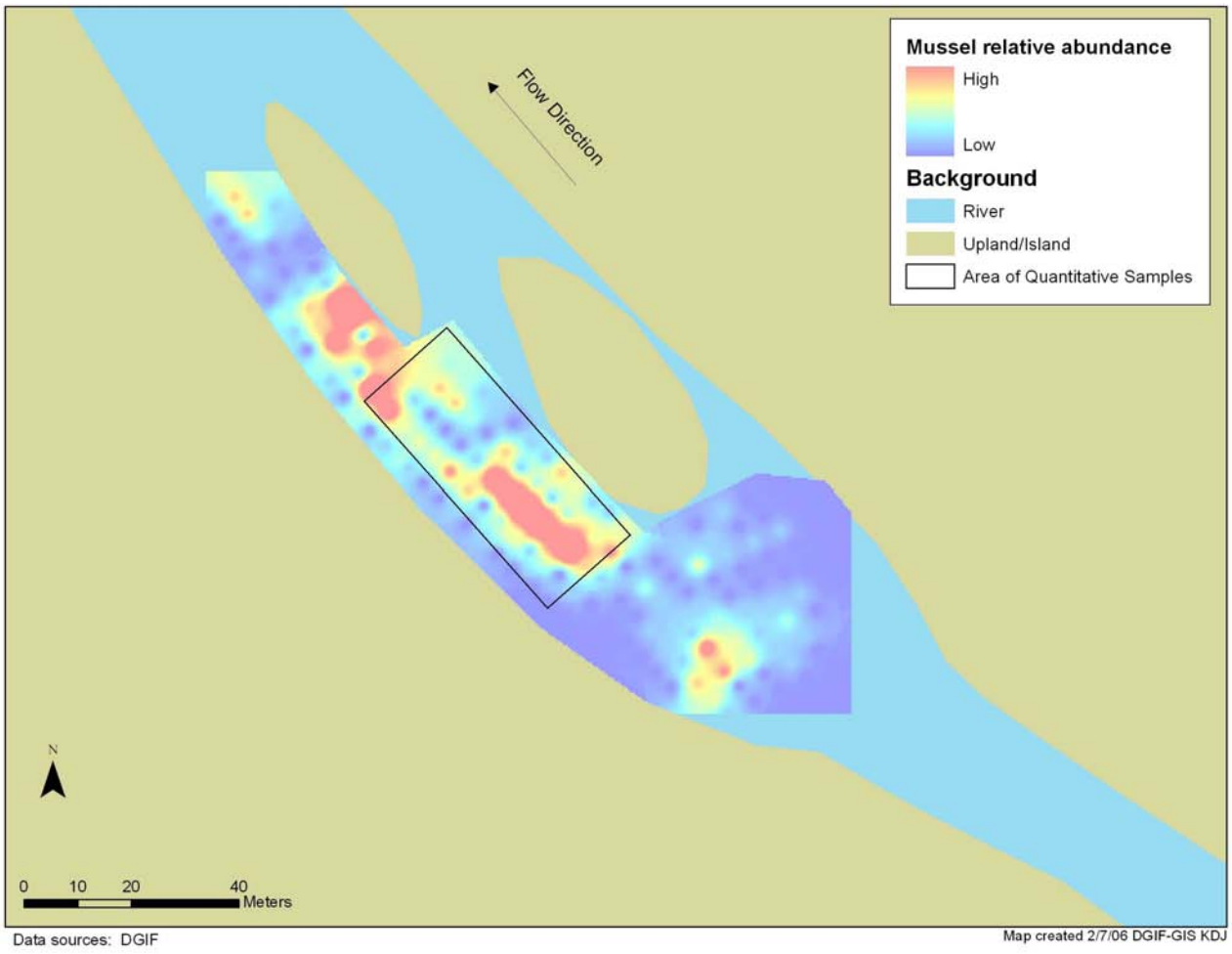

Figure 11. Relative abundance of mussels found during semi-quantitative sampling at Fletcher Ford. The red areas denote regions of higher density within the sample. The square outlines the area that was selected for quantitative sampling.

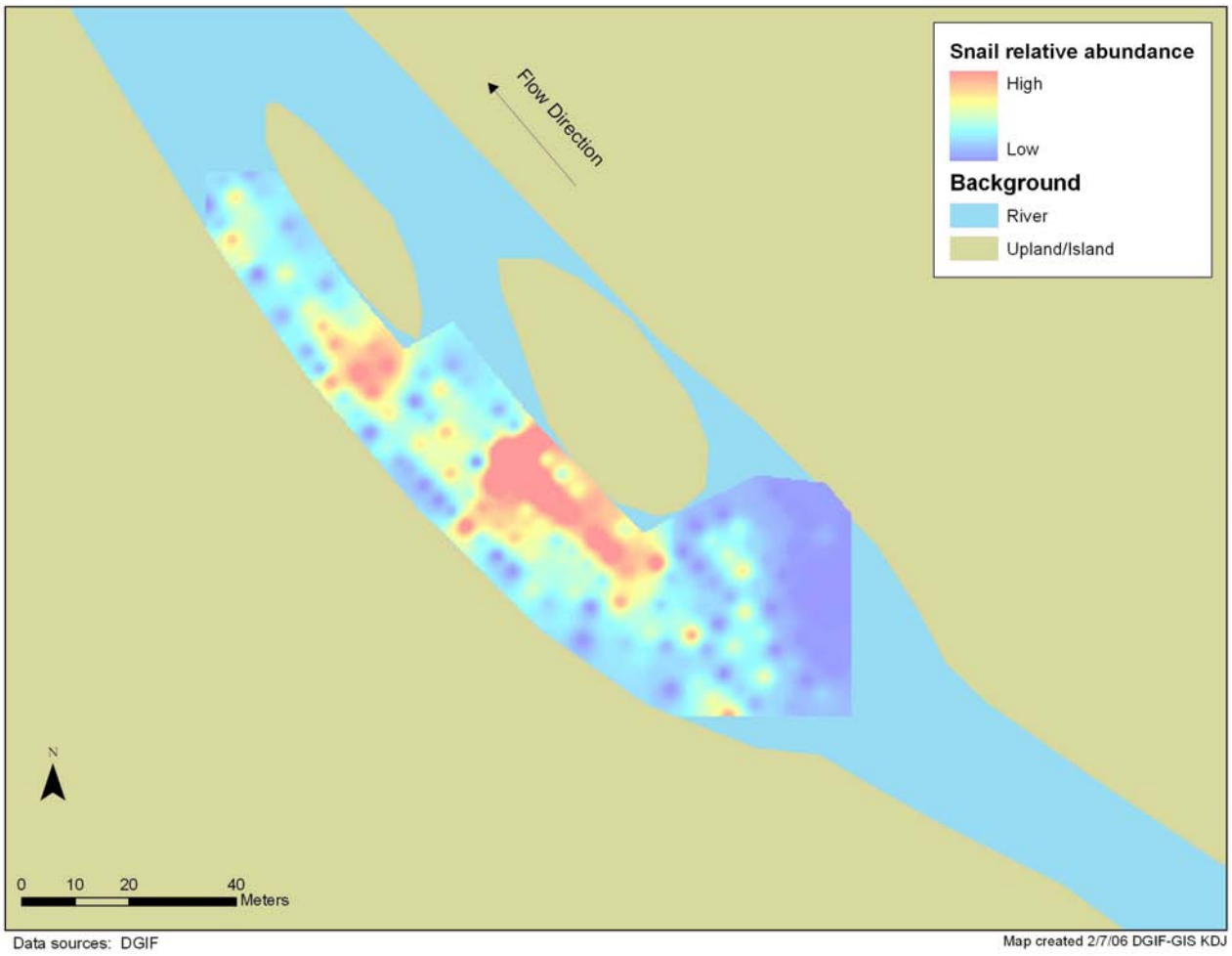

Figure 12. Relative abundance of spiny riversnail, *Io fluvialis,* collected during semi-quantitative sampling at Fletcher Ford. The red areas denote regions of higher density of spiny riversnail within the sample.

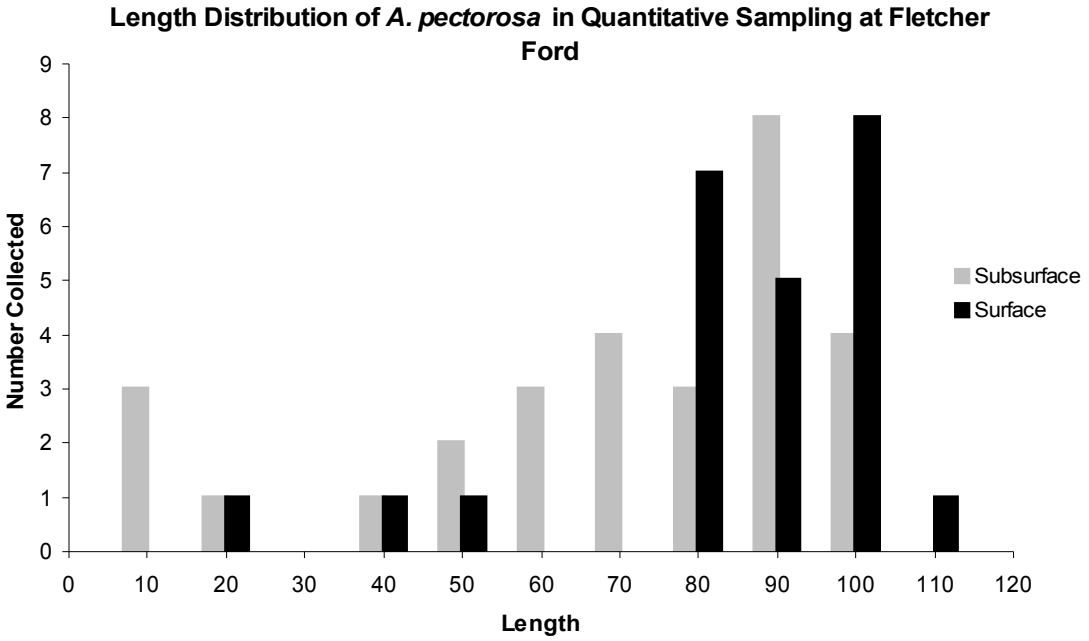

Figure 13. Length distribution of *Actinonaias pectorosa* collected during quantitative sampling in the Powell River at Fletcher Ford. Individuals were measured separately based on surface or subsurface collection. Individuals below 30 mm are considered evidence of recent recruitment.

Appendix 1. Scientific name, common name, state and federal status of species mentioned in this report.

Species Name	Common Name	State*	Federal*
Actinonaias ligamentina	mucket	-----	-----
Actinonaias pectorosa	pheasantshell	-----	-----
Amblema plicata	threeridge	-----	-----
Cyclonaias tuberculata	purple wartyback	-----	-----
Cyprogenia stegaria	fanshell	**SE**	**FE**
Dromus dromas	dromedary pearlymussel	**SE**	**FE**
Elliptio crassidens	elephant-ear	**SE**	-----
Elliptio dilatata	spike	-----	-----
Epioblasma brevidens	Cumberland combshell	**SE**	**FE**
Epioblasma capsaeformis	oystermussel	**SE**	**FE**
Epioblasma triquetra	snuffbox	**SE**	**SOC**
Fusconaia barnesiana	Tennessee pigtoe	-----	-----
Fusconaia cor	shiny pigtoe	**SE**	**FE**
Fusconaia cuneolus	fine-rayed pigtoe	**SE**	**FE**
Fusconaia subrotunda	long-solid	-----	-----
Hemistena lata	crackling pearlymussel	**SE**	**FE**
Io fluvialis	spiny riversnail	**ST**	**SOC**
Lampsilis fasciola	wavy-rayed lampmussel	-----	-----
Lampsilis ovata	pocketbook	-----	-----
Lemiox rimosus	birdwing pearlymussel	**SE**	**FE**
Leptodea fragilis	fragile papershell	**ST**	-----
Ligumia recta	black sandshell	**ST**	-----
Medionidus conradicus	moccansinshell	-----	-----
Plethobasus cyphyus	sheepnose	**ST**	**FC**
Pleurobema oviforme	Tennessee clubshell	-----	-----
Potamilus alatus	pink heelsplitter	-----	-----
Ptychobranchus fasciolaris	kidneyshell	-----	-----
Ptychobranchus subtentum	fluted kidneyshell	-----	**FC**
Quadrula cylindrica strigillata	rough rabbitsfoot	**SE**	**FE**
Quadrula intermedia	Cumberland monkeyface	**SE**	**FE**
Quadrula pustulosa	pimpleback	**ST**	-----
Quadrula sparsa	Appalachian monkeyface	**SE**	**FE**
Toxolasma lividus	purple lilliput	-----	-----
Villosa iris	rainbow mussel	-----	-----
Villosa vanuxemensis	mountain creekshell	-----	-----

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