

**Freshwater Mussel Survey of Cleveland Island, Clinch River, Virginia:
Augmentation Monitoring Site: 2008**



By:

Nathan L. Eckert and Michael J. Pinder

Contributors:

Amanda E. Duncan, Joe J. Ferraro, Brian T. Watson

Virginia Department of Game and Inland Fisheries
Bureau of Wildlife Resources
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Introduction

Freshwater mussel populations have recently experienced dramatic declines across the country compared 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 widespread attempts to restore declining or extirpated populations by releasing cultured juvenile mussels or translocating adult mussels. Before implementing restoration activities, 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 after 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); Cleveland Island (CRM 270.8), Russell Co., (2002) and Cedar Bluff (CRM 322.7), Tazewell Co., (2007, Eckert & Pinder 2009). 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 (2008) was conducted on the Clinch River at Cleveland Island (CRM 270.8). This is the first follow-up mussel survey at Cleveland Island after the baseline survey in 2002. No formal report was generated for the 2002 Cleveland Island survey. Therefore, the 2002 survey data will be summarized in this report and used for comparison to the present study.

Objective

At Cleveland Island, 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 fluviialis*).
2. To quantify sections of high density mussel aggregations at the site.
3. To verify ideal mussel habitat at the site for mussel augmentation.
4. Compare results of the present study to previous sampling events at Cleveland.

Study Area

The site known as Cleveland Island on the Clinch River is found approximately 1 km southwest of the town of Cleveland in Russell Co., Virginia and is located at CRM

270.8 (Figure 2). Approximately 2.7 acres of riparian habitat along the left ascending side of the island complex is owned by The Nature Conservancy. A Norfolk Southern Railroad runs parallel to the stream along the right ascending bank. Cleveland Island is a complex of three mature islands that create four braided channels (Figure 3). This site was selected as a representative of Virginia Freshwater Mussel Restoration Plan reach 4 which is defined as Nash Ford (CRM 279) downstream to Carbo (CRM 267), a distance of approximately twelve river miles. This area has been sampled several times previously (Table 1). Presence/absence records and density data from these samples can be compared to the current study.

Methods

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 along the bank and every 40 m with ropes overhead. Ropes were marked every 5 m across the stream with flagging tape to provide lanes and serve as a visual guide while sampling (Figure 4).

Each 20 m section was divided into lanes 5 m wide. The number of lanes per section was determined by 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. Lane position for each sampler was identical to assure even spacing of sampling effort. 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 5).

At every quadrat, depth, habitat type, visibility and dominant substrate class was 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. No significant substrate excavation occurred during the semi-quantitative sample. 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 9.3 (ESRI) to visually highlight areas of higher density.

Quantitative

Areas of highest mussel density during semi-quantitative sampling were selected for quantitative sampling. Quantitative sampling was used to estimate population size and age structure for monitoring purposes. The quantitative survey method for the

present study differed from the methodology used during the 2002 augmentation survey. Therefore, both methods will be mentioned here and the derived data will be manipulated to make comparisons between the two surveys as seamless as possible.

2008 Quantitative

The quantitative sampling approach for the present study involves systematic transect sampling within the selected area using 0.25-m² quadrats. Systematic quadrat sampling of evenly spaced quadrats has been found to be more accurate than simple random sampling (Pooler & Smith 2005). Six samples were taken along each transect by samplers spaced evenly along the transect line approximately 2 m apart. Transects were spaced every 4 m moving upstream with a random start generated 3 times during each sample. Each quadrat was excavated to approximately 20 cm depth using a Ferraro streambed sampler. First, the mussels on the surface were removed, identified, counted, and measured, and then the substrate was excavated into the sampler. 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 contents. 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, 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, 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.

2002 Quantitative

This survey was conducted using an aggregation or cluster sampling method. First the quantitative survey site was qualitatively sampled and survey flags were placed by each mussel. Sampling began by placing a quadrat at the location of one survey flag (mussel). This quadrat was sampled in an identical fashion to present methodology. Upon completion of the first quadrat the quadrat immediately upstream was sampled and then the quadrat directly on the left side of the second quadrat. If live mussels are collected in the third quadrat the three quadrat cycle repeats beginning with the quadrat immediately upstream, if not the process starts over at another randomly determined survey flag.

Qualitative

Upon completion of the quantitative sampling, a qualitative sample was taken to record 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 sample area is a braided channel formed by three islands; we estimated the total area surveyed at the site to be 16,930 m². The semi-quantitative sample at Cleveland Island included 889-1-m² quadrats (Figure 6). Average depth of the site was 29.5 cm, ranging from 0 cm to 88 cm (Figure 7). Visibility generally varied from slightly less than one meter to greater than one meter. Substrate size was predominantly pebble (59%) with much lower percentages of gravel, sand, cobble, boulder, and mud.

A total of 1,131 mussels were collected to yield a mean density of 1.27/m² (Table 2). A total of eight *Io fluvialis* were collected for an overall density of less than 0.01 snails/m². The entire RAR1 section showed a high density of mussels as well as the lower portion of the LA1 section (Figure 8). Nineteen mussel species were collected alive with six species showing signs of recent recruitment (*Actinonaias ligamentina*, *Elliptio dilatata*, *Epioblasma capsaeformis*, *Fusconaia barnesiana*, *Medionidus conradicus* and *Villosa iris*, length < 30 mm; 3.0% of individuals collected). The most abundant species were *Actinonaias pectorosa* (481), *E. dilatata* (221) and *M. conradicus* (199).

Quantitative

During the present study, two quantitative samples were taken. The two areas selected for sampling were the RAR1 and LA1 sections. The LA1 section was not completely sampled due to a large section of unsuitable habitat in the middle of the section. In LA1 the quantitative sample occurred above and below the unsuitable habitat (Figure 9). Data for LA1 includes both survey areas.

RAR1 sample

The entire length of the RARI section (0 m – 160 m) was quantitatively sampled. Average depth in this quantitative sample area was 25.8 cm. In 225-0.25-m² quadrats, 511 mussels were collected for a density of 2.27/0.25 m² (Table 3) with a precision of 9.2%. Sixteen species were collected and recent recruitment was seen in three species, *A. pectorosa*, *E. capsaeformis* and *M. conradicus* (3.3% of individuals collected). Of the mussels collected, 34.4% (176) were visible at the surface, 64.6% (335) were collected subsurface. Individuals of the most common species (*A. pectorosa*; N=209) were not significantly larger on the surface compared to subsurface collections (P>0.05).

However, individuals of the second most abundant species (*M. conradicus*, N=145) were significantly larger on the surface compared to individuals collected below the surface (P>0.02). A length frequency analysis of both species showed signs of recent recruitment, but little difference in patterns collected surface vs. subsurface (Figure 10).

For comparison to the 2002 survey, the data from the sections that overlapped the previous quantitative samples was separated. Transects 35 through 40 of the present study correspond with cluster 1 of the 2002 survey while transects 15 through 20 match the location for cluster 2.

In 36-0.25-m² quadrats, 137 mussels were collected between transects 35-40 for a density of 3.81/0.25 m² (Table 4) with a precision of 25.6%. Twelve species were collected and recent recruitment was seen in two species, *A. pectorosa* and *M. conradicus* (1.5% of individuals collected).

In 35-0.25-m² quadrats, 61 mussels were collected between transects 15-20 for a density of 1.74/0.25 m² (Table 4) with a precision of 32.3%. Eight species were collected and recent recruitment was seen in one species, *A. pectorosa* (1.6% of individuals collected).

LA1 sample

The left ascending quantitative sample ran from 0 m to 105 m and also 138 m to 210 m. Average depth in this quantitative sample area was 24.5 cm. In 253-0.25-m² quadrats, 272 mussels were collected for a density of 1.075/0.25 m² (Table 5) with a precision of 14.3%. Recent recruitment was seen in five species, *E. dilatata*, *F. barnesiana*, *M. conradicus*, *V. iris* and *Villosa vanuxemensis* (8.1% of individuals collected). Of the mussels collected, 44.1% (120) were visible at the surface, 55.9% (152) were collected subsurface. Individuals of the two most common species (*E. dilatata*; N=79; *A. pectorosa*, N=73) were significantly smaller in length in subsurface collections than surface collections (P<0.002). A length frequency analysis of both species showed signs of recent recruitment and a trend towards larger individuals in surface collections can also be seen (Figure 11).

Qualitative

A 22.6 person-hour visual search was conducted systematically from the downstream to upstream end of the survey site. This search yielded 22 species live and 4

represented by relic or fresh dead shell only for a total of 26 species (Table 6). This sampling added five species to our collection list (2 live and 3 relic only; Table 7). *Ligumia recta* and *Villosa perpurpurea* were both found live, while *Alasmidonta marginata*, *Potamilus alatus* and *Truncilla truncata* were collected as relic shell material only.

Incidental

No rare species were collected during site preparations that were not also collected during the structured portion of the survey. This site is frequently sampled qualitatively to collect broodstock for propagation. During recent brood stock collections, a live *A. marginata* and *Cumberlandia monodonta* were found at the site. These species were not represented live in the structured sampling but should currently be considered extant.

2002 Survey Results

Semi-quantitative

The 2002 semi-quantitative sample at Cleveland Island included 875-1-m² quadrats. Average depth of the site during the survey was 36.3 cm. A total of 1,707 mussels were collected to yield a mean density of 1.95/m² (Table 8). The RAR1 section showed high density levels along with a small portion on the downstream end of the LA1 section (Figure 12). Twenty-two mussel species were collected alive; the most abundant species were *A. pectorosa* (675), *M. conradicus* (320) and *E. dilatata* (265). Evidence of recruitment was seen in 13 species (Table 8).

Quantitative

Two samples were taken during this survey, cluster 1 and cluster 2. Exact location for the two samples was the RAR1 section from 140 m to 160 m (Cluster one) and 60 m to 80 m (Cluster two).

Cluster one: In 42-0.25-m² quadrats, 172 mussels were collected for a density of 4.09/0.25 m² (Table 9) with a precision of 20.6%. Of the mussels collected, 59.9% were collected subsurface. Nine species were collected live and recent recruitment was seen in four species, *A. pectorosa*, *M. conradicus*, *Ptychobranthus fasciolaris* and *Ptychobranthus subtentum* (9.9% of individuals collected).

Cluster two: In 39-0.25-m² quadrats, 96 mussels were collected for a density of 2.44/0.25 m² (Table 9) with a precision of 29.8%. Of the mussels collected, 39.6% were collected subsurface. Ten species were collected live and recent recruitment was seen in four species, *A. pectorosa*, *F. barnesiana*, *Fusconaia cor* and *M. conradicus* (5.1% of individuals collected).

The aggregation/cluster method for this survey began initially with quadrats placed directly over known mussels. This is not a random sampling method. For comparison to the present study data from the aggregation/cluster sampling was altered, removing the non-random starts from the data set.

After alteration the data for cluster 1: In 34-0.25-m² quadrats, 137 mussels were collected for a density of 4.03/0.25 m² (Table 4) with a precision of 24.9%. Nine species were collected live and recent recruitment was seen in three species, *A. pectorosa*, *M. conradicus* and *P. subtentum* (8.8% of individuals collected).

After alteration the data for cluster 2: In 31-0.25-m² quadrats, 76 mussels were collected for a density of 2.45/0.25 m² (Table 4) with a precision of 34.4%. Eight species

were collected live and recent recruitment was seen in four species, *A. pectorosa*, *F. barnesiana*, *F. cor* and *M. conradicus* (7.9% of individuals collected).

A comparison of length frequency was made for the most common species (*A. pectorosa*) in both cluster 1 and 2 (Figure 13). Comparison showed that mussels collected in the subsurface sample were significantly smaller than those collected on the surface ($P < 0.001$) for both cluster samples.

The most common species at the site in both surveys, *A. pectorosa*, was compared between the two quantitative samples to look for changes in the population demographic (Figure 14). In cluster 1 ($P = 0.44$) and cluster 2 ($P = 0.38$) no significant difference was seen in length between *A. pectorosa* collected in 2002 vs. 2008.

Qualitative

A 9.0 person-hour visual search was conducted systematically from the downstream to upstream end of the survey site. Twenty-two species were collected live with one as relic only (Table 10). Most notable finds include live *P. alatus*, and *Quadrula sparsa* and relic shell material of *V. perpurpurea*.

Discussion

Previous surveys have recorded 34 species live while the current study found 23 with 3 represented by relic shell only. Of previously known species from this location *Alasmidonta viridus*, *Hemistena lata*, *Leptodea fragilis*, *Pleurobema cordatum*, *Quadrula intermedia*, *Q. sparsa*, *Strophitus undulatus* and *Villosa fabilis* were not recorded in the present study. These species dropping from the extant list is not surprising considering that they are all considered rare in the Clinch River and a few are presumed extirpated

from the Clinch River at this time. The present study did collect several *E. capsaeformis* which have recently been reintroduced at the site after being extirpated during the 1980's.

Semi-quantitative results of the present study show a decline in the overall mussel assemblage since 2002. Overall mussel density has dropped from 1.95/m² to 1.27/m². The total number of mussels collected was down from 1,707 to 1,131. Excluding potential sampling bias, these numbers are directly comparable as the number of quadrats sampled is equivalent (889 versus 875). Quantitative assessment, however, revealed mussel bed densities had not significantly declined since the previous survey. The Cluster 1 and 2 survey areas have not significantly decreased in mussel density since 2002 (Table 4). Compared to other recent surveys mussel bed density has fluctuated between 4.3/ m² and 16.1/ m² over the last thirty years (Table 11). In addition to overall numbers remaining consistent the size demographic of animals in quantitative sampling was nearly identical to that of the 2002 augmentation site survey (Figure 14). These results indicate that while a few species appear to have dropped out of the assemblage recently, the mussel community as a whole has remained relatively stable over the last six years.

The combination of quantitative and qualitative sampling methods worked effectively to address the objectives of the present study. Semi-quantitative and quantitative sampling collected identical numbers of live species while the qualitative portion of the survey recorded additional live species and those represented by relic shell only (Table 7). The combination of methods provides us with reliable robust data on both the number of extant species and density for common species.

The density of *I. fluviialis* at Cleveland Island was not recorded during the 2002 augmentation site survey. While they were documented in the present study (8 animals in semi-quantitative sampling), a widespread viable population was not observed. Further augmentation work is required for this species to occur in significant densities at Cleveland Island.

The present study documented a total of 15 *E. capsaeformis* at Cleveland Island. At the time of the survey 400 individuals had been placed at the site with an additional 1,000 planned for future stocking events. Source for these stocking events is the Clinch River downstream in Tennessee. Individuals of several size classes were included, even a portion of animals recorded in the present study fall within the juvenile size class (Table 3). Our quantitative estimate of density for *E. capsaeformis* in the RAR1 section is 0.248/m² indicating that a significant portion of the stocked individuals survived the translocation process.

Cleveland Island represents a biologically significant section in the upper Tennessee River system. Considering all factors and data sets the mussel fauna at Cleveland Island persists at a level nearly identical to that in 2002. A solid mussel assemblage at Cleveland Island can serve as a source to help natural augmentation of the surrounding stream reaches that have recently experienced declines. Several species can be collected at this site for captive propagation including *A. pectorosa*, *E. dilatata*, *F. cor*, *Lampsilis fasciola*, *Lampsilis ovata*, *P. fasciolaris*, *P. subtentum*, *V. iris* and *V. vanuxemensis*. Captive reared progeny should continue to be stocked at this site. Restoration efforts should focus on the RAR1 and LA1 sections. In addition, sub-adult

individuals with a greater chance of long term survival should be stocked whenever possible as opposed to newly metamorphosed juveniles.

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Table 1. Previously recorded live and relic mussel collections in the Clinch River at Cleveland.

Species	1913 ¹	1978 ²	1979 ³	1988 ⁴	1991 ⁵	1992 ⁶	1994 ⁴	1999 ⁷	2002 ⁸	Present Study ⁹
<i>A. ligamentina</i>		L	L	L	L	L	L		L	L
<i>A. pectorosa</i>	L	L	L	L	L	L	L	L	L	L
<i>A. marginata</i>	L		L		L	L			L	R
<i>A. viridus</i>	L									
<i>A. plicata</i>	L		L	L	L		L	L	L	L
<i>C. tuberculata</i>					L	L		L	L	L
<i>E. dilatata</i>	L	L	L	L	L	L	L	L	L	L
<i>E. capsaeformis</i>	L	L								L
<i>F. barnesiana</i>			L	L	L	L			L	L
<i>F. cor</i>	L	L	L		L	L	L		L	L
<i>F. cuneolus</i>			L		L	L				L
<i>F. subrotunda</i>	L		L	L	L			L	L	L
<i>H. lata</i>	L									
<i>L. fasciola</i>	L		L	L	L	L	L	L	L	L
<i>L. ovata</i>	L		L	L	L	L		L	L	L
<i>L. costata</i>	L		L	L	L	L	L	L	L	L
<i>L. rimosus</i>						R				
<i>L. fragilis</i>			L	L						
<i>L. dolabelloides</i>	L				L		L	L	L	L
<i>L. recta</i>									L	L
<i>M. conradicus</i>	L		L	L	L	L	L	L	L	L
<i>P. cordatum</i>	L									
<i>P. oviforme</i>	L		L	L		L			L	L
<i>P. alatus</i>			L	L	L	L			L	R
<i>P. fasciolaris</i>	L		L	L	L	L	L	L	L	L
<i>P. subtentum</i>	L		L	L	L	L	L	L	L	L
<i>O. c. strigillata</i>	L	L	L			L	L		L	L
<i>O. intermedia</i>	L									
<i>O. sparsa</i>									L	
<i>S. undulatus</i>	L									
<i>T. truncata</i>			L							R
<i>V. fabilis</i>	L									
<i>V. iris</i>	L		L		L	L			L	L
<i>V. perpurpurea</i>	L		L			R				L
<i>V. vanuxemensis</i>			L			R			L	L
Live	24	6	23	15	19	18	12	12	23	23
Relic	--	--	--	--	--	3	--	--	--	3
Total	24	6	23	15	19	21	12	12	23	26

¹Records from Ortmann (1918)

²Records from Bates & Dennis (1978)

³Records from Ahlstedt (1991)

⁴Records from Ahlstedt & Tuberville (1997)

⁵Records from Hubbs et al. (1991)

⁶Records from Church (1992)

⁷Records from Ahlstedt et al. (2005)

⁸Records from DGIF augmentation site survey conducted June 18th – July 18th, 2002.

⁹Present study was conducted at Cleveland Island from July 29th -August 15th, 2008.

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

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per m ²)
<i>Actinonaias pectorosa</i>	481	0	42.5	0.541
<i>Elliptio dilatata</i>	221	5	19.5	0.248
<i>Medionidus conradicus</i>	199	15	17.6	0.224
<i>Fusconaia barnesiana</i>	53	4	4.7	0.059
<i>Ptychobranthus fasciolaris</i>	51	0	4.5	0.057
<i>Villosa iris</i>	30	8	2.7	0.034
<i>Lampsilis fasciola</i>	21	0	1.9	0.024
<i>Fusconaia cor</i>	14	0	1.2	0.016
<i>Actinonaias ligamentina</i>	11	1	1.0	0.012
<i>Ptychobranthus subtentum</i>	11	0	1.0	0.012
<i>Pleurobema oviforme</i>	9	0	0.8	0.010
<i>Amblema plicata</i>	7	0	0.6	0.007
<i>Fusconaia subrotunda</i>	5	0	0.4	0.006
<i>Lexingtonia dolabelloides</i>	5	0	0.4	0.006
<i>Lasmigona costata</i>	5	0	0.4	0.006
<i>Cyclonaias tuberculata</i>	4	0	0.3	0.005
<i>Epioblasma capsaeformis</i>	1	1	0.1	0.001
<i>Lampsilis ovata</i>	1	0	0.1	0.001
<i>Villosa vanuxemensis</i>	1	0	0.1	0.001
<i>Alasmidonta marginata</i>	0	0	0	0
<i>Fusconaia cuneolus</i>	0	0	0	0
<i>Ligumia recta</i>	0	0	0	0
<i>Potamilus alatus</i>	0	0	0	0
<i>Quadrula sparsa</i>	0	0	0	0
<i>Quadrula c. strigillata</i>	0	0	0	0
<i>Truncilla truncata</i>	0	0	0	0
<i>Villosa perpurpurea</i>	0	0	0	0
Total	1,131	34	100	1.27

Table 3. Total number and density of mussel species collected in the Clinch River at Cleveland Island in the RAR1 quantitative sample. Individuals measuring less than 30 mm were considered juveniles.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per 0.25m ²)
<i>Actinonaias pectorosa</i>	209	2	40.9	0.928
<i>Medionidus conradicus</i>	145	12	28.3	0.644
<i>Elliptio dilatata</i>	45	0	8.8	0.200
<i>Ptychobranthus fasciolaris</i>	26	0	5.1	0.115
<i>Lampsilis fasciola</i>	16	0	3.1	0.071
<i>Ptychobranthus subtentum</i>	15	0	2.9	0.067
<i>Epioblasma capsaeformis</i>	14	3	2.7	0.062
<i>Fusconaia barnesiana</i>	10	0	1.9	0.044
<i>Villosa iris</i>	10	0	1.9	0.044
<i>Pleurobema oviforme</i>	7	0	1.4	0.031
<i>Fusconaia cor</i>	6	0	1.2	0.027
<i>Amblema plicata</i>	3	0	0.6	0.013
<i>Fusconaia subrotunda</i>	3	0	0.6	0.013
<i>Lasmigona costata</i>	1	0	0.2	0.004
<i>Lexingtonia dolabelloides</i>	1	0	0.2	0.004
<i>Quadrula c. strigillata</i>	1	0	0.2	0.004
<i>Actinonaias ligamentina</i>	0	0	0	0
<i>Alasmidonta marginata</i>	0	0	0	0
<i>Cyclonaias tuberculata</i>	0	0	0	0
<i>Fusconaia cuneolus</i>	0	0	0	0
<i>Lampsilis ovata</i>	0	0	0	0
<i>Ligumia recta</i>	0	0	0	0
<i>Potamilus alatus</i>	0	0	0	0
<i>Quadrula sparsa</i>	0	0	0	0
<i>Truncilla truncata</i>	0	0	0	0
<i>Villosa perpurpurea</i>	0	0	0	0
<i>Villosa vanuxemensis</i>	0	0	0	0
Total	511	17	100	2.271

Table 4. Comparison of quantitative data at Cleveland Island in 2002 and the present study. Data has been adjusted to account for differences in sampling methodology.

Cluster 1	2002	2008
# Samples	34	36
# Collected	137	137
# Species	9	12
Density (per/0.25m²)	4.03	3.81
Precision	24.90%	25.60%
Cluster 2	2002	2008
# Samples	31	35
# Collected	76	61
# Species	10	8
Density (per/0.25m²)	2.45	1.74
Precision	34.40%	32.30%

Table 5. Total number and density of mussel species collected in the Clinch River at Cleveland Island in the LA1 quantitative sample. Individuals measuring less than 30 mm were considered juveniles.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per 0.25m ²)
<i>Elliptio dilatata</i>	79	4	29.0	0.312
<i>Actinonaias pectorosa</i>	73	0	26.8	0.288
<i>Medionidus conradicus</i>	48	7	17.6	0.190
<i>Ptychobranthus fasciolaris</i>	17	0	6.3	0.067
<i>Fusconaia barnesiana</i>	16	2	5.9	0.063
<i>Villosa iris</i>	12	7	4.4	0.047
<i>Fusconaia cor</i>	6	0	2.2	0.024
<i>Fusconaia subrotunda</i>	6	0	2.2	0.024
<i>Lampsilis fasciola</i>	5	0	1.8	0.020
<i>Ptychobranthus subtentum</i>	3	0	1.1	0.012
<i>Villosa vanuxemensis</i>	2	2	0.7	0.008
<i>Amblema plicata</i>	1	0	0.4	0.004
<i>Cyclonaias tuberculata</i>	1	0	0.4	0.004
<i>Fusconaia cuneolus</i>	1	0	0.4	0.004
<i>Lasmigona costata</i>	1	0	0.4	0.004
<i>Pleurobema oviforme</i>	1	0	0.4	0.004
<i>Actinonaias ligamentina</i>	0	0	0	0
<i>Alasmidonta marginata</i>	0	0	0	0
<i>Epioblasma capsaeformis</i>	0	0	0	0
<i>Lampsilis ovata</i>	0	0	0	0
<i>Lexingtonia dolabelloides</i>	0	0	0	0
<i>Ligumia recta</i>	0	0	0	0
<i>Potamilus alatus</i>	0	0	0	0
<i>Quadrula c. strigillata</i>	0	0	0	0
<i>Quadrula sparsa</i>	0	0	0	0
<i>Truncilla truncata</i>	0	0	0	0
<i>Villosa perpurpurea</i>	0	0	0	0
Total	272	22	100	1.075

Table 6. Live and relic mussel species collected in the Clinch River at Cleveland Island during qualitative sampling, August 2008.

Species	LA1	LAR1	RA1	RA2	RAR1	RAL2	RA3	MC	Overall
<i>Actinonaias ligamentina</i>	L		R	R	R	R	L		L
<i>Actinonaias pectorosa</i>	L	L	L	L	L	L	L	L	L
<i>Alasmidonta marginata</i>	R								R
<i>Amblema plicata</i>	L	L	L	L	L	R	L		L
<i>Cyclonaias tuberculata</i>	L			R	L	R	R		L
<i>Elliptio dilatata</i>	L	L	L	L	L	L	L	R	L
<i>Epioblasma capsaeformis</i>			R	L	L	L			L
<i>Fusconaia barnesiana</i>	L	L	R	L	L	L	L		L
<i>Fusconaia cor</i>	L	L	R	L	L	L	L		L
<i>Fusconaia cuneolus</i>	R				R				R
<i>Fusconaia subrotunda</i>	L	L		R	R	R	L		L
<i>Lampsilis fasciola</i>	L	L	R	L	L	L	L		L
<i>Lampsilis ovata</i>		R	R	L		R	R		L
<i>Lasmigona costata</i>	L	R	L		R	R			L
<i>Lexingtonia dolabelloides</i>	L	L		L	L	L			L
<i>Ligumia recta</i>						L			L
<i>Medionidus conradicus</i>	L	L	L	L	L	L	L		L
<i>Pleurobema oviforme</i>	L	L		R	L	L	L		L
<i>Potamilus alatus</i>							R		R
<i>Ptychobranthus fasciolaris</i>	L	L	L	L	L	L			L
<i>Ptychobranthus subtentum</i>	L	L	L	L	L	L	L		L
<i>Quadrula c. strigillata</i>	L	R		L	R	R			L
<i>Quadrula sparsa</i>									
<i>Truncilla truncata</i>			R			R			R
<i>Villosa iris</i>	L	L	L	L	L	L	L		L
<i>Villosa perpurpurea</i>						L			L
<i>Villosa vanuxemensis</i>	L					L			L
Live	18	13	8	14	14	15	12	1	22
Relic	2	3	7	4	5	8	3	1	4
Total	20	16	15	18	19	23	15	2	26

Table 7. Mussel species collected in the Clinch River at Cleveland Island in the present study by sampling method.

Species	Semi-Quantitative	Quantitative	Qualitative	Overall
<i>Actinonaias ligamentina</i>	L		L	L
<i>Actinonaias pectorosa</i>	L	L	L	L
<i>Alasmidonta marginata</i>			R	R
<i>Amblema plicata</i>	L	L	L	L
<i>Cyclonaias tuberculata</i>	L	L	L	L
<i>Elliptio dilatata</i>	L	L	L	L
<i>Epioblasma capsaeformis</i>	L	L	L	L
<i>Fusconaia barnesiana</i>	L	L	L	L
<i>Fusconaia cor</i>	L	L	L	L
<i>Fusconaia cuneolus</i>		L	R	L
<i>Fusconaia subrotunda</i>	L	L	L	L
<i>Lampsilis fasciola</i>	L	L	L	L
<i>Lampsilis ovata</i>	L		L	L
<i>Lasmigona costata</i>	L	L	L	L
<i>Lexingtonia dolabelloides</i>	L	L	L	L
<i>Ligumia recta</i>			L	L
<i>Medionidus conradicus</i>	L	L	L	L
<i>Pleurobema oviforme</i>	L	L	L	L
<i>Potamilus alatus</i>			R	R
<i>Ptychobranhus fasciolaris</i>	L	L	L	L
<i>Ptychobranhus subtentum</i>	L	L	L	L
<i>Quadrula c. strigillata</i>		L	L	L
<i>Quadrula sparsa</i>				
<i>Truncilla truncata</i>			R	R
<i>Villosa iris</i>	L	L	L	L
<i>Villosa perpurpurea</i>			L	L
<i>Villosa vanuxemensis</i>	L	L	L	L
Totals	19	19	26	26

Table 8. Total number and density of mussel species collected during semi-quantitative sampling of the Clinch River at Cleveland Island during the 2002 survey. Individuals measuring less than 30 mm were considered juveniles.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per m²)
<i>Actinonaias pectorosa</i>	675	2	39.54	0.771
<i>Medionidus conradicus</i>	320	44	18.75	0.366
<i>Elliptio dilatata</i>	265	3	15.52	0.303
<i>Lampsilis fasciola</i>	84	1	4.92	0.096
<i>Ptychobranchnus fasciolaris</i>	83	1	4.86	0.095
<i>Ptychobranchnus subtentum</i>	62	3	3.63	0.071
<i>Fusconaia subrotunda</i>	36	5	2.11	0.041
<i>Fusconaia cor</i>	34	2	1.99	0.039
<i>Villosa iris</i>	32	4	1.87	0.036
<i>Pleurobema oviforme</i>	27	4	1.58	0.031
<i>Actinonaias ligamentina</i>	17	0	1.00	0.019
<i>Fusconaia barnesiana</i>	14	5	0.82	0.016
<i>Lexingtonia dolabelloides</i>	13	1	0.76	0.015
<i>Quadrula c. strigillata</i>	11	1	0.64	0.012
<i>Amblema plicata</i>	10	0	0.58	0.011
<i>Lampsilis ovata</i>	9	0	0.53	0.010
<i>Lasmigona costata</i>	5	0	0.29	0.006
<i>Villosa vanuxemensis</i>	4	0	0.23	0.005
<i>Cyclonaias tuberculata</i>	3	0	0.17	0.003
<i>Alasmidonta marginata</i>	1	0	0.06	0.001
<i>Ligumia recta</i>	1	0	0.06	0.001
<i>Quadrula sparsa</i>	1	0	0.06	0.001
<i>Epioblasma capsaeformis</i>	0	0	0	0
<i>Fusconaia cuneolus</i>	0	0	0	0
<i>Potamilus alatus</i>	0	0	0	0
<i>Truncilla truncata</i>	0	0	0	0
<i>Villosa perpurpurea</i>	0	0	0	0
Total	1,707	76	100	1.95

Table 9. Total number and density of mussel species collected in the Clinch River at Cleveland Island during 2002 quantitative sampling. Sample was collected in the RAR1 section from 140 m - 160 m (Cluster 1) and 60 m - 80 m (Cluster 2). Individuals measuring less than 30 mm were considered juveniles.

Species	Total Collected	Number of Juveniles	Percent of Collection	Density (per 0.25m ²)
Cluster 1				
<i>Actinonaias pectorosa</i>	60	1	34.9	1.43
<i>Elliptio dilatata</i>	16	0	9.3	0.38
<i>Fusconaia cor</i>	1	0	0.6	0.02
<i>Fusconaia subrotunda</i>	4	0	2.3	0.09
<i>Lampsilis fasciola</i>	7	0	4.1	0.17
<i>Lexingtonia dolabelloides</i>	2	0	1.2	0.04
<i>Medionidus conradicus</i>	62	13	36.0	1.48
<i>Ptychobranthus fasciolaris</i>	6	1	3.5	0.14
<i>Ptychobranthus subtentum</i>	14	1	8.1	0.33
Total (Cluster 1)	172	16	100	4.08
Cluster 2				
<i>Actinonaias ligamentina</i>	1	0	1.0	0.02
<i>Actinonaias pectorosa</i>	54	1	56.3	1.38
<i>Elliptio dilatata</i>	6	0	6.3	0.15
<i>Fusconaia barnesiana</i>	1	1	1.0	0.02
<i>Fusconaia cor</i>	2	1	2.1	0.05
<i>Lampsilis fasciola</i>	3	0	3.1	0.08
<i>Medionidus conradicus</i>	21	3	21.9	0.54
<i>Ptychobranthus fasciolaris</i>	4	0	4.2	0.10
<i>Ptychobranthus subtentum</i>	1	0	1.0	0.02
<i>Villosa iris</i>	3	1	3.1	0.08
Total (Cluster 2)	96	7	100	2.44

Table 10. Live and relic mussel species collected in the Clinch River at Cleveland Island during qualitative sampling, June 2002.

Species	LA1	LAR1	RA1	RA2	RAR1	RAL2	RA3	MC	Overall
<i>Actinonaias ligamentina</i>	L		L	L	L				L
<i>Actinonaias pectorosa</i>	L	L	L	L	L	L	L	L	L
<i>Alasmidonta marginata</i>									
<i>Amblema plicata</i>	L	R	R		L	L		L	L
<i>Cyclonaias tuberculata</i>			L	L	L	L			L
<i>Elliptio dilatata</i>	L	L	L	L	L	L	L	L	L
<i>Epioblasma capsaeformis</i>									
<i>Fusconaia barnesiana</i>	L	R	R			L	R		L
<i>Fusconaia cor</i>	L	L	L	L		L	L	L	L
<i>Fusconaia cuneolus</i>									
<i>Fusconaia subrotunda</i>	L	L			L		L		L
<i>Lampsilis fasciola</i>	L	L	L	L	L	L	L	L	L
<i>Lampsilis ovata</i>	L	L	R	L			R	L	L
<i>Lasmigona costata</i>	L		R	R	L	R		R	L
<i>Lexingtonia dolabelloides</i>	L	R	L	L	R	R		L	L
<i>Ligumia recta</i>					L			L	L
<i>Medionidus conradicus</i>	L	L	L	L	L	R		L	L
<i>Pleurobema oviforme</i>	L				R		L	L	L
<i>Potamilus alatus</i>		R						L	R
<i>Ptychobranchus fasciolaris</i>	L	L	L	L	L	L	L	L	L
<i>Ptychobranchus subtentum</i>	L	L	R	L	L	L	R	R	L
<i>Quadrula c. strigillata</i>	L	L			L				L
<i>Quadrula sparsa</i>	L								
<i>Truncilla truncata</i>									
<i>Villosa iris</i>	L	R	L	L		L			L
<i>Villosa perpurpurea</i>				R					R
<i>Villosa vanuxemensis</i>						R	L		L
Live	18	10	10	12	13	10	8	12	20
Relic	0	5	5	2	2	4	3	2	2
Total	18	15	15	14	15	14	11	14	22

Table 11. Previous 0.25m² quadrat sampling data from Cleveland Island.

Year	Location	# Quadrats	# Species	Density (per m²)
1979 ¹	RAR1	20	8	5.4
1988 ²	RAR1	20	15	14.0
1991 ³	RAL2	80	17	6.45
1991 ³	LA1	80	16	3.0
1992 ⁴	Entire Site	36	18	6.9
1994 ²	RAR1	20	12	5.8
1999 ⁵	RAR1	20	12	11.6
2002 ⁶	RAR1 (Cluster 1)	34	9	16.1
2002 ⁶	RAR1 (Cluster 2)	31	10	9.8
2008 ⁷	RAR1 (Cluster 1)	36	12	15.2
2008 ⁷	RAR1 (Cluster 2)	35	8	6.9
2008 ⁷	LA1	253	16	4.3

¹Records from Ahlstedt (1991)

²Records from Ahlstedt & Tuberville (1997)

³Records from Hubbs et al. (1991)

⁴Records from Church (1992)

⁵Records from Ahlstedt et al. (2005)

⁶Records from DGIF augmentation site survey conducted June 18th – July 18th, 2002.

⁷Present study was conducted at Cleveland Island from July 29th -August 15th, 2008.

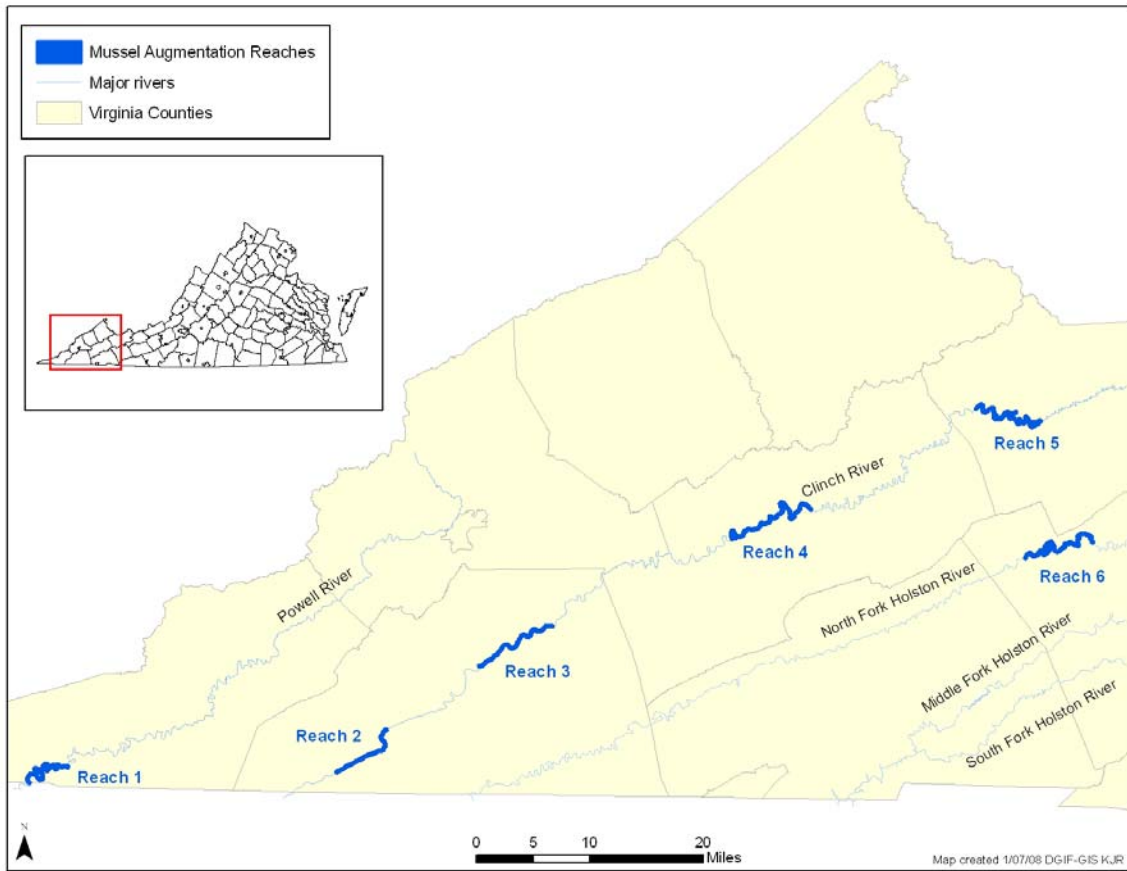


Figure 1. Stream reaches designated as augmentation reaches by the Virginia Department of Game and Inland Fisheries mussel restoration plan. Six reaches are divided between the Powell River (1), Clinch River (4) and North Fork Holston River (1).

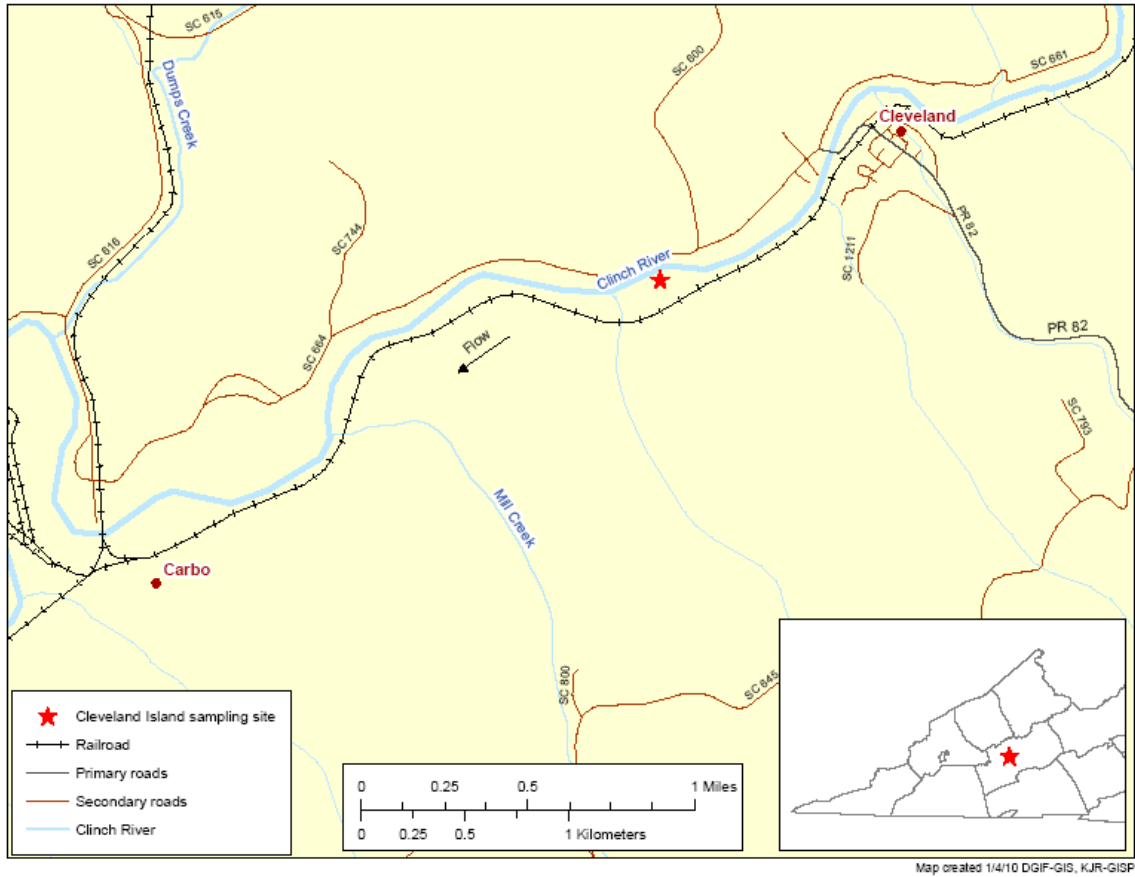


Figure 2. Location of present study site in relation to the towns of Cleveland and Carbo in Russell County, Virginia.

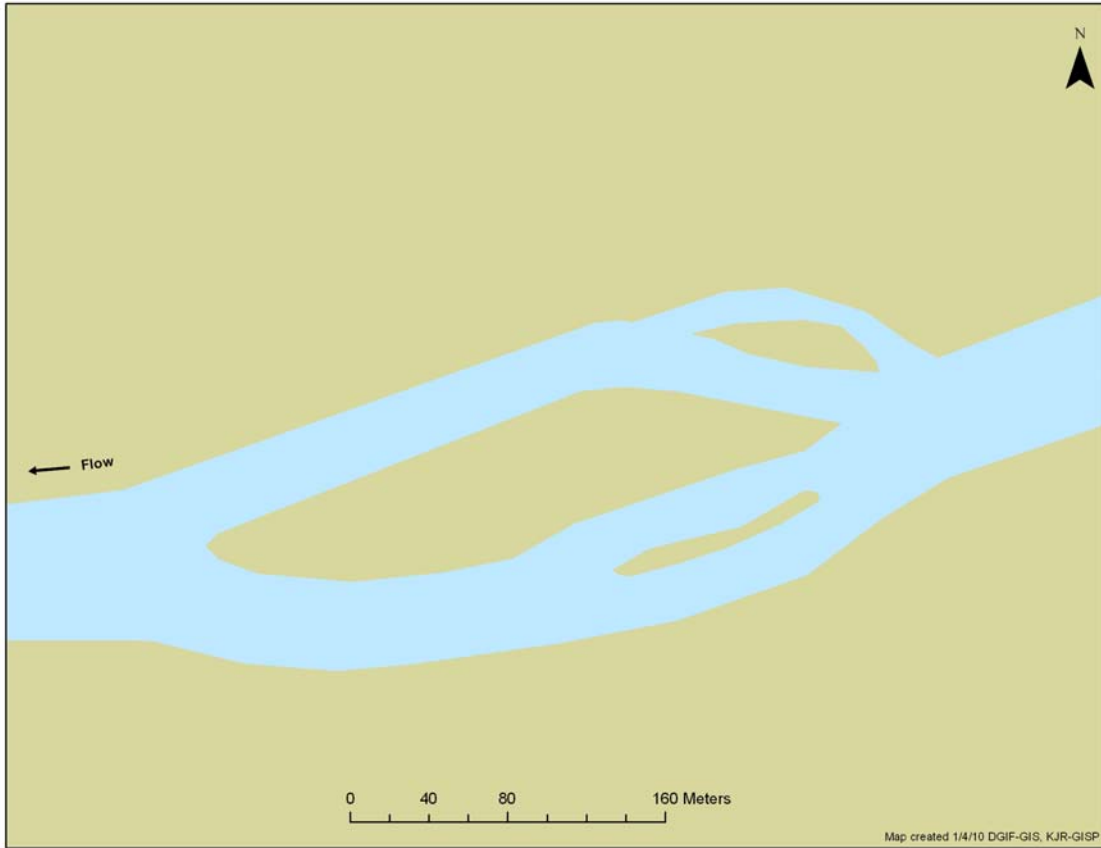


Figure 3. Illustration of the Clinch River at Cleveland Island, Russell County; Virginia. Site of the present study in 2008. Three mature islands create a braided channel complex at the site.



Figure 4. Overhead view of a survey site. Ropes are stretched every 40 meters with flags every 5 meters to delineate lanes and serve as a visual guide. Black lines show one lane.

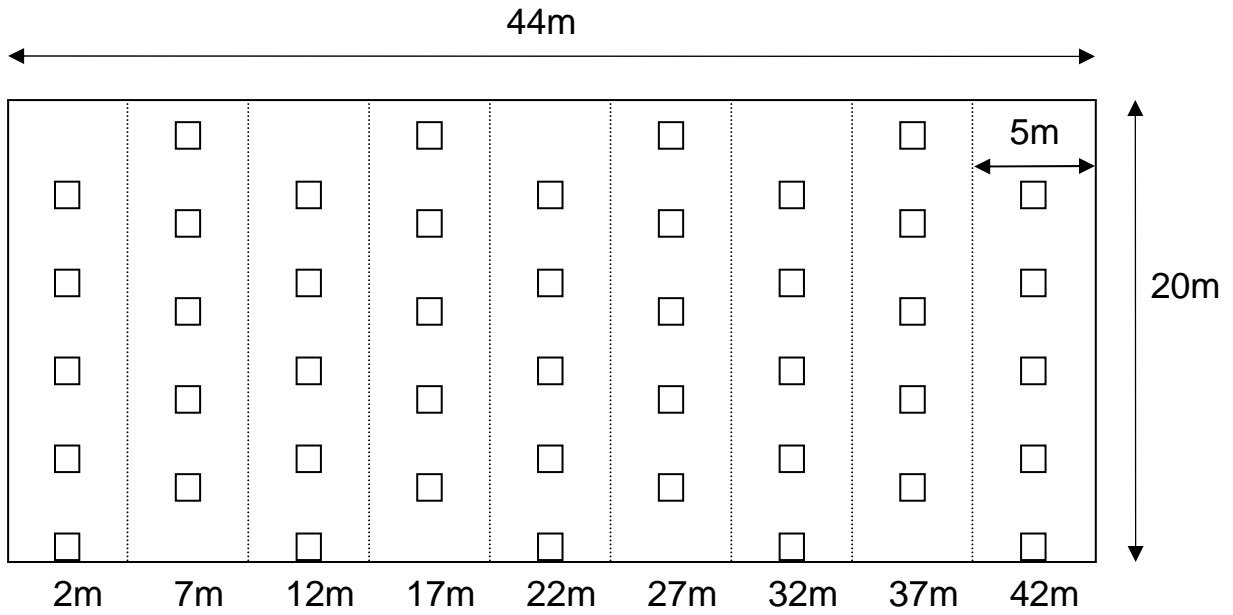


Figure 5. Representation of semi-quantitative sampling method at a site 44m wide. Squares indicate sampling location and lines show lane boundaries. Each lane is 5m wide and 20m long. Five samples are taken representing 5% of overall habitat. Starting position of samplers alternates between 1m and 3m.

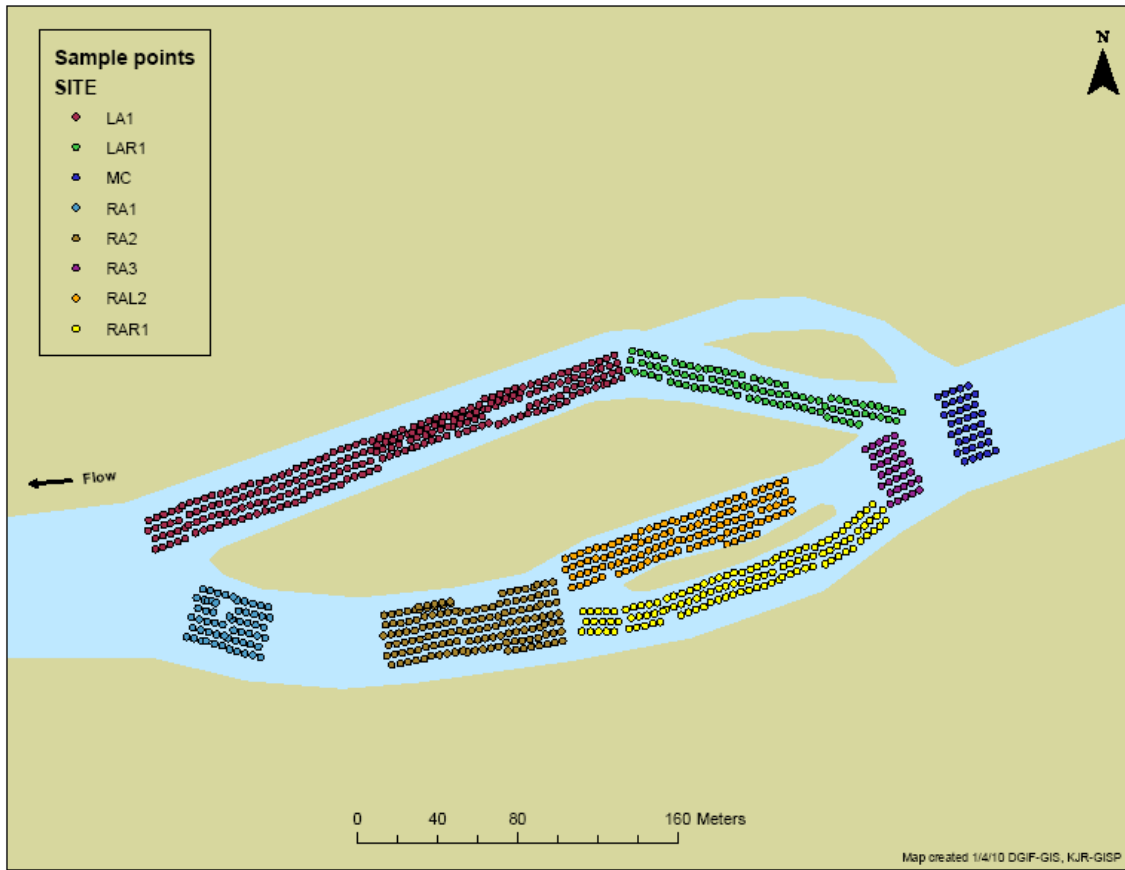


Figure 6. Location of 1m quadrats sampled during semi-quantitative sampling at Cleveland Island.

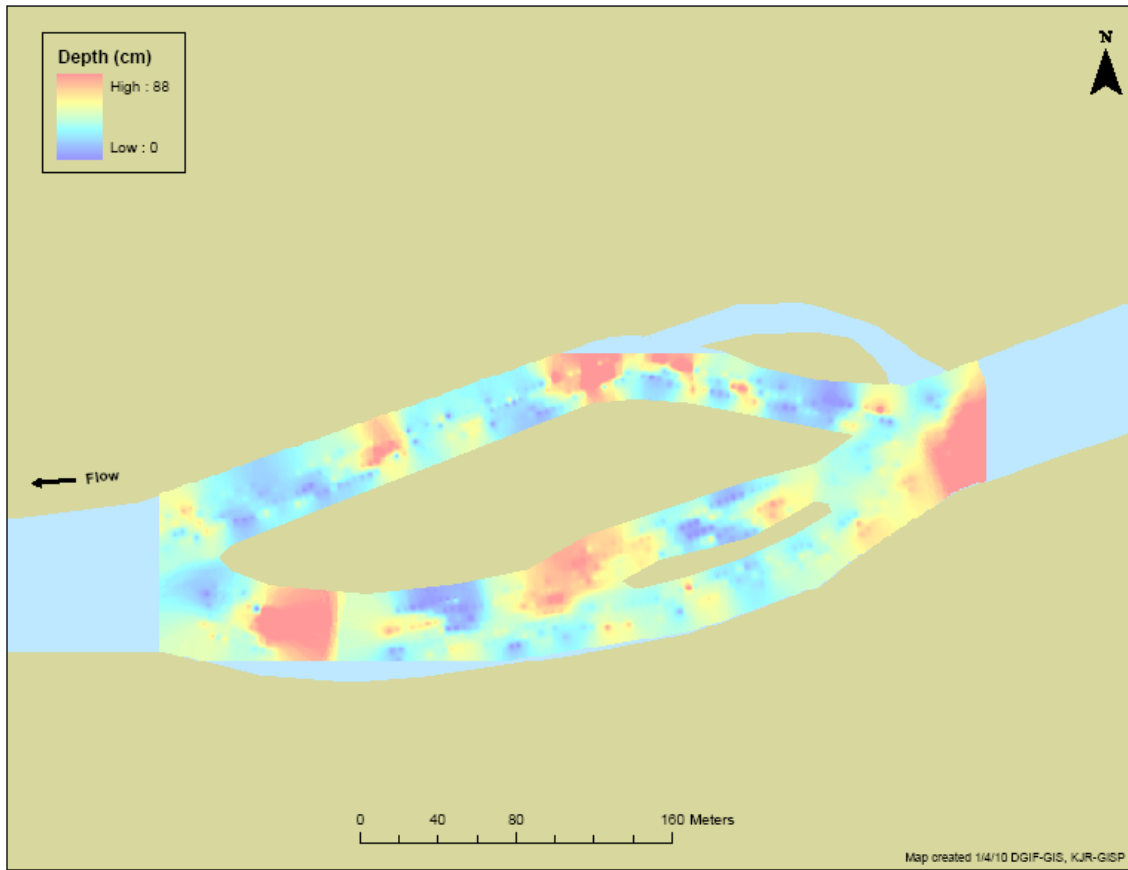


Figure 7. Depth profile of the Clinch River at Cleveland Island, July – August 2008.

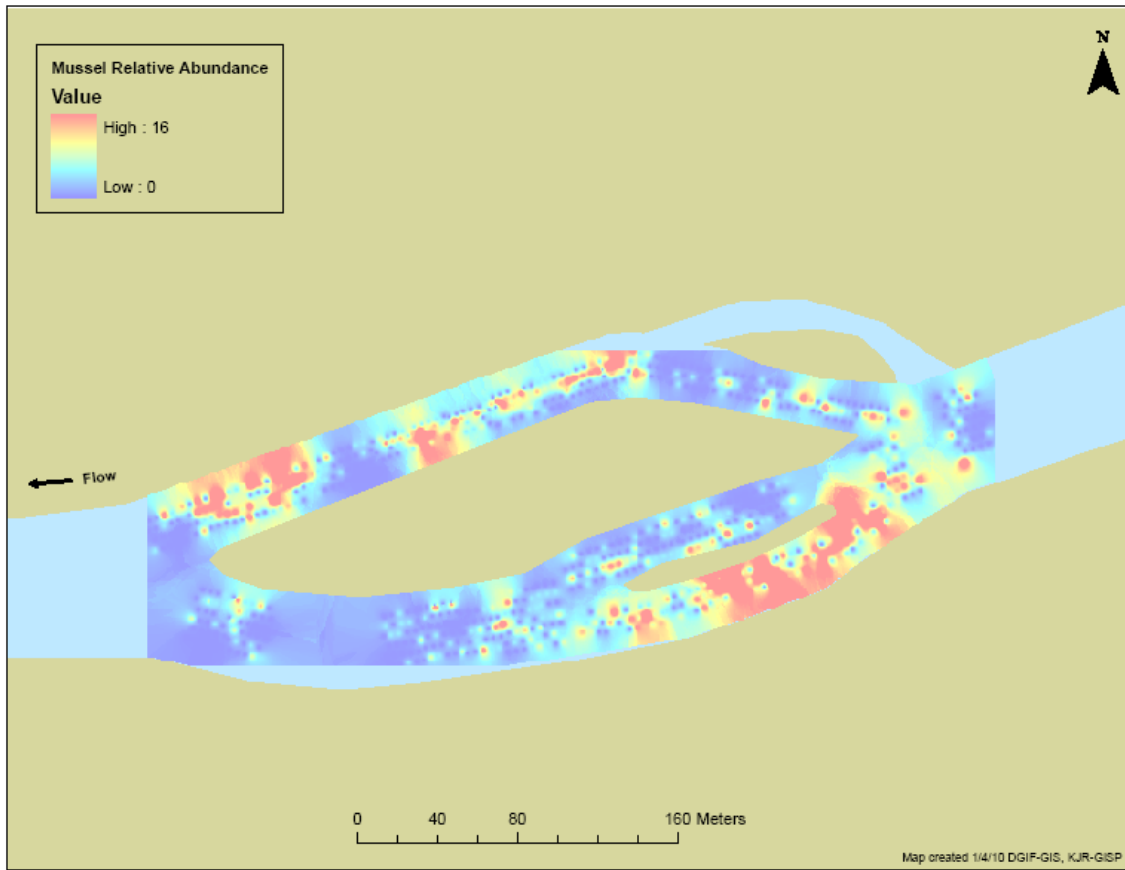


Figure 8. Relative abundance and location of mussels collected at Cleveland Island in the semi-quantitative sample during the present study.

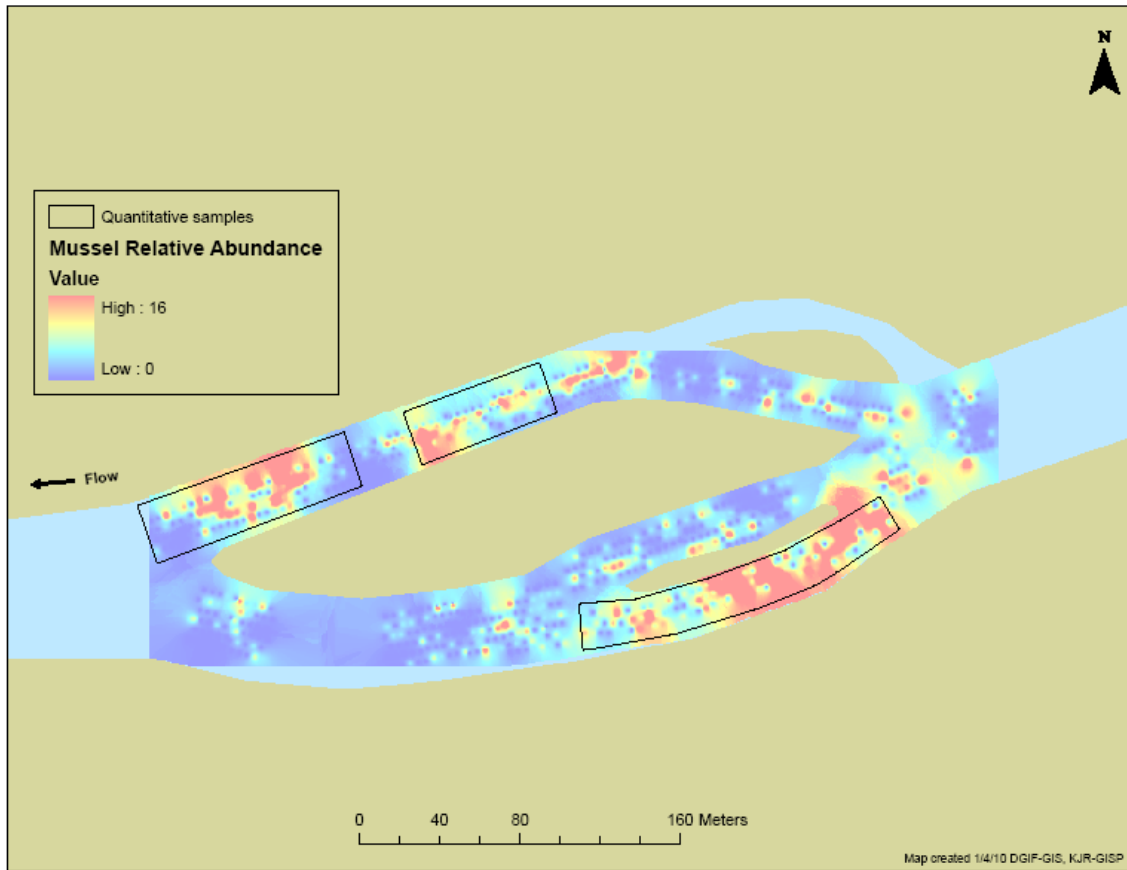
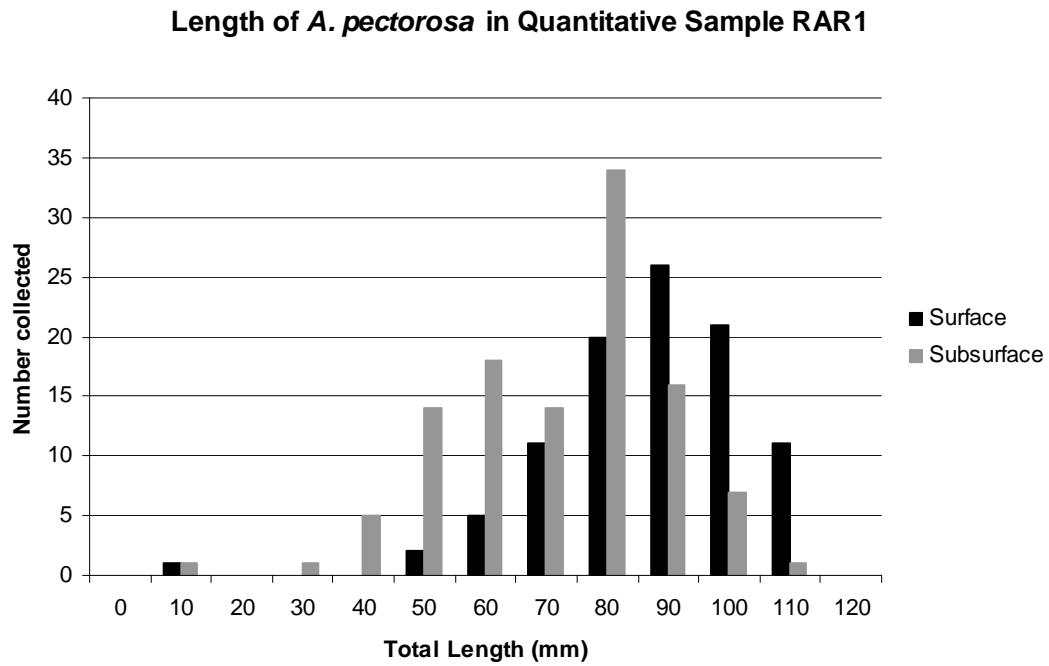


Figure 9. Cleveland Island mussel abundance and location. Boxes indicate sites selected for quantitative sampling.

A



B

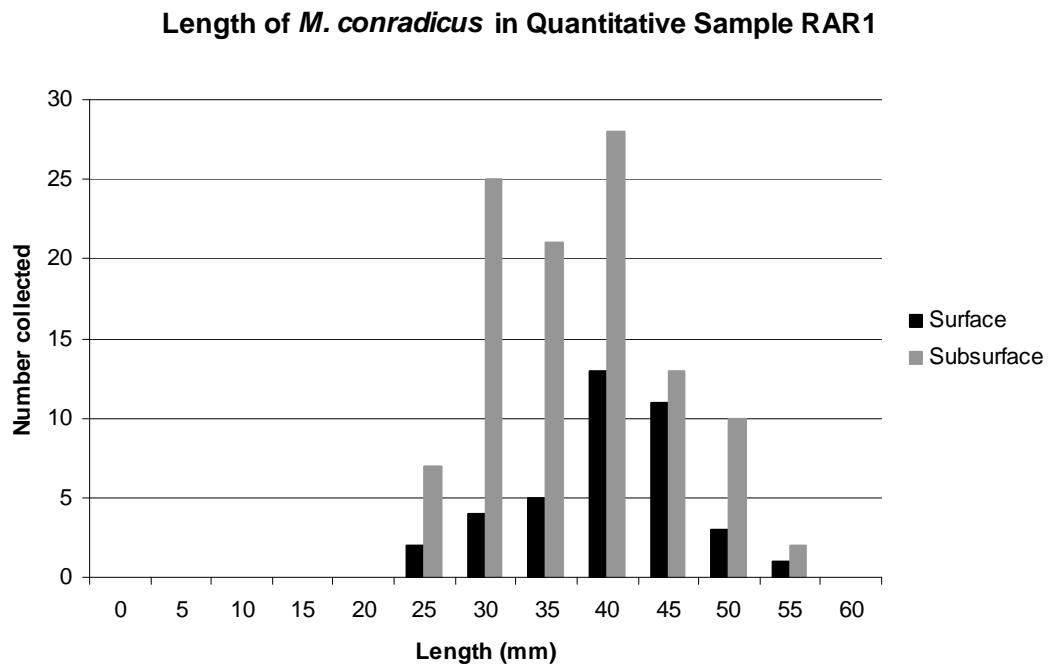
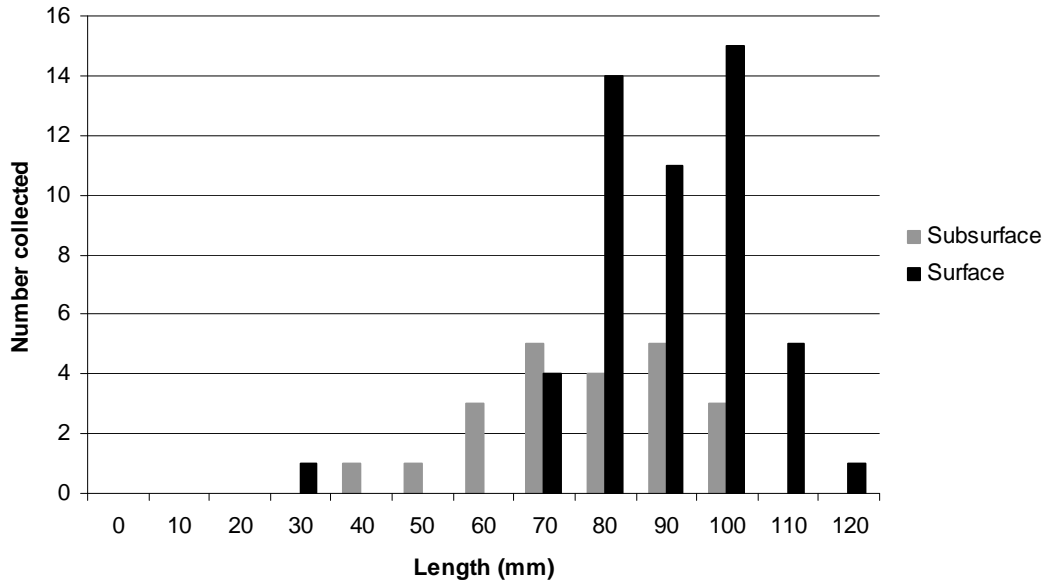


Figure 10. Length frequency of *Actinonaias pectorosa* (A) and *Medionidus conradicus* (B) collected during the RAR1 quantitative sample of the Clinch River at Cleveland, 2008. Sample was taken in the far right ascending channel of the Cleveland Island complex.

A

Length of *A. pectorosa* in Quantitative Sample LA1



B

Length of *E. dilatata* in Quantitative Sample LA1

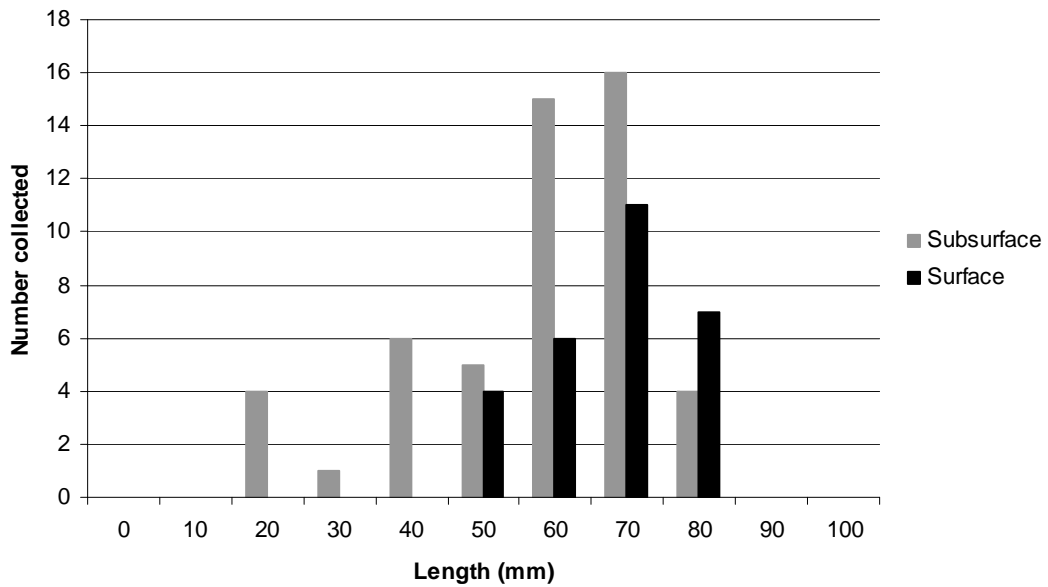


Figure 11. Length frequency of *Actinonaias pectorosa* (A) and *Ellipto dilatata* (B) collected during the LA1 quantitative sample of the Clinch River at Cleveland, 2008. Sample was taken in the lower left ascending channel of the Cleveland Island complex.

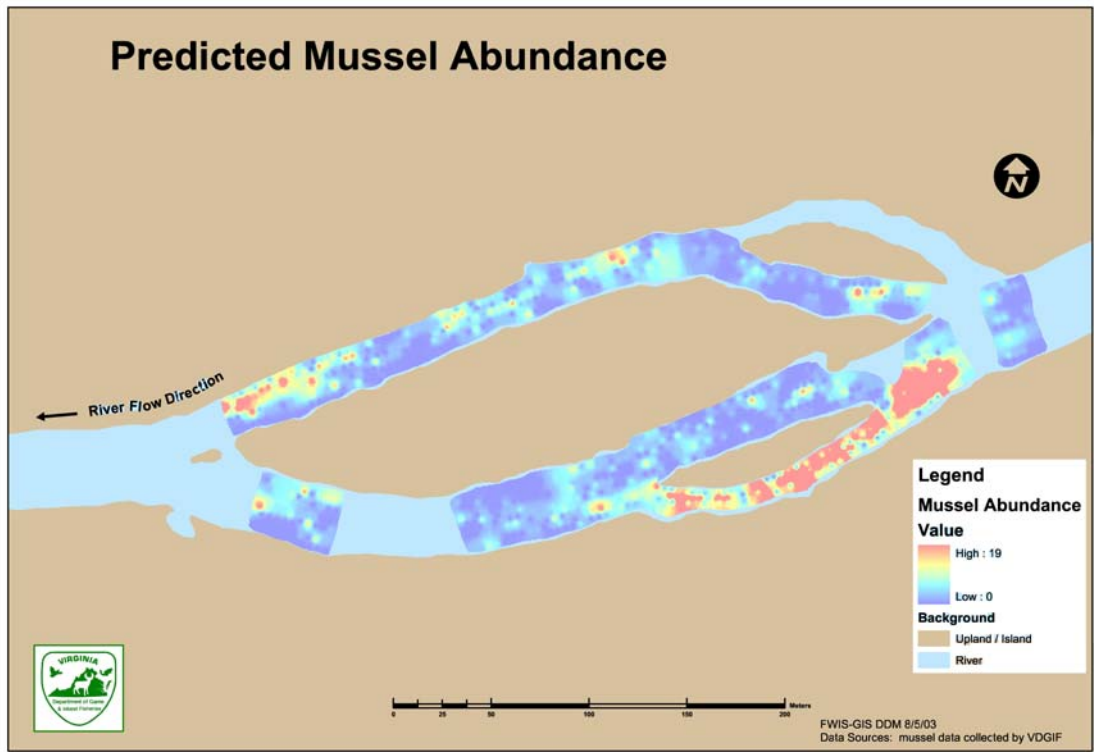
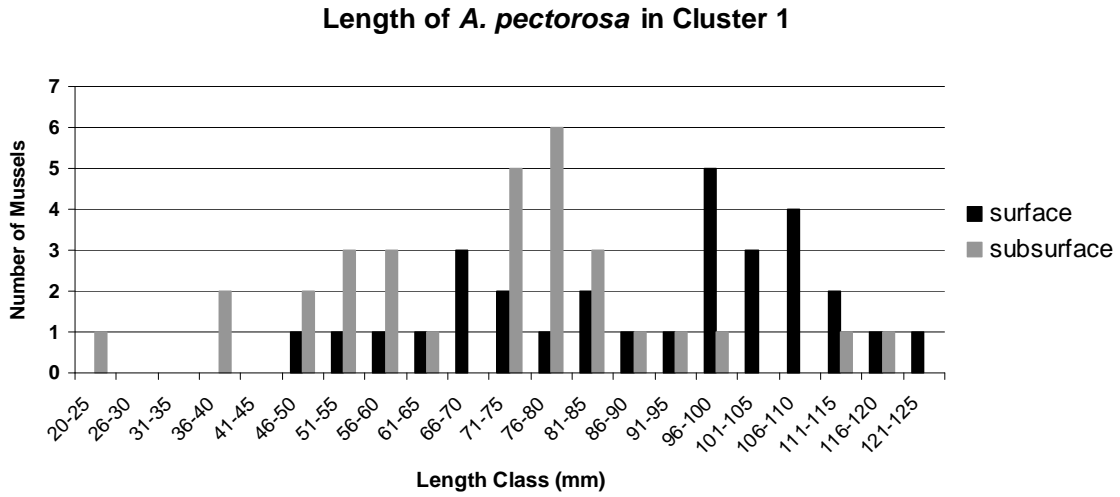


Figure 12. Relative abundance and location of mussels collected at Cleveland Island during 2002 augmentation site survey.

A)



B)

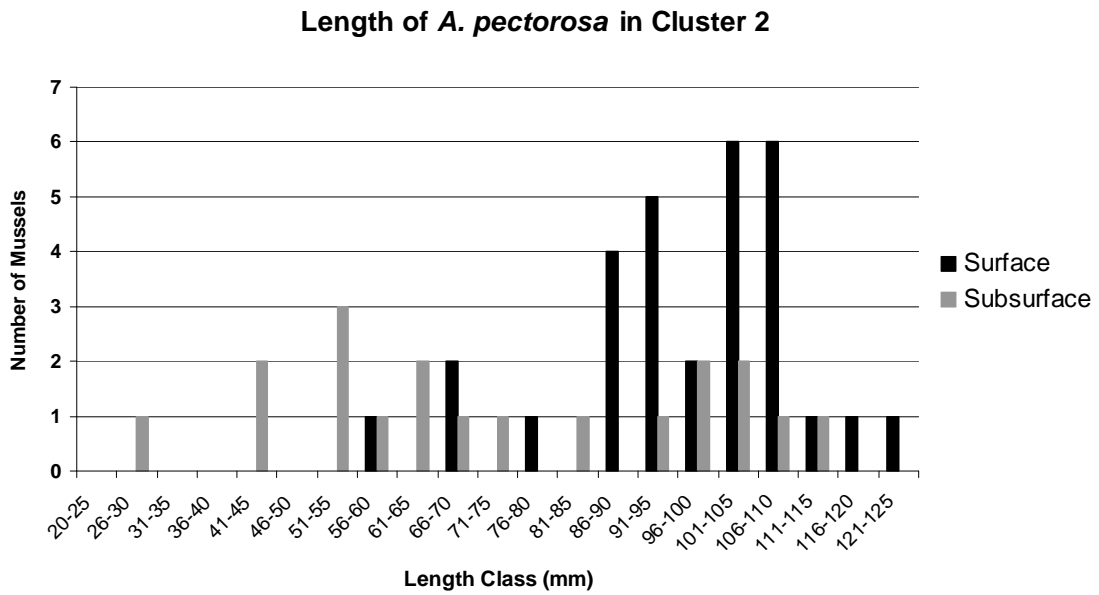
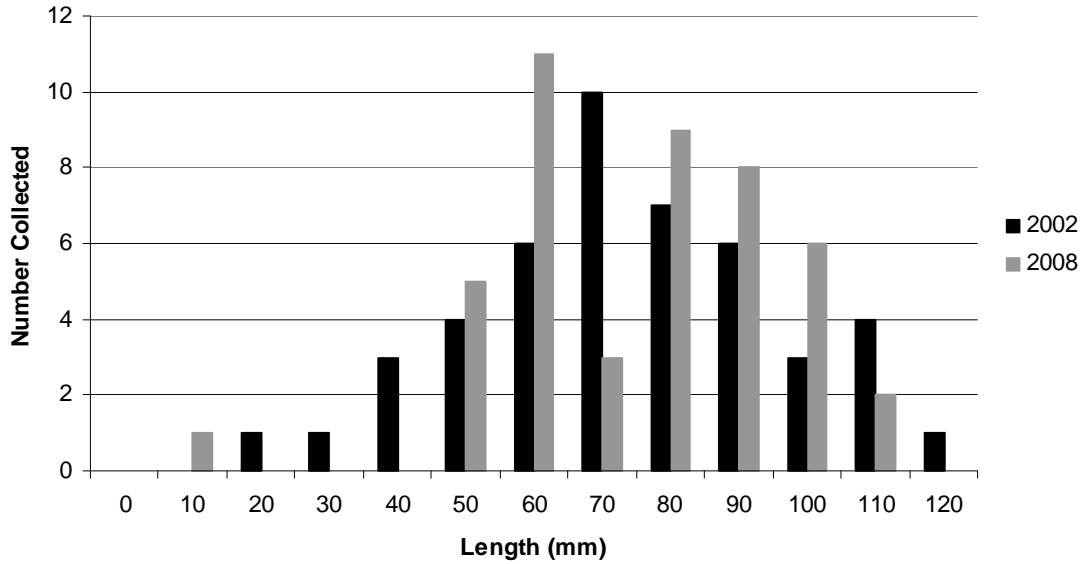


Figure 13. Length frequency of *Actinonaias pectorosa* in cluster/aggregation sampling of the Clinch River at Cleveland Island during the 2002 augmentation site survey. **A)** Cluster 1 taken in RAR1 section 140m – 160m **B)** Cluster 2 taken RAR1 section 60m – 80m.

A)

Length of *A. pectorosa* in Cleveland Island Cluster 1 sampling area



B)

Length of *A. pectorosa* in Cleveland Island Cluster 2 sampling area

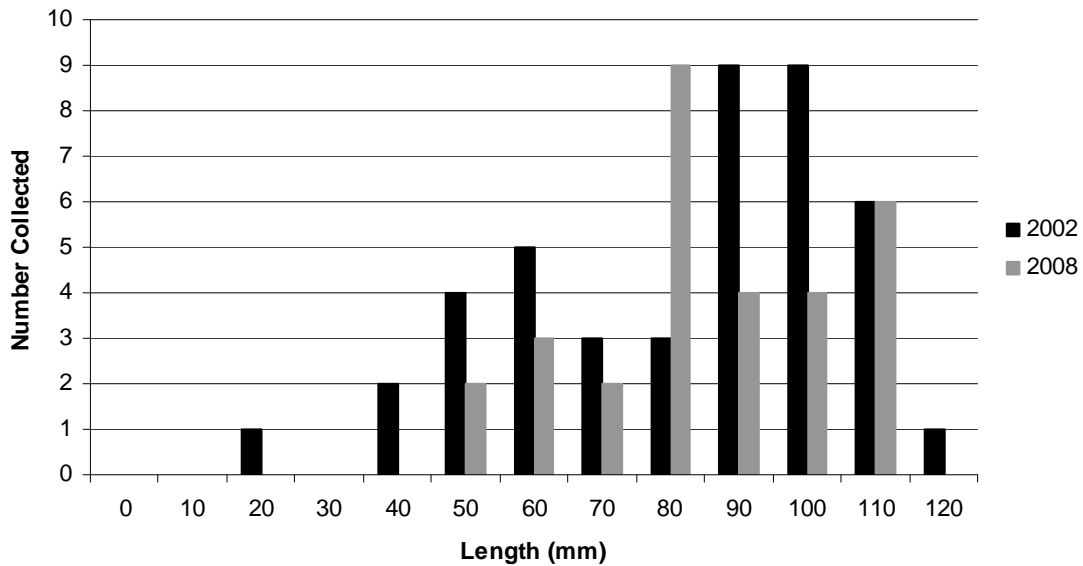


Figure 14. Length frequency of *A. pectorosa* collected at Cleveland Island in quantitative sampling of the Cluster 1 (A) and Cluster 2 (B) areas from the 2002 and 2008 augmentation site surveys.

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>Amblema plicata</i>	threeridge	---	----	----
<i>Cumberlandia monodonta</i>	spectaclecase	II	SE	FC
<i>Cyclonaias tuberculata</i>	purple wartyback	---	----	----
<i>Elliptio dilatata</i>	spike	---	----	----
<i>Epioblasma capsaeformis</i>	oystermussel	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>Hemistena lata</i>	crackling pearlymussel	I	SE	FE
<i>Io fluvialis</i>	spiny riversnail	III	ST	SOC
<i>Lampsilis fasciola</i>	wavyrayed lampmussel	---	----	----
<i>Lampsilis ovata</i>	pocketbook	IV	----	----
<i>Lasmigona costata</i>	flutedshell	---	----	----
<i>Lemiox rimosus</i>	birdwing pearlymussel	I	SE	FE
<i>Leptodea fragilis</i>	fragile papershell	IV	ST	----
<i>Lexingtonia dolabelloides</i>	slabside pearlymussel	II	ST	FC
<i>Ligumia recta</i>	black sandshell	III	ST	----
<i>Medionidus conradicus</i>	moccasinshell	---	----	----
<i>Pleurobema cordatum</i>	Ohio pigtoe	III	SE	SOC
<i>Pleurobema oviforme</i>	Tennessee clubshell	III	----	SOC
<i>Potamilus alatus</i>	pink heelsplitter	---	----	----
<i>Ptychobranhus fasciolaris</i>	kidneyshell	---	----	----
<i>Ptychobranhus subtentum</i>	fluted kidneyshell	II	----	FC
<i>Quadrula c. strigillata</i>	rough rabbitsfoot	I	SE	FE
<i>Quadrula intermedia</i>	Cumberland monkeyface	I	SE	FE
<i>Quadrula sparsa</i>	Appalachian monkeyface	I	SE	FE
<i>Strophitus undulatus</i>	creeper	IV	----	----
<i>Truncilla truncata</i>	deertoe	IV	SE	----
<i>Villosa fabilis</i>	rayed bean	II	----	SOC
<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.