Population Size Estimates and Distribution of Freshwater Mussels in Shoal Creek, Talladega National Forest, Alabama

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Submitted to

Shoal Creek Ranger District

Talladega National Forest

Heflin, Alabama

by

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Final Report
April 1, 2004

Executive Summary

Shoal Creek (Choccolocco Creek system, Coosa River drainage), Alabama, supports two federally listed mussels (finelined pocketbook and southern pigtoe), represents one of few intact examples of the headwater mussel fauna of the Coosa River system, and is designated a freshwater conservation priority area by The Nature Conservancy. Dams fragment Shoal Creek into three segments, isolating the mussel fauna in each, precluding gene exchange among populations, and likely lowering probability of long-term viability. Managers need accurate population size estimates to assess mussel viability and response to management activities and need quantitative survey information to serve as a baseline for future monitoring.

We conducted a quantitative survey of freshwater mussels in two separate segments of Shoal Creek: between High Rock and Sweetwater lakes (Segment A) and between Sweetwater and Coleman lakes (Segment B). Our goals were to: 1) conduct segment-wide surveys of distribution and abundance of freshwater mussels; 2) estimate total population sizes and evaluate viability; and 3) establish a repeatable, quantitative baseline for future monitoring of populations trends.

The species richness of mussels, spatial distribution of species, and lengths of individuals suggest that despite isolation, reproducing mussel communities persist in both segments. Most of the seven species in Shoal Creek occurred widely in riffle and pool habitats. The southern pigtoe occurred only in Segment A but was widespread within the segment. Small minimum lengths and high percentages of small individuals indicate successful recruitment of mussels in both segments. Low mussel densities in both segments may reflect naturally low productivity in Shoal Creek but, coupled with isolation, are cause for concern.

Segment-wide population sizes for most species are near the ostensible minimum for long-term persistence, and suggest most mussel species in both segments are highly vulnerable to environmental fluctuations and catastrophic events. The two federally listed species, southern pigtoe and finelined pocketbook, are of primary conservation concern. The southern pigtoe has an estimated population of < 1000 and lower bounds of confidence intervals are much less than 500. The population of the southern pigtoe in Shoal Creek may be the best-remaining population of the species. Although the finelined pocketbook occurs in both segments, segment-wide population size estimates and confidence intervals indicate vulnerability in both segments. One catastrophic event or the chance juxtaposition of several smaller natural or human-induced impacts to the mussel fauna could reduce populations of these and other species to below minimum viable levels which, in the absence of sources of re-colonization, would result in a slow but unrecoverable downward spiral.

The most tangible threat to long-term persistence of mussels is the fragmentation of Shoal Creek by dams and impoundments. In an impoundment-free conservation scenario, an additional 5.5-stream km of mussel habitat that is now reservoir bottom would be available to the mussel fauna. As a result, currently isolated mussel populations would be joined into a single, larger population covering 26.2 stream km, and connectivity with Choccolocco Creek would be restored. The development of a long-term conservation strategy and evaluation of risks of action or inaction are beyond the scope of our analysis. However, we recommend that the un-surveyed segment between High Rock Dam and the mouth of Shoal Creek be quantitatively surveyed for mussels so that populations in those segments, if any, can be considered in any overall conservation strategy.

Introduction

Shoal Creek (Coosa River drainage), Alabama, represents one of few intact examples of the headwater mussel fauna of the Coosa River system. The stream supports an aquatic community that includes two federally listed mussels endemic to the Mobile Basin, the finelined pocketbook (*Lampsilis altilis*) and southern pigtoe (*Pleurobema georgianum*) (Haag 2004a,b) and other freshwater mussels and fish of conservation concern (Williams et al. 1993, Warren et al. 2000). The Shoal Creek watershed, nested within the Choccolocco Creek drainage, is largely forested and mostly in federal ownership within the Talladega National Forest. The biological significance of Shoal Creek and the Choccolocco Creek watershed provided the impetus for their designation as priority areas for freshwater conservation action (Smith et al. 2002). Because aquatic communities of Choccolocco Creek are degraded (Smith et al. 2002), Shoal Creek is important as a potential source of colonists for Choccolocco Creek if conditions improve in that stream. However, a series of small impoundments along Shoal Creek has fragmented the existing fauna into three isolated populations, precluding genetic exchange among segments and lowering the probability of re-colonization of Choccolocco Creek from Shoal creek. Isolation and habitat fragmentation raise serious concerns about the long-term population viability of freshwater mussels and other aquatic organisms in Shoal Creek.

Available data on the Shoal Creek mussel fauna are limited to a qualitative survey of six sites arrayed from near the mouth to the headwaters (Pierson 1992). Quantitative data necessary for assessment of viability and monitoring of this resource are lacking. In 2000 and 2003, we conducted a quantitative survey of two separate segments of Shoal Creek: A) between High Rock and Sweetwater lakes and, B) between Sweetwater and Coleman lakes. For each segment, we had three goals: 1) conduct a segment-wide survey of distribution and abundance of freshwater mussels; 2) estimate total population size of mussels in each segment to evaluate the viability of the populations; and 3) establish a repeatable, quantitative baseline for monitoring of future population trends in the creek.

Study Area

Shoal Creek, a fifth-order tributary of Choccolocco Creek (Coosa River system) in Cleburne and Calhoun counties, Alabama, lies within the Weisner Ridge physiographic district, a high relief (about 400 m elevation) portion of the Valley and Ridge physiographic region (Mettee et al. 1996). The stream drains 122 km^2 and is about 32 km long (Figure 1). The watershed of Shoal Creek is highly dissected with narrow, constricted valleys and is almost completely forested. Stream substrate consists of boulders interspersed with cobbles, gravel, and sand, and limited areas of bedrock. All tributaries to the stream are small, but many are perennial. With the exception of the downstream-most 4 km of the stream, the watershed lies entirely within the proclamation boundary of the Shoal Creek Ranger District, Talladega National Forest, and is almost entirely in federal ownership.

The mainstem of Shoal Creek is fragmented by three impoundments and a fourth occurs on a tributary (Fig. 1). Whitesides Mill Dam lies 2.5 km upstream of the mouth of Shoal Creek and impounds 2.7 km of the mainstem. Highrock Dam is 10.7 km above the mouth and impounds 0.7 km of the mainstem. Sweetwater Dam is located 21.0 km above the mouth and impounds 2.1 km of mainstem. Coleman Dam impounds an unnamed western tributary and lies about 28 km from the mouth. The Pinhoti Trail, a hiking trail, parallels a portion of the creek, and a campground, the Pine Glen Recreation area, is located between High Rock Lake and Sweetwater Dam. Four public roads cross the creek, and the watershed contains a network of gravel and unimproved roads, hiking trails, and horseback trails.

Methods

We estimated mussel abundance and species composition in two segments of Shoal Creek totaling 15.5 stream km. Segment A extended from the upstream terminus of High Rock Lake at Shoal Creek kilometer (SCK) 11.4 to Sweetwater Lake Dam (SCK 21.1) (totaling 9.7 stream km). Segment B extended from the upstream terminus of Sweetwater Lake (SCK 23.1) to SCK 29.1 near Coleman Dam (totaling 6.0 stream km) (Figure 2). We sampled Segment A in July and August 2000 and Segment B in September and October 2003. We did not sample impounded segments of the mainstem (totaling about 5.5 stream km). The impoundments may support lentic-adapted freshwater mussels (e.g., paper pondshell, *Utterbackia imbecillis*), but lotic-adapted species likely do not occur in significant numbers in these habitats. We did not sample any tributaries to Shoal Creek because they are too small to support mussels (Pierson 1992).

We used a Basin Area Visual Estimation Technique (Hankin and Reeves 1988, Dolloff et al. 1993) to delineate and measure all habitat units within segments A and B. We classified each habitat unit as a riffle or a pool (Dolloff et al. 1993). We classified areas with high to moderate gradient, convex or flat stream bottoms, shallow depths, turbulent to smooth surface waters, and fast flow as riffles. The riffle category includes areas intermediate between pools and riffles, which are often classified as runs. We classified deep areas with low gradients, concave stream bottoms, and slow flows as pools. We measured the length (m) and maximum and average depths (cm) and visually classified the dominant and subdominant substrates and the number of pieces of in-stream wood in each unit. We did not use the substrate or in-stream wood information in this study, but these data are included in the raw dataset for potential future use. We visually estimated widths (m) of all units and measured actual widths of every sampled habitat unit.

We used a two-stage, stratified sampling design in which we sampled mussels at every fifth riffle and every tenth pool. We sampled pools less frequently because these habitats generally are assumed to support lower mussel densities than riffles (e.g., Neves and Widlak 1987). At each selected habitat unit (riffle or pool), we sampled a number of transects proportional to the length of the unit. In Segment A, for units ≤ 30 m in length, we sampled two transects. For units > 30 m, we sampled one additional transect for each additional 20 m in length >30. In Segment B more field personnel were available, and we sampled three transects for units ≤ 30 m and sampled two additional transects for each additional 20 m in length >30. Sampled units ranged from 3 to 289 m in length (Table 1, Appendix A). We determined the locations of each transect within the habitat unit by drawing a random number between 0 and the length of the unit in meters. The random number specified the distance from the downstream end of the unit to the location of the transect. We sampled transects by placing a 0.5-m^2 quadrat next to the shore at the starting point, searching the quadrat, then flipping the quadrat end-over-end, perpendicular to the stream channel, to the other shore. Using this approach, we sampled randomly selected cross-sections of stream, and the area sampled for each transect was 0.5-m^2 times the number of quadrats sampled.

We sampled first by visually inspecting the substrate through a view bucket or mask, then moving large rocks, thoroughly disturbing the surface layer substrate with our hands, and inspecting the substrate again to detect partially buried mussels. We identified, measured (nearest 0.1 mm), and released all live mussels at the point of collection (Appendix A). We made an effort to collect all empty shells found within the segment and bagged shells found in each sampled unit separately. We returned shells to the laboratory where we discarded highly weathered shells and identified and enumerated only shells that appeared to have been dead < ~ 1 yr (Haag 2002). We recognized recently-dead shells by the presence of intact periostracum on the exterior of the shell and lustrous nacre inside the shell. We counted but did not measure live Asian clams (*Corbicula fluminea*) encountered in transects. We numbered sampling sites corresponding to Segment A and Segment B (Figure 2).

We calculated estimated population size (τ , and variance) for all species combined and for individual species for each segment and over the entire study area following Thompson (1992) and Hankin and Reeves (1988). We refer to the separate estimates for segments A and B as segment-wide population sizes. We did not estimate population size for *Utterbackia imbecillis* because we found only one live individual. We generated percentile bootstrapped confidence intervals around estimates of segment-wide population size at the 95% and 90% levels (10,000 randomizations). Because population size estimates for freshwater mussels tend to have skewed distributions (Strayer and Smith 2003), we also present the percentage of bootstrapped values that were lower than the segment-wide population estimate. Values > 50% suggest upper and lower bounds are too low, and those < 50% suggest upper and lower bounds are too high (Dixon 2001). We calculated segment-wide mean mussel densities (± 95% confidence intervals) for all species combined following Thompson (1992) and Strayer and Smith (2003). We used randomization for all correlations (Pearson's coefficient, 10,000 randomizations, Manly 1997).

Results

Segment A

We sampled 487 m^2 in Segment A, including 15 pools (250 m^2) and 25 riffles (237 m^2). Pools and riffles represented 74.7% and 25.3%, respectively, of the total habitat area in Segment A (Table 2). Pools were longer, wider, and deeper than riffles.

We found 109 individual freshwater mussels (73 in pools; 36 in riffles) representing six species in quantitative samples from Segment A (Table 3, Appendix A). Species richness in individual pools ranged from 0 to 5 species (mean ± 95% CI, 2.0 ± 0.86) and in riffles from 0 to 4 species (1.1 ± 0.53), but all six of the lotic-adapted species known from the creek (excludes *Utterbackia imbecillus*) occurred in both habitat types. Species richness in habitat units was not related to longitudinal stream position ($r = 0.01$, $p < 0.48$), but high richness values did tend to cluster among habitat units from about SCK 16 – 20 (AP80 to AP130) (Table 3). We encountered live Asian clams in most sampled units in Segment A (Appendix A).

Our estimate of segment-wide population size (all species combined) in Segment A was 18,206 mussels. Two species, *Villosa vibex* and *Strophitus connasaugaensis*, constituted 69.2% of the estimated number of mussels in the segment (Table 4). *Pleurobema georgianum* was the only species with segment-wide population estimates of < 1000 individuals, but lower bounds of 95% confidence intervals were < 500 individuals for all species except *V. vibex* and *S. connasaugaensis.* For all species combined, estimated population size was about five times greater in pools than in riffles (Table 4). Population sizes of *S. connasaugaensis, Villosa lienosa*, and *V. vibex* were an order of magnitude higher in pools than in riffles. Confidence intervals around these estimates did not overlap between habitats for *S. connasaugaensis* or *V. vibex* and overlapped only slightly for *V. lienosa*. In contrast, confidence intervals around estimated population sizes overlapped widely between pools and riffles for *Lampsilis altilis*, *P. georgianum*, and *V. nebulosa.*

Mean segment-wide mussel density for all species combined was 0.20 ± 0.067 individuals m^{-2} (mean ± 95% CI) (pools, 0.30 ± 0.134 individuals m^{-2}; riffles, 0.15 ± 0.083 individuals m^{-2}). Maximum observed density was 0.83 individuals m^{-2} in pools and 0.48

individuals m^{-2} in riffles (Table 1). Mussel density was correlated positively with species richness ($r = 0.686$, $p < 0.0001$) indicating species-rich units tended to have the highest densities. Mussel density was not correlated with longitudinal position of units along the segment ($r = 0.09$, $p < 0.29$).

Length distributions and the percentages of small individuals indicated recent reproduction and recruitment had occurred for all species in Segment A. Minimum length was < 20 mm for all species except *Lampsilis altilis* (Table 5). The percentage of individuals < 20 mm in length was: 5.0%, *Villosa vibex*; 4.2%, *Strophitus connasaugaensis*; 20.0%, *Villosa nebulosa*; 18.2%, *Villosa lienosa*; and 14.3%, *Pleurobema georgianum*. Minimum length of *L. altilis* was 32.5 mm, and 20% of individuals were < 40 mm in length.

We found little evidence of muskrat predation on mussels and, in general, found few recently dead shells in segment A. We collected 67 recently-dead shells in the entire reach (Table 6). Some of the shells had scratches on the exterior surface indicative of muskrat predation, but we observed no intensive muskrat feeding stations in any sampled unit or elsewhere in segment A. All species found in quantitative samples were represented among dead shells and, in addition, we found a single dead shell of *Utterbackia imbecillis* in the upstream portion of the segment near Sweetwater Dam.

Segment B

We sampled 486.0 m^2 in Segment B, including 9 pools (136.5 m^2) and 21 riffles (349.5 m^2). Pools and riffles represented 63.0% and 37.0%, respectively, of the total habitat area in Segment B (Table 2). Pools were longer and deeper, but not wider, than riffles.

We found 76 individual freshwater mussels (18 in pools; 58 in riffles) representing six species in quantitative samples from Segment B (Table 7, Appendix A). Species richness in individual pools ranged from 0 to 3 species (mean ± 95% CI, 1.1 ± 0.83) and in riffles from 0 to 4 species (1.7 ± 0.65). However, all species known from this segment occurred in both habitat types with the exception of *Utterbackia imbecillis*, which was observed only in one pool. Species richness in habitat units was not related to longitudinal stream position ($r = -0.285$, $p < 0.062$) (Table 6). We encountered live Asian clams in most sampled units in Segment B (Appendix A).

Our estimate of segment-wide population size (all species combined) in Segment B was 6,074 mussels. Two species, *Strophitus connasaugaensis* and *Villosa nebulosa*, constituted 60.4% of the estimated number of mussels in the segment and were the only species with segment-wide population estimates > 1000 (Table 8). Lower bounds of 95% confidence intervals were < 500 individuals for all species except *S. connasaugaensis.* Confidence intervals around estimated total population sizes overlapped widely between pools and riffles for all species combined and for all individual species.

Mean segment-wide mussel density for all species combined was 0.15 ± 0.064 individuals m^{-2} (mean ± 95% CI) (pools, 0.14 ± 0.132 individuals m^{-2}; riffles, 0.16 ± 0.074 individuals m^{-2}). Maximum observed density was 0.62 individuals m^{-2} in pools and 0.53 individuals m^{-2} in riffles (Table 1). Density was correlated positively with species richness ($r = 0.819$, $p < 0.0001$) but not longitudinal position of units along the segment ($r = 0.206$, $p < 0.136$).

Length distributions and percentages of small individuals indicated recent reproduction and recruitment had occurred for all species in Segment B. Minimum length was < 30 mm for all species except *Lampsilis altilis* (Table 5). The percentage of individuals < 30 mm in length were: 10.0%, *Villosa vibex*; 3.4% *Strophitus connasaugaensis*; 9.5%, *Villosa nebulosa*; and 16.7%, *Villosa lienosa*. Minimum length of *L. altilis* was 35.2 mm, and 11% of individuals were < 40 mm in length.

We found evidence of intense muskrat predation on mussels in segment B. We collected 786 recently-dead shells in the segment. Although we did not record the provenance of each shell, the vast majority came from muskrat feeding stations which were conspicuous and common throughout the segment. We collected 252 recently-dead shells (all species combined) in all sampled habitat units, an average of 8.4 (± 2.3 SE) shells/unit, and a maximum of 58 shells in a single unit (Table 6). In the remainder of the segment outside of sampled reaches, we collected 534 shells, again, mostly from muskrat feeding stations. All species found alive in quantitative samples in the segment except *Utterbackia imbecillis* were represented in muskrat feeding stations.

Discussion

Our survey of freshwater mussels of Shoal Creek was successful in documenting distribution and abundance of the fauna throughout the entire length and between habitat types in Segments A and B. We also were able to estimate population sizes for the entire fauna as well as provide reasonably precise estimates for population size of individual species. The survey provides a quantitative, repeatable baseline for monitoring of future population trends. Our survey and subsequent analysis highlighted considerations for: interpretation of population estimates; execution of future surveys; and diversity, distribution, viability, and conservation of the fauna.

Interpretation of Population Estimates

Interpretation of our estimates of population sizes in Shoal Creek should be made with the following considerations. First, the precision of population estimates was low for some species. In particular, the lower bounds of the 90% or 95% confidence intervals included zero for riffle or pool habitats of several species in both segments. Nevertheless, lower bounds of confidence intervals for segment-wide population estimates included zero for only one species (*Villosa lienosa*, Segment B). Second, the percent of bootstrap values less than the population estimates for most species were close to 50%, supporting reliability of bounds for bootstrapped percentile confidence intervals. For other species, the values were well above or below 50% indicating our estimated confidence intervals for specific habitat types are unreliably high or low (e.g., *Lampsilis altilis*, pools, Segment B.)

Issues for Future Surveys

Both pool and riffle habitats along the entire lengths of both segments clearly are important for the mussel fauna. We incorrectly assumed that pool habitats would support fewer mussels than riffle habitats (e.g., Neves and Widlak 1987), and by design, we sampled a higher percentage of riffles than pools. In fact, mussel species richness and density in pools were higher than or comparable to that observed in riffles in both segments. We emphasize, however, that application of our pool and riffle habitat definitions in Shoal Creek segregated units primarily based on bottom contour and surface turbulence. Although depths were different in the two habitat types in both segments, the difference in mean depth was only about 20 cm and that of mean maximum depth only about 34 cm. In Shoal Creek, there were few deep, silty pools that are poor habitat for stream-dwelling mussels. Future surveys and management activities should consider all habitat units throughout the lengths of both segments as important for the freshwater mussel community.

Our survey was limited to two, isolated stream segments upstream of High Rock Lake, and did not include stream segments downstream of Segment A that encompass about 34% of existing stream habitats in Shoal Creek. The un-surveyed, isolated segment sandwiched between High Rock Dam and Whitesides Mill Lake constitutes about 5.5 km of potential mussel habitat. Another 2.8 km of un-surveyed habitat exists downstream of Whitesides Mill Dam. Live individuals or shells of all mussel species known from Shoal

Creek (except *Utterbackia imbecillis*) were observed previously downstream of High Rock dam, and shells of two species were noted downstream of Whitesides Mill dam (Pierson 1992). The potential or realized contribution of these segments to the total population size of mussel species and their conservation in the Shoal Creek system needs to be documented. We recommend that these segments be quantitatively surveyed as soon as possible.

Diversity, Distribution, Viability, and Conservation of the Fauna

The species richness of mussels, spatial distribution of species, and lengths of individuals suggest that despite isolation, reproducing mussel communities persist in Segment A and Segment B. All but two species occurred widely in riffle and pool habitats in both segments, and nearly all species occurred together in at least some habitat units in both segments. *Pleurobema georgianum* occurred only in Segment A but was widespread within the segment. Likewise, small minimum lengths and relatively high percentages of small individuals indicate successful recruitment of mussels in both segments. Our discovery of *Utterbackia imbecillis* in Shoal Creek increases the known fauna to seven species. This species likely entered the drainage as larvae attached to fishes stocked in the reservoirs. Although rare in un-impounded sections of Shoal Creek, we expect it is common in the reservoirs. We acknowledge that the densities of freshwater mussels observed in both segments of Shoal Creek are low relative to those observed in many stream systems. We suspect, however, that the low densities are natural and may reflect low productivity in headwater streams like Shoal Creek. Nevertheless, despite evidence indicating an intact, reproducing community of mussels, the low density levels coupled with isolation are cause for concern.

Segment-wide population sizes for most species are at or near the ostensible minimum for long-term persistence in Segments A and B of Shoal Creek notwithstanding evidence of continued recruitment. Determination of minimum viable population size requires detailed demographic and genetic information not currently available for most freshwater mussel species or for most rare organisms. A widely used order-of-magnitude guideline for conservation purposes is that a minimum effective population size ($N_{e\ critical}$) of 50 is necessary for short-term population conservation, and a $N_{e\ critical}$ of 500 is necessary for long-term conservation (Hallerman 2003). These are reasonable guidelines for freshwater mussels because long-lived species that live in stable environments and do not exhibit wild, cyclical population fluctuations (likely characteristics of many mussel species) generally have lower minimum viable population sizes than fluctuating species (Hallerman 2003). Further, preliminary modeling of freshwater mussel extinction trajectories showed that the probability of survival is high for populations ≥ 1000 individuals but decreases sharply for populations < 500 (Haag 2002). Nevertheless, minimum viable population size may be much higher depending on factors that influence N_e and population growth rate. For mussels, these factors include sex ratio of the population, the number of females that reproduce each year, the distance viable sperm can be carried by stream currents, survivorship of juvenile mussels, and periodic high mortality rates. Importantly, isolated populations near $N_{e\ critical}$ are highly vulnerable to environmental fluctuations and catastrophic events.

Segment-wide population estimates suggest most mussel species in both segments are highly vulnerable to environmental fluctuations and catastrophic events. Lower bounds of estimated confidence intervals for segment-wide estimates of population sizes were < 500 for all species in Segment B except *Strophitus connasaugaensis* and for three species in Segment A (*Lampsilis altilis*, *Pleurobema georgianum*, and *Villosa lienosa*). The two federally listed species, *P. georgianum* and *L. altilis*, are of primary conservation concern. *Pleurobema georgianum* is restricted to Segment A with an estimated population of < 1000 individuals and lower bounds of confidence intervals were << 500. Importantly, the population of *P. georgianum* in Shoal Creek (as one of only four known, USFWS 2003) may be the best remaining population of the species on Earth. Although *L. altilis* occurs in both segments, segment-wide population size estimates and confidence intervals indicate vulnerability in both segments. A catastrophic event or the chance juxtaposition of several smaller natural or human-induced impacts to the mussel fauna (e.g., drought, sustained heavy muskrat predation, chemical spill, dam failure) could reduce populations to below minimum viable levels which, in the absence of sources of re-colonization, would result in a slow but unrecoverable downward spiral.

We observed heavy muskrat predation on mussels in Segment B, but the impact of muskrat predation on mussel population dynamics is unknown. At the site where we observed the most intense muskrat predation (BR30), muskrats had removed an estimated 61% of the local population; across all sites, muskrats had removed an average of 25% of local populations. Although the rates of predation observed in 2003 are obviously unsustainable in the long-term, the year-to-year variation in muskrat predation is a critical but unknown variable in this relationship. Sustained, heavy predation pressure by muskrats at a single location likely is rare. Under a premise of optimal foraging, muskrats would move to a new area as the mussel resource in any particular area is reduced but before local extinction of mussels occurs. In the Sipsey River, Alabama, we observed heavy muskrat predation pressure in only one out of five years of consecutive monitoring at one site and not at all at another site (Haag and Warren unpublished data). These observations lend support to the idea of high year-to-year variability in muskrat predation on mussels and the sustainability of such predation in an interconnected stream network conducive to mussel re-colonization. Because of the isolated and fragmented nature of Shoal Creek, the long-term survival of the relatively small mussel populations in either segment may be threatened by natural processes, such as muskrat predation, if populations remain isolated.

The most tangible and manifest threat to long-term persistence of the mussel fauna in Shoal Creek is the fragmentation of the stream by a series of dams and impoundments. In an impoundment-free scenario, an additional 5.5-stream km of mussel habitat that is now reservoir bottom would be available to the mussel fauna. As a result, the relatively small, currently isolated populations would be joined into a single, larger panmictic population covering 26.2 stream km, and connectivity with Choccolocco Creek would be restored. The consideration of the full range of costs and benefits of dam removal, the attendant risks of action or inaction, and the possible alternatives is beyond the scope of our analysis. An important consideration for any conservation plan in the watershed is the extent to which the lower, un-surveyed segments of Shoal Creek can or could potentially contribute to the viability of the aquatic fauna. The viability of the mussel fauna needs to be considered in the context of the entire stream, not just the segments we analyzed in this report.

Acknowledgments

The study was supported by the USDA Forest Service: Southern Research Station, Center for Bottomland Hardwoods Research and the Center for Aquatic Technology; Southern Regional Office, Biological and Physical Resources; Alabama National Forests, Talladega National Forest, Shoal Creek Ranger District. We are indebted to the Center for Aquatic Technology Transfer, Shoal Creek Ranger District, Southern Region, and Alabama Forestry Commission for providing personnel for field work. For administrative and logistical support, we thank Kevin Leftwich, Craig Roghair, and Earl Stewart. Gordon McWhirter prepared the figures and with Amy Commens entered and proofed the data. For field assistance, we thank Derek Adams, Bryan Cage, Amy Commens, Jeff Gardner, Kevin Leftwich, Ryan Prince, Ryan

Shurette, Leann Staton, Earl Stewart, Rhonda Stewart, Craig Roghair, and the 2003 Center for Aquatic Technology Field Crew.

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Table 1. Sample site locations, lengths, area sampled, habitat unit areas, and mussel densities in pool and riffle units of Segments A and B of Shoal Creek, Shoal Creek Ranger District, Talladega National Forest, Alabama. SCK is Shoal Creek kilometer, measured upstream from the mouth. Units in each segment are arranged from downstream to upstream and referenced in Figure 2.

Sample unit	SCK	Latitude (N)	Longitude (W)	Unit Length (m)	Area sampled (m^2)	Unit area (m^2)	Estimated total mussel density (number · m^2)
				Segment A			
Pools							
AP10	12.29	33°43”19’	85°37”15’	9	9.00	74.80	0.000
AP20	12.72	33°43”29’	85°37”07’	24	8.00	197.64	0.250
AP30	13.28	33°43”24’	85°36”54’	18	10.50	136.80	0.095
AP40	13.98	33°43”31’	85°36”43’	31	20.75	329.56	0.000
AP50	14.47	33°43”44’	85°36”36’	58	5.00	46.90	0.400
AP60	15.21	33°43”22’	85°36”35’	18	9.00	235.80	0.667
AP70	15.73	33°43”19’	85°36”22’	9	7.50	44.00	0.000
AP80	16.43	33°43”32’	85°36”06’	17	14.00	201.84	0.571
AP90	16.99	33°43”26’	85°35”47’	64	41.75	790.89	0.192
AP100	17.37	33°43”38’	85°35”44’	31	22.50	343.20	0.489
AP110	18.05	33°44”00’	85°35”40’	24	10.00	212.08	0.300
AP120	18.96	33°44”24’	85°35”42’	140	39.50	1664.81	0.203
AP130	19.57	33°44”18’	85°35”23’	104	39.75	750.96	0.453
AP140	19.98	33°44”23’	85°35”21’	7	5.50	28.56	0.000
AP150	20.63	33°44”28’	85°35”14’	13	7.25	83.08	0.828
Riffles							
AR05	11.94	33°43”13’	85°37”05’	22	8.00	83.60	0.250
AR10	12.33	33°43”23’	85°37”16’	22	7.00	129.21	0.000
AR15	12.69	33°43”27’	85°37”07’	20	8.00	78.00	0.125
AR20	13.01	33°43”32’	85°36”58’	38	11.50	226.56	0.087
AR25	13.34	33°43”22’	85°36”53’	58	14.25	302.64	0.140
AR30	13.73	33°43”24’	85°36”50’	24	13.00	110.45	0.308
AR35	14.07	33°43”34’	85°36”43’	57	16.75	332.34	0.239
AR40	14.30	33°43”40’	85°36”40’	35	12.50	337.40	0.080
AR45	14.48	33°43”44’	85°36”35’	11	6.25	47.30	0.320
AR50	15.00	33°43”29’	85°36”36’	21	7.00	120.06	0.000
AR55	15.43	33°43”20’	85°36”31’	25	7.75	175.00	0.129
AR60	15.67	33°43”17’	85°36”22’	52	21.00	597.40	0.048
AR65	16.20	33°43”32’	85°36”15’	18	10.00	131.76	0.100
AR70	16.70	33°43”25’	85°35”57’	32	4.00	136.30	0.500
AR75	17.09	33°43”30’	85°35”44’	26	5.75	322.50	0.057
AR80	17.39	33°43”39’	85°35”44’	19	12.75	156.62	0.392

AR85	17.79	33°43”51’	85°35”39’	37	10.50	214.02	0.476
AR90	18.08	33°44”02’	85°35”40’	28	4.50	243.76	0.000
AR95	18.57	33°44”14’	85°35”48’	13	8.13	75.98	0.000
AR100	19.03	33°44”25’	85°35”39’	6	8.25	35.20	0.364
AR105	19.25	33°44”23’	85°35”33’	15	7.50	81.20	0.000
AR110	19.82	33°44”18’	85°35”18’	49	9.38	241.57	0.000
AR120	20.17	33°44”29’	85°35”22’	28	8.75	136.22	0.000
AR125	20.53	33°44”31’	85°35”17’	8	8.00	61.40	0.000
AR130	20.77	33°44”27’	85°35”09’	18	6.50	82.72	0.000
				Segment B			
Pools							
BP10	23.50	33°45”22’	85°34”06’	46	23.50	530.15	0.213
BP20	25.91	33°45”32’	85°34”17’	15	8.50	92.80	0.000
BP30	25.76	33°45”48’	85°34”07’	15	6.50	57.00	0.615
BP40	26.20	33°45”45’	85°33”53’	11	9.50	71.69	0.000
BP50	26.88	33°46”00’	85°33°37’	29	14.00	222.30	0.071
BP60	27.49	33°46”02’	85°33°16’	58	23.00	356.50	0.000
BP70	27.94	33°46”15’	85°33°21’	49	26.00	370.50	0.115
BP80	28.53	33°46”28’	85°33°24’	67	21.00	498.76	0.238
BP90	29.25	33°46”45’	85°33°17’	14	4.50	42.16	0.000
Riffles							
BR05	23.65	33°45”08’	85°34”23’	22	23.00	205.20	0.043
BR10	23.78	33°45”07’	85°34”20’	16	22.50	141.10	0.444
BR15	23.97	33°45”12’	85°34”16’	26	17.50	186.20	0.171
BR20	24.43	33°45”24’	85°34”04’	10	19.00	70.29	0.158
BR25	24.68	33°45”27’	85°34”10’	25	17.00	181.04	0.529
BR30	25.01	33°45”28’	85°34”17’	38	31.50	294.84	0.127
BR35	25.15	33°45”35’	85°34”16’	24	20.50	222.78	0.098
BR40	25.33	33°45”39’	85°34”10’	29	12.00	195.64	0.167
BR45	25.64	33°45”45’	85°34”04’	21	16.50	147.70	0.242
BR50	25.97	33°45”48’	85°34”02’	9	16.00	63.00	0.000
BR55	26.22	33°45”45’	85°33”52’	12	18.50	79.06	0.000
BR60	26.46	33°45”51’	85°33”48’	12	14.00	56.40	0.214
BR65	26.78	33°45”58’	85°33”39’	21	19.00	150.50	0.211
BR70	27.01	33°46”00’	85°33”33’	11	8.00	36.80	0.000
BR75	27.21	33°46”03’	85°33”27’	15	18.50	71.91	0.000
BR80	27.71	33°46”10’	85°33”14’	45	25.50	394.98	0.078
BR85	27.89	33°46”13’	85°33”19’	9	8.50	27.59	0.000
BR90	28.18	33°46”23’	85°33”19’	8	21.50	62.40	0.326
BR95	28.58	33°46”31’	85°33”24’	17	7.50	99.12	0.533

BR100	28.93	33°46”43’	85°33”25’	12	8.00	60.95	0.000
BR105	29.24	33°46”45’	85°33”18’	11	5.00	42.90	0.000

Table 2. Summary of physical features of riffle and pool habitats surveyed from Segment A (km 11.4 – 21.1) and Segment B (km 23.1– 29.1) in Shoal Creek, Shoal Creek Ranger District, Talladega National Forest, Alabama, July and August 2000 and September and October 2003.

	Area (m^2)	**Length (m)**	**Width (m)**	**Depth (cm)**	**Max Depth (cm)**
			Segment A		
Riffles (n = 134)					
Total	21976.64	3451.4			
Mean	164.0	25.8	6.4	15.8	30.7
SD	145.07	19.21	2.40	6.50	10.54
95% Confidence Interval	24.56	3.25	0.41	1.10	1.78
Pools (n = 153)					
Total	65003.39	6342.5			
Mean	424.9	41.5	9.1	36.9	64.4
SD	577.45	43.64	2.56	19.88	32.84
95% Confidence Interval	91.50	6.91	0.41	3.15	5.20
			Segment B		
Riffles (n = 111)					
Total	13845.78	2229.2			
Mean	125.9	20.3	5.9	17.5	29.3
SD	100.9	14.1	1.7	4.5	7.7
95% Confidence Interval	18.9	2.6	0.3	0.8	1.4
Pools (n = 97)					
Total	23599.36	3501.6			
Mean	245.8	36.5	6.1	38.9	63.3
SD	27.51	2.12	0.71	24.75	38.89
95% Confidence Interval	5.50	0.42	0.14	4.93	7.74
			Segments Combined		
Riffles (n = 245)					
Total	35822.42	5680.6			
mean	146.2	23.2	6.2	16.6	30.1
SD	128.34	17.29	2.13	5.73	9.36
95% Confidence Interval	16.07	2.17	0.27	0.72	1.17
Pools (n = 250)					
Total	88602.75	9844.1			
Mean	354.4	39.4	7.9	37.7	64.0
SD	22.92	5.44	0.07	31.82	35.36
95% Confidence Interval	2.84	0.67	0.01	3.94	4.38

Table 3. Occurrence and number of species in quantitative samples of habitat units in Segment A (km 11.4 – 21.1), Shoal Creek, Shoal Creek Ranger District, Talladega National Forest, Alabama. Sample unit locations are arranged from downstream to upstream and are referenced in Figure 2 and Table 1. P = present in quantitative samples; a dash indicates a species was not detected in that unit.

Sample unit	V. vibex	S. connasaugaensis	V. lienosa	V. nebulosa	L. altilis	P. georgianum	No. spp.
AR05	P	-	-	-	-	P	2
AP10	-	-	-	-	-	-	0
AR10	-	-	-	-	-	-	0
AR15	-	P	-	-	-	-	1
AP20	P	P	-	-	-	-	2
AR20	P	-	-	-	-	-	1
AP30	-	-	-	-	P	-	1
AR25	P	-	-	-	-	P	2
AR30	P	P	-	-	-	-	2
AP40	-	-	-	-	-	-	0
AR35	-	-	-	P	P	-	2
AR40	P	-	-	-	-	-	1
AP50	P	-	-	-	-	-	1
AR45	P	-	P	-	-	-	2
AR50	-	-	-	-	-	-	0
AP60	P	-	-	P	-	-	2
AR55	-	-	-	P	-	-	1
AR60	-	-	-	P	-	-	1
AP70	-	-	-	-	-	-	0
AR65	-	-	-	-	-	P	1
AP80	P	P	P	P	-	-	4
AR70	-	-	-	P	-	P	2
AP90	P	P	P	P	-	-	4
AR75	-	-	-	P	P	-	2
AP100	P	P	P	-	P	P	5
AR80	-	P	P	-	P	P	4
AR85	-	P	-	-	-	-	1
AP110	P	P	-	-	-	-	2
AR90	-	-	-	-	-	-	0
AR95	-	-	-	-	-	-	0
AP120	P	P	P	-	-	-	3
AR100	P	-	-	P	-	-	2
AR105	-	-	-	-	-	-	0
AP130	P	P	-	P	P	-	4
AR110	-	-	-	-	-	-	0

AP140	-	-	-	-	-	-	0
AR120	-	-	-	-	-	-	0
AR125	-	-	-	-	-	-	0
AP150	P	-	-	-	P	-	2
AR130	-	-	-	-	-	-	0

Table 4. Estimates of segment-wide population size of freshwater mussels in Segment A (km 11.4 – 21.1), Shoal Creek, Shoal Creek Ranger District, Talladega National Forest, Alabama. Population estimates (τ and standard deviation, SD) were made for species found alive in quantitative samples.

				Confidence Intervals				
Segment A		**Estimated population size (τ)**	**SD**	**90% lower**	**90% upper**	**95% lower**	**95% upper**	**% of bootstrap values < τ**
Villosa vibex	Riffle	643	233.5	282	1045	228	1127	51.7
southern rainbow	Pool	7156	2590.1	3241	11755	2704	12693	52.4
	Segment-wide	7799	2823.6	3523	12800	2932	13821	NA
Strophitus connasaugaensis	Riffle	382	213.8	66	812	46	904	54.3
Alabama creekmussel	Pool	4425	1512.9	2089	7038	1714	7586	52.0
	Segment-wide	4808	1726.7	2155	7850	1760	8490	NA
Villosa lienosa	Riffle	172	123.5	0	436	0	476	48.8
little spectaclecase	Pool	2134	1315.8	386	4491	294	5025	54.3
	Segment-wide	2307	1439.2	386	4927	294	5501	NA
Villosa nebulosa	Riffle	896	390.8	319	1573	228	1733	52.9
Alabama rainbow	Pool	1362	668.8	386	2530	193	2772	50.5
	Segment-wide	2257	1059.6	705	4103	422	4505	NA
Lampsilis altilis	Riffle	391	238.3	66	828	0	934	51.5
finelined pocketbook	Pool	908	437.3	234	1678	156	1830	52.8
	Segment-wide	1298	675.6	300	2506	156	2764	NA
Pleurobema georgianum	Riffle	489	217.7	168	894	114	971	51.5
southern pigtoe	Pool	311	298.1	0	934	0	934	35.1
	Segment-wide	800	515.8	168	1828	114	1905	NA
Total unionids	Riffles	3082	726.9	1947	4355	1749	4601	51.7
	Pools	15123	4343.7	8390	22738	7321	24239	51.6
	Segment-wide	18206	5070.5	10337	27093	9070	28841	NA

Table 5. Lengths of freshwater mussels by species encountered in quantitative sampling of Segments A (km 11.4 – 21.1) and B (km 23.1– 29.1) of Shoal Creek, Shoal Creek Ranger District, Talladega National Forest, Alabama.

Species	**n**	**Minimum (mm)**	**Maximum (mm)**	**Mean (mm)**	**SD**	**95% Confidence Interval**
Lampsilis altilis						
Segment A	10	32.5	84.6	61.4	17.07	10.58
Segment B	9	35.2	57.3	47.8	7.31	4.77
Pleurobema georgianum						
Segment A	7	14.1	49.9	32.3	12.21	9.04
Strophitus connasaugaensis						
Segment A	24	19.5	87.5	50.2	18.21	7.28
Segment B	29	22.1	104.4	59.0	15.92	16.55
Villosa lienosa						
Segment A	11	18.5	44.6	33.5	9.20	5.43
Segment B	6	28.8	43.8	38.2	6.02	4.82
Villosa nebulosa						
Segment A	15	16.0	53.9	34.3	11.56	5.85
Segment B	21	20.7	61.4	40.4	10.18	4.35
Villosa vibex						
Segment A	40	18.6	83.1	51.3	18.01	5.58
Segment B	10	21.9	63.4	50.3	13.91	8.62

Table 6. Recently dead shells collected from Segments A (km 11.4-21.1) and B (km 23.1-29.1) of Shoal Creek, Shoal Creek Ranger District, Talladega National Forest, Alabama, July and August 2000 and September and October 2003.

Species	Mean no. of shells · habitat unit^{-1} (SE)	Maximum no. of shells ·habitat unit^{-1}	Total no. of shells
Segment A			
Entire segment			
Lampsilis altilis	-	-	5
Strophitus connasaugaensis	-	-	16
Pleurobema georgianum	-	-	6
Utterbackia imbecillis	-	-	1
Villosa lienosa	-	-	8
V. nebulosa	-	-	11
V. vibex	-	-	20
All species combined	-	-	67
Segment B			
Within sampled habitat units			
Lampsilis altilis	0.6 (0.2)	4	19
Strophitus connasaugaensis	4.0 (1.4)	36	119
Villosa lienosa	0.9 (0.3)	7	28
V. nebulosa	1.2 (0.4)	5	37
V. vibex	1.6 (0.4)	9	49
All species combined	8.4 (2.3)	58	252
Outside sampled habitat units			
Lampsilis altilis	-	-	82
Strophitus connasaugaensis	-	-	145
Villosa lienosa	-	-	80
V. nebulosa	-	-	98
V. vibex	-	-	129
All species combined	-	-	534

Table 7. Occurrence and number of species in quantitative samples of habitat units in Segment B (km 23.1– 29.1), Shoal Creek, Shoal Creek Ranger District, Talladega National Forest, Alabama. Sample unit locations are arranged from downstream to upstream and are referenced in Figure 2 and Table 1. P = present in quantitative samples; a dash indicates a species was not detected in that unit.

Sample unit	V. nebulosa	S. connasaugaensis	V. vibex	L. altilis	V. lienosa	U. imbecillis	No. spp.
BR05	P	-	-	-	-	-	1
BR10	P	P	P	P	-	-	4
BR15		P	P	-	-	-	2
BP10	P	P	-	-	P	-	3
BR20	P	P	-	P	-	-	3
BR25	P	P	P	P	-	-	4
BR30	P	-	-	P	-	-	2
BP20	-	-	-	-	-	-	0
BR35	P	P	-	-	-	-	2
BR40	P	-	-	P	-	-	2
BR45	P	P	-	-	-	-	2
BP30	P	P	-	-	-	-	2
BR50	-	-	-	-	-	-	0
BP40	-	-	-	-	-	-	0
BR55	-	-	-	-	-	-	0
BR60	-	P	-	-	-	-	1
BR65	-	-	P	P	P	-	3
BP50	-	-	-	P	-	-	1
BR70	-	-	-	-	-	-	0
BR75	-	-	-	-	-	-	0
BP60	-	-	-	-	-	-	0
BR80	P	-	P	-	-	-	2
BR85	-	-	-	-	-	-	0
BP70	-	P	-	-	-	-	1
BR90	P	P	P	-	P	-	4
BP80	-	P	P	-	-	P	3
BP90	-	-	-	-	-	-	0
BR95	P	-	P	P	P	-	4
BR100	-	-	-	-	-	-	0
BR105	-	-	-	-	-	-	0

Table 8. Estimates of segment-wide population size of freshwater mussels in Segment B (km 23.1– 29.1), Shoal Creek, Shoal Creek Ranger District, Talladega National Forest, Alabama. Population estimates (τ and standard deviation, SD) were made for species found alive in quantitative samples.

				Confidence Intervals				
Segment B		**Estimated population size (τ)**	**SD**	**90% lower**	**90% upper**	**95% lower**	**95% upper**	**% of bootstrap values < τ**
Strophitus connasaugaensis	Riffle	767	260.3	356	1235	292	1324	52.5
Alabama creekmussel	Pool	1392	609.5	461	2390	378	2595	48.7
	Segment-wide	2159	869.8	816	3625	671	3919	NA
Villosa nebulosa	Riffle	839	218.9	497	1212	436	1291	50.7
Alabama rainbow	Pool	675	484.8	0	1540	0	1650	47.0
	Segment-wide	1515	703.7	497	2752	436	2941	NA
Villosa vibex	Riffle	430	145.1	204	671	164	727	50.6
southern rainbow	Pool	256	254.0	0	768	0	768	33.9
	Segment-wide	686	399.1	204	1438	164	1495	NA
Lampsilis altilis	Riffle	406	143.0	188	654	151	706	51.9
finelined pocketbook	Pool	171	168.5	0	513	0	513	93.0
	Segment-wide	577	311.6	188	1167	151	1220	NA
Villosa lienosa	Riffle	127	77.9	15	267	0	296	51.2
little spectaclecase	Pool	243	240.9	0	729	0	729	34.2
	Segment-wide	370	318.8	15	996	0	1025	NA
Total unionids	Riffles	2569	576.0	1615	3584	1474	3820	51.9
	Pools	3506	1505.7	1264	6079	891	6585	51.7
	Segment-wide	6074	2081.8	2879	9663	2366	10405	NA

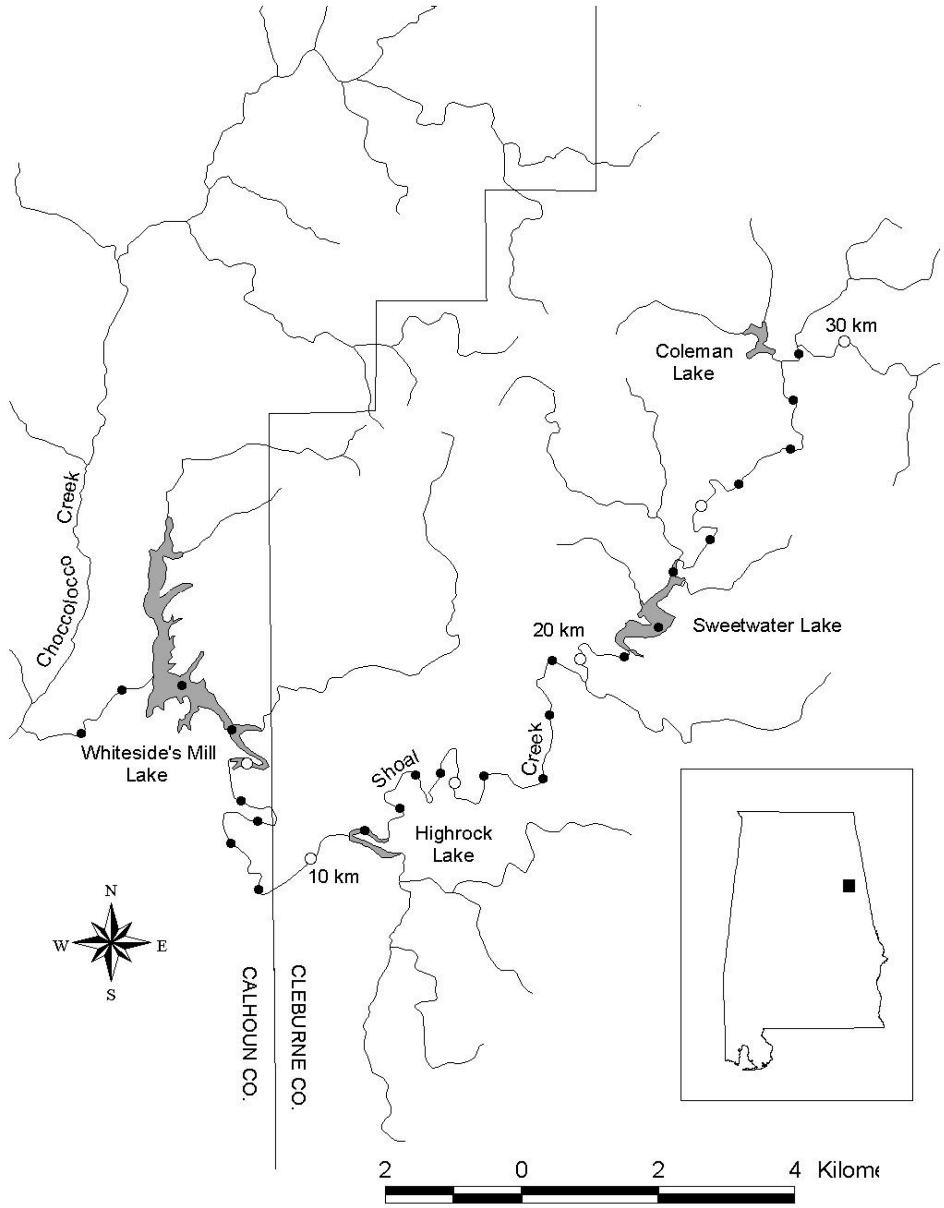

Figure 1. Shoal Creek watershed and vicinity, Talladega National Forest, Alabama. Circles indicate approximate stream kilometers. Solid circles are at intervals of 1 stream km and open circles at intervals of 5 stream km.

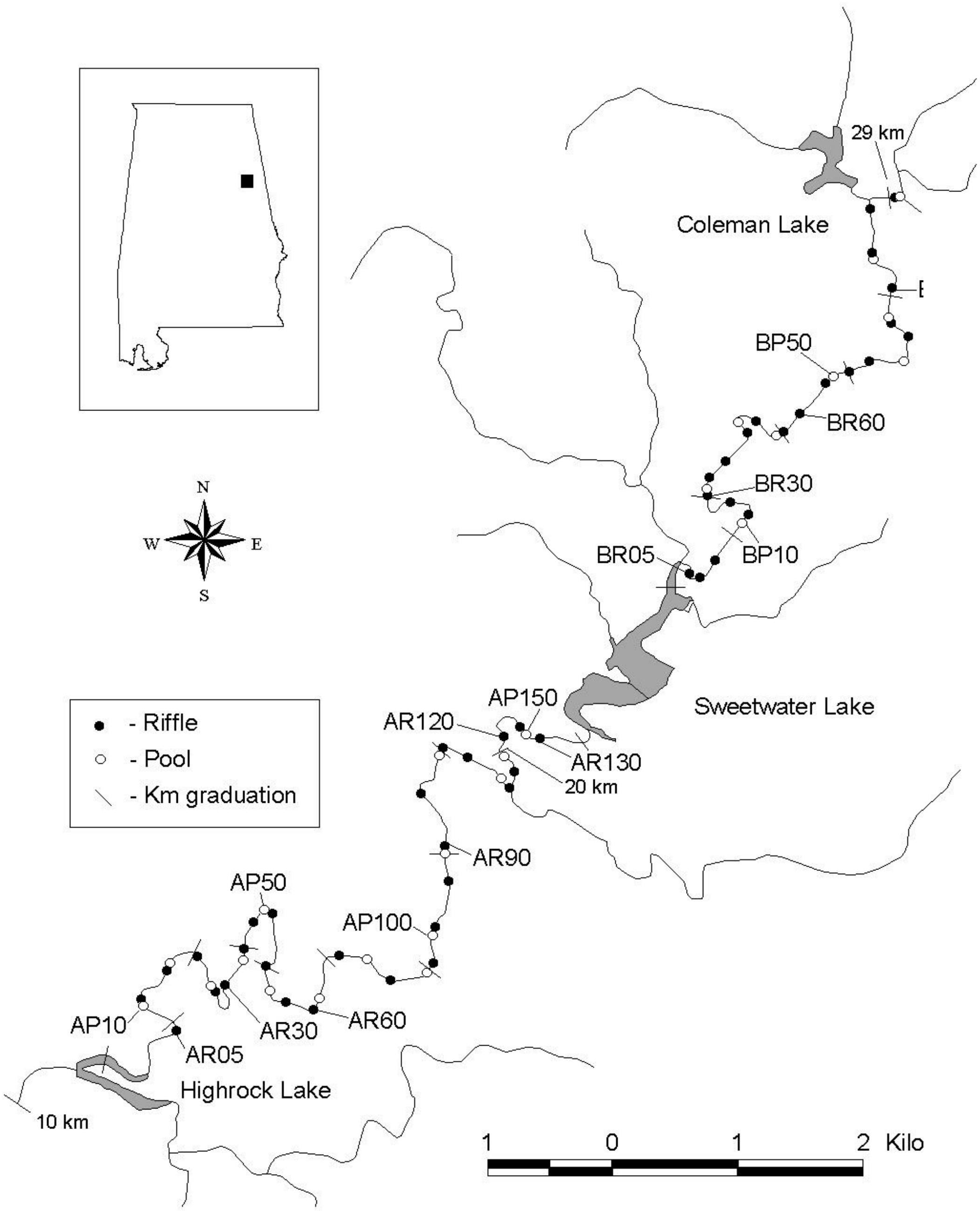

Figure 2. Approximate locations of riffle and pool habitat units sampled for freshwater mussels in Shoal Creek, Talladega National Forest, Alabama. Alpha-numeric site numbers are referenced in Table 1 and Appendix A.

Appendix A. Raw data for quantitative mussel survey of Segments A (km 11.4 – 21.1) and B (km 23.1– 29.1) in Shoal Creek, Shoal Creek Ranger District, Talladega National Forest, Alabama, July and August 2000 (Section A) and September and October 2003 (Section B). Alpha-numeric habitat unit numbers beginning with A and B are located in Segments A and B, respectively.

Species abbreviations are: CFLU = *Corbicula fluminea*; LALT = *Lampsilis altilis*; PGEO = *Pleurobema georgianum*; SCON = *Strophitus connasaugaensis*; UIMB = *Utterbackia imbecillis*; VLIE = *Villosa lienosa*; VNEB = *Villosa nebulosa*; VVIB = *Villosa vibex*; NONE = no bivalves.

Habitat Unit		Unit Length (m)	Transect	Area sampled (m^2)	Species	Length (mm) of unionids	Number of Corbicula
AR005	Riffle	22	1	3	NONE		
AR005	Riffle	22	2	4	PGEO	49.9	
AR005	Riffle	22	2	4	VVIB	49.4	
AR010	Riffle	22	1	4	NONE		
AR010	Riffle	22	2	3	NONE		
AR015	Riffle	20	1	5.5	CFLU		3
AR015	Riffle	20	1	5.5	SCON	37.7	
AR015	Riffle	20	2	2.5	CFLU		2
AR020	Riffle	38	1	4.5	CFLU		3
AR020	Riffle	38	2	3.5	NONE		
AR020	Riffle	38	3	3.5	CFLU		5
AR020	Riffle	38	3	3.5	VVIB	60.8	
AR025	Riffle	58	1	3.5	VVIB	49.1	
AR025	Riffle	58	2	5.25	NONE		
AR025	Riffle	58	3	3	CFLU		3
AR025	Riffle	58	4	2.5	CFLU		5
AR025	Riffle	58	4	2.5	PGEO	37.2	
AR030	Riffle	24	1	4.5	NONE		
AR030	Riffle	24	2	4	CFLU		2
AR030	Riffle	24	2	4	SCON	41.0	
AR030	Riffle	24	2	4	VVIB	53.2	
AR030	Riffle	24	2	4	VVIB	55.7	
AR030	Riffle	24	2	4	VVIB	55.7	
AR030	Riffle	24	3	4.5	NONE		
AR035	Riffle	57	1	4.75	CFLU		18
AR035	Riffle	57	1	4.75	SPHA		1
AR035	Riffle	57	2	5.5	CFLU		21
AR035	Riffle	57	2	5.5	VNEB	53.9	
AR035	Riffle	57	2	5.5	VNEB	53.1	
AR035	Riffle	57	3	4	NONE		
AR035	Riffle	57	4	2.5	CFLU		8
AR035	Riffle	57	4	2.5	LALT	51.2	
AR035	Riffle	57	4	2.5	VNEB	40.3	
AR040	Riffle	35	1	4.5	CFLU		2
AR040	Riffle	35	1	4.5	VVIB	48.0	
AR040	Riffle	35	2	3	NONE		
AR040	Riffle	35	3	5	NONE		
AR045	Riffle	11	1	2.25	CFLU		1
AR045	Riffle	11	2	4	VLIE	44.6	
AR045	Riffle	11	2	4	VVIB	65.4	
AR050	Riffle	21	1	4	CFLU		7

Appendix A	continued						
Habitat Unit		Unit Length (m)	Transect	Area sampled (m^2)	Species	Length (mm) of unionids	Number of Corbicula
AR050	Riffle	21	2	3	SPHA		1
AR055	Riffle	25	1	3.75	CFLU		34
AR055	Riffle	25	1	3.75	VNEB	35.4	
AR055	Riffle	25	2	4	CFLU		9
AR060	Riffle	52	1	2.5	CFLU		20
AR060	Riffle	52	2	6	CFLU		23
AR060	Riffle	52	3	6	CFLU		12
AR060	Riffle	52	3	6	SPHA		1
AR060	Riffle	52	3	6	VNEB	35.0	
AR060	Riffle	52	4	6.5	CFLU		30
AR065	Riffle	18	1	5	CFLU		30
AR065	Riffle	18	1	5	PGEO	14.1	
AR065	Riffle	18	2	5	CFLU		2
AR070	Riffle	32	1	2	CFLU		28
AR070	Riffle	32	2	2	CFLU		10
AR070	Riffle	32	2	2	PGEO	36.2	
AR070	Riffle	32	2	2	VNEB	41.7	
AR075	Riffle	26	1	2.75	CFLU		19
AR075	Riffle	26	1	2.75	VNEB	37.9	
AR075	Riffle	26	2	3	NONE		
AR080	Riffle	19	1	6	CFLU		22
AR080	Riffle	19	1	6	SCON	66.0	
AR080	Riffle	19	1	6	VLIE	18.5	
AR080	Riffle	19	2	6.75	CFLU		30
AR080	Riffle	19	2	6.75	LALT	71.4	
AR080	Riffle	19	2	6.75	PGEO	44.6	
AR080	Riffle	19	2	6.75	VLIE	18.5	
AR085	Riffle	37	1	3.5	CFLU		15
AR085	Riffle	37	1	3.5	SCON	56.9	
AR085	Riffle	37	2	3	CFLU		8
AR085	Riffle	37	3	4	CFLU		48
AR085	Riffle	37	3	4	LALT	36.0	
AR085	Riffle	37	3	4	LALT	64.7	
AR085	Riffle	37	3	4	SCON	60.4	
AR085	Riffle	37	3	4	VB?	20.0	
AR090	Riffle	28	1	3.5	CFLU		21
AR090	Riffle	28	2	1	CFLU		15
AR095	Riffle	13	1	4.125	CFLU		14
AR095	Riffle	13	2	4	CFLU		112
AR100	Riffle	6	1	3.5	CFLU		16
AR100	Riffle	6	2	4.75	CFLU		17
AR100	Riffle	6	2	4.75	VNEB	33.3	
AR100	Riffle	6	2	4.75	VVIB	41.8	
AR100	Riffle	6	2	4.75	VVIB	22.0	
AR105	Riffle	15	1	4	CFLU		8
AR105	Riffle	15	2	3.5	CFLU		22
AR110	Riffle	49	1	4	CFLU		24
AR110	Riffle	49	2	2.75	CFLU		11
AR110	Riffle	49	3	2.625	CFLU		9
AR120	Riffle	28	1	3.25	CFLU		38
AR120	Riffle	28	2	5.5	CFLU		75

Appendix A	continued						
Habitat Unit		Unit Length (m)	Transect	Area sampled (m^2)	Species	Length (mm) of unionids	Number of Corbicula
AR125	Riffle	8	2	4	CFLU		62
AR125	Riffle	8	2	4	SPHA		MANY
AR130	Riffle	18	1	3.5	CFLU		26
AR130	Riffle	18	1	3.5	SPHA		MANY
AR130	Riffle	18	2	3	CFLU		65
AR130	Riffle	18	2	3	SPHA		MANY
BR005	Riffle	16	1	6	CFLU		4
BR005	Riffle	16	1	6	VNEB	35.8	
BR005	Riffle	16	2	7.5	CFLU		1
BR005	Riffle	16	3	9.5	CFLU		8
BR010	Riffle	22	1	6.5	CFLU		15
BR010	Riffle	22	1	6.5	SCON	46.8	
BR010	Riffle	22	1	6.5	SCON	68.8	
BR010	Riffle	22	1	6.5	VVIB	59.5	
BR010	Riffle	22	2	7.5	CFLU		29
BR010	Riffle	22	2	7.5	LALT	48.2	
BR010	Riffle	22	2	7.5	SCON	62.2	
BR010	Riffle	22	2	7.5	VNEB	42.2	
BR010	Riffle	22	2	7.5	VNEB	48.1	
BR010	Riffle	22	2	7.5	VVIB	46.8	
BR010	Riffle	22	3	8.5	CFLU		29
BR010	Riffle	22	3	8.5	SCON	74.3	
BR010	Riffle	22	3	8.5	VNEB	36.2	
BR015	Riffle	26	1	6	CFLU		3
BR015	Riffle	26	2	5.5	CFLU		6
BR015	Riffle	26	2	5.5	VVIB	33.7	
BR015	Riffle	26	3	6	CFLU		8
BR015	Riffle	26	3	6	SCON	65.4	
BR015	Riffle	26	3	6	SCON	49.5	
BR020	Riffle	10	1	6.5	CFLU		10
BR020	Riffle	10	1	6.5	SCON	42.0	
BR020	Riffle	10	1	6.5	VNEB	37.6	
BR020	Riffle	10	2	6.5	CFLU		3
BR020	Riffle	10	2	6.5	LALT	53.5	
BR020	Riffle	10	3	6	CFLU		8
BR025	Riffle	25	1	5.5	CFLU		15
BR025	Riffle	25	1	5.5	SCON	52.7	
BR025	Riffle	25	1	5.5	VNEB	44.9	
BR025	Riffle	25	1	5.5	VNEB	48.9	
BR025	Riffle	25	2	7	CFLU		9
BR025	Riffle	25	2	7	LALT	46.9	
BR025	Riffle	25	2	7	SCON	61.6	
BR025	Riffle	25	2	7	SCON	56.5	
BR025	Riffle	25	2	7	SCON	58.7	
BR025	Riffle	25	2	7	VNEB	38.9	
BR025	Riffle	25	2	7	VVIB	62.9	
BR025	Riffle	25	3	4.5	CFLU		4
BR030	Riffle	38	1	6.5	VNEB	53.1	
BR030	Riffle	38	2	6	CFLU		2
BR030	Riffle	38	2	6	VNEB	48.2	

Appendix A	continued						
Habitat Unit		Unit Length (m)	Transect	Area sampled (m^2)	Species	Length (mm) of unionids	Number of Corbicula
BR030	Riffle	38	3	6	LALT	41.1	
BR030	Riffle	38	4	7	LALT	42.4	
BR030	Riffle	38	5	6	CFLU		5
BR035	Riffle	24	1	6.5	CFLU		4
BR035	Riffle	24	2	6.5	CFLU		2
BR035	Riffle	24	2	6.5	SCON	52.5	
BR035	Riffle	24	3	7.5	VNEB	29.3	
BR040	Riffle	29	1	5	CFLU		7
BR040	Riffle	29	1	5	LALT	35.2	
BR040	Riffle	29	1	5	VNEB	22.2	
BR040	Riffle	29	2	4.5	CFLU		25
BR040	Riffle	29	3	2.5	CFLU		8
BR045	Riffle	21	1	6.5	CFLU		11
BR045	Riffle	21	1	6.5	SCON	42.0	
BR045	Riffle	21	1	6.5	VNEB	33.1	
BR045	Riffle	21	1	6.5	VNEB	44.0	
BR045	Riffle	21	2	5	CFLU		6
BR045	Riffle	21	2	5	SCON	58.2	
BR045	Riffle	21	3	5	CFLU		11
BR050	Riffle	9	1	5	CFLU		15
BR050	Riffle	9	2	5.5	CFLU		11
BR050	Riffle	9	3	5.5	CFLU		1
BR055	Riffle	12	1	6.5	CFLU		19
BR055	Riffle	12	2	6	CFLU		14
BR055	Riffle	12	3	6	NONE		
BR060	Riffle	12	1	4.5	CFLU		26
BR060	Riffle	12	1	4.5	SCON	54.5	
BR060	Riffle	12	2	4	CFLU		47
BR060	Riffle	12	3	5.5	CFLU		13
BR060	Riffle	12	3	5.5	SCON	72.4	
BR060	Riffle	12	3	5.5	SCON	56.2	
BR065	Riffle	21	1	6	CFLU		23
BR065	Riffle	21	2	6.5	CFLU		24
BR065	Riffle	21	2	6.5	LALT	56.0	
BR065	Riffle	21	2	6.5	VLIE	42.8	
BR065	Riffle	21	2	6.5	VVIB	46.9	
BR065	Riffle	21	2	6.5	VVIB	46.8	
BR065	Riffle	21	3	6.5	CFLU		14
BR070	Riffle	11	1	2.5	CFLU		28
BR070	Riffle	11	2	2.5	CFLU		33
BR070	Riffle	11	3	3	CFLU		49
BR075	Riffle	15	1	3	CFLU		72
BR075	Riffle	15	2	4	CFLU		76
BR075	Riffle	15	3	11.5	CFLU		83
BR080	Riffle	45	1	4.5	CFLU		7
BR080	Riffle	45	2	5.5	CFLU		9
BR080	Riffle	45	3	5	CFLU		7
BR080	Riffle	45	4	7	CFLU		32
BR080	Riffle	45	4	7	VNEB	30.7	
BR080	Riffle	45	4	7	VVIB	63.4	

Appendix A	continued						
Habitat Unit		Unit Length (m)	Transect	Area sampled (m^2)	Species	Length (mm) of unionids	Number of Corbicula
BR085	Riffle	9	1	3	CFLU		5
BR085	Riffle	9	2	2.5	CFLU		8
BR090	Riffle	8	1	7	CFLU		1
BR090	Riffle	8	1	7	SCON	57.2	
BR090	Riffle	8	1	7	SCON	104.4	
BR090	Riffle	8	1	7	VVIB	59.7	
BR090	Riffle	8	2	6.5	CFLU		2
BR090	Riffle	8	2	6.5	SCON	85.0	
BR090	Riffle	8	2	6.5	SCON	86.1	
BR090	Riffle	8	2	6.5	VLIE	28.8	
BR090	Riffle	8	2	6.5	VNEB	61.4	
BR090	Riffle	8	3	8	CFLU		1
BR095	Riffle	17	1	2.5	CFLU		1
BR095	Riffle	17	1	2.5	LALT	49.6	
BR095	Riffle	17	1	2.5	VNEB	20.7	
BR095	Riffle	17	1	2.5	VVIB	21.9	
BR095	Riffle	17	2	2.5	CFLU		1
BR095	Riffle	17	3	2.5	VLIE	35.2	
BR100	Riffle	12	1	2.5	NONE		
BR100	Riffle	12	2	2.5	NONE		
BR100	Riffle	12	3	3	NONE		
BR105	Riffle	11	1	2	NONE		
BR105	Riffle	11	2	1	NONE		
BR105	Riffle	11	3	2	NONE		
AP010	Pool	9	1	3.5	CFLU		3
AP010	Pool	9	2	5.5	NONE		
AP020	Pool	24	1	4.5	SCON	32.1	
AP020	Pool	24	1	4.5	VVIB	50.2	
AP020	Pool	24	2	2	NONE		
AP030	Pool	18	1	6	CFLU		8
AP030	Pool	18	2	4.5	CFLU		10
AP030	Pool	18	2	4.5	LALT	32.5	
AP040	Pool	31	1	8.25	CFLU		9
AP040	Pool	31	2	6.5	CFLU		2
AP040	Pool	31	3	6	CFLU		2
AP050	Pool	7	1	2.5	CFLU		6
AP050	Pool	7	1	2.5	VVIB	47.8	
AP050	Pool	7	1	2.5	VVIB	60.0	
AP050	Pool	7	2	2.5	CFLU		39
AP060	Pool	18	1	4.5	CFLU		3
AP060	Pool	18	1	4.5	VVIB	48.6	
AP060	Pool	18	2	4.5	CFLU		29
AP060	Pool	18	2	4.5	VNEB	33.4	
AP060	Pool	18	2	4.5	VNEB	33.5	
AP060	Pool	18	2	4.5	VVIB	23.8	
AP060	Pool	18	2	4.5	VVIB	23.5	
AP060	Pool	18	2	4.5	VVIB	22.7	
AP070	Pool	9	1	4	CFLU		74
AP070	Pool	9	2	3.5	CFLU		11

Appendix A	continued						
Habitat Unit		Unit Length (m)	Transect	Area sampled (m^2)	Species	Length (mm) of unionids	Number of Corbicula
AP080	Pool	17	1	6	VVIB	20.8	
AP080	Pool	17	2	8	SPHA		1
AP080	Pool	17	2	8	SCON	39.4	
AP080	Pool	17	2	8	SCON	30.7	
AP080	Pool	17	2	8	VNEB	41.1	
AP080	Pool	17	2	8	VNEB	18.1	
AP080	Pool	17	2	8	VNEB	21.9	
AP090	Pool	64	1	8.25	CFLU		57
AP090	Pool	64	1	8.25	VVIB	44.0	
AP090	Pool	64	2	9.5	CFLU		2
AP090	Pool	64	2	9.5	VVIB	76.5	
AP090	Pool	64	3	8	CFLU		6
AP090	Pool	64	3	8	SCON	82.6	
AP090	Pool	64	3	8	VNEB	16.0	
AP090	Pool	64	4	8	CFLU		125
AP090	Pool	64	4	8	VLIE	41.4	
AP090	Pool	64	5	8	CFLU		180
AP090	Pool	64	5	8	SCON	61.0	
AP090	Pool	64	5	8	SCON	42.9	
AP090	Pool	64	5	8	VLIE	34.2	
AP100	Pool	31	1	8	CFLU		60
AP100	Pool	31	1	8	SCON	41.1	
AP100	Pool	31	1	8	SCON	40.8	
AP100	Pool	31	1	8	VLIE	34.8	
AP100	Pool	31	1	8	VLIE	35.8	
AP100	Pool	31	1	8	VVIB	48.6	
AP100	Pool	31	1	8	VVIB	54.4	
AP100	Pool	31	2	7.25	CFLU		17
AP100	Pool	31	2	7.25	PGEO	23.0	
AP100	Pool	31	2	7.25	SCON	23.1	
AP100	Pool	31	2	7.25	VVIB	37.3	
AP100	Pool	31	3	7.25	CFLU		28
AP100	Pool	31	3	7.25	LALT	61.7	
AP100	Pool	31	3	7.25	PGEO	21.1	
AP110	Pool	24	1	4	CFLU		22
AP110	Pool	24	1	4	SCON	45.4	
AP110	Pool	24	1	4	SCON	51.3	
AP110	Pool	24	2	6	CFLU		45
AP110	Pool	24	2	6	LALT		
AP110	Pool	24	2	6	VVIB	53.0	
AP120	Pool	140	1	4	CFLU		217
AP120	Pool	140	1	4	SCON	39.4	
AP120	Pool	140	2	2.5	CFLU		15
AP120	Pool	140	3	3.5	CFLU		27
AP120	Pool	140	3	3.5	SPHA		1
AP120	Pool	140	4	3.5	CFLU		32
AP120	Pool	140	4	3.5	VVIB	41.1	
AP120	Pool	140	5	4.5	CFLU		59
AP120	Pool	140	5	4.5	VVIB	53.9	
AP120	Pool	140	6	5	CFLU		44
AP120	Pool	140	6	5	SCON		
AP120	Pool	140	6	5	VLIE	41.1	

AP120	Pool	140	6	5	VLIE	27.5	

Habitat Unit		Unit Length (m)	Transect	Area sampled (m^2)	Species	Length (mm) of unionids	Number of Corbicula
AP120	Pool	140	6	5	VVIB		
AP120	Pool	140	6	5	VVIB		
AP120	Pool	140	7	5.5	CFLU		31
AP120	Pool	140	8	4.5	CFLU		76
AP120	Pool	140	8	4.5	VVIB	26.7	
AP120	Pool	140	9	3.5	CFLU		24
AP120	Pool	140	9	3.5	SCON	19.5	
AP120	Pool	140	10	3	CFLU		3
AP130	Pool	104	1	5.25	CFLU		30
AP130	Pool	104	1	5.25	SCON	87.5	
AP130	Pool	104	1	5.25	SCON	70.1	
AP130	Pool	104	1	5.25	VVIB	70.9	
AP130	Pool	104	2	7	CFLU		38
AP130	Pool	104	2	7	SCON	45.8	
AP130	Pool	104	3	6	CFLU		15
AP130	Pool	104	4	6	CFLU		13
AP130	Pool	104	4	6	SCON	79.4	
AP130	Pool	104	5	6	CFLU		120
AP130	Pool	104	5	6	LALT	65.7	
AP130	Pool	104	5	6	VVIB	34.7	
AP130	Pool	104	6	4.5	CFLU		46
AP130	Pool	104	6	4.5	LALT	66.1	
AP130	Pool	104	6	4.5	VVIB	53.8	
AP130	Pool	104	6	4.5	VVIB	73.9	
AP130	Pool	104	7	5	CFLU		56
AP130	Pool	104	7	5	SCON	66.5	
AP130	Pool	104	7	5	VNEB	19.2	
AP130	Pool	104	7	5	VVIB	18.6	
AP130	Pool	104	7	5	VVIB	73.2	
AP130	Pool	104	7	5	VVIB	73.3	
AP130	Pool	104	7	5	VVIB	74.2	
AP130	Pool	104	7	5	VVIB	83.1	
AP130	Pool	104	7	5	VVIB	77.4	
AP140	Pool	7	1	2.5	CFLU		28
AP140	Pool	7	2	3	CFLU		25
AP150	Pool	13	1	3.25	CFLU		71
AP150	Pool	13	1	3.25	LALT	80.1	
AP150	Pool	13	1	3.25	VVIB	80.6	
AP150	Pool	13	2	4	LALT	84.6	
AP150	Pool	13	2	4	VI?	40.3	
AP150	Pool	13	2	4	VVIB	58.3	
AP150	Pool	13	2	4	VVIB	46.4	
BP010	Pool	46	1	4.5	CFLU		15
BP010	Pool	46	1	4.5	SCON	53.9	
BP010	Pool	46	1	4.5	VLIE	43.0	
BP010	Pool	46	1	4.5	VNEB	53.3	
BP010	Pool	46	2	5.5	CFLU		4
BP010	Pool	46	3	4.5	CFLU		20
BP010	Pool	46	4	5	CFLU		8
BP010	Pool	46	5	4	CFLU		18
BP010	Pool	46	5	4	SCON	45.8	
BP010	Pool	46	5	4	VNEB	40.9	

Habitat Unit		Unit Length (m)	Transect	Area sampled (m^2)	Species	Length (mm) of unionids	Number of Corbicula
BP020	Pool	15	2	2.5	CFLU		2
BP020	Pool	15	3	3	NONE		
BP030	Pool	15	1	2.5	CFLU		4
BP030	Pool	15	2	2.5	CFLU		9
BP030	Pool	15	2	2.5	SCON	52.9	
BP030	Pool	15	2	2.5	SCON	55.3	
BP030	Pool	15	2	2.5	VNEB	43.5	
BP030	Pool	15	2	2.5	VNEB	35.4	
BP030	Pool	15	3	1.5	CFLU		3
BP040	Pool	11	1	3.5	CFLU		22
BP040	Pool	11	2	2.5	CFLU		8
BP040	Pool	11	3	3.5	CFLU		6
BP050	Pool	29	1	8	CFLU		10
BP050	Pool	29	2	3	CFLU		3
BP050	Pool	29	3	3	CFLU		7
BP050	Pool	29	3	3	LALT	57.3	
BP060	Pool	58	1	3.5	NONE		
BP060	Pool	58	2	4	CFLU		1
BP060	Pool	58	3	4	CFLU		2
BP060	Pool	58	4	5	CFLU		4
BP060	Pool	58	5	3.5	NONE		
BP060	Pool	58	6	3	CFLU		3
BP070	Pool	57	1	3.5	CFLU		5
BP070	Pool	57	1	3.5	SCON	50.2	
BP070	Pool	57	1	3.5	SCON	22.1	
BP070	Pool	57	1	3.5	SCON	76.5	
BP070	Pool	57	2	4.5	CFLU		33
BP070	Pool	57	3	4.5	CFLU		2
BP070	Pool	57	4	4.5	CFLU		3
BP070	Pool	57	5	4.5	NONE		
BP070	Pool	57	6	4.5	NONE		
BP080	Pool	67	1	2.5	NONE		
BP080	Pool	67	2	2.5	NONE		
BP080	Pool	67	3	3.5	UIMB	56.7	
BP080	Pool	67	3	3.5	VVIB	61.2	
BP080	Pool	67	4	3.5	SCON	47.9	
BP080	Pool	67	5	5	CFLU		2
BP080	Pool	67	5	5	VLIE	43.8	
BP080	Pool	67	6	4	VLIE	35.3	
BP090	Pool	14	1	1.5	NONE		
BP090	Pool	14	2	0.5	NONE		
BP090	Pool	14	3	0.5	NONE		