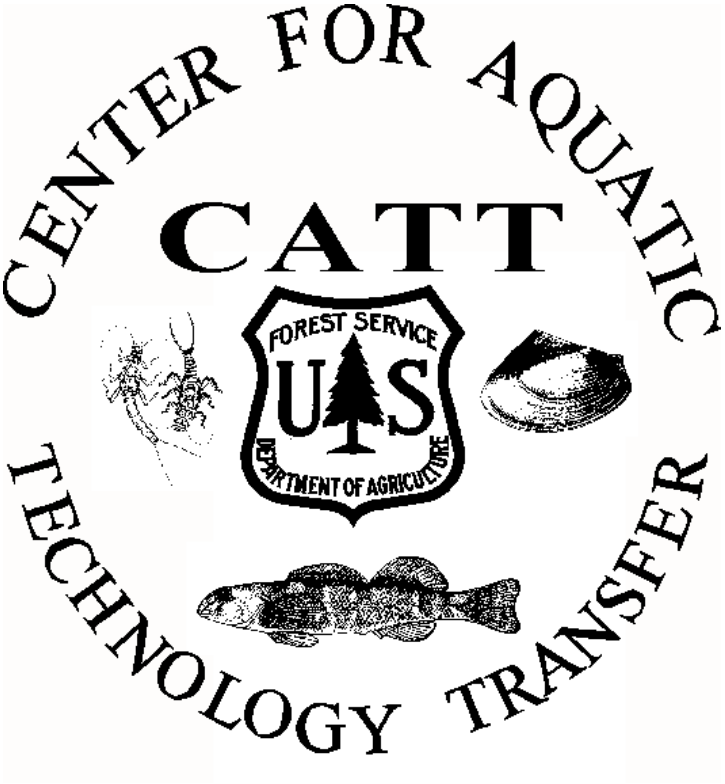
Freshwater Mussel Inventory in Cheaha Creek and Shoal Creek, Talladega National Forest, Alabama, 2011



United States Department of Agriculture Forest Service
Southern Research Station
Center for Aquatic Technology Transfer
1710 Research Center Drive
Blacksburg, VA 24060-6349

C. Andrew Dolloff, Team Leader

Report prepared by:
Colin Krause, Craig Roghair, and John Moran
June 2012

USDA

SRS
Southern Research Station

Table of Contents

List of Tables

List of Figures

Introduction

In 2011, the National Forests in Alabama (NFAL) and the Southern Research Station (SRS) began a collaborative effort to implement a freshwater mussel inventory and monitoring program on NFAL. A wide range of qualitative and quantitative survey methods are available for sampling freshwater mussel populations. Designing a survey requires careful consideration of objectives, target populations, available resources, and study sites (Strayer and Smith 2003). The NFAL inventory and monitoring plan has a 2-stage approach: 1) use of qualitative methods such as timed surveys with view buckets and snorkel gear to locate mussel populations, and 2) use of quantitative methods such as systematic quadrat surveys for monitoring populations at sites with high diversity and abundance. We selected reaches on two Talledega National Forest streams to pilot proposed methods for the inventory and monitoring program.

Mussels are known to be present in Cheaha Creek, but little information exits on mussel population distribution and abundance. Objectives for Cheaha Creek include assessment of relative density and distribution of mussel populations, with hopes of locating high density areas for quantitative monitoring. Shoal Creek has been extensively studied by Warren et al. (2004). The mussel community is well known, and includes the federally listed finelined pocketbook (*Hamiota altilis*) and the "best remaining population" of the federally listed southern pigtoe (*Pleurobema georgianum*) (Warren et al. 2004). Shoal Creek is fragmented by 3 mainstem impoundments and 1 tributary impoundment. Warren et al. (2004) provide baseline population estimates for mussel species. Given the presence of federally listed species and the fragmented nature of the watershed the NFAL would like to establish a long-term population monitoring program for Shoal Creek. Objectives for Shoal Creek include location of areas of relatively high diversity and abundance, and estimation of population size and density at those sites.

Participants in the development and execution of the 2011 surveys include NFAL Fishery Biologist, John Moran, SRS Research Scientists Mel Warren and Wendell Haag, and SRS Center for Aquatic Technology Transfer Fishery Biologists (CATT), Colin Krause and Craig Roghair. We selected a combination of qualitative and quantitative methods intended to allow the NFAL to meet their stated objectives for both streams, while remaining within their project budget. Our initial efforts provide baseline qualitative mussel community information for Cheaha Creek, qualitative community information and quantitative population estimates for comparison with previous and future Shoal Creek surveys, and insight as to methodological changes to the existing NFAL inventory and monitoring plan that may be necessary to sustain a long-term, Forest-wide mussel monitoring effort.

Methods

Site Selection and Layout

John Moran selected 1 survey site on Cheaha Creek (site 1) and 4 survey sites (sites 2, 3, 4, and 5) on Shoal Creek (Figure 1, Table 1). He added an additional site (actually a single habitat unit) on Shoal Creek (site 4b) after field work began. The reaches are known to support mussel populations (Warren et al. 2004; J. Moran, pers. obs) and range in width from 6 – 12 m (Table 2). We conducted qualitative community surveys at all sites, and quantitative population estimates at sites 4, 4b, and 5 on Shoal Creek (Table 2). In addition we collected detailed stream habitat information at sites 4 and 5 on Shoal Creek. John Moran performed qualitative surveys between April and June, 2011. A CATT field crew (Sara Sweeten + 3 summer techs) assisted John Moran with quantitative sampling in August, 2011.

Reach delineation at all sites was based on wetted stream width. If the average wetted width was less than or equal to 5 m or greater than or equal to 10 m the reach length was 150 m or 300 m, respectively. In all other cases, sample reach length was 30 times the average wetted width. Average wetted width was calculated by taking width measurements in representative fast and slow-water habitat units within each reach.

Qualitative Mussel Inventory

We conducted timed visual searches using a view bucket or mask and snorkel. The entire wetted area of the stream channel was visually searched in a haphazard manner from downstream to upstream. All live mussels were identified to species, measured to the nearest millimeter (mm), and returned to the point of collection. General habitat conditions were noted during the survey.

Habitat Inventory

We used a modified version of the basinwide visual estimation technique (BVET) (Dolloff et al. 1993) to delineate and measure all habitat units prior to quantitative surveys on reaches 4 and 5. Each habitat unit was classified as a pool or glide (deep areas with concave bottoms and slow flows) or as a riffle or run (shallow areas with flat bottoms and turbulent or fast flows). For each habitat unit contained wholly or partially within the sample reach, the crew visually estimated or measured several attributes (see Appendix A for detailed description).

Quantitative Mussel Inventory

We used an established systematic sampling method to estimate mussel population size and density (Strayer and Smith 2003; see Box 2, pgs. 14 – 17). We randomly selected 5 habitat units within each reach based on unit distance from the start of the inventory reach. Within each of the 5 randomly

selected habitat units we searched a minimum of 10, 0.25 m^2 quadrats. Quadrat location was determined using 3 random starts and the following quadrat spacing formula:

$$d = \sqrt{\frac{L \cdot W}{n_k}}$$

where *d* is the distance between quadrats, *L* is the length of the habitat unit, *W* is width of habitat unit, *n* is the total number of desired quadrats (here, 10), and *k* is the number of random starts (here, 3). We rounded the result down to the nearest half meter to insure at least 10 quadrats would be searched. To determine the starting location for each of the 3 random starts we generated 3 pairs of random numbers (representing x, y coordinates in the sampling grid) between 0 and *d* using an excel spreadsheet on a netbook computer. The x, y coordinates for all other quadrats were calculated by adding *d* units to the x and y coordinates of the starting point for each random start.

After placing a quadrat on the stream bed we visually estimated the dominant and subdominant substrate sizes within the quadrat and measured water depth at its center. We visually searched the surface within each quadrat for exposed mussels and then excavated to a depth of up to 10 cm (finger depth) in an attempt to locate mussels buried in the substrate. All live mussels were identified to species, measured to the nearest millimeter (mm), and returned to the point of collection.

We calculated mussel population estimates and densities in each habitat unit using methods described by Strayer and Smith (2003, Box 2, pages 14 - 17). To extend the estimates from individual habitat units to the reach as a whole, we calculated the reach population (*T*) as:

$$T = M\,(\sum x_i / m),$$

where *M* = the total number of possible random starts in the entire reach (based on surface area of both sampled and unsampled habitat units in the reach), $\sum x_i$ = sum of mussel counts in each systematic sample, and *m* = the total number of systematic samples used. We applied the whole reach *M* and *m* results to the population estimate and variance formulas to estimate population size and density with 90% confidence intervals (Strayer and Smith 2003; Box 2, page 17).

Results

Qualitative Sampling

Reach #1 - Cheaha Creek On 05/19/2011, a 366 m reach of Cheaha Creek (Figure 3) was qualitatively sampled in 96 min and 26 live mussels were found representing 4 species (Tables 2-4). Live *Corbicula fluminea* were found throughout this reach. The drainage area at the start point of the Cheaha Creek site is approximately 22 mi^2. The habitat within the reach consists of 2 very long pools and 2 small shallow riffles. Areas of this reach were too deep to sample with a view bucket or snorkeling gear.

Because of these characteristics it was determined that this segment of Cheaha Creek is not suitable for further qualitative or quantitative sampling using the selected methods.

Reach #2 - Shoal Creek On 06/01/2011, a 240 m reach of Shoal Creek located between Whiteside's Mill Lake and Highrock Lake (Figure 2-3) was qualitatively sampled in 75 min and 8 live mussels were found representing 3 species (Tables 2-4). A gravid Villosa vibex with mantle fold displayed was found in this reach. The water temperature was 22.5° C at 10:45 am. Live *Corbicula fluminea* were found throughout this reach. The drainage area at the start point of the site is approximately 28 mi^2. The habitat units within this reach are very long and deep in areas. Because mussel abundance and richness was low and habitat conditions were not suitable for sampling with the selected methods, this reach was not selected for quantitative sampling.

Reach #3 - Shoal Creek On 06/01/2011, a 300 m reach of Shoal Creek located between Whiteside's Mill Lake and Highrock Lake (Figures 2-3) was qualitatively sampled in 45 min and 9 live mussels were found representing 1 species (Tables 2-4). The search time was relatively short because much of the area in this reach was too deep to sample with a view bucket and was by-passed. Two gravid V. vibex were found in this reach. The water temperature was 26.5° C at 2:15 pm. Live *Corbicula fluminea* were found throughout this reach. The drainage area at the start point of the site is approximately 27 mi^2. Because mussel abundance and richness was low and habitat conditions were not suitable for sampling with the selected methods, this reach was not selected for quantitative sampling.

Reach #4 - Shoal Creek On 06/02/2011, a 300 m reach of Shoal Creek located between Highrock Lake and Sweetwater Lake (Figures 2-3) was qualitatively sampled in 75 min and 30 live mussels were found representing 5 species (Table 3). Live *Corbicula fluminea* were found throughout this reach. The drainage area at the start point of the site is approximately 18 mi^2. Relative to the previous qualitative sites the habitat units were smaller, shallower, and more numerous. Because mussel abundance and richness were relatively high and habitat conditions were suitable for sampling with the selected methods, this reach was selected for quantitative sampling.

Reach #4B (additional habitat unit) - Shoal Creek On 08/08/2011, a 17.2 m long and 6.0 m wide habitat unit categorized as a run located just upstream past the end of the reach 4 (Table 1) was observed to contain numerous mussels. Three observers using snorkeling gear qualitatively sampled this run for a total of 94.5 min (31.5 min X 3 observers) and 73 individual live mussels were found representing 6 species (Tables 2-4) including 2 federally endangered southern pigtoes (*Pleurobema georgianum*).

Reach #5 - Shoal Creek On 06/09/2011, a 182 m reach of Shoal Creek located upstream of Sweetwater Lake (Figures 2-3) was qualitatively sampled in 54 min and 23 live mussels were found representing 5 species (Tables 2-4). Live *Corbicula fluminea* were found throughout this reach. The

drainage area at the start point of the site is approximately 6 mi^2. Relative to the previous qualitative sites the habitat units were smaller, shallower, and more numerous. Because mussel abundance and richness were relatively high and habitat conditions were suitable for sampling with the selected methods, this reach was selected for quantitative sampling.

Quantitative Sampling

Reach #4 - Shoal Creek On 08/07 and 08/08/2011 a 293 m reach of Shoal Creek located between Highrock Lake and Sweetwater Lake was sampled quantitatively for mussels. The start location for this reach was the same as the qualitative inventory (Figures 2-3). The total wetted surface area of the reach was 2,549 m^2 and included 6 pools/glides and 4 riffles (Table 6). A total of 50, 0.25 m^2 quadrats (10 per habitat unit) were sampled within 3 pools/glides and 2 riffles (Table 7) and 8 mussels were found representing 3 species (Tables 8-9). Reach-wide density for all species combined was 0.61(90% CI: 0.26, 1.42) individuals per m^2 and estimated reach-wide population size for all species combined was 1559 (90% CI: 671, 3621) mussels (Tables 8-9).

Reach #4B (additional habitat unit) - Shoal Creek On 08/08/2011 a 17.2 m long x 6.0 m wide habitat unit categorized as a run located just upstream past the end of reach 4 (Table 1) was quantitatively sampled. This sampling occurred immediately after a qualitative effort attempted to remove (and not replace) all mussels visible at the surface of the substrate (n = 73). After the qualitative survey, we conducted a quantitative survey by sampling a total of 10, 0.25 m^2 quadrats in the 103 m^2 run (Table 7). We found 7 mussels representing 4 species (Table 8-9). The estimated post-removal density of this single unit for all species combined was 2.73 (90% CI: 1.81, 4.13) individuals per m^2 and the estimated post-removal population size for this unit was 282 (90% CI: 187, 426) mussels (Tables 8-9).

Reach #5 - Shoal Creek On 08/06/2011 a 184 m reach of Shoal Creek located upstream of Sweetwater Lake was sampled quantitatively for mussels. The start location for this reach was the same as the qualitative inventory (Figures 2-3). The total wetted surface area of the reach was 1,072 m^2 and included 6 pools/glides and 4 riffles (Table 6). A total of 49, 0.25 m^2 quadrats were sampled within 4 pools/glides and 1 riffle (Table 7) and 35 mussels were found representing 5 species (Tables 8-9). Mean reach-wide density for all species combined was 2.65 (90% CI: 1.96, 3.57) individuals per m^2 and estimated reach-wide population size for all species combined was 2,842 (90% CI: 2108, 3832) mussels (Tables 8-9).

Discussion

We were able to meet our goals of collecting baseline mussel community data for Cheaha Creek and producing community data and population estimates for Shoal Creek. However, we encountered challenges with both approaches (qualitative and quantitative) that should result in changes for future inventories. In Cheaha Creek, we noted the difficulty of executing even relatively simple snorkel and view bucket inventories due to the water depth in many habitat units. Inventorying mussels in deep water may require the use of specialized equipment such as a hookah dive system or SCUBA. Specialized training and equipment expenses often limit the use of such techniques in all but a few special cases. Given the current time and budgetary limitations for mussel surveys on the NFAL, inventorying such stream reaches will likely be very limited. The qualitative approach was much more successful in Shoal Creek, where habitat conditions were generally very good for snorkel or view bucket use. The qualitative approach allowed us to rapidly search a relatively large proportion of each reach while also detecting rare species that may be missed during a more structured quantitative survey.

The quantitative approach yielded population and density estimates, but with very large confidence intervals. Unfortunately, this is common when sampling species with high variation in spatial distribution and low population density. The spatial variability in mussel populations is highlighted by our results from reach 4b. Reach 4b was a single habitat unit located immediately upstream of reach 4. The population density in reach 4 was very low in comparison to reach 4b, especially considering we removed over 70 mussels from reach 4b before we even started the population estimate! If the start point for reach 4 had been placed just slightly further upstream it would have included reach 4b and the results for reach 4 would have been very different, as would the confidence intervals. Increasing effort to search a larger proportion of the total surface area in each habitat unit may help to shrink confidence intervals, but this inherent spatial variability will limit the effectiveness of any approach intended to shrink confidence intervals. While it is difficult to make conclusions regarding the trajectory of populations when confidence intervals are large, it is possible to conclude that Shoal Creek continues to support a sizeable mussel population.

The quantitative approach also proved to be challenging to implement in the field. The selection of random start locations and calculating subsequent quadrat placement required the use of a netbook computer with a spreadsheet program. Also, pre-determining the number of quadrats to be searched resulted in uneven effort in different sized habitat units (Tables 4 & 5). Alternative approaches to random start selection and quadrat placement are available (W. Haag, pers. comm., e.g. Appendix B) and should be considered prior to the next inventory. These alternative approaches simplify locating random starts and quadrat placements, and they consistently sample the same proportion of habitat area within selected habitat units.

In summary, the methods outlined above provided valuable mussel community and population size information. The qualitative approach proved to be an effective method for detecting mussel species when water depth was not excessive. With a few minor changes, the site layout for the quantitative approach can be simplified and still provide comparable data. Used together, the two approaches can be complimentary parts of a long-term mussel monitoring program on the NFAL.

Data Availability

The 2011 habitat and mussel inventory data are stored in a Microsoft Access database, which is stored at the CATT and an offsite backup (O:\RD\SRS\Site\BlacksburgVA\Admin\CATT Center for Aquatic Technology Transfer\National Forest System\ACCESS Databases), and a copy has been provided to the NFAL. We will support the migration of this data into the USFS database tool, Natural Resource Information System Aquatic Surveys (NRIS AqS), as needed. In the interim, we are working with the NFAL to develop custom queries and reports for the MS Access database. John Moran, NFAL Fish Biologist, received a copy of all data in electronic format. Past reports are available on the CATT website: www.srs.fs.usda.gov/catt.

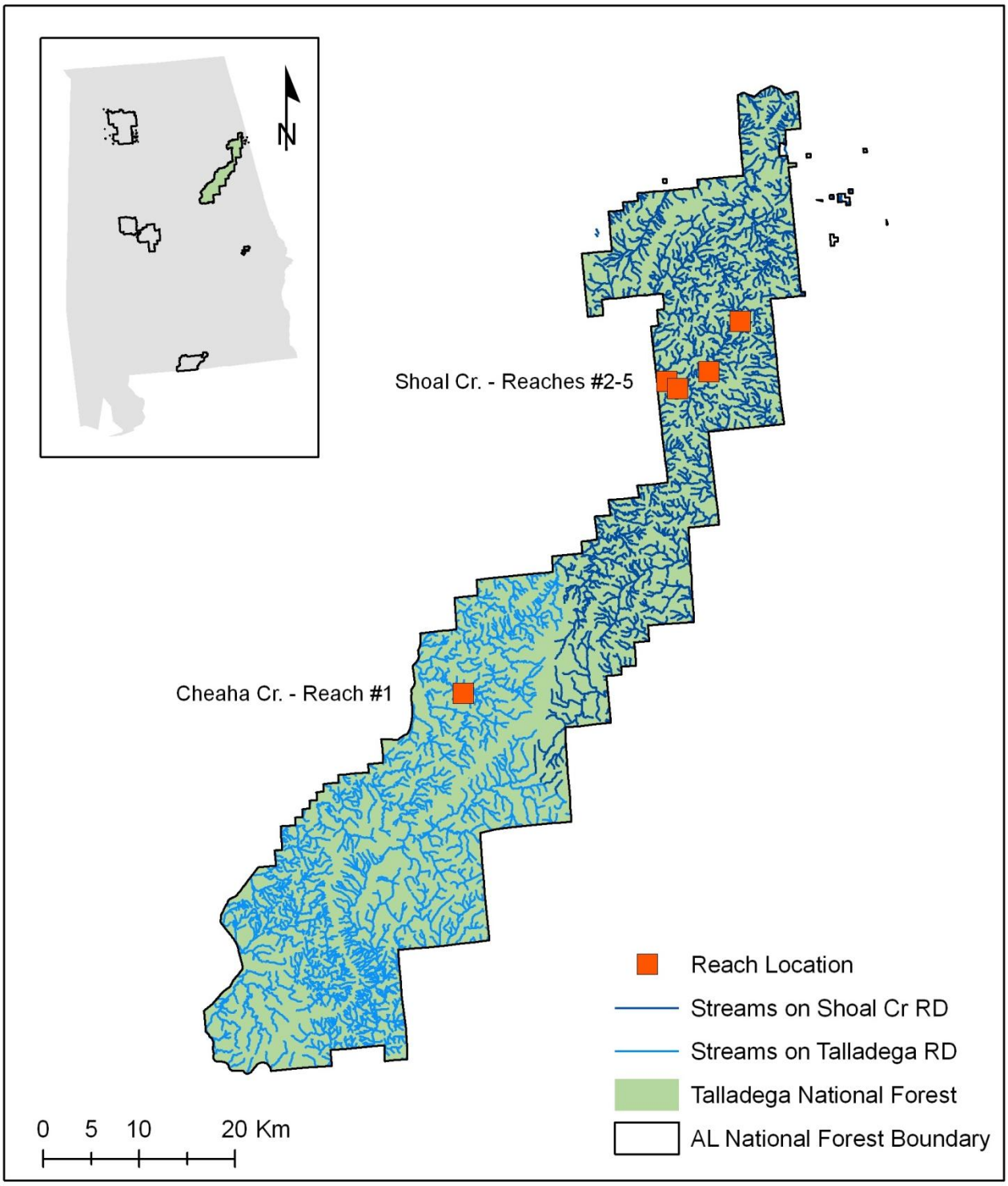


Figure 1. Location of reaches inventoried on the Shoal Creek and Talladega Ranger District; Talladega National Forest, Alabama, 2011.

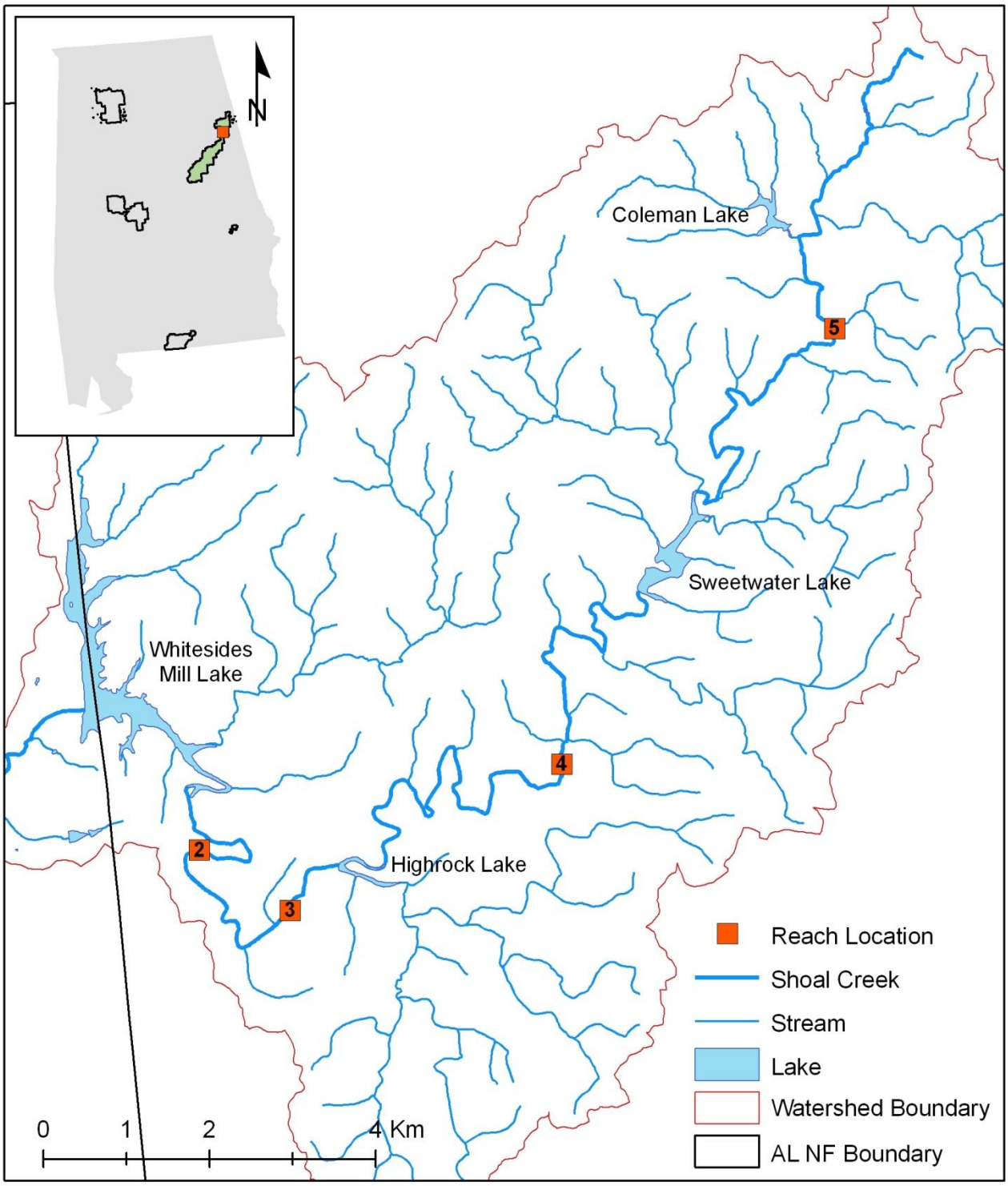


Figure 2. Location of reaches (#2-5) inventoried on Shoal Creek; Shoal Creek Ranger District, Talladega National Forest, Alabama, 2011.

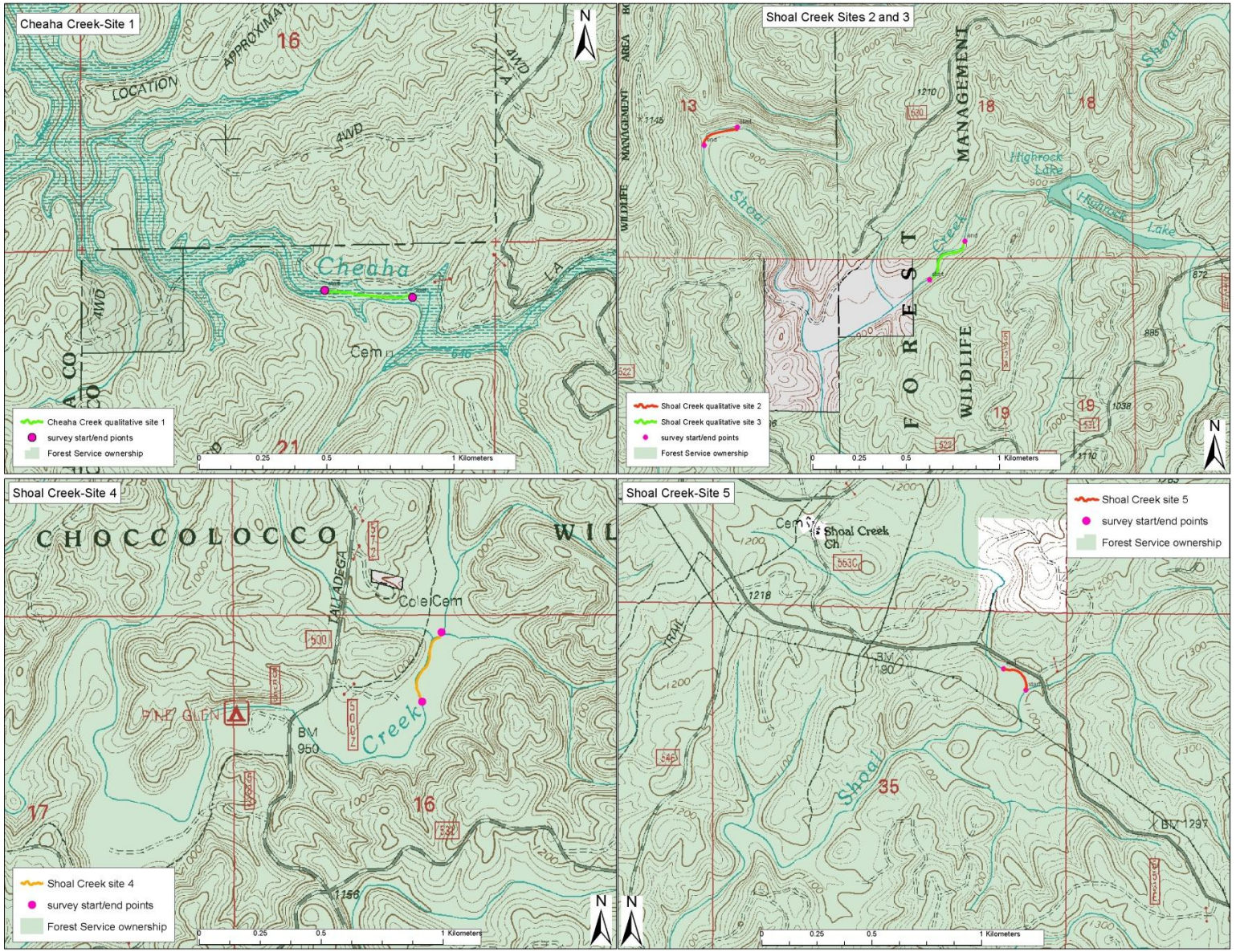


Figure 3. Cheaha Creek sample site 1, and Shoal Creek sample sites 2, 3, 4, and 5 on the Talledega National Forest, AL, 2011.

Table 1. Location of and sampling techniques used at inventory reaches, Talladega National Forest, AL, 2011.

		Inventory Type Completed			GPS (UTM NAD83)	
Stream	Reach #	Qualitative	Habitat	Quantitative	Start	End
Cheaha Creek	1	✓			16 S 601067 3702044	16 S 601411 3702017
Shoal Creek	2	✓			16 S 625621 3732026	16 S 625444 3731928
Shoal Creek	3	✓			16 S 626650 3731207	16 S 626839 3731415
Shoal Creek	4	✓	✓	✓	16 S 630113 3732640	16 S 630190 3732899
Shoal Creek	4B*	✓		✓	16 S 630196 3732906	NA
Shoal Creek	5	✓	✓	✓	16 S 633930 3737479	16 S 633811 3737590

*Additional run habitat unit sampled upstream of reach 4.

Table 2. Inventory reach characteristics and qualitative inventory (timed search) results.

		Qualitative Inventory					
Stream	Reach #	Avg. Wetted Width at Start (m)	Reach Length (m)	Drainage Area at Start (mi^2)	Search Time (min)	Number of Mussels Found	Species Richness
Cheaha Creek	1	12.2	366	22	96	26	4
Shoal Creek	2	8.0	240	28	75	8	3
Shoal Creek	3	10.0	300	27	45	9	1
Shoal Creek	4	10.5	300	18	75	30	5
Shoal Creek	4B	6.0	12	18	95	73	6
Shoal Creek	5	6.1	182	6	54	23	5

Table 3. Mussel species detected in Shoal Creek in 2003 (Warren et al. 2004) and 2011.

Scientific Name	Common Name	2003	2011
Hamiota altilis	finelined pocketbook	✓	✓
Pleurobema georgiamum	southern pigtoe	✓	✓
Strophitus connasaugaensis	Alabama creekmussel	✓	✓
Utterbackia imbecillis	paper pondshell	✓	
Villosa lienosa	little spectaclecase	✓	
Villosa nebulosa	Alabama rainbow	✓	✓
Villosa umbrans	Coosa creekshell		✓
Villosa vibex	southern rainbow	✓	✓

Table 4. Minimum lengths (mm) for mussels in 2003 (Warren et al. 2004) and 2011.

		2003		2011	
Scientific Name	Common Name	Minimum Length (mm)	n	Minimum Length (mm)	n
Hamiota altilis	finelined pocketbook	33	19	50	10
Pleurobema georgiamum	southern pigtoe	14	7	45	2
Strophitus connasaugaensis	Alabama creekmussel	24	53	36	82
Utterbackia imbecillis	paper pondshell	57	1	--	0
Villosa lienosa	little spectaclecase	6	17	--	0
Villosa nebulosa	Alabama rainbow	15	36	25	52
Villosa umbrans	Coosa creekshell	--	0	30	29
Villosa vibex	southern rainbow	10	50	31	43

Table 5. Qualitative inventory mussel counts and relative abundance by species.

		Qualitative Inventory					
		Cheaha Cr.	Shoal Cr.				
Mussel Species		Reach 1	Reach 2	Reach 3	Reach 4	Reach 4B	Reach 5
Hamiota altilis	# of individuals	0	0	0	2	4	1
(finelined pocketbook)	Rel. abundance	0%	0%	0%	7%	5%	4%
Pleurobema georgianum	# of individuals	0	0	0	0	2	0
(southern pigtoe)	Rel. abundance	0%	0%	0%	0%	3%	0%
Strophitus connasaugaensis	# of individuals	12	0	0	11	18	14
(Alabama creekmussel)	Rel. abundance	58%	0%	0%	37%	25%	61%
Villosa nebulosa	# of individuals	4	5	0	3	25	1
(Alabama rainbow)	Rel. abundance	15%	63%	0%	10%	34%	4%
Villosa umbrans	# of individuals	4	2	0	3	9	1
(Coosa creekshell)	Rel. abundance	15%	25%	0%	10%	12%	4%
Villosa vibex	# of individuals	3	1	9	11	15	6
(southern rainbow)	Rel. abundance	12%	13%	100%	37%	21%	26%

Table 6. Quantitative inventory physical habitat characteristics of the reach.

		Quantitative Inventory							
Stream	Reach #	Avg. Wetted Width at Start (m)	Reach Length (m)	# Habitat Units	# of Pools & Glides	# of Riffles & Runs	Pool & Glide Area (m^2)	Riffle & Run Area (m^2)	Total Habitat Area (m^2)
Shoal Creek	4	9.7	293	10	6	4	1,981	336	2,317
Shoal Creek	4B	6.0	17	1	NA	1	NA	103	103
Shoal Creek	5	5.9	184	10	6	4	990	102	1,092

Table 7. Quantitative inventory physical habitat characteristics of the sampled habitat units.

		Quantitative Inventory						
Stream	Reach #	# of Pools & Glides Sampled	# of Riffles & Runs Sampled	Total # of Habitat Units Sampled	Total Area of Pools Sampled (m^2)	Total Area of Riffles Sampled (m^2)	Total Area of Habitat Units Sampled (m^2)	Total Number of Quadrats Sampled
Shoal Creek	4	3	2	5	463	261	724	50
Shoal Creek	4B	NA	1	1	NA	103	103	10
Shoal Creek	5	4	1	5	423	22	445	49

Table 8. Quantitative inventory results for population size and density. Numbers in parentheses are 90% confidence intervals. The estimate for reach 4B was made *after* removal of 73 mussels.

		Quantitative Inventory			
Stream	Reach #	Total # of Individual Mussels in Sample	Species Richness	Estimated Mussel Density (mussels/m^2)	Estimated Population Size
Shoal Creek	4	8	3	0.61 (0.26, 1.42)	1559 (671, 3621)
Shoal Creek	4B	7	4	2.73 (1.81, 4.13)	282 (43, 1883)
Shoal Creek	5	35	5	2.65 (1.96, 3.57)	2842 (2108, 3832)

Table 9. Quantitative inventory mussel population size and density (mussels/m^2) for each observed species in Shoal Creek. Numbers in parentheses are 90% confidence intervals.

		Quantitative Inventory		
Mussel Species		Reach 4	Reach 4B	Reach 5
Hamiota altilis	Density	0.08 (0.01, 0.44)	NA	0.30 (0.14, 0.66)
(finelined pocketbook)	Population size	195 (34, 1129)	NA	325 (150, 706)
Pleurobema georgianum	Density	NA	NA	NA
(southern pigtoe)	Population size	NA	NA	NA
Strophitus connasaugaensis	Density	0.23 (0.09, 0.59)	0.78 (0.19, 3.30)	0.98 (0.59, 1.65)
(Alabama creekmussel)	Population size	585 (229, 1496)	81 (19, 340)	1056 (630, 1770)
Villosa nebulosa	Density	NA	0.39 (0.02, 7.10)	0.76 (0.41, 1.39)
(Alabama rainbow)	Population size	NA	40 (2, 73)	812 (441, 1494)
Villosa umbrans	Density	0.31 (0.11, 0.84)	0.39 (0.02, 7.10)	0.53 (0.32, 0.87)
(Coosa creekshell)	Population size	780 (284, 2140)	40 (2, 73)	568 (344, 937)
Villosa vibex	Density	NA	1.17 (0.22, 1.17)	0.08 (0.01, 0.44)
(southern rainbow)	Population size	NA	121 (23, 639)	81 (14, 468)

Literature Cited

Dolloff, C. A., D. G. Hankin, and G. H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. General Technical Report SE-83. Asheville, North Carolina: U.S. Department of Agriculture, Southeastern Forest Experiment Station.

Strayer, D. L., and D. R. Smith. A guide to sampling freshwater mussel populations. American Fisheries Society, Monograph 8, Bethesda, Maryland.

Warren, Jr., M.L., W.R. Haag, S.B. Adams, and A.L. Sheldon. 2004. Population size estimates and distribution of freshwater mussels in Shoal Creek, Talladega National Forest, Alabama. Unpublished File Report. USDA Forest Service, Center for Aquatic Technology Transfer, Oxford, Mississippi. 42pp.

Appendix A – Habitat Survey Results

Table A1.

Stream	Reach #	Description	GPS (UTM NAD83)
Shoal Creek	4	Riffle at 0 m	16 S 630101 3732648
		Pool at 125 m	16 S 630108 3732746
		Glide at 241 m	16 S 630148 3732868
		Glide at 262 m	16 S 630169 3732889
		Riffle at 275 m	16 S 630177 3732895
Shoal Creek	5	Pool at 18 m	16 S 633930 3737479
		Riffle at 67 m	16 S 633906 3737522
		Pool at 79 m	16 S 633885 3737528
		Glide at 108 m	16 S 633859 3737540
		Pool at 175 m	16 S 633834 3737556

Table A2.

		Reach 4	Reach 4B	Reach 5
	Avg. Width (m)	8.1	6.0	4.8
	Length (m)	293	17	184
	Area (m^2)	2,366	103	884
	Water Temp. (C)	23	NA	23
% Area	Slow-Water	85	0	89
	Fast-Water	15	100	11
Mean Maximum Depth (cm)	Slow-Water	64	NA	49
	Fast-Water	19	NA	10
Mean Average Depth (cm)	Slow-Water	37	NA	28
	Fast-Water	11	NA	6
LW Pieces per km	< 5 m long, 10-55 cm diameter	92	NA	125
	< 5 m long, > 55 cm diameter	0	NA	0
	> 5 m long, 10-55 cm diameter	0	NA	5
	> 5 m long, > 55 cm diameter	0	NA	0

Table A3.

Reach #	Unit Type	Distance Upstream of Start (m)	Unit Area (m^2)	Avg Water Depth (cm)	Num. Quadrats	Num. Quadrats w/ Mussels	Num. Mussels	Search Duration (sec)		Dominant Substrate[1]					
								Avg. Sec. per Quadrat	Total Sec. for all Quadrats	Clay	Sand	Small Gravel	Large Gravel	Cobble	Boulder
4	Riffle	0	90	10	10	0	0	477	4,769	0	2	3	4	1	0
4	Pool	125	191	42	10	2	4	610	6,095	1	7	0	0	2	0
4	Glide	241	209	17	10	2	3	985	9,853	0	2	4	2	2	0
4	Glide	262	64	23	10	1	1	459	4,588	0	2	0	0	7	1
4	Riffle	275	171	9	10	0	0	521	5,212	0	0	0	7	3	0
4B[2]	Run	0	103	29	10	5	7	537	5,371	0	2	5	2	1	0
5	Pool	18	55	24	10	5	8	690	6,897	0	9	0	0	1	0
5	Riffle	67	22	9	9	4	4	601	5,407	0	7	1	1	0	0
5	Pool	79	90	26	10	3	4	521	5,214	0	8	0	1	1	0
5	Glide	108	71	18	10	7	12	636	6,355	0	6	3	1	0	0
5	Pool	175	207	39	10	4	7	597	5,969	0	9	0	0	1	0

[1] Number of quadrats containing a dominant substrate type. Other substrate types evaluated, but not present were organic matter, silt, and bedrock.

[2] Quadrat inventory of mussels buried and/or missed by roving snorkelers in an extra habitat unit upstream of Reach 4.

Table A4.

Species	Number Found in Reach #			Length (mm)			N	Habitat Type Observed In			
	4	4B*	5	Min.	Avg.	Max.		Pool	Glide	Riffle	Run
Hamiota altilis	1	0	4	50	59	68	9	✓	✓	✓	✓
Pleurobema georgianum	0	0	0	45	50	54	2				✓
Strophitus connasaugaensis	3	2	13	36	66	86	36	✓	✓		✓
Villosa nebulosa	0	1	10	25	47	67	36	✓	✓	✓	✓
Villosa umbrans	4	1	7	30	46	60	21	✓	✓	✓	✓
Villosa vibex	0	3	1	31	63	78	19	✓			✓

*Number of mussels found in reach 4B excludes 73 mussels removed during the qualitative inventory.

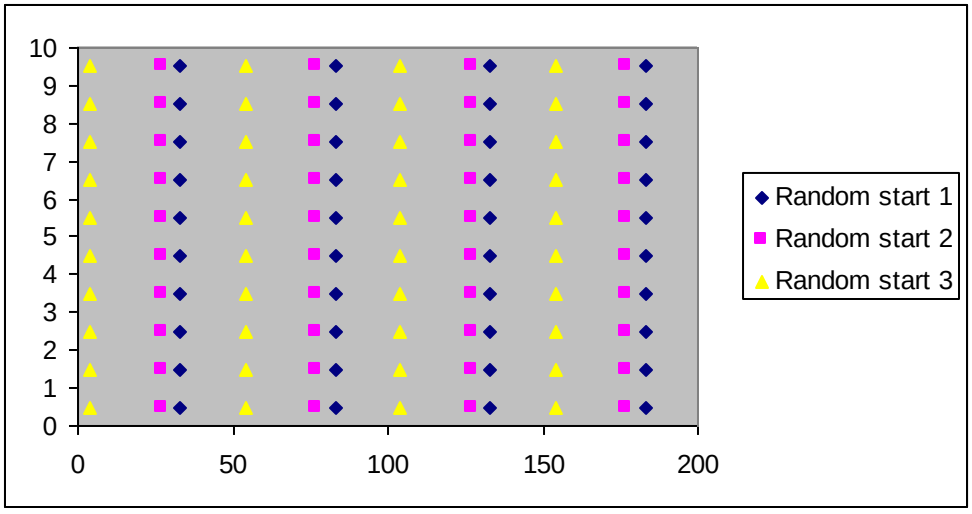
Appendix B – Alternative Systematic Survey

This sampling approach was developed by Wendell Haag, SRS. Visiting the sample site prior to the survey to measure the total wadeable area would allow us to determine the sampling layout for each site in the office, saving valuable field time. Regardless, this layout should be easier to implement in the field, and samples a similar proportion of unit area at each site. Sample layout will proceed for each site as follows:

- Sampling unit: quadrat = 0.25 m^2, 0.5 m x 0.5 m
- Example site: length = 100 m, width = 10 m, area = 1000 m^2, 4000 possible quadrats
- Sample 2.5% of site = 4000 * 0.025 = 100 total quadrats
- Quadrats are 0.5 m on a side, so there are 200 possible transects along the 100 m length of the unit
- Within each transect take sample at a point every 1 m across stream, so 10 quadrats/transect (sampling point will be in the middle of the quadrat, so after sampling a quadrat, flip quadrat twice to find new location, quadrats are 0.5 m on each side so two flips = 1.0 m)
- 100 total quadrats desired ÷ 10 quadrats/transect = 10 total transects
- 10 transects/3 random starts = 3.3 transects/random start, round up to 4
- 200 possible transects ÷ 4 transects/random start = 50 possible transect arrays
- Draw 3 random numbers between 0 and 49, these are the starting points for the first transect in each random start. Example: 33, 27, 4
- Add 50 to each point to give the position of the next transect in each random start. Example: 33+50=**83**, 27+50=**77**, 4+50=**54**
- Add 50 to each point two more times. This will give you the locations of all transects as follows:
  Random start 1: 33, 83, 133, 183
  Random start 2: 27, 77, 127, 177
  Random start 3: 4, 54, 104, 154
- Divide each of these numbers by 2 to give the transect starting position in meters:
  Random start 1: 16.5, 41.5, 66.5, 91.5
  Random start 2: 13.5, 38.5, 63.5, 88.5
  Random start 3: 2, 27, 52, 77
- If the starting number of a random start is odd, then place the first quadrat of each transect in that random start next to the bank. If the starting number is even, place the first quadrat of all transects one quadrat length from the bank. Example: Random start 3 (starting number=2) begins one quadrat length from shore

Although this gives 12 transects and 120 total quadrats, slightly more than planned, it is an easy way to allocate effort and gives the desired number of samples as a minimum. It is important to note that n=3 here not 12, 40, or 120. Each random start constitutes a single sample because the placement of all subsequent quadrats in the sample is dependent on the placement of the first one. With this worked out for each site, the only remaining layout necessary in the field is to stretch a meter tape, find the starting points and begin sampling

Below is a map of the hypothetical site; stream length is along the x-axis and width is represented by the y-axis (stream flow is parallel to the x-axis).



Expected Results

Computation of an estimate of total number of mussels at the site (τ), is straight-forward. Using the previous example, there are 50 possible transect arrays and 2 possible bank starting positions (next to bank or 1 quadrat length offshore), so there is a total of 100 possible random starts at the site (*N*). There are n = 3 samples, and y = the number of mussels in each sample.

$$\tau = \frac{N}{n}\sum_{i=1}^{n} y_i$$

As an example consider the following dataset:

Site	Random start	Transect	Number of *Elliptio* spp.
Camp Creek	1	a	8
		b	2
		c	3
		d	5
	total		18
	2	a	7
		b	1
		c	0
		d	6
	total		14
	3	a	9
		b	2
		c	5
		d	2
	total		18

$\tau = \frac{100}{3}(18+14+18)$ = **1667** mussels at the site

The variance is computed as follows:

$$\text{var}(\tau) = \frac{N(N-n)}{n} \times \frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-1}$$

So, the variance for the example above would be 17247, and standard deviation = 131.

This approach allows us to calculate the number of mussels at each sample site. Density is calculated as the number of mussels divided by the total area of the sample site. Repeating this sampling protocol at the same sample sites at some time in the future allows us to detect temporal changes in mussel population sizes using t-tests (Strayer and Smith 2003, pages 79-81).