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Freshwater Mussels (Bivalvia: Margaritiferidae and Unionidae) of the Buffalo River Drainage, Tennessee

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To the Graduate Council:

I am submitting herewith a thesis written by Matthew Philip Reed entitled "Freshwater Mussels (Bivalvia: Margaritiferidae and Unionidae) of the Buffalo River Drainage, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

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ABSTRACT

The Buffalo River in Tennessee once hosted a rich population of freshwater mussels. During the 1980s, monitoring efforts demonstrated evidence of drastic declines and extirpation of entire assemblages. Increases in municipal development in the headwater tributaries and agriculture in the main stem of the Buffalo River are suspected causes for mussel community declines throughout the river. In 2011, collection data documented evidence of recovery in the lower Buffalo River. The aims of this project were: 1) to update the status, distribution, and species composition of mussels in the Buffalo River and its major tributaries through qualitative sampling, and 2) to analyze healthy community structures through quantitative sampling.

Timed qualitative searches to establish Catch Per Unit Effort (CPUE) were conducted at approximately 8 km intervals (5 river miles) in the main channel and in major tributaries. A total of 33 species including three species new to the river drainage were recorded at 57 collecting sites. The highest number of live species per site was 20, recorded 3.2 mi (5.1 km) above the confluence with the Duck River. The most abundant and widely distributed mussels recorded in qualitative sampling were *Villosa taeniata* and *Lampsilis fasciola*, which were observed at 21 and 18 sampling sites, respectively. Catch Per Unit Effort varied throughout the drainage, demonstrating isolated pockets of healthy mussel assemblages as well as stretches of river with few live individuals. Quantitative sampling was conducted at Buffalo River Mile 3.2 (BRM 3.2) because of its community's abundance and species richness. Twenty species and 178 live mussels were observed, with an average of 1.8 mussels per quadrat. The once-abundant mussel fauna in the middle and upper Buffalo River has yet to recover, but encouraging signs of limited recovery in the lower reaches of the river should be strongly considered in the watershed's future management and conservation efforts.

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CHAPTER 1

INTRODUCTION

North America is home to the greatest diversity of freshwater mussels (Mollusca: Bivalvia: Unionoidea) in the world, with approximately 300 species (Carter et al. 2011). Located in the center of aquatic biodiversity, Tennessee is known as the most biologically rich inland state with an impressive system of freshwater ecosystems. More species of fish occur in Tennessee than any other state and its mussel diversity ranks second only to Alabama (Starnes and Bogan 1988, Etnier and Starnes 1993, Parmalee and Bogan 1998). Due to their unique roles in aquatic ecosystems and severe declines in the last century, mussels have become a major focal point for conservation efforts in Tennessee.

Freshwater mussels are excellent indicators of water quality and habitat stability (Watters 2000). More importantly, they provide numerous ecological services and play important roles in aquatic ecosystems. Dense assemblages are able to filter large quantities of water, often equal to or exceeding discharge volumes. Even at low densities, they often constitute large proportions of benthic biomass. Mussels provide many other important ecosystem services including aquatic bioturbation, nutrient cycling, biodeposition, and ecosystem engineering (Watters 2000, Vaughn and Hakenkamp 2001, Howard and Cuffey 2006, Zimmerman and de Szalay 2007, Vaughn et al. 2008, Vaughn 2010). Consequently, their contribution to freshwater rivers and streams is invaluable. This growing body of knowledge continues to provide reason for concern in light of global declines observed in freshwater bivalve faunas.

Significant declines have placed freshwater mussels at the forefront of imperiled faunal groups in North America, with approximately 40 of the 300 North American freshwater mussel

species reaching extinction in the last century. The U.S. Fish and Wildlife Service (USFWS) currently lists 88 mussel species as either endangered (75 taxa) or threatened (13 taxa). Haag (2009) predicts another 25% of the remaining fauna to go extinct in the next three decades.

Declines may be attributed to a number of factors including habitat disruption and loss, channelization, point and nonpoint source pollution, dredging, nutrient increase, sedimentation, invasive species, and impoundments (Neves et al. 1997, Neves 1999, Lydeard et al. 2004). Such negative impacts often work synergistically and lead to local extirpations or range reduction of species (Williams et al. 1992, Bogan 1993). Collectively, these factors have led to an extinction crisis for the Southeast, making conservation and careful monitoring of remaining populations a crucial step in preserving our freshwater native fauna.

Tennessee has experienced its own set of significant mussel declines over recent decades. Parmalee and Bogan (1998) described 129 species of mussels known historically to occur in Tennessee. Subsequent taxonomic changes raised this number to a total of 137 species once known to Tennessee's freshwater systems. To date, roughly 30 have been lost to extinction or statewide extirpation, lowering the total number to approximately 107 (G. Dinkins, pers. comm.).

The Duck River has long been recognized as the one of the most biologically diverse rivers in the United States, home to roughly 151 species of fish, 66 species of mussels, and 22 species of aquatic snails (Etnier and Starnes 1993, Ahlstedt et al. 2004, Hubbs et al. 2011, D. Nieland, unpublished data). While its mussel fauna has been studied extensively, no study has ever focused solely on the mussel fauna of its largest tributary, the Buffalo River drainage (Ortmann 1924, Isom and Yokley 1968, Van der Schalie 1973, Jenkinson 1988, Ahlstedt 1991, Schilling and Williams 2002). Instead, the Buffalo River has only been examined intermittently

within larger studies (Ahlstedt 1991), and Parmalee and Bogan (1998) reported it to contain 40 species of mussels.

Ahlstedt (1991) is the most extensive recent study to investigate the Buffalo River. Surveys covered the headwater region extensively, but only a few sites were visited on the lower river due to the lack of mussels encountered. At the time of Ahlstedt's survey, the river's mussel fauna was considered depleted. This downward spiral began as early as 1965, according to Isom and Yokley's assessment of two sites in the upper reaches of the river (Isom and Yokley 1968). Likely causes for mussel declines in the Buffalo River, like many large rivers, are due to anthropogenic activities accompanying human population increases and agricultural activities.

The Buffalo River is one of the longest free-flowing rivers in Tennessee (125 mi, 201 km) and worthy of extensive study. Despite infrequent studies, the assumed knowledge of the river's mussel fauna was roughly 40 taxa prior to this study, including eight federally listed species: *Epioblasma ahlstedti*, *E. florentina walkeri*, *E. turgidula*, *Hemistena lata*, *Pleuronaia dolabelloides*, *Ptychobranchus subtentum*, *Quadrula cylindrica cylindrica*, and *Toxolasma cylindrellus* (Ortmann 1924, Isom and Yokley 1968, Van der Schalie 1973, Ahlstedt 1991, Parmalee and Bogan 1998, Schilling and Williams 2002, USFWS 2014). Prior to this research, no extensive mussel survey of the Buffalo River and its major tributaries existed to provide baseline distribution data for precise monitoring efforts. Preliminary surveys for this study identified three new species records, one of which is a federally endangered species, *Cumberlandia monodonta* (USFWS 2014). Furthermore, in their study of the lower Duck River, Schilling and Williams (2002) noted several species (i.e., *C. monodonta*, *P. dolabelloides*) had extended their ranges into the lower reaches of the Duck River, near its confluence with the Buffalo River.

In designing this project, it was determined that an assessment of the Buffalo River's mussel fauna was long overdue. The objectives of this study were as follows: 1) to update the current status and distribution of freshwater mussels in the Buffalo River and its major tributaries through qualitative sampling, and 2) to conduct quantitative sampling in a healthy community to establish baseline information regarding species richness, evenness, diversity, and recruitment.

CHAPTER 2

STUDY AREA

The Buffalo River is located in western Middle Tennessee, in the Western Highland Rim of the Interior Low Plateau physiographic province (Mast and Turk 1999). It is the largest tributary of the Duck River, and approximately 125 mi (201 km) in length. Rising in Lawrence County, the river flows west through Lewis and Wayne counties before turning north to flow through Perry and Humphreys counties. The Buffalo River drains approximately 763 mi^2 (1,227 km^2), and is one of the longest unimpounded rivers remaining in Tennessee. The upper reach of the river in Lawrence County is designated a 'State Scenic River' under the Tennessee State Scenic Rivers Act. Its confluence with the Duck River is about 15 mi (24 km) above the confluence of the Duck and Tennessee Rivers in Humphreys County.

The Western Highland Rim is highly dissected by perennial streams, creating irregular topography consisting of peneplain ridgelines and flat-bottomed drainages, separated by steep-sided ridges. The Western subdivision of the highland rim province encompasses the entire Buffalo River, and ranges in elevation from approximately 157 - 305 m in elevation within the watershed. Mississippian limestone, chert, sandstone, and shale compose primary deposits, with sinkholes, caves, and karst topography occurring throughout the region (Smalley 1981).

Climate in this region is distinguished by relatively long and hot summers followed by shorter, milder winters. Mean temperatures range from 8.8˚C in January to 31.6˚C in July. Mean annual precipitation is approximately 142 cm, with peak precipitation occurring in May and December. May is generally the wettest month for the river, with an average of 15.5 cm. Conversely, the average driest months are August through October.

Mast and Turk (1999) and TDEC (2005) designated land use in the Buffalo River watershed as primarily forests (77%) and agriculture (18%). Private land constitutes over 90% with urban development constituting less than 1% of the watershed.

Despite its rural and relatively undeveloped geographic setting, the Buffalo River experienced considerable alterations in the mid-1960s to mid-1980s resulting from anthropogenic activity in the headwater region of the watershed. The following chapter will correlate these impacts with mussel declines observed over several historical surveys of the Buffalo River during the past century.

CHAPTER 3

HISTORICAL REVIEW

Published Studies

The mussel fauna of the Buffalo River is surprisingly understudied. Only a few published surveys exist documenting its diverse and apparently once-abundant mussel population. At one time, it was noted to contain a mussel community equal in diversity and abundance to that of the Duck River (Van der Schalie 1973).

Because of the watershed's remote setting and lack of development, a total of six sites served as the only documented survey records for the entire river until the late 1980s. Thus, for a mere six sites to contain as many mussel species as the Duck, as observed by Van der Schalie in his 1931 study, the Buffalo River must have once hosted an exceptionally healthy and diverse mussel community. Unfortunately, by the time Ahlstedt (1991) surveyed the river more extensively, its mussel population had nearly disappeared. The degree of diversity and abundance once present in the Buffalo River's mussel communities may never be fully known.

In 1922, renowned naturalist and malacologist Arnold E. Ortmann visited the Buffalo River during a study encompassing the entire Duck River drainage. Ortmann visited only one site, located at a bridge crossing in the small streamside community of Riverside, Tennessee (BRM 90.6). He noted an extremely healthy fauna, and reported 20 species (Ortmann 1924) (Table 1).

Table 1. Species reported (n=20) by Arnold E. Ortmann at Riverside on September 7, 1922, at BRM 90.6. All species reported were observed live (Ortmann 1924).

Species
Actinonaias pectorosa
Alasmidonta marginata
Alasmidonta viridis
Elliptio crassidens
Elliptio dilatata
Lampsilis cardium
Lampsilis fasciola
Lampsilis ovata
Lasmigona costata
Obovaria subrotunda
Pleurobema cordatum
Pleurobema oviforme
Pleuronaia barnesiana
Pleuronaia dolabelloides
Ptychobranchus subtentum
Strophitus undulatus
Toxolasma cylindrellus
Villosa iris
Villosa taeniata
Villosa vanuxemensis

Almost a decade later, in the early 1930s, Calvin Goodrich and Henry van der Schalie revisited the Duck River drainage for a mussel study that would be published approximately 40 years later (Van der Schalie 1973). During their study, they sampled four sites on the Buffalo River in 1931, and added 13 species to Ortmann's original species list (Ortmann 1924), with 33 live species found at one site in Lobelville, Tennessee, near BRM 26 (Table 2). At this point, the fauna seemed to be doing well and was apparently even more abundant in numbers in the lower portion of the river (Van der Schalie 1973).

Table 2. Species reported (n=33) in 1931 by Goodrich and Van der Schalie at four sites from the Buffalo River. Localities listed according to river mile (Van der Schalie 1973).

Species	RM 80.5	RM 40.9	RM 31.5	RM 19.2
Actinonaias ligamentina	-	-	-	X
Actinonaias pectorosa	X	X	X	X
Amblema plicata	-	-	-	X
Cyclonaias tuberculata	-	-	X	X
Elliptio crassidens	-	-	-	X
Epioblasma ahlstedti	-	-	-	X
Epioblasma florentina aureola	-	X	-	X
Hemistena lata	-	-	-	X
Lampsilis cardium	X	-	X	X
Lampsilis ovata	X	-	X	X
Lampsilis teres	-	-	-	X
Lasmigona complanata	-	-	-	X
Lasmigona costata	X	-	-	X
Leptodea fragilis	-	-	-	X
Obliquaria reflexa	-	-	-	X
Obovaria subrotunda	X	X	X	X
Pleurobema cordatum	-	-	-	X
Pleurobema oviforme	X	-	X	X
Pleurobema sintoxia	-	-	-	X
Pleuronaia barnesiana	-	-	-	X
Pleuronaia dolabelloides	-	-	-	X
Potamalis alatus	-	X	X	X
Pyganodon grandis	X	-	X	-
Quadrula cylindrica	-	-	-	X
Quadrula pustulosa	-	-	-	X
Quadrula quadrula	-	-	-	X
Quadrula verrucosa	-	-	-	X
Strophitus undulatus	X	X	X	X
Toxolasma cylindrellus	-	-	-	X
Truncilla truncata	-	-	-	X
Utterbackia imbecillis	X	-	-	-
Villosa iris	-	-	-	X
Villosa vanuxemensis	-	-	-	X
Total	9	5	9	31

Severe mussel loss was first reported during Isom and Yokley's surveys in 1965, during which they revisited Ortmann's original site in Riverside, Tennessee, at BRM 90.6 (Isom and Yokley 1968). No sign of mussels, live or dead, was encountered. However, downstream at

approximately BRM 74.6, they found 16 species, with several new additions to the river's historical record (Table 3). In light of these new findings, as well as additional unpublished surveys, Van der Schalie (1973) concluded that "The Duck and Buffalo Rivers had a surprisingly rich mussel fauna, both in the numbers of species and in individuals. Both streams have some of the finest shoals in the world but, as previously indicated, the mussels have now been depleted drastically."

Table 3. Species reported (n=16) in 1965 by Isom and Yokley at two sites from the Buffalo River. No mussels (live or dead) observed at Ortmann's Riverside site at BRM 90.6. Localities listed according to river mile (Isom and Yokley 1968).

Species	BRM 90.6	BRM 74.8
Actinonaias ligamentina	-	X
Actinonaias pectorosa	-	X
Alasmidonta marginata	-	X
Cyclonaias tuberculata	-	X
Elliptio crassidens	-	X
Hemistena lata	-	X
Lampsilis fasciola	-	X
Lampsilis ovata	-	X
Lasmigona costata	-	X
Obovaria subrotunda	-	X
Pleurobema oviforme	-	X
Potamalis alatus	-	X
Ptychobranchus fasciolaris	-	X
Pyganodon grandis	-	X
Quadrula verrucosa	-	X
Villosa taeniata	-	X
Total	0	16

In September 1971, Richard Fitz conducted a habitat and fish population assessment in the Buffalo River for the Tennessee Valley Authority. This was part of an ongoing project aimed at characterizing the relative abundance of aquatic diversity in six Tennessee Valley streams. Other rivers within this study included the Emory, Powell, Flint, upper Little Tennessee, and Sequatchie. Of these, the Buffalo River was reported to have the highest diversity, with 67 fish

species collected. Despite the generally high diversity and abundance of fish in the river, Fitz noted that the Green River and Trace Creek (two tributaries in the upper Buffalo River) both had significantly lower diversity and numbers. He suggested municipal sewage effluent was a primary factor for these low diversity scores (Fitz 1980).

In a study designed to evaluate the mussel fauna of six Tennessee Valley streams during 1980, Ahlstedt (1991) conducted what was at that time the most extensive survey of the Buffalo River. Ahlstedt and his crew started in the upper reaches of the river just above BRM 100, and worked approximately 75 mi (121 km) downstream to Lobelville, Tennessee. They surveyed a total of 24 sites and found only six species (Table 4). Not more than three live species were found at any site, and most sites yielded none. Ahlstedt's surveys demonstrated severe mussel loss in this reach; mussel communities once extant at sites surveyed in 1922 by Ortmann (1924) and in 1931 by Goodrich and Van der Schalie (1973) were considered extirpated.

Table 4. Species reported (n=6) in 1980 by Ahlstedt at 24 sites from the Buffalo River. Localities listed according to river mile (Ahlstedt 1991).

	BRM																							
Species	25.9	31.7	55.1	55.6	58.1	59.1	63.7	64.7	68.6	69	71.2	72	72.7	73	73.2	80.5	93.5	96.5	97.3	97.7	100.1	101	101.8	102.8
Actinonaias ligamentina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-
Cyclonaias tuberculata	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronaia barnesiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Villosa iris	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	-	-
Villosa vanuxemensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-
Total	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	2	1	3	2	1	1	0

Mast and Turk (1999) noted significant increases in stream-water sodium (Na) and chloride (Cl) near the U.S. Geological Survey (USGS) gauging station in Flatwoods. These increases coincided with a 20% population growth in Lewis, Lawrence, and Wayne counties from 1970-1980. They hypothesized human population increases in the Hohenwald and Waynesboro areas to be the primary drivers of water quality decline, given the fact that tributaries originating from these areas exhibited signs of water quality impairment.

In summary, observations of water quality issues reported by Fitz (1980) and Mast and Turk (1999) indicated municipal effluent as the primary source of degradation in four tributaries in the upper headwaters: Green River, Trace Creek, Rockhouse Creek, and Saw Creek. The Green River flows through Waynesboro and carries effluent from a wastewater treatment plant (WWTP), joining the main channel at BRM 73.5. Both Rockhouse and Trace Creeks originate below Hohenwald and carry municipal effluent, entering the main channel at BRM 89.2 and 88.9, respectively. Saw Creek runs through Summertown and carries effluent from a WWTP, and enters the main channel at BRM 113.7. It is important to note that all four tributaries enter the Buffalo River above BRM 73. Sites reported to have experienced depletion or extirpation in the historical surveys leading up to Ahlstedt (1991) were entirely confined to the upper reaches of the river.

Combined with increased herbicide and pesticide use during that time period, these changes to the hydrology and chemical composition of the river may well have been the driving forces behind the river's mussel collapse in the 1960s and 1970s.

Museum Records

Because of the infrequent and sporadic nature of mussel studies in the Buffalo River, the author collected all known museum records to enhance the level of confidence associated with historical species lists (Table 5). Museums with Buffalo River mussel specimens included the Carnegie Museum of Natural History (CM), McClung Museum of Natural History and Culture at the University of Tennessee, Knoxville, TN (UTK), North Carolina State Museum of Natural Sciences in Raleigh, NC (NCMNS), Museum of Biological Diversity at The Ohio State University in Columbus, OH (OSUM), and University of Michigan Museum of Zoology in Ann Arbor, MI (UMMZ). In several instances, only one record existed for a given species. For example, *Epioblasma turgidula* was never reported in any of the published studies; the single known record came from Herb Athearn's private collection, which was donated to the North Carolina State Museum of Natural Sciences.

Other significant findings from museum collections included several comments in field notes by Isom and Yokley (1968): "The Buffalo is a clear, cool, rapidly flowing small river with no evident pollution. In spite of limestone bedrock, cobbles, and gravel, the mollusks were not abundant (Isom and Yokley 1968)." From the Ohio State Bivalve Collection, a comment from a collection of specimens collected in 1972 reads: "Water low, clear and cool… Naiades [freshwater mussels] all but absent, a single *Toxolasma lividus lividus* [=*lividum lividum*] was taken alive along with a few dead shells of other species." This provided documentation that *Toxolasma lividum* historically occurred in the upper Buffalo River, despite its absence in published studies, and in Parmalee and Bogan (1998).

Table 5. Species record of Buffalo River mussel specimens housed in five museum collections.

Species	CM	UTK	UMMZ	NCMNS	OSUM
*Cumberlandia monodonta**	-	X	-	-	-
Actinonaias pectorosa	X	X	X	X	X
Alasmidonta marginata	X	-	-	X	X
Alasmidonta viridis	X	-	-	-	-
Amblema plicata	-	X	X	X	-
Anodonta suborbiculata	-	X	-	-	-
Cyclonaias tuberculata	-	X	X	X	X
*Ellipsaria lineolata**	-	X	-	-	-
Elliptio crassidens	-	-	X	X	-
Elliptio dilatata	-	X	-	-	-
Epioblasma ahlstedti	-	-	X	-	-
Epioblasma florentina aureola	-	-	X	-	-
*Epioblasma turgidula**	-	-	-	X	-
*Fusconaia subrotunda**	-	X	-	-	-
Hemistena lata	-	-	-	-	X
Lampsilis cardium	X	X	-	-	-
Lampsilis fasciola	X	X	-	X	-
Lampsilis ovata	-	X	-	X	X
Lampsilis teres	-	X	-	-	-
Lasmigona costata	-	X	-	X	-
Leptodea fragilis	-	X	-	-	-
*Ligumia recta**	-	X	-	-	-
*Megalonaias nervosa**	-	-	-	X	-
Obliquaria reflexa	-	X	-	-	-
Obovaria subrotunda	X	-	-	X	X
Pleurobema oviforme	X	X	-	-	X
Pleuronaia barnesiana	X	X	-	-	-
Pleuronaia dolabelloides	X	X	-	X	-
Potamalis alatus	-	X	-	X	-
Ptychobranchus subtentum	X	-	-	-	-
Pyganodon grandis	-	X	-	X	-
Quadrula cylindrica cylindrica	-	X	-	X	-
Quadrula pustulosa	-	X	-	-	-
Quadrula verrucosa	-	X	-	-	-
Strophitus undulatus	X	-	-	-	-
Toxolasma cylindrellus	X	-	-	-	-
*Toxolasma lividum**	-	X	-	X	X
Truncilla truncata	-	X	-	-	-
Utterbackia imbecillis	-	X	-	-	-
Villosa iris	X	X	-	X	-
Villosa taeniata	X	X	-	-	X
Villosa vanuxemensis	X	X	-	X	X
Total (42 species)	15	30	6	18	10

*Indicates species not recorded in published studies.

In 2011, McClung Museum received several mussel specimens from fish Index of Biotic Integrity (IBI) sampling conducted by the Tennessee Valley Authority in the Buffalo River. A brief search for historical records indicated that one of the specimens—federally endangered *Cumberlandia monodonta*—was a new drainage record for the river (Parmalee and Bogan 1998). Schilling and Williams (2002) reported it in the lower Duck River, but it was apparently never documented in the Buffalo River. Further queries into existing literature with data pertaining to the Buffalo River's mussel fauna revealed a surprising knowledge gap in known occurrences for this watershed. Preliminary surveys near the mouth of the river revealed a surprising degree of diversity and abundance, which spurred the current study.

CHAPTER 4

METHODS AND DATA ANALYSES

The following section details survey methods used to assess the current status of mussels in the Buffalo River. Aforementioned historical sites were re-surveyed to provide insight into temporal trends, and new sites were established throughout the river drainage to better examine spatial distributions. Mussel taxonomy follows Turgeon et al. (1998) and Williams et al. (2008).

Sampling Methods

Methods for sampling freshwater mussels are well established and used frequently. Both qualitative and quantitative methods are often used to assess streams and large rivers for mussel assemblages based on the goals and funding of the study. Qualitative sampling typically involves thorough timed snorkel searches, whereas quantitative sampling is much more rigorous and often very costly (Miller et al. 1993), requiring established transect lines and/or quadrats to delineate substrate excavations. Miller and Payne (1993) found that both methods yielded similar results in community composition, species richness, diversity, and evenness. Hornbach and Deneka (1996) had similar results in terms of community structure, but observed considerable differences in mussel sizes. They concluded that quantitative excavations were more efficient in detecting smaller individuals, as well as cryptic species. In an additional study examining the potential differences between qualitative and quantitative sampling methods, Obermeyer (1998) concluded that qualitative sampling was more suitable for studying large-scale distribution patterns, whereas quantitative sampling was more effective at analyzing small-scale community structures in terms of size classes, density and biomass.

Thus, due to the lack of established sites in the Buffalo River prior to this study, it was determined to utilize both sampling methods. Qualitative sampling was conducted at selected locations in the main channel and tributaries to determine current distribution of mussels. Quantitative sampling was restricted to the healthiest community identified by qualitative sampling.

Qualitative Sampling

This was the first mussel-intensive study to encompass the entire Buffalo River drainage. Prior to sampling, access points via boat ramps and private landowners were determined to effectively arrange float plans for qualitative surveys. Due to the large percentage of private landownership in the watershed, many areas had never been accessed for mussel surveys. To compensate for this, multi-day floats were designed throughout the river to avoid missing any previously unknown suitable habitat.

Fifty-seven sites were sampled in 2012 and 2013 when flow levels were at or below 350 cubic feet/second (cfs) (Figure 1). Canoes and expedition kayaks were utilized for site access. Sampling locations were chosen to include historically surveyed sites as well as new sites with suitable habitat and major tributaries. Sampling localities were recorded in decimal degrees using Global Positioning System (GPS) equipment (Garmin GPSmap 76Cx) (Table 6). Additional data recorded in field notes included sampling date, surveyors, total sampling time (CPUE), river mile, county, notable landmarks, and descriptions of habitat type.

Wading and snorkeling techniques were used for all qualitative surveys. All specimens encountered were removed from the substrate and placed in mesh bags for sorting and identification. Fresh-dead (shiny nacre, hinge ligament intact, tissue in shell) and relict (old, weathered) shells were identified, recorded in field data sheets, and placed in collecting bags for

transportation to McClung Museum of Natural History and Culture. Once at McClung, they were cleaned, verified, catalogued, and added to the Malacology Collection. Live mussels were identified, measured for total shell length (mm) (anterior-posterior) using dial calipers, photographed, recorded in field data sheets, and returned to the substrate. Surveys were conducted by a minimum of two or three experienced biologists and were conducted for periods of 60 min or greater. Banks and shoreline areas were also searched at each site for muskrat feeding stations (shell midden deposits). A total of 57 sites were surveyed during qualitative efforts, from the headwaters to the confluence with the Duck River.

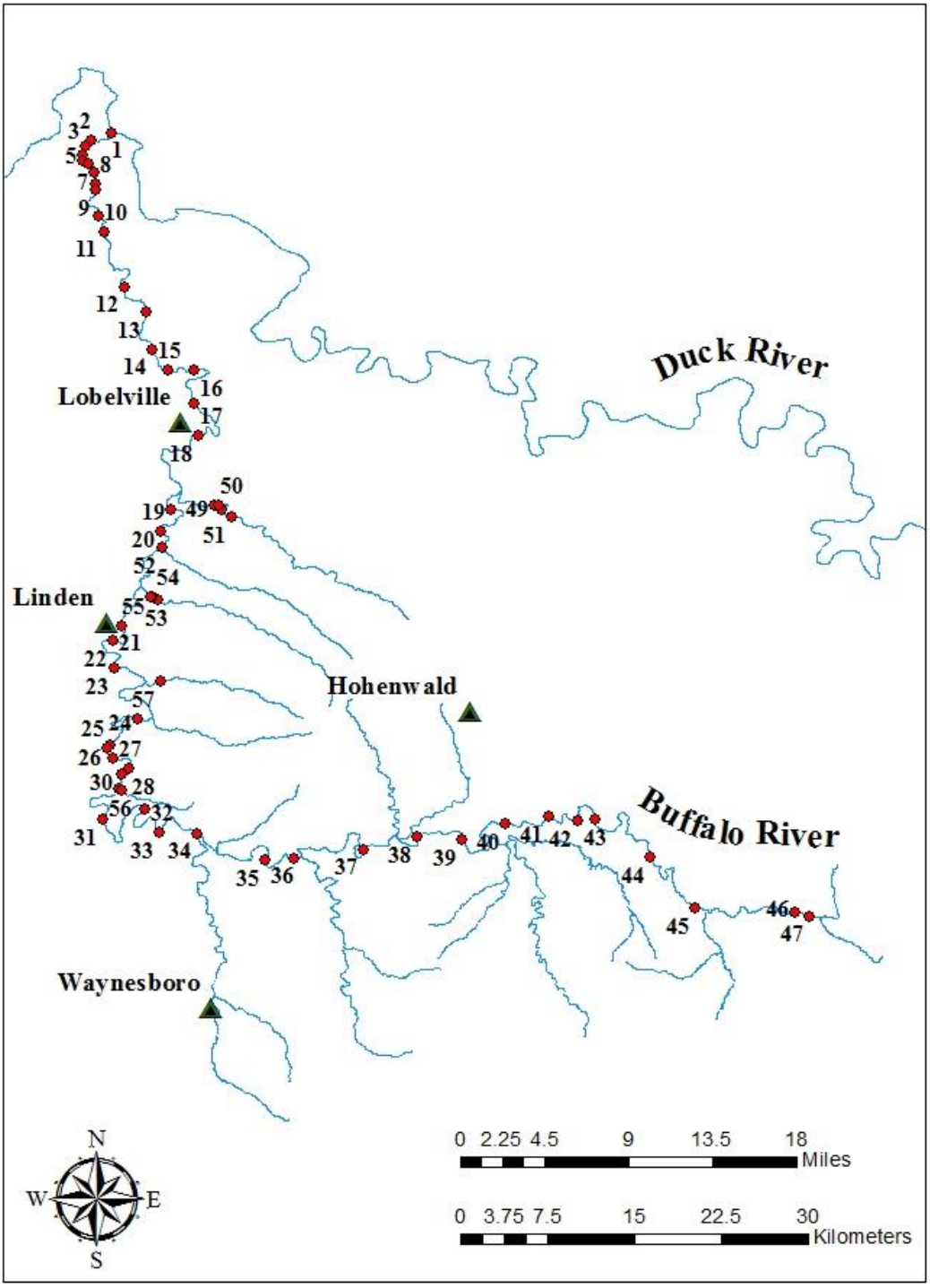

Figure 1. Map of sampling sites and corresponding site numbers surveyed within the Buffalo River drainage, Tennessee.

Table 6. Site locations and dates sampled.

Site #	Location	Date	Latitude	Longitude
1	Buffalo River (BRM 0.2)	10/11/2012	35.995733	-87.840750
2	Buffalo River (BRM 1.9)	11/16/2012	35.989440	-87.855560
3	Buffalo River (BRM 2.2)	11/16/2012	35.985050	-87.860310
4	Buffalo River (BRM 2.8)	11/16/2012	35.978430	-87.862610
5	Buffalo River (BRM 3.2)	11/16/2012	35.974680	-87.862750
6	Buffalo River (BRM 3.5)	11/17/2012	35.972240	-87.857710
7	Buffalo River (BRM 4.0)	11/17/2012	35.965700	-87.854140
8	Buffalo River (BRM 4.6)	11/17/2012	35.956710	-87.852400
9	Buffalo River (BRM 4.9)	11/17/2013	35.951720	-87.852200
10	Buffalo River (BRM 6.8)	10/11/2013	35.931659	-87.850196
11	Buffalo River (BRM 8.0)	10/11/2013	35.919500	-87.846100
12	Buffalo River (BRM 12.0)	10/11/2013	35.876667	-87.830350
13	Buffalo River (BRM 13.8)	8/30/2013	35.857617	-87.813567
14	Buffalo River (BRM 16.3)	8/30/2013	35.827967	-87.808683
15	Buffalo River (BRM 17.7)	8/30/2013	35.812183	-87.796450
16	Buffalo River (BRM 19.4)	8/30/2013	35.812617	-87.775900
17	Buffalo River (BRM 22.4)	8/29/2013	35.786733	-87.776667
18	Buffalo River (BRM 25.8)	8/29/2013	35.762083	-87.772750
19	Buffalo River (BRM 32.0)	8/10/2013	35.704910	-87.793770
20	Buffalo River (BRM 34.3)	8/10/2013	35.688030	-87.802620
21	Buffalo River (BRM 41.4)	8/9/2013	35.615430	-87.832030
22	Buffalo River (BRM 42.8)	8/9/2013	35.604070	-87.838790
23	Buffalo River (BRM 45.6)	8/9/2013	35.582740	-87.838520
24	Buffalo River (BRM 52.1)	8/9/2013	35.543290	-87.820100
25	Buffalo River (BRM 55.1)	12/18/2012	35.523550	-87.841967
26	Buffalo River (BRM 55.6)	12/18/2012	35.520633	-87.843567
27	Buffalo River (BRM 56.0)	12/18/2012	35.512527	-87.839599
28	Buffalo River (BRM 57.4)	12/18/2012	35.505050	-87.826633
29	Buffalo River (BRM 58.0)	12/18/2012	35.500400	-87.832233
30	Buffalo River (BRM 59.0)	12/18/2012	35.489084	-87.834299

Table 6. (continued).

Site #	Location	Date	Latitude	Longitude
31	Buffalo River (BRM 62.7)	6/21/2013	35.465750	-87.847600
32	Buffalo River (BRM 67.4)	6/21/2013	35.473483	-87.814867
33	Buffalo River (BRM 70.6)	6/21/2013	35.455667	-87.802950
34	Buffalo River (BRM 73.5)	5/25/2013	35.455100	-87.773767
35	Buffalo River (BRM 78.7)	5/25/2013	35.434350	-87.721000
36	Buffalo River (BRM 80.5)	5/25/2013	35.436017	-87.699050
37	Buffalo River (BRM 87.0)	5/24/2013	35.442717	-87.645117
38	Buffalo River (BRM 90.6)	5/24/2013	35.452150	-87.603017
39	Buffalo River (BRM 93.6)	7/17/2013	35.449770	-87.569090
40	Buffalo River (BRM 98.2)	7/17/2013	35.462580	-87.535200
41	Buffalo River (BRM 100.6)	7/17/2013	35.468120	-87.501290
42	Buffalo River (BRM 102.9)	7/16/2013	35.464510	-87.478670
43	Buffalo River (BRM 105.3)	7/17/2013	35.465480	-87.465290
44	Buffalo River (BRM 111.3)	7/17/2013	35.436700	-87.423230
45	Buffalo River (BRM 116.7)	7/18/2013	35.397140	-87.387710
46	Buffalo River (BRM 121.0)	7/18/2013	35.393980	-87.311150
47	Buffalo River (BRM 122.0)	7/18/2013	35.391110	-87.299460
48	Cane Creek	12/11/2012	35.704817	-87.755467
49	Cane Creek	12/11/2012	35.708667	-87.760150
50	Cane Creek	12/11/2012	35.707782	-87.757528
51	Cane Creek	12/11/2012	35.699283	-87.747533
52	Brush Creek	12/12/2012	35.675117	-87.801500
53	Coon Creek	12/12/2012	35.634900	-87.804533
54	Coon Creek	12/12/2012	35.637550	-87.808867
55	Coon Creek	12/12/2012	35.637700	-87.810180
56	Little Opossum Creek	12/18/2012	35.487834	-87.832571
57	Hurricane Creek	8/10/2013	35.572110	-87.801950

Quantitative Sampling

After completion of qualitative sampling, the most diverse and abundant mussel community was chosen for quantitative surveying. This site was located at BRM 3.2 (5.1 km above mouth), an exceptional shoal habitat downstream of Whery Lake (Figure 2). The quantitative survey area was 67 m (220 ft) in length, and covered an area of 2,345 m^2 in size (Figure 3).

Twelve transect lines were established perpendicular to the river and spaced at intervals of 6 m (20 ft). A total of 100 quadrats (0.25 m^2 in size) was sampled along transect lines. Quadrats were evenly spaced 4 m (13 ft) apart, and were excavated to a minimum depth of 15 cm using skin diving equipment and SCUBA. Contents of each quadrat were placed in mesh collecting bags for processing. Live mussels were identified, measured for total shell length (mm) using dial calipers, photographed, recorded in field data sheets, and returned to the substrate.

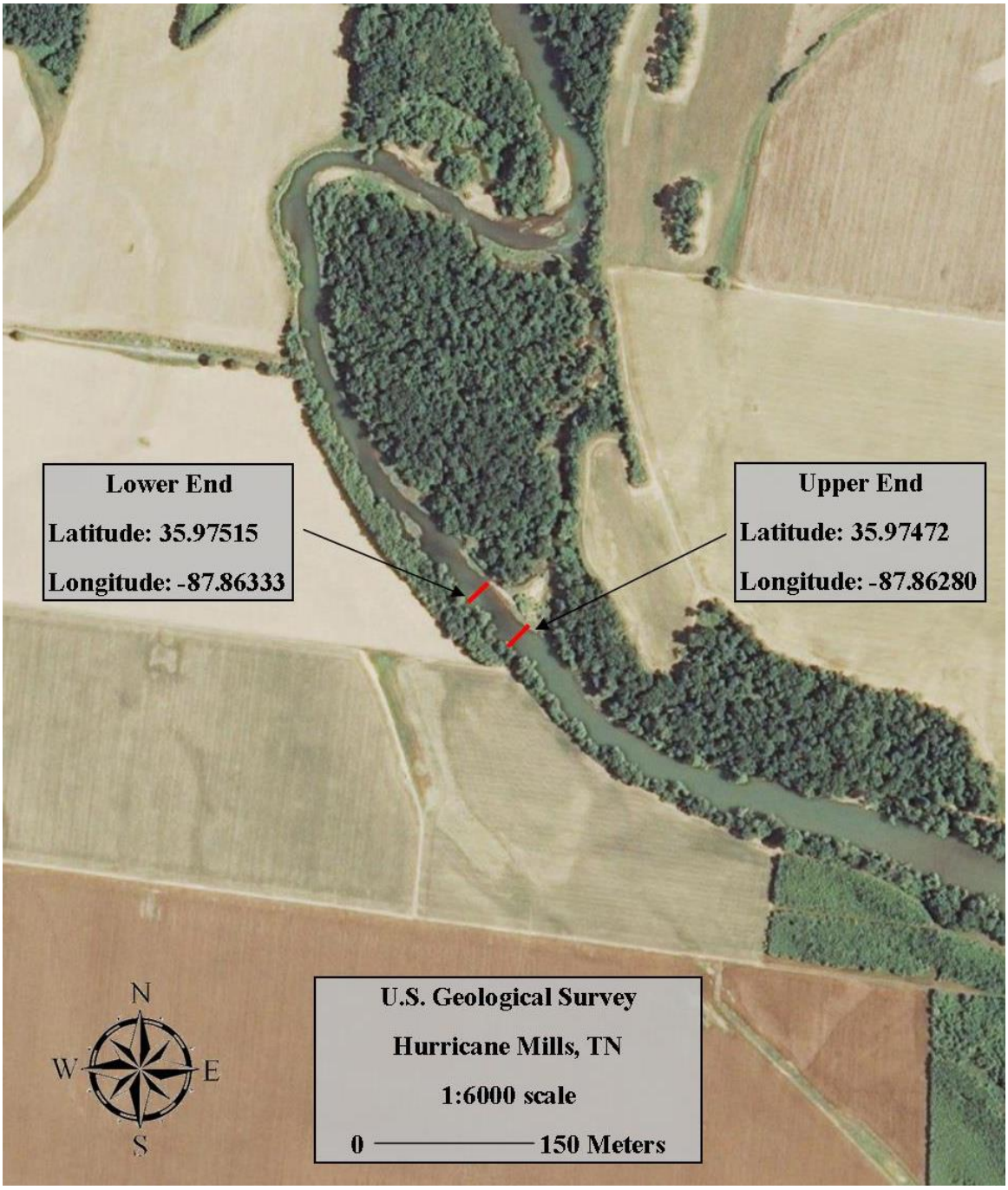

Figure 2. Area map of quantitative sampling conducted at BRM 3.2.

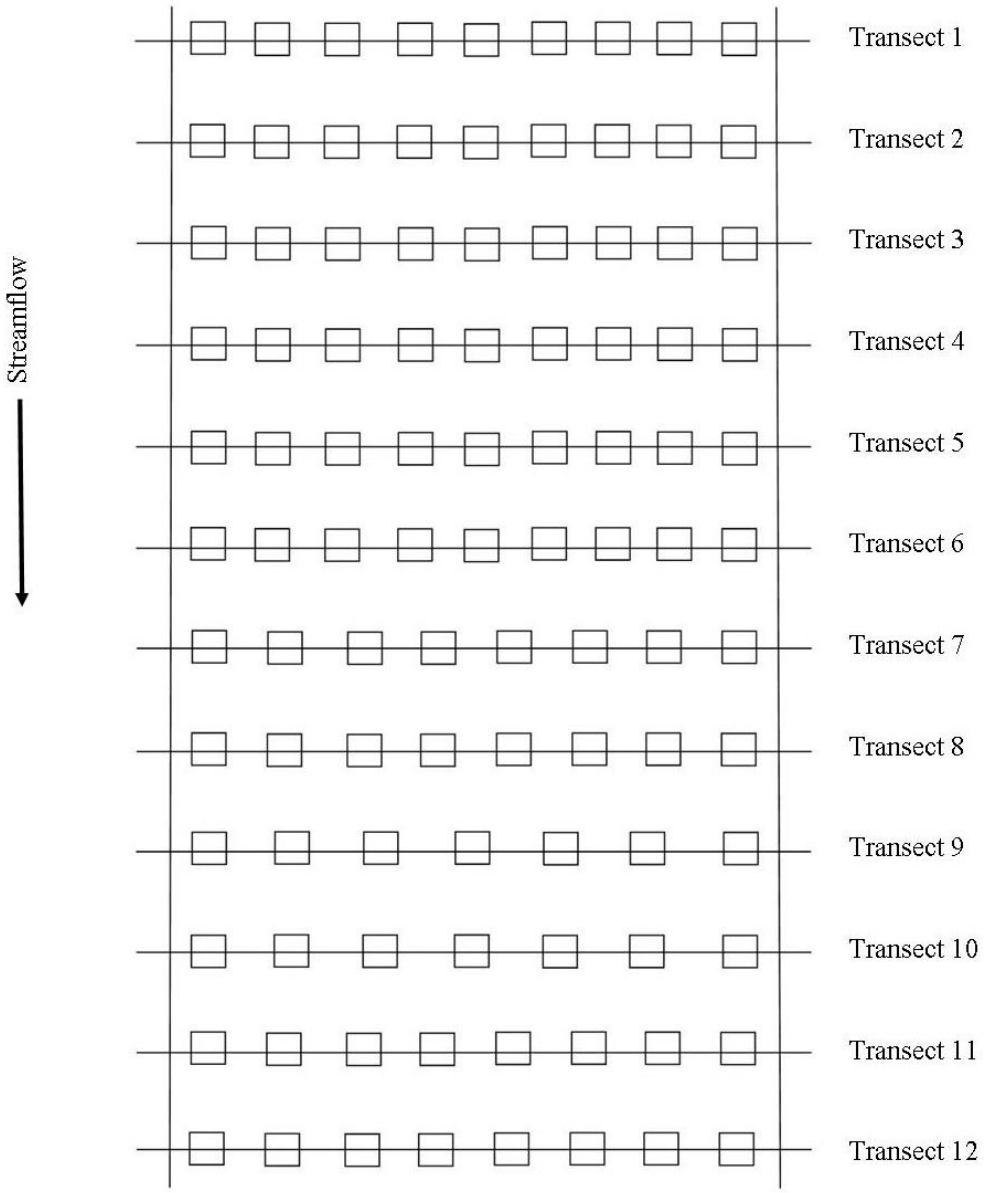

Figure 3. Diagram of transect and quadrat survey design. Number of quadrats placed along transects varied slightly according to channel width. Length of channel surveyed was 67 m (220 ft). Total area surveyed was 2,345 m^2.

Data Analyses

Qualitative sampling data was used to assess the current status and distribution of freshwater mussels in the Buffalo River. Metrics analyzed for each site surveyed in qualitative sampling efforts included species richness, relative abundance, and Catch Per Unit Effort (CPUE). Catch Per Unit Effort was calculated as CPUE= *# of observed live mussels/snorkel time per observer * # of observers*.

There are no preexisting quantitative data for mussel communities in the Buffalo River. Metrics resulting from this study will provide comparative population information for future studies and management decisions. Metrics analyzed from quantitative survey data taken from BRM 3.2 included the Shannon Diversity Index (SDI) (Shannon 1948) and Equitability Index (E) (Simpson 1949). Length frequency was recorded for all species observed in both qualitative and quantitative surveys to determine successful recruitment efforts.

Numerous studies involving freshwater mussels have documented the potential bias of size-class detection resulting from qualitative versus quantitative sampling methods (Miller and Payne 1993, Miller et al. 1993, Hornbach and Deneka 1996, Obermeyer 1998). To test for potential bias toward detecting larger individuals during qualitative sampling in this study, a two-tailed Kolmogorov-Smirnov (K-S) nonparamentric test (Smirnov 1948) was used to examine size-class variance detected in qualitative versus quantitative sampling for the most abundant species, *P. dolabelloides*. Size-class data from qualitative sampling was hypothesized to vary significantly from quantitative size-class data. Data analyses were conducted using XLSTAT statistical software.

CHAPTER 5

RESULTS

Qualitative Results

Mussel diversity varied throughout the river drainage, but exhibited significant improvement since the last sampling efforts of Ahlstedt (1991). At the time of Ahlstedt's survey, the mussel fauna was nearly extirpated. The current study demonstrated several healthy communities in the upper and lower reaches. Live or fresh dead mussels were found at 40 of the 57 sampling locations (Appendix A).

Thirty-three species were observed during qualitative sampling (Table 7), the most species reported in the Buffalo River since Goodrich and Van der Schalie's survey in 1931 (Van der Schalie 1973). This number included live, fresh dead, and relict shell material; only 15 live species were observed. *Villosa taeniata* and *Lampsilis fasciola* were the most abundant and widespread species, and were found at 21 and 18 sampling locations, respectively (Table 8).

Catch Per Unit Effort from qualitative sampling indicated sites with the greatest abundance of live mussels (Appendix B). Species richness varied similarly to CPUE throughout the river (Appendix C). At many sites, no live mussels or fresh dead material were found. Sampling in the middle portion of the river (BRM 30-BRM 98) resulted in few observations of live mussels with the exception of a few sites. In a similar pattern, species richness was low in this stretch of the river, especially below Linden.

Table 7. Species record from published studies of the Buffalo River, in addition to the present study. Studies listed according to survey year.

	Sampling Date of Previous Studies				
Species	1922	1931	1965	1980	This Study
*Cumberlandia monodonta** [1]	-	-	-	-	X
Actinonaias ligamentina	-	X	X	X	X
Actinonaias pectorosa	X	X	X	-	X
Alasmidonta marginata	X	-	X	-	-
Alasmidonta viridis	X	-	-	-	-
Amblema plicata	-	X	-	-	X
Cyclonaias tuberculata	-	X	X	X	X
Ellipsaria lineolata	-	-	-	-	X
Elliptio crassidens	X	X	X	-	X
Elliptio dilatata	X	-	-	-	X
*Epioblasma ahlstedti**	-	X	-	-	-
*Epioblasma florentina aureola**	-	X	-	-	-
*Epioblasma turgidula**	-	-	-	-	-
Fusconaia subrotunda [1]	-	-	-	-	X
*Hemistena lata**	-	X	X	-	-
Lampsilis cardium	X	X	-	-	-
Lampsilis fasciola	X	-	X	-	X
Lampsilis ovata	X	X	X	-	X
Lampsilis teres	-	X	-	-	-
Lasmigona complanata	-	X	-	-	-
Lasmigona costata	X	X	X	-	X
Leptodea fragilis	-	X	-	X	X
Ligumia recta [1]	-	-	-	-	X
Megalonaias nervosa	-	-	-	-	X
Obliquaria reflexa	-	X	-	-	X
Obovaria subrotunda	X	X	X	-	X
Pleurobema cordatum	X	X	-	-	X
Pleurobema oviforme	X	X	X	-	X
Pleurobema sintoxia	-	X	-	-	-
Pleuronaia barnesiana	X	X	-	X	X
*Pleuronaia dolabelloides**	X	X	-	-	X
Potamalis alatus	-	X	X	-	X
Ptychobranchus fasciolaris	-	-	X	-	-
*Ptychobranchus subtentum**	X	-	-	-	-
Pyganodon grandis	-	X	X	-	X
*Quadrula cylindrica cylindrica**	-	X	-	-	X
Quadrula pustulosa	-	X	-	-	X
Quadrula quadrula	-	X	-	-	X
Quadrula verrucosa	-	X	X	-	X
Strophitus undulatus	X	X	-	-	-
*Toxolasma cylindrellus**	X	X	-	-	-
Toxolasma lividum	-	-	-	-	X
Truncilla truncata	-	X	-	-	X
Utterbackia imbecillis	-	X	-	-	-
Villosa iris	X	X	-	X	X
Villosa taeniata	X	-	X	-	X
Villosa vanuxemensis	X	X	-	X	X
Total (46 species)	20	33	16	6	33

*Federally Threatened or Endangered.

[1]New Drainage Records.

Table 8. Summary of live and fresh dead mussel observations from the Buffalo River, 2012-2013.

Species	Number collected	Percentage of collection	Sites of occurrence	Distribution range (River Miles)
Cumberlandia monodonta *[1]	1	0.2	1	3.2
Actinonaias ligamentina	2	0.4	1	3.2
Actinonaias pectorosa	1	0.2	1	3.2
Amblema plicata	7	1.1	5	0.2-22.4
Cyclonaias tuberculata	34	5.9	9	0.2-57.4
Ellipsaria lineolata	4	0.7	2	0.2-3.2
Elliptio crassidens	4	0.7	3	0.2-78.7
Elliptio dilatata	35	6	9	0.2-22.4
Fusconaia subrotunda [1]	1	0.2	1	4.6
Lampsilis cardium	2	0.4	1	0.2
Lampsilis fasciola	42	7.3	18	0.2-102.9
Lampsilis ovata	5	0.9	4	3.2-17.7
Lasmigona costata	9	1.6	7	1.9-25.8
Leptodea fragilis	7	1.1	6	3.5-19.4
Ligumia recta [1]	1	0.2	1	4.6
Megalonaias nervosa	1	0.2	1	3.2
Obliquaria reflexa	3	0.5	2	3.2-3.5
Obovaria subrotunda	1	0.2	1	3.2
Pleurobema cordatum	1	0.2	1	3.5
Pleurobema oviforme	14	2.4	2	3.2-3.5
Pleuronaia barnesiana	65	11.2	13	0.2-102.9
*Pleuronaia dolabelloides**	96	16.6	13	0.3-102.9
Potamalis alatus	13	2.2	7	1.9-59.0
Pyganodon grandis	1	0.2	1	3.2
*Quadrula cylindrica cylindrica**	10	1.7	4	2.2-17.7
Quadrula pustulosa	46	7.9	3	3.2-4.9
Quadrula quadrula	2	0.4	1	3.5
Quadrula verrucosa	8	1.4	4	0.2-22.4
Toxolasma lividum	4	0.7	2	3.2-3.5
Truncilla truncata	15	2.6	2	3.2-3.5
Villosa iris	4	0.7	3	4.6-62.7
Villosa taeniata	133	23	21	4.9-102.9
Villosa vanuxemensis	6	1	5	3.2-102.9
Total (33 species)	578	100		

*Federally Threatened or Endangered.

[1]New Drainage Records.

Length frequency data taken from common and federally listed species provided insight into recruitment. Multiple size-classes indicated successful recruitment in *Villosa taeniata*, *Lampsilis fasciola*, *Pleuronaia barnesiana*, and *P. dolabelloides* (Appendix D). Multiple size classes of *Potamilus alatus* and *Quadrula cylindrica cylindrica* were observed, but there were insufficient specimens to infer information regarding recruitment.

No live or dead mussels were observed in any of the tributaries surveyed in this study (i.e., Cane, Brush, Coon, Little Opossum, and Hurricane creeks). Casual observations in the other major tributaries (Green River and Fortyeight Creek) revealed no indication that mussels were present. Consequently, tributary surveys were discontinued and are not represented in Appendix A.

While conducting quantitative sampling at BRM 3.2, an expansive muskrat midden was encountered just outside of the study area. After a brief assessment, it became evident that this midden contained in excess of 2,000 mussels. However, to avoid bias, these numbers were not included in the study results.

Quantitative Results

A total of 100 quadrats were excavated along 12 transect lines arranged perpendicular to the river channel. Quadrat excavations yielded 20 species and 178 live individuals, an average of 1.8 mussels per quadrat (Table 9).

It is commonly accepted that Shannon Diversity Index (SDI) values greater than 3.3 typically indicate stable biotic communities with minimal impact, while values less than 3.3 indicate degraded conditions with higher levels of impact (Weber 1973). Species diversity at BRM 3.2 resulted in a SDI value of 3.2 (Table 10). Federally threatened and endangered (T&E) species comprised 27.9% of the community. An Equitability Index (E) value of 0.7 also indicated a stable degree of evenness in the community. The federally listed Slabside Pearlymussel, *Pleuronaia dolabelloides*, was the most abundant species and comprised 26.4% of the community. This species also exhibited one of the healthiest length frequency distributions with multiple size-classes, indicating successful recruitment (Appendix E). Other species with multiple size-classes included *Cyclonaias tuberculata*, *Elliptio dilatata*, and *Quadrula pustulosa*. Recruitment success was inconclusive for *Lampsilis fasciola*, *P. barnesiana*, *Q. c. cylindrica*, *Q. verrucosa*, and *Truncilla truncata* due to lack of specimens observed.

Kilmogorov-Smirnov testing indicated no significant difference in size-class of *P. dolabelloides* in qualitative versus quantitative data; an alpha level of 0.05 resulted in a p-value of 0.093, with a 9.3% risk of rejecting the null hypothesis (Table 11). This suggested that qualitative sampling methods were not biased toward detecting larger individuals.

Table 9. Species, percent composition, and size range of live individuals recorded in quantitative sampling at BRM 3.2.

Species	# Observed	% Composition	Size Range (mm)
Pleuronaia dolabelloides	47	26.4	11-65
Cyclonaias tuberculata	46	26	18-99
Elliptio dilatata	20	11.2	15-85
Quadrula pustulosa	15	8.4	20-61
Truncilla truncata	9	5	18-37
Lampsilis fasciola	6	3.3	47-82
Quadrula cylindrica cylindrica	6	3.3	64-94
Quadrula verrucosa	6	3.3	64-89
Pleuronaia barnesiana	5	2.8	18-59
Ellipsaria lineolata	3	1.7	22-54
Elliptio crassidens	3	1.7	111-141
Lampsilis ovata	2	1.1	16-74
Lasmigona costata	2	1.1	82-149
Potamilus alatus	2	1.1	109-113
Actinonaias ligamentina	1	0.6	49
Actinonaias pectorosa	1	0.6	14
Megalonaias nervosa	1	0.6	88
Obliquaria reflexa	1	0.6	29
Toxolasma lividum	1	0.6	16
Villosa taeniata	1	0.6	84
Total	178	100	

Table 10. Shannon Diversity Index (SDI), Equitability Index (E), and relative abundance of federally threatened and endangered (T&E) species at BRM 3.2.

Community Metric Analyses	
Parameter	Value
SDI	3.2
E	0.7
T&E Abundance (%)	29.7

Table 11. Results of a two-tailed Kolmogorov-Smirnov test for size-class differences in qualitative versus quantitative sampling for *Pleuronaia dolabelloides*.

	Sampling Method	
Parameter	Qualitative	Quantitative
Minimum size	36.000	11.000
Maximum size	69.000	65.000
Mean	50.733	39.787
Standard Deviation	11.970	16.520
p-value	0.093	
alpha	0.050	

Species Accounts

A compilation of museum records, published surveys, and new records from the present study indicate 48 species were known to occur in the Buffalo River (Table 12). Species accounts are listed alphabetically by genus, and include former and current distributions, brief descriptions of habitat preferences, and known occurrences in the Buffalo River. Federal status is provided according to the U.S. Fish and Wildlife Service (USFWS) listings (USFWS 2014), and the pending conservation status was provided by the American Fisheries Society (AFS) (Williams et al. 2014 in review).

Table 12. Conservation status of historic and current mussels of the Buffalo River, TN. Conservation statuses given according to letter codes: X = Extinct; E = Endangered; T = Threatened; SC = Special Concern; V = Vulnerable; and CS = Currently Stable.

	Status	
Species	USFWS	AFS
Cumberlandia monodonta	E	E
Actinonaias ligamentina		CS
Actinonaias pectorosa		T
Alasmidonta marginata		V
Alasmidonta viridis		V
Amblema plicata		CS
Anodonta suborbiculata		CS
Cyclonaias tuberculata		CS
Ellipsaria lineolata		CS
Elliptio crassidens		V
Elliptio dilatata		V
Epioblasma ahlstedti	E	E
Epioblasma florentina aureola	E	E
Epioblasma turgidula	E	X
Fusconaia subrotunda		E
Hemistena lata	E	E
Lampsilis cardium		CS
Lampsilis fasciola		CS
Lampsilis ovata		CS
Lampsilis teres		CS
Lasmigona complanata		CS
Lasmigona costata		CS
Leptodea fragilis		CS
Ligumia recta		V
Megalonaias nervosa		CS
Obliquaria reflexa		CS
Obovaria subrotunda		T
Pleurobema cordatum		V
Pleurobema oviforme		T
Pleurobema sintoxia		V
Pleuronaia barnesiana		V
Pleuronaia dolabelloides	E	E
Potamilus alatus		CS
Ptychobranchus fasciolaris		V
Ptychobranchus subtentum	E	E
Pyganodon grandis		CS
Quadrula cylindrica cylindrica	T	T
Quadrula pustulosa		CS
Quadrula quadrula		CS
Quadrula verrucosa		CS
Strophitus undulatus		CS
Toxolasma cylindrellus	E	E
Toxolasma lividum		V
Truncilla truncata		CS
Utterbackia imbecillis		CS
Villosa iris		CS
Villosa taeniata		V
Villosa vanuxemensis		V
Total (48 species)		

Family Margaritiferidae

Cumberlandia monodonta (Say, 1829) – Spectaclecase.

Cumberlandia monodonta has a widespread distribution in the Mississippi River drainage, including the Tennessee and Cumberland rivers. It has become an increasingly rare species in Tennessee; the only viable population occurs in the Clinch River. Schilling and Williams (2002) noted this species had extended its range into the lower Duck River from the upper reaches at the time of their surveys, which could help explain its presence in the lower reaches of the Buffalo River. Ahlstedt et al. (2004) also reported *C. monodonta* in the Duck River. It has been collected in various types of substrate habitat, including gravel, sand, and mud in medium to large rivers. It is known to bury itself in mud or sandy substrate among roots of eelgrass (*Vallisneria americana*) or water willow (*Justicia americana*) and between boulders or bedrock in swift current. *Cumberlandia monodonta* is a new drainage record to the Buffalo River, and was found (relict shell only) at a single location: BRM 3.2 (Site 5). It is federally endangered (USFWS 2014) and is considered endangered throughout its range by the American Fisheries Society (Williams et al. 2014 in review).

Family Unionidae

Actinonaias ligamentina (Lamarck, 1819) – Mucket

Actinonaias ligamentina has a widespread distribution throughout the Mississippi River drainage, and is currently extant in tributaries of the Tennessee and Cumberland River drainages. This species is often found in shallow depths (<1 m) with moderate current. *Actinonaias ligamentina* was documented at numerous sites throughout the Buffalo River in previous studies: BRM 19.2 in 1931 (Van der Schalie 1973), BRM 74.8 (Isom and Yokley 1968), and at BRM

96.5 and BRM 97.7 (Ahlstedt 1991). *Actinonaias ligamentina* was found at a single location during this study at BRM 3.2 (Site 5): two specimens were found fresh dead during qualitative sampling in 2012, and one was found live during quadrat excavations (measuring 49 mm) in 2013. The live individual found at Site 5 was in relatively shallow water (<0.5 m). *Actinonaias ligamentina* is considered stable throughout its range (Williams et al. 2014 in review), but appears nearly extirpated from this river.

Actinonaias pectorosa (Conrad, 1834) – Pheasantshell

Actinonaias pectorosa is a Cumberlandian endemic species that remains extant in tributaries of the Cumberland and Tennessee rivers. It is typically found in medium to large rivers with swift current at relatively shallow depths. Similar to *A. ligamentina*, it was reported in 1922 by Ortmann (1924) at BRM 90.6, and was later observed at numerous localities ranging from BRM 19.2 upstream to BRM 74.8 (Isom and Yokley 1968, Van der Schalie 1973). Ahlstedt (1991) did not report *A. pectorosa*. It was found at a single location during this study at BRM 3.2 (Site 5). One shell was found fresh dead during qualitative sampling in 2012, and one was found live during quadrat excavations (measuring 14 mm) in 2013. *Actinonaias pectorosa* is considered threatened throughout its range (Williams et al. 2014 in review), and appears nearly extirpated from this river.

Alasmidonta marginata Say, 1818 – Elktoe

Alasmidonta marginata is distributed in the upper Interior drainage of the Ohio, Cumberland, and Tennessee rivers. In the Tennessee River drainage, it is currently restricted to isolated populations in tributary streams, and prefers swift current at shallow depths with fine

gravel and sand substrate. It was reported in the Buffalo River in previous studies at two locations: BRM 90.6 (Ortmann 1924), and BRM 74.8 (Isom and Yokley 1968). Isom and Yokley reported it had been extirpated from Ortmann's Riverside site (BRM 90.6) during their survey. Museum records indicate Herb Athearn collected *A. marginata* at BRM 41, above Linden. It was not reported in subsequent studies, and is possibly extirpated from the Buffalo River. *Alasmidonta marginata* is considered vulnerable throughout its range (Williams et al. 2014 in review).

Alasmidonta viridis (Rafinesque, 1820) – Slippershell Mussel

Alasmidonta viridis is distributed throughout the upper Mississippi River drainage, including the Ohio, Tennessee, and Cumberland rivers. It prefers shoal habitat at shallow depths and is currently restricted to small creeks and shallow streams in the upper reaches of the Cumberland and Tennessee River drainages, as well as a few isolated communities in the Duck River. It is typically found in sand and gravel substrate, and may be found in mud or sand among roots of water willow (*Justicia americana*). *Alasmidonta viridis* was reported in the Buffalo River by Ortmann (1924) at BRM 90.6, but was not documented in subsequent studies. It was not found during this survey, and is possibly extirpated from the river. *Alasmidonta viridis* is considered vulnerable throughout its range (Williams et al. 2014 in review).

Amblema plicata (Say, 1817) – Threeridge

Amblema plicata has a widespread distribution in the Mississippi River drainage and occurs throughout the Interior Basin. It is common in the Cumberland and Tennessee River drainages, and can be found in a variety of habitats ranging from shallow areas with swift current

to large rivers at depths up to 9 m (30 ft) (Parmalee and Bogan 1998). It is considered a habitat and host-generalist species (eurytopic), as it has over 20 confirmed fish host species. *Amblema plicata* was first reported in the Buffalo River in 1931 at BRM 19.2 (Van der Schalie 1973). It was not documented again until the present study. Fresh dead individuals of *A. plicata* were found at only two sites: BRM 0.2 (Site 1) and BRM 4.6 (Site 8). Relict shells were found at three additional sampling locations: BRM 4.9 (Site 9), BRM 8 (Site 11), and BRM 22.4 (Site 17). Current range described for *A. plicata* in this survey was synonymous with previous studies, but no live individuals were found. *Amblema plicata* is considered stable throughout its range (Williams et al. 2014 in review), but appears nearly extirpated from this river.

Anodonta suborbiculata Say, 1818 – Flat Floater

Anodonta suborbiculata has a widespread distribution throughout the Mississippi River drainage and occurs primarily in lakes and rivers. It is tolerant of increased siltation associated with impoundments, and has extended its range in the Tennessee River drainage under such conditions. It was not reported in the Buffalo River during publishes studies, but Parmalee and Bogan (1998) considered it to occur in the river based on an unpublished collection donated to McClung Museum. This specimen was collected in 1973 at BRM 31.5, near Beardstown. *Anodonta suborbiculata* was not found during this study, but is considered stable throughout its range (Williams et al. 2014 in review).

Cyclonaias tuberculata (Rafinesque, 1820) – Purple Wartyback

Cyclonaias tuberculata has a widespread distribution in the Mississippi River drainage and throughout the Interior Basin. It remains extant throughout the Tennessee and Cumberland

River drainages, and is found in a variety of habitats. It was documented in the Buffalo River in numerous studies at BRM 19.2, BRM 31.5, BRM 63.7, BRM 64.7, and BRM 74.8 (Isom and Yokley 1968, Van der Schalie 1973, Ahlstedt 1991). *Cyclonaias tuberculata* was found live at five sites during this study, from BRM 0.2 (Site 1) upstream to BRM 4.9 (Site 9). Relict *C. tuberculata* were found at four additional sites; BRM 57.4 (Site 28) was the furthest upstream locality. *Cyclonaias tuberculata* was one of the most abundant species found during quantitative sampling, and comprised 26% of the community at BRM 3.2 (Site 5). Length frequency data indicated successful recruitment at this site. Hubbs et al. (2010) reported numerous communities with large numbers of *C. tuberculata* in the Duck River. Despite large numbers in the lower reaches of the Buffalo River, *C. tuberculata* is one of several species whose range no longer extends into the upper reaches of the river. It is considered stable throughout its range (Williams et al. 2014 in review).

Ellipsaria lineolata (Rafinesque, 1820) – Butterfly

Ellipsaria lineolata occurs throughout the Mississippi River drainage, and remains extant in the Tennessee and Cumberland River drainages. It typically prefers strong current in sand and gravel substrate, but has adapted to impoundment conditions in the Tennessee and Cumberland rivers. It was not reported in published studies of the Buffalo River, and Parmalee and Bogan (1998) did not consider it to occur in the river. Schilling and Williams (2001) reported it at the mouth of the river in their survey of the lower Duck River, and Hubbs et al. (2010) documented it in several locations in the middle and upper reaches of the Duck River. Museum specimens donated to McClung Museum indicated its presence in the Buffalo River by 2011. Three fresh dead specimens were found during this study at BRM 0.2 (Site 1), and three live individuals (22-

54 mm) were recorded at BRM 3.2 (Site 5) during quadrat excavations. Its current range is apparently limited to the extreme lower reaches of the river. *Ellipsaria lineolata* is considered stable throughout its range (Williams et al. 2014 in review).

Elliptio crassidens (Lamarck, 1819) – Elephantear

Elliptio crassidens is distributed throughout the Mississippi River drainage, and remains extant primarily in the Tennessee and Cumberland rivers and a few tributaries. It was reported in the Buffalo River at BRM 90.6 (Ortmann 1924), BRM 19.2 in 1931 (Van der Schalie 1973), and BRM 74.8 (Isom and Yokley 1968). Isom and Yokley noted it had been extirpated from Ortmann's Riverside site (BRM 90.6), and Ahlstedt (1991) found no evidence of *E. crassidens* during his survey. Live individuals of *E. crassidens* were found during this study at BRM 3.2 (Site 5) during qualitative sampling in 2012, and during quadrat excavations in 2013. All live individuals were >110 mm in length; no evidence of successful recruitment was found. Relict specimens were encountered at two sites in the upper reaches of the river: BRM 55.6 (Site 26) and BRM 78.7 (Site 35). *Elliptio crassidens* is considered vulnerable throughout its range (Williams et al. 2014 in review), and appears nearly extirpated from this river.

Elliptio dilatata (Rafinesque, 1820) – Spike

Elliptio dilatata is widespread throughout the Mississippi River drainage and Interior Basin. It is extant in many tributaries of the Cumberland and Tennessee River rivers, and has been found in various habitats at depths ranging from 0.5 m (2 ft) to 8 m (26 ft). It was reported in the Buffalo River at BRM 90.6 (Ortmann 1924), but was not reported in any subsequent studies. However, its presence in the Buffalo River was not reported in Parmalee and Bogan

(1998). *Elliptio dilatata* was found at six sites in the lower reaches of the river during this survey, and was one of the most commonly occurring species observed during quadrat excavations at BRM 3.2 (Site 5). It comprised 11.2% of the community and exhibited healthy size-class distribution at this location. Relict shells were encountered upstream as far as BRM 22.4 (Site 17). As was noted with numerous species, its range no longer extends into the upper reaches of the river. *Elliptio dilatata* is considered vulnerable throughout its range (Williams et al. 2014 in review).

Epioblasma ahlstedti Jones and Neves, 2010 – Duck River Dartersnapper

Jones and Neves (2010) described *Epioblasma ahlstedti* as a distinct species from *Epioblasma capsaeformis* after identifying genetic distinctions between *E. capsaeformis* in tributaries of the upper Tennessee River drainage and the Duck River. *Epioblasma ahlstedti* is a Cumberlandian endemic species and historically occurred in the lower Tennessee River drainage in various locations including Shoal Creek and the Tennessee River at Muscle Shoals, Alabama. It is now restricted to limited reaches of the Duck River. Goodrich and Van der Schalie reported *E. capsaeformis* (=*ahlstedti*) in the Buffalo River in 1931 at BRM 19.2, near Lobelville (Van der Schalie 1973). Species within the genus *Epioblasma* are highly specialized and prefer swift, shallow currents, which contributed to their decline with the onset of impoundments. Of the 23 species and subspecies of *Epioblasma* known historically to Tennessee, only 5 remain extant (G. Dinkins, pers. comm.) *Epioblasma ahlstedti* is currently restricted to the Duck River, and has not been reported in the Buffalo River since 1931. It is federally endangered (USFWS 2014), considered endangered throughout its range by the American Fisheries Society (Williams et al. 2014 in review), and possibly extirpated from this river.

Epioblasma florentina aureola Jones and Neves, 2010 – Golden Riffleshell

Jones and Neves (2010) described *Epioblasma florentina aureola* as a distinct subspecies after identifying genetic distinctions between isolated populations of *Epioblasma florentina walkeri* in the Tennessee and Cumberland River drainages. It is a Cumberlandian endemic species and is currently restricted to a single population in Indian Creek, a tributary to the upper Clinch River, Virginia. Van der Schalie reported *E. f. walkeri* (=*florentina aureola*) in the Buffalo River at two sites in 1931: BRM 19.2, near Lobelville, and BRM 40.9, below Linden (Van der Schalie 1973). It has not been reported in the Buffalo River since 1931. *Epioblasma florentina aureola* is federally endangered (USFWS 2014), considered endangered throughout its range by the American Fisheries Society (Williams et al. 2014 in review), and possibly extirpated from this river.

Epioblasma turgidula (Lea, 1858) – Turgid Blossom

Epioblasma turgidula formerly occurred in several rivers originating in the Ozark Mountains, and in several tributaries of the Tennessee and Cumberland rivers including the Clinch, Emory, Holston, Elk, and Duck rivers. Published studies never reported *E. turgidula* in the Buffalo River, but museum records indicate Herb Athearn found three *E. turgidula* at BRM 22.7 in 1966, downstream from Lobelville at Gilmore Bridge. *Epioblasma turgidula* is federally endangered (USFWS 2014), and considered extinct by the American Fisheries Society (Williams et al. 2014 in review).

Fusconaia subrotunda (Lea, 1831) – Longsolid

Fusconaia subrotunda formerly had a widespread distribution throughout the Cumberland, Ohio, and Tennessee River drainages, but has been extirpated from much of is range. It remains extant in several of the major Tennessee River tributaries, but was not reported in the Duck or Buffalo River drainages by Parmalee and Bogan (1998). *Fusconaia subrotunda* typically prefers moderate current in riffle areas at relatively shallow depths. Relict individuals of *F. subrotunda* were found at BRM 4.6 (Site 8) during this study, but no live specimens were found. It is considered endangered throughout its range (Williams et al. 2014 in review).

Hemistena lata (Rafinesque, 1820) – Cracking Pearlymussel

Hemistena lata formerly occurred in the Ohio, Cumberland, and Tennessee River drainages, but has been extirpated from much of its historic range. In Tennessee, the only known extant populations occur in the Elk and Clinch rivers. It was reported in the Buffalo River at BRM 19.2 in 1931 (Van der Schalie 1973), and BRM 74.8 (Isom and Yokley 1968), but not found in subsequent surveys. It is federally endangered (USFWS 2014), considered endangered throughout its range by the American Fisheries Society (Williams et al. 2014 in review), and possibly extirpated from this river.

Lampsilis cardium Rafinesque, 1820 – Plain Pocketbook

Lampsilis cardium is distributed widely in the upper Mississippi River drainage and is extant in the Tennessee and Cumberland River drainages. It has been found in a variety of habitats at depths ranging from 0.5 m (1.5 ft) to 6 m (20 ft). It was reported in the Buffalo River at BRM 90.6 (Ortmann 1924), BRM 80.5, BRM 31.5, and BRM 19.2 (Van der Schalie 1973),

but not reported by Isom and Yokley (1968) or Ahlstedt (1991). A single fresh dead specimen of *L. cardium* was found during this survey at BRM 0.2 (Site 1), but no live individuals were found. *Lampsilis cardium* is considered stable throughout its range (Williams et al. 2014 in review), but appears nearly extirpated from this river.

Lampsilis fasciola Rafinesque, 1820 – Wavyrayed Lampmussel

Lampsilis fasciola has a widespread distribution in the Great Lakes and upper Mississippi River drainages, and is extant in many tributaries of the Tennessee and Cumberland rivers. It typically prefers small to medium-sized rivers at shallow depths, but is often tolerant of impacted habitat conditions unsuitable to other species. It was reported in the Buffalo River at BRM 90.6 (Ortmann 1924), and BRM 74.8 (Isom and Yokley 1968). While Ahlstedt (1991) did not report any occurrence of *L. fasciola* at 24 sampling locations, it was one of the most wide-ranging species found during this study. Live and fresh dead specimens of *L. fasciola* were found at 18 sites. Most were found below BRM 25.8, but several sites contained single individuals as far upstream as BRM 102.9 (Site 42). *Lampsilis fasciola* is considered stable throughout its range (Williams et al. 2014 in review).

Lampsilis ovata (Say, 1817) – Pocketbook

Lampsilis ovata is distributed widely throughout the Interior Basin and is currently extant in the Tennessee and Cumberland River drainages. It is typically found in small to medium-sized rivers in shallow habitat, and has also been reported in deeper, big-river environments in the Cumberland and Tennessee reservoirs (Parmalee and Bogan 1998). *Lampsilis ovata* was reported at five sites in previous studies: BRM 90.6 (Ortmann 1924), BRM 80.5, BRM 31.5, and BRM

19.2 (Van der Schalie 1973), and BRM 74.8 (Isom and Yokley 1968). Ahlstedt (1991) did not report *L. ovata* during his survey. It was found during this study at four locations: fresh dead shells were collected at BRM 3.2 (Site 5), BRM 4 (Site 7), BRM 17.7 (Site 15), and relict shells were collected at BRM 3.5 (Site 6). Two live *L. ovata* (16 and 74 mm) were found during quadrat excavations at BRM 3.2 (Site 5). It is considered stable throughout its range (Williams et al. 2014 in review).

Lampsilis teres (Rafinesque, 1820) – Yellow Sandshell

Lampsilis teres has a widespread distribution throughout the Mississippi River drainage and is extant in the lower Tennessee and Cumberland River drainages. *Lampsilis teres* typically prefers sand and muddy substrate, and is known to tolerate to impoundment conditions with increased siltation. It was reported at a single location in the Buffalo River: BRM 19.6, below Lobelville (Van der Schalie 1973). Subsequent studies found no *L teres* in the Buffalo River, and Parmalee and Bogan (1998) did not report it to occur there. No live or dead individuals of *L. teres* were found during this study. It is considered stable throughout its range (Williams et al. 2014 in review), but possibly extirpated from this river.

Lasmigona complanata (Barnes, 1823) – White Heelsplitter

Lasmigona complanata has a widespread distribution throughout the Mississippi and Great Lakes drainages. It is extant in the Tennessee and Cumberland River drainages, and may be found in a variety of habitats. It was reported at a single location in the Buffalo River: BRM 19.6, below Lobelville (Van der Schalie 1973). Subsequent studies found no *L. complanata* in the river, but Schilling and Williams (2001) reported it at the mouth of the Buffalo River in

2000. This survey found no sign of *L. complanata*. It is considered stable throughout its range (Williams et al. 2014 in review), but possibly extirpated from the river.

Lasmigona costata (Rafinesque, 1820) – Flutedshell

Lasmigona costata has a widespread distribution throughout the Mississippi and Great Lakes drainages. It is extant in the Tennessee and Cumberland River drainages, and typically prefers medium-sized rivers with moderate current. It was reported at four locations in the Buffalo River during previous studies: BRM 90.6 (Ortmann 1924), BRM 80.5, BRM 19.2 (Van der Schalie 1973), and BRM 74.8 (Isom and Yokley 1968). It was found at nine locations during this study, ranging from BRM 1.9 (Site 2) to BRM 25.8 (Site 18). Two live individuals (82 and 149 mm) were found during quadrat excavations at BRM 3.2 (Site 5). *Lasmigona costata* is considered stable throughout its range (Williams et al. 2014 in review).

Leptodea fragilis (Rafinesque, 1820) – Fragile Papershell

Leptodea fragilis is distributed widely throughout Tennessee in the Mississippi, Tennessee, and Cumberland River drainages. It is found in a variety of habitats at depths ranging from 0.6 m (2 ft) to 6 m (20 ft). It was reported in the Buffalo River at two locations in previous studies: BRM 19.2 (Van der Schalie 1973), and BRM 68.6 (Ahlstedt 1991). Live and fresh dead *L. fragilis* were found at six locations during this study, ranging from BRM 3.5 (Site 6) to BRM 19.4 (Site 16). *Leptodea fragilis* is considered stable throughout its range (Williams et al. 2014 in review).

Ligumia recta (Lamarck, 1819) – Black Sandshell

Ligumia recta has a widespread distribution throughout the Mississippi River and Gulf Coast drainages, but has experienced localized declines in recent years. It currently remains extant in the Tennessee and Cumberland River drainages, and prefers medium to large rivers with strong current. It was not reported in the Buffalo River prior to this survey, but Schilling and Williams (2001) reported fresh dead specimens near the mouth of the Buffalo River in 2000. A single relict shell was collected at BRM 4.6 (Site 8) during this study, but no live specimens were found. *Ligumia recta* is considered vulnerable throughout its range (Williams et al. 2014 in review).

Megalonaias nervosa (Rafinesque, 1820) – Washboard

Megalonaias nervosa has widespread distribution in the Mississippi River drainage and is currently extant in the lower Tennessee River and its tributaries. It is primarily found in large rivers, but has been reported in a variety of habitats including small, shallow streams. *Megalonaias nervosa* was not reported in published studies of the Buffalo River, but Schilling and Williams (2001) reported it live near the mouth of the Buffalo River in 2000. Museum records indicate Herb Athearn found two specimens of *M. nervosa* in the Buffalo River in 1966 at BRM 22.7, downstream from Lobelville at Gilmore Bridge. A single live *M. nervosa* (88 mm) was found during this survey at BRM 3.2 (Site 5). *Megalonaias nervosa* is considered stable throughout its range (Williams et al. 2014 in review), but appears nearly extirpated from this river.

Obliquaria reflexa Rafinesque, 1820 – Threehorn Wartyback

Obliquaria reflexa has a widespread distribution throughout the Interior Basin and is extant in the Cumberland and Tennessee River drainages, where it has been reported in a variety of habitats. It was reported at a single location in the Buffalo River during previous studies: BRM 19.6, downstream from Lobelville (Van der Schalie 1973). Schilling and Williams (2001) reported it live near the mouth of the Buffalo River in 2000. Fresh dead and relict individuals of *O. reflexa* were found at BRM 3.2 (Site 5) and BRM 3.5 (Site 6). A single live individual (29 mm) was found during quadrat excavations at BRM 3.2 (Site 5). *Obliquaria reflexa* is considered stable throughout its range (Williams et al. 2014 in review), but appears nearly extirpated from this river.

Obovaria subrotunda (Rafinesque, 1820) – Round Hickorynut

Obovaria subrotunda was once widely distributed throughout the Ohio, Cumberland, and Tennessee River drainages but has been extirpated from much of its former range. In the Tennessee River drainage, it remains extant in the Duck and Paint Rock rivers, and in Bear Creek. It is typically found in medium to large rivers in gravel and sand substrate in moderate current. *Obovaria subrotunda* was reported at six sites in previous studies: BRM 90.6 by Ortmann (1924), BRM 80.5, BRM 40.9, BRM 31.5, and BRM 19.2 in 1931 (Van der Schalie 1973), and BRM 74.8 in 1965 (Isom and Yokley 1968). Ahlstedt (1991) did not report this species during his survey. *Obovaria subrotunda* was collected fresh dead at BRM 3.2 (Site 5) during this survey, but no live specimens were found. It is considered threatened throughout its range (Williams et al. 2014 in review), and possibly extirpated from this river.

Pleurobema cordatum (Rafinesque, 1820) – Ohio Pigtoe

Pleurobema cordatum has a widespread distribution in the upper Mississippi River drainage and throughout the Interior Basin, and remains extant in the Tennessee and Cumberland River drainages. It is typically most abundant in large rivers with strong current. *Pleurobema cordatum* was reported at two sites on the Buffalo River in previous studies: BRM 90.6 (Ortmann 1924), and BRM 19.2 (Van der Schalie 1973). No subsequent studies of the Buffalo River reported *P. cordatum*. Relict specimens were collected during this study at BRM 3.5 (Site 6) during qualitative sampling, but no live individuals were found. It is considered vulnerable throughout its range (Williams et al. 2014 in review), and possibly extirpated from this river.

Pleurobema oviforme (Conrad, 1834) – Tennessee Clubshell

Pleurobema oviforme is a Cumberlandian endemic species and remains extant in many tributaries of the Tennessee and Cumberland rivers. It is typically found in small, shallow streams with moderate current in sandy and gravel substrate. *Pleurobema oviforme* was reported in the Buffalo River at five sites in previous studies: BRM 90.6 (Ortmann 1924), BRM 80.5, BRM 31.5, BRM 19.2 (Van der Schalie 1973), and BRM 74.8 (Isom and Yokley 1968). Relict individuals of *P. oviforme* were found at BRM 3.2 (Site 5) and BRM 3.5 (Site 6) during this study, but no live specimens were found. It is considered threatened throughout its range (Williams et al. 2014 in review), and possibly extirpated from this river.

Pleurobema sintoxia (Rafinesque, 1820) – Round Pigtoe

Pleurobema sintoxia has a widespread distribution throughout the upper Mississippi River drainage, but has become increasingly rare in the Cumberlandian Region. It is typically

found in medium to large-sized rivers in gravel and sand substrate with moderate current. It was reported at a single location in the Buffalo River during previous studies: BRM 19.6, downstream from Lobelville (Van der Schalie 1973). It was not reported in subsequent studies of the Buffalo River, and Schilling and Williams (2001) did not report it in their survey of the lower Duck River. In their recent quantitative survey of the Duck River, Hubbs et al. (2010) did not report any accounts of *P. sintoxia* at six sampling locations, and it was not found during this study. *Pleurobema sintoxia* is considered vulnerable throughout its range (Williams et al. 2014 in review), and possibly extirpated from this river.

Pleuronaia barnesiana (Lea, 1838) – Tennessee Pigtoe

Pleuronaia barnesiana is a Cumberlandian endemic species and currently restricted to the Tennessee River drainage. The largest extant population occurs in the Duck River (Ahlstedt et al. 2004, Hubbs et al. 2011). This mussel is found in small to medium-sized rivers at shallow depths, and generally associated with sand, silt, and gravel substrate. *Pleuronaia barnesiana* was reported in the Buffalo River at three locations in previous studies: BRM 90.6 (Ortmann 1924), BRM 19.2 (Van der Schalie 1973), and BRM 101.8 (Ahlstedt 1991). It was both abundant and wide-ranging in this survey. Live and fresh dead individuals were found at 13 locations, ranging from the lower Buffalo River at BRM 3.2 (Site 5), to the upper reaches at BRM 102.9 (Site 42) at the Metal Ford picnic area along Natchez Trace Parkway. Multiple size-classes indicated active recruitment at BRM 102.9. Live individuals found during quadrat excavations at BRM 3.2 measured 18-69 mm in length. *Pleuronaia barnesiana* is considered vulnerable throughout its range (Williams et al. 2014 in review).

Pleuronaia dolabelloides (Lea, 1840) – Slabside Pearlymussel

Pleuronaia dolabelloides is a Cumberlandian endemic species that remains extant in eight streams within the Tennessee River drainage, occurring in fragmented and isolated areas. It is typically found in moderately strong current and a substrate composition of sand, gravel and cobble. It was reported at two locations in the Buffalo River during previous studies: BRM 90.6 (Ortmann 1924) and BRM 19.2 (Van der Schalie 1973), but not reported in subsequent surveys (Isom and Yokley 1968, Ahlstedt 1991). Schilling and Williams (2002) noted that *P. dolabelloides* had extended its range into the lower Duck River at the time of their survey. Subsequent studies also suggested portions of the Duck River contained healthy communities of *P. dolabelloides* (Ahlstedt et al. 2004, Hubbs et al. 2011). It was one of the most abundant and wide-ranging species found during this study, as well as the most densely populated species found in quadrat excavations conducted at BRM 3.2 (Site 5), where it exhibited a healthy size-class distribution (11-65 mm) with strong evidence of recruitment. Currently, it appears to be thriving in the Buffalo River, as it was found at various locations throughout the main stem, as far upstream as BRM 102.9 (site 42) at Metal Ford. Clinal variation for this species was synonymous with observations made by Ortmann (1924) and Van der Schalie (1973) during their surveys of the Buffalo River: individuals of *P. dolabelloides* collected at BRM 102.9 were notably compressed in comparison to individuals collected at BRM 3.2. *Pleuronaia dolabelloides* is federally endangered (USFWS 2014), and considered endangered throughout its range by the American Fisheries Society (Williams et al. 2014 in review).

Potamilus alatus (Say, 1817) – Pink Heelsplitter

Potamilus alatus has a widespread distribution throughout the Mississippi River drainage and Interior Basin. It is extant in the Tennessee and Cumberland River drainages, and often found in a variety of habitats. It was reported in the Buffalo River at four locations in previous studies: BRM 40.9, BRM 31.5, BRM 19.2 (Van der Schalie 1973), and BRM 74.8 (Isom and Yokley 1968). *Potamilus alatus* was found at seven sites during this study, ranging from BRM 1.9 (Site 2) to BRM 59 (Site 30). Two live individuals (109 and 113 mm) were found during quadrat excavations at BRM 3.2 (Site 5). *Potamilus alatus* is considered stable throughout its range (Williams et al. 2014 in review).

Ptychobranchus fasciolaris (Rafinesque, 1820) – Kidneyshell

Ptychobranchus fasciolaris is distributed throughout the Ohio, Tennessee, and Cumberland River drainages, and often found in a variety of habitats. It was reported at a single location in the Buffalo River during previous surveys: BRM 74.8 at Bartley Bridge (Isom and Yokley (1968). It was not reported in subsequent studies on the Buffalo River, and was not found by Schilling and Williams (2001) during their survey of the lower Duck River. Hubbs et al. (2010) reported *P. fasciolaris* at two sites in the middle reach of the Duck River, but none were found during this survey. It is considered vulnerable throughout its range (Williams et al. 2014 in review), and possibly extirpated from this river.

Ptychobranchus subtentum (Say, 1825) – Fluted Kidneyshell

Ptychobranhcus subtentum is a Cumberlandian endemic species currently restricted to tributaries of the Tennessee and Cumberland River drainages. It typically prefers small, shallow

streams in riffle habitat with swift current. Ortmann (1924) reported *Ptychobranchus subtentum* in the Buffalo River at BRM 90.6, but it has not been found in the Buffalo River since his survey. No *P. subtentum* was found during this study. *Ptychobranchus subtentum* is federally endangered (USFWS 2014), considered endangered throughout its range by the American Fisheries Society (Williams et al. 2014 in review), and possibly extirpated from this river.

Pyganodon grandis (Say, 1829) – Giant Floater

Pyganodon grandis is common throughout the Mississippi River drainage and occurs widely in the Tennessee and Cumberland River drainages. It is known to tolerate habitats with heavy siltation common to impoundments (Parmalee and Bogan 1998). *Pyganodon grandis* was reported in the Buffalo River at three sites during previous studies: BRM 80.5, BRM 31.5 (Van der Schalie 1973), and BRM 74.8 (Isom and Yokley 1968). A single relict specimen of *P. grandis* was collected during this study at BRM 3.2 (Site 5), but no live individuals were found. It is considered stable throughout its range (Williams et al. 2014 in review).

Quadrula cylindrica cylindrica (Say, 1817) – Rabbitsfoot

Quadrula cylindrica cylindrica has a widespread distribution in the Mississippi River drainage and remains extant in fragmented populations in the Tennessee and Cumberland River drainages. It is typically found in medium to large rivers with moderate current. Prior to this survey, *Q. c. cylinrica* had not been reported in the Buffalo River since 1931 (Isom and Yokley 1968, Van der Schalie 1973, Ahlstedt 1991). Five live *Q. c. cylindrica* (80-107 mm) were found at one site: BRM 3.2 (Site 5). Relict specimens were recorded at BRM 2.2 (Site 3), BRM 3.5 (Site 5), and BRM 17.7 (Site 15). Six live individuals (64-94 mm) were found during subsequent

quadrat excavations at BRM 3.2. Multiple live individuals were observed in pool habitat ≥ 2 m in depth, and near the stream bank in shallow riffles. The critical habitat range of *Q. c. cylindrica* doesn't include any portions of the Buffalo River, and recent status updates of this species assume it to be entirely extirpated from the river. It is federally threatened (USFWS 2014), and considered threatened throughout its range by the American Fisheries Society (Williams et al. 2014 in review).

Quadrula pustulosa (Lea, 1831) – Pimpleback

Quadrula pustulosa is distributed widely throughout the Mississippi River drainage, occurs statewide in Tennessee, and is considered a habitat generalist. It was reported at a single location in the Buffalo River during previous studies: BRM 19.2, downstream from Lobelville (Van der Schalie 1973), but was not reported in subsequent surveys. It was found at three sampling locations during this study: BRM 3.2 (Site 5), BRM 3.5 (Site 6), and BRM 4.9 (Site 9). Though its range appeared to be limited to the lower reaches of the river, it occurred in large numbers where found. Over 40 relict specimens were recorded at BRM 3.5, and several hundred were collected at the muskrat midden found at BRM 3.2 while excavating quadrats. Live and fresh dead shells exhibited successful recruitment with multiple size classes. *Quadrula pustulosa* is considered stable throughout its range (Williams et al. 2014 in review).

Quadrula quadrula (Rafinesque, 1820) – Mapleleaf

Quadrula quadrula has a widespread distribution in the Mississippi River drainage, and occurs in the middle and lower Tennessee and Cumberland River drainages in Tennessee. It was reported at a single location in the Buffalo River during previous studies: BRM 19.2,

downstream from Lobelville (Van der Schalie 1973), but was not reported in subsequent surveys. Only two individuals were found during this study at BRM 3.5 (Site 6): one live (16 mm) and one fresh dead. *Quadrula quadrula* is considered stable throughout its range (Williams et al. 2014 in review), but appears nearly extirpated from this river.

Quadrula verrucosa (Rafinesque, 1820) – Pistolgrip

Quadrula verrucosa is distributed widely throughout the Mississippi River drainage, occurs statewide in Tennessee, and is considered a habitat generalist. It was reported at two locations during previous studies of the Buffalo River: BRM 19.2 (Van der Schalie 1973) and BRM 74.8 (Isom and Yokley 1968). *Quadrula verrucosa* was found at four sites during this study: BRM 0.2 (Site 1), BRM 6.8 (Site 10), BRM 12 (Site 12), and BRM 22.4 (Site 17). Six individuals were found live (64-89 mm) during quadrat excavations at BRM 3.2 (Site 5). This survey suggested the range of *Q. verrucosa* to be restricted to the lower reaches of the river. It considered stable throughout its range (Williams et al. 2014 in review).

Strophitus undulatus (Say, 1817) – Creeper

Strophitus undulatus is distributed widely throughout the entire Mississippi River drainage and the Interior Basin, and occurs in the Tennessee and Cumberland River drainages. It has been reported in a variety of habitats throughout Tennessee. *Strophitus undulatus* was reported at five sites in the Buffalo River during previous studies: BRM 90.6 (Ortmann 1924), BRM 80.5, BRM 40.9, BRM 31.5, and BRM 19.2 (Van der Schalie 1973). No accounts of *S. undulatus* were reported in subsequent studies, and Schilling and Williams (2001) did not report

it in their study of the lower Duck River. It is considered stable throughout its range (Williams et al. 2014 in review), but possibly extirpated from this river.

Toxolasma cylindrellus (Lea, 1868) – Pale Lilliput

Toxolasma cylindrellus is a rare Cumberlandian endemic species currently restricted to tributaries of the Tennessee River. It prefers small tributary rivers and headwater streams in gravel and sand substrate with moderate current. It was reported at two locations in previous studies of the Buffalo River: BRM 90.6 (Ortmann 1924) and BRM 19.2 (Van der Schalie 1973). It has not been reported in the Buffalo River since 1931, and was not found in this study. *Toxolasma cylindrellus* is federally endangered (USFWS 2014), considered endangered throughout its range by the American Fisheries Society (Williams et al. 2014 in review), and possibly extirpated from this river.

Toxolasma lividum Rafinesque, 1831 – Purple Lilliput

Toxolasma lividum formerly occurred throughout the Ohio, Tennessee, and Cumberland River drainages. It remains extant in tributaries of the Tennessee and Cumberland rivers but is increasingly rare. This species is found primarily in small to medium-sized rivers in sand and gravel substrate. *Toxolasma lividum* was not reported in any published studies of the Buffalo River, but museum records indicate it was collected at multiple locations in the 1960s and 1970s. Herb Athearn found five specimens at BRM 22.7 in 1966, and in 1972 an unpublished study reported it in the upper reaches of the river. One live *T. lividum* (16 mm) was found during this study at BRM 3.2 (Site 5), and 2 dead shells were collected at BRM 3.5 (Site 6). It considered vulnerable throughout its range (Williams et al. 2014 in review).

Truncilla truncata Rafinesque, 1820 – Deertoe

Truncilla truncata has a widespread distribution throughout the Mississippi River and Interior Basin, and occurs in the Tennessee and Cumberland River drainages in a variety of habitats. It was reported at single location in previous studies of the Buffalo River: BRM 19.2, downstream from Lobelville (Van der Schalie 1973). Five live specimens (18-37 mm) were found during this study at BRM 3.2 (Site 5), and 10 relict specimens were found at BRM 3.5 (Site 6). *Truncilla truncata* is considered stable throughout its range (Williams et al. 2014 in review).

Utterbackia imbecillis (Say, 1829) – Paper Pondshell

Utterbackia imbecillis occurs widely in the Mississippi and Great Lakes drainages and throughout the Interior Basin, and is a species common to impoundments throughout Tennessee. It was reported at one location in previous studies of the Buffalo River: BRM 80.5 (Van der Schalie 1973). No accounts of *U. imbecillis* have been reported in the Buffalo River since 1931, and Schilling and Williams (2001) did not report it in their study of the lower Duck River. It is considered stable throughout its range (Williams et al. 2014 in review), but possibly extirpated from this river.

Villosa iris (Lea, 182) – Rainbow

Villosa iris is distributed widely throughout the Ohio, Cumberland, and Tennessee River drainages. It typically prefers moderate to strong current in shallow riffles. As in other river drainages, morphology varies considerably amongst species within the genus *Villosa* in the Buffalo River. Both Ortmann (1924) and Van der Schalie (1973) reported *Villosa nebulosa* at

various locations, but under current taxonomy these records are considered *V. iris*. Museum records indicate Herb Athearn collected *V. iris* at BRM 22.7 in 1966 (downstream from Lobelville at Gilmore Bridge). Athearn originally identified this collection as *V. planicosta*. Ahlstedt (1991) reported *V. iris* at six locations in the upper reaches of the river from BRM 72.7 to BRM 101. Live *V. iris* was found at only one site during this study: BRM 6.8 (Site 10). Relict specimens were collected at BRM 4.6 (Site 8), and BRM 62.7 (Site 31). It is considered stable throughout its range (Williams et al. 2014 in review).

Villosa taeniata (Conrad, 1834) – Painted Creekshell

Villosa taeniata is a Cumberlandian endemic species restricted to tributaries of the Tennessee and Cumberland rivers. It is typically found at shallow depths with moderate current, and is associated with a substrate composition consisting of sand and gravel. It was reported in the Buffalo River during previous studies at BRM 90.6 (Ortmann 1924) and BRM 74.8 (Isom and Yokley 1968). Isom and Yokley (1968) identified two subspecies of *V. taeniata* at various locations in the Buffalo River: *V. taeniata picta* and *V. taeniata taeniata*. While *V. taeniata* was not reported anywhere in the Buffalo River by Ahlstedt (1991), it was the most abundant and wide-ranging species observed in this study. Live and fresh dead individuals were found at 21 sites, ranging from BRM 4.9 (Site 9) to BRM 102.9 (Site 42). It was found at nine sampling locations where no other mussels were encountered, often in heavily impacted areas with visible levels of sedimentation or channel instability. *Villosa taeniata* is considered vulnerable throughout its range (Williams et al. 2014 in review), but is widespread in this river.

Villosa vanuxemensis (Lea, 1838) – Mountain Creekshell

Villosa vanuxemensis is a Cumberlandian endemic species extant in tributaries of the Tennessee and Cumberland rivers. It is often found in small to medium-sized streams in shallow riffles with gravel and sand substrate. It was reported in the Buffalo River at BRM 90.6 (Ortmann 1924) and BRM 19.2 (Van der Schalie 1973). Museum records indicate Herb Athearn collected one specimen at BRM 41 (above Linden) in 1962, and 29 specimens at BRM 22.7 in 1966 (downstream from Lobelville at Gilmore Bridge). Both collections were originally identified as *V. lienosa*, and the 29 individuals taken at BRM 22.7 were noted as having considerable variation. Live individuals of *V. vanuxemensis* were found at three sites during this study: BRM 59 (Site 30), BRM 100.6 (Site 41), and BRM 102.9 (Site 42). Relict specimens were collected at BRM 3.2 (Site 5) and BRM 4 (Site 7). It is considered vulnerable throughout its range (Williams et al. 2014 in review).

CHAPTER 6

DISCUSSION AND RECOMMENDATIONS

The Buffalo River is a rare example of a large unimpounded stream with suitable mussel habitat intact in many reaches throughout its range. Analyses of literature, museum records, and unpublished surveys indicate this river once contained a minimum of 45 mussel species, a greater species richness value than reported by Parmalee and Bogan (1998), who reported 40 species. Unfortunately, its once-abundant mussel fauna was nearly extirpated in the decades following early surveys conducted in the 1920s and 30s (Ortmann 1924, Isom and Yokley 1968, Van der Schalie 1973, Ahlstedt 1991). As a result, management decisions and conservation efforts aimed at recovering imperiled species dismissed the river's potential for hosting rare mussels.

The present survey recorded 33 species of mussels in the Buffalo River during 2012-2013, three of which were new drainage records not reported in Parmalee and Bogan (1998). Additionally, this study documented the loss of 15 species once known to occur in the river (Table 13).

Table 13. Species presumed extirpated from the Buffalo River, TN.

Species	Date of last observation
Alasmidonta marginata	1965
Alasmidonta viridis	1922
Anodonta suborbiculata	1973
Epioblasma ahlstedti	1931
Epioblasma florentina aureola	1931
Epioblasma turgidula	1966
Hemistena lata	1965
Lampsilis teres	1931
Lasmigona complanata	1931
Pleurobema sintoxia	1931
Ptychobranchus fasciolaris	1965
Ptychobranchus subtentum	1922
Strophitus undulatus	1931
Toxolasma cylindrellus	1931
Utterbackia imbecillis	1931

The degree of species richness noted in many of the early studies was rarely encountered. Twenty-three species were represented by 10 individuals or less. Of those, eight species were represented by relict shells only. Significant portions of the river had few or no live mussels. The middle reach from BRM 32 (Site 19) to BRM 58 (Site 29) contained no mussels other than a limited number of *Lampsilis fasciola* and *Villosa taeniata*. These species are known to be resilient and appeared to be the only species present in degraded conditions. In the main channel, habitat loss and sedimentation are likely the primary factors prohibiting further improvement and upstream expansion of the mussel fauna. Of the 33 species still present in the river, a minimum of nine species with historic ranges in the upper reaches are now restricted to the lower reaches of the river. Obvious signs of channel and stream bank instability, likely due to riparian zone removal and agricultural practices, were observed in various stretches of the river, which corresponded with low CPUE values. Other factors prohibiting upstream expansions of the

river's mussel fauna may include exposure to toxic metals. Denton (2007) reported elevated levels of mercury in Smallmouth Bass tissue at BRM 17.7, resulting in a mercury advisory from BRM 31.6 at Highway 438 downstream to the mouth of the river. Naimo (1995) reported alterations to filtration rate, enzyme activity, weight, and increased mortality in freshwater mussels when exposed to increased concentrations of mercury.

Numerous channel alterations resulting from gravel dredging and livestock access were observed in many of the tributaries surveyed. No tributary sampling locations contained a single mussel shell, live or dead. Most of these sampling sites appeared to be destabilized, and in several instances unstable substrate and heavy siltation appeared to be a direct result of gravel mining nearby. Despite areas of channel instability and heavy sedimentation, fish diversity is excellent in the Buffalo River and its tributaries (TVA, unpublished data).

Analysis of spatial distributions observed in the present study demonstrated several findings of immediate conservation importance. The river reach in need of most conservation attention extends from BRM 3.2 to BRM 4.9. In this region, 15 species were found that occurred nowhere else in the river. This was the principal area in which several new drainage records and federally listed species were found. The federally endangered *P. dolabelloides* occurred in large numbers and was common in this reach, and this was the only portion of the river where *Q. c. cylindrica* was found live.

In addition, the area extending from BRM 100.6 at Many Cedars Campground to BRM 102.9 at Natchez Trace Parkway should be re-examined and considered for potential re-introductions. Metal Ford (BRM 102.9) below Natchez Trace Parkway had a viable community of both *P. barnesiana* and *P. dolabelloides*, and both species demonstrated strong evidence of successful recruitment. The habitat at locations sampled in this reach was excellent with minimal

disturbance, and could serve in the future as a translocation area to enhance genetic diversity in the upper reaches of the river. No mussels were found above Metal Ford at BRM 102.9, further increasing the importance of preserving and potentially augmenting this isolated region.

The continued monitoring of healthy assemblages identified in this study is highly recommended for future management efforts and subsequent studies. Fish hosts of threatened and endangered species should also be monitored carefully if the mussels that rely on them are expected to continue occurring in this river. Perhaps most important is the immediate need to conserve and monitor the surprisingly diverse and abundant assemblages found in the lower Buffalo River. Specifically, the site chosen for quadrat excavations at BRM 3.2 could serve as baseline data for future community metric studies in the river.

Given the proper attention and management, this river has the potential to regain much of its lost mussel biodiversity. Sedimentation and channel instability appeared to be the primary factors of degraded conditions in the river. It is strongly recommended that agricultural landowners throughout the Buffalo River Watershed be encouraged to participate in agricultural best management practices. Managing riparian zones and cattle movements near the main channel and tributaries could play a pivotal role in diminishing sedimentation and habitat loss in the Buffalo River.

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APPENDICES

Appendix A: Species and CPUE recorded at qualitative sampling sites in the Buffalo River (2012-2013). Includes live and fresh dead mussels.

	BRM									
Species	0.2	1.9	2.2	2.8	3.2	3.5	4	4.6	4.9	6.8
Actinonaias ligamentina	-	-	-	-	2	-	-	-	-	-
Actinonaias pectorosa	-	-	-	-	1	-	-	-	-	-
Amblema plicata	2	-	-	-	-	-	-	2	-	-
Cyclonaias tuberculata	1	-	-	-	3	-	2	2	1	-
Ellipsaria lineolata	3	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	2	-	-	-	-	-
Elliptio dilata	2	-	-	-	2	-	-	1	1	1
Lampsilis cardium	1	-	-	-	-	-	-	-	-	-
Lampsilis fasciola	2	-	1	-	2	-	1	1	2	1
Lampsilis ovata	-	-	-	-	1	-	1	-	-	-
Lasmigona costata	-	-	-	-	-	1	-	-	1	-
Leptodea fragilis	-	-	-	-	1	1	-	-	-	-
Obliquaria reflexa	-	-	-	-	-	2	-	-	-	-
Obovaria subrotunda	-	-	-	-	1	-	-	-	-	-
Pleuronaia barnesiana	6	-	-	2	1	-	-	-	-	1
Pleuronaia dolabelloides	6	-	-	1	2	-	1	-	-	1
Potamilus alatus	-	1	-	-	2	1	-	-	-	-
Quadrula cylindrica cylindrica	-	-	2	-	6	-	-	-	-	-
Quadrula pustulosa	-	-	-	-	4	-	-	-	1	-
Quadrula quadrula	-	-	-	-	-	1	-	-	-	-
Quadrula verrucosa	4	-	-	-	-	-	-	-	-	1
Toxolasma lividum	-	-	-	-	2	1	-	-	-	-
Truncilla truncata	-	-	-	-	1	-	-	-	-	-
Villosa taeniata	-	-	-	-	-	-	-	-	1	-
Villosa vanuxemensis	-	-	-	-	-	-	-	-	-	-
Total Individuals/Site	27	1	3	3	33	7	5	6	7	5
CPUE	18	1	3	3	22	4.67	5	6	7	5

Appendix A: (continued).

	BRM								
Species	8	12	13.8	16.3	17.7	19.4	22.4	25.8	32
Actinonaias ligamentina	-	-	-	-	-	-	-	-	-
Actinonaias pectorosa	-	-	-	-	-	-	-	-	-
Amblema plicata	-	-	-	-	-	-	-	-	-
Cyclonaias tuberculata	-	-	-	-	-	-	-	-	-
Ellipsaria lineolata	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-
Elliptio dilata	-	-	-	-	-	-	1	-	-
Lampsilis cardium	-	-	-	-	-	-	-	-	-
Lampsilis fasciola	-	-	2	4	2	2	-	1	-
Lampsilis ovata	-	-	-	-	1	-	-	-	-
Lasmigona costata	-	-	-	-	-	1	1	1	-
Leptodea fragilis	-	-	-	1	1	1	-	-	-
Obliquaria reflexa	-	-	-	-	-	-	-	-	-
Obovaria subrotunda	-	-	-	-	-	-	-	-	
Pleuronaia barnesiana	-	-	-	-	1	-	-	-	-
Pleuronaia dolabelloides	-	-	-	-	1	-	1	-	-
Potamilus alatus	-	-	-	-	1	2	-	-	-
Quadrula cylindrica cylindrica	-	-	-	-	1	-	-	-	-
Quadrula pustulosa	-	-	-	-	-	-	-	-	-
Quadrula quadrula	-	-	-	-	-	-	-	-	-
Quadrula verrucosa	-	1	-	-	-	-	1	-	-
Toxolasma lividum	-	-	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-
Villosa taeniata	-	-	-	-	1	1	2	1	-
Villosa vanuxemensis	-	-	-	-	-	-	-	-	-
Total Individuals/Site	0	1	2	5	9	7	6	3	0
CPUE	0	1	2	5	9	7	4	2	0

Appendix A: (continued).

	BRM									
Species	34.3	41.4	42.8	45.6	52.1	55.1	55.6	56	57.4	58
Actinonaias ligamentina	-	-	-	-	-	-	-	-	-	-
Actinonaias pectorosa	-	-	-	-	-	-	-	-	-	-
Amblema plicata	-	-	-	-	-	-	-	-	-	-
Cyclonaias tuberculata	-	-	-	-	-	-	-	-	-	-
Ellipsaria lineolata	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-	-
Elliptio dilata	-	-	-	-	-	-	-	-	-	-
Lampsilis cardium	-	-	-	-	-	-	-	-	-	-
Lampsilis fasciola	-	-	-	-	-	1	-	-	1	-
Lampsilis ovata	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	-	-	-	-	-	-	-	-	-	-
Obliquaria reflexa	-	-	-	-	-	-	-	-	-	-
Obovaria subrotunda	-	-	-	-	-	-	-	-	-	-
Pleuronaia barnesiana	-	-	-	-	-	-	-	-	-	-
Pleuronaia dolabelloides	-	-	-	-	-	-	-	-	-	-
Potamilus alatus	-	-	-	-	-	-	-	-	-	-
Quadrula cylindrica cylindrica	-	-	-	-	-	-	-	-	-	-
Quadrula pustulosa	-	-	-	-	-	-	-	-	-	-
Quadrula quadrula	-	-	-	-	-	-	-	-	-	-
Quadrula verrucosa	-	-	-	-	-	-	-	-	-	-
Toxolasma lividum	-	-	-	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-	-
Villosa taeniata	-	-	2	-	-	1	1	3	-	-
Villosa vanuxemensis	-	-	-	-	-	-	-	-	-	-
Total Individuals/Site	0	0	2	0	0	2	1	3	1	0
CPUE	0	0	2	0	0	2	1	3	1	0

Appendix A: (continued).

	BRM									
Species	59	62.7	67.4	70.6	73.5	78.7	80.5	87	90.6	93.6
Actinonaias ligamentina	-	-	-	-	-	-	-	-	-	-
Actinonaias pectorosa	-	-	-	-	-	-	-	-	-	-
Amblema plicata	-	-	-	-	-	-	-	-	-	-
Cyclonaias tuberculata	-	-	-	-	-	-	-	-	-	-
Ellipsaria lineolata	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-	-
Elliptio dilata	-	-	-	-	-	-	-	-	-	-
Lampsilis cardium	-	-	-	-	-	-	-	-	-	-
Lampsilis fasciola	-	-	-	-	-	-	-	-	-	1
Lampsilis ovata	-	-	-	-	-	-	-	-	-	-
Lasmigona costata	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis	-	-	-	-	-	-	-	-	-	-
Obliquaria reflexa	-	-	-	-	-	-	-	-	-	-
Obovaria subrotunda	-	-	-	-	-	-	-	-	-	-
Pleuronaia barnesiana	-	1	-	-	-	-	-	-	-	-
Pleuronaia dolabelloides	-	-	-	-	-	-	-	-	-	-
Potamilus alatus	1	-	-	-	-	-	-	-	-	-
Quadrula cylindrica cylindrica	-	-	-	-	-	-	-	-	-	-
Quadrula pustulosa	-	-	-	-	-	-	-	-	-	-
Quadrula quadrula	-	-	-	-	-	-	-	-	-	-
Quadrula verrucosa	-	-	-	-	-	-	-	-	-	-
Toxolasma lividum	-	-	-	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-	-	-
Villosa taeniata	-	1	-	2	-	3	-	2	-	-
Villosa vanuxemensis	1	-	-	-	-	-	-	-	-	-
Total Individuals/Site	2	2	0	2	0	3	0	2	0	1
CPUE	2	2	0	2	0	3	0	2	0	1

Appendix A: (continued).

	BRM							
Species	98.2	100.6	102.9	105.3	111.3	116.7	121	122
Actinonaias ligamentina	-	-	-	-	-	-	-	-
Actinonaias pectorosa	-	-	-	-	-	-	-	-
Amblema plicata	-	-	-	-	-	-	-	-
Cyclonaias tuberculata	-	-	-	-	-	-	-	-
Ellipsaria lineolata	-	-	-	-	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-
Elliptio dilata	-	-	-	-	-	-	-	-
Lampsilis cardium	-	-	-	-	-	-	-	-
Lampsilis fasciola	-	-	1	-	-	-	-	-
Lampsilis ovata	-	-	-	-	-	-	-	-
Lasmigona costata	-	-	-	-	-	-	-	-
Leptodea fragilis	-	-	-	-	-	-	-	-
Obliquaria reflexa	-	-	-	-	-	-	-	-
Obovaria subrotunda	-	-	-	-	-	-	-	-
Pleuronaia barnesiana	-	3	5	-	-	-	-	-
Pleuronaia dolabelloides	-	2	5	-	-	-	-	-
Potamilus alatus	-	-	-	-	-	-	-	-
Quadrula cylindrica cylindrica	-	-	-	-	-	-	-	-
Quadrula pustulosa	-	-	-	-	-	-	-	-
Quadrula quadrula	-	-	-	-	-	-	-	-
Quadrula verrucosa	-	-	-	-	-	-	-	-
Toxolasma lividum	-	-	-	-	-	-	-	-
Truncilla truncata	-	-	-	-	-	-	-	-
Villosa taeniata	-	7	12	-	-	-	-	-
Villosa vanuxemensis	-	2	1	-	-	-	-	-
Total Individuals/Site	0	14	24	0	0	0	0	0
CPUE	0	9.33	16	0	0	0	0	0

Appendix B

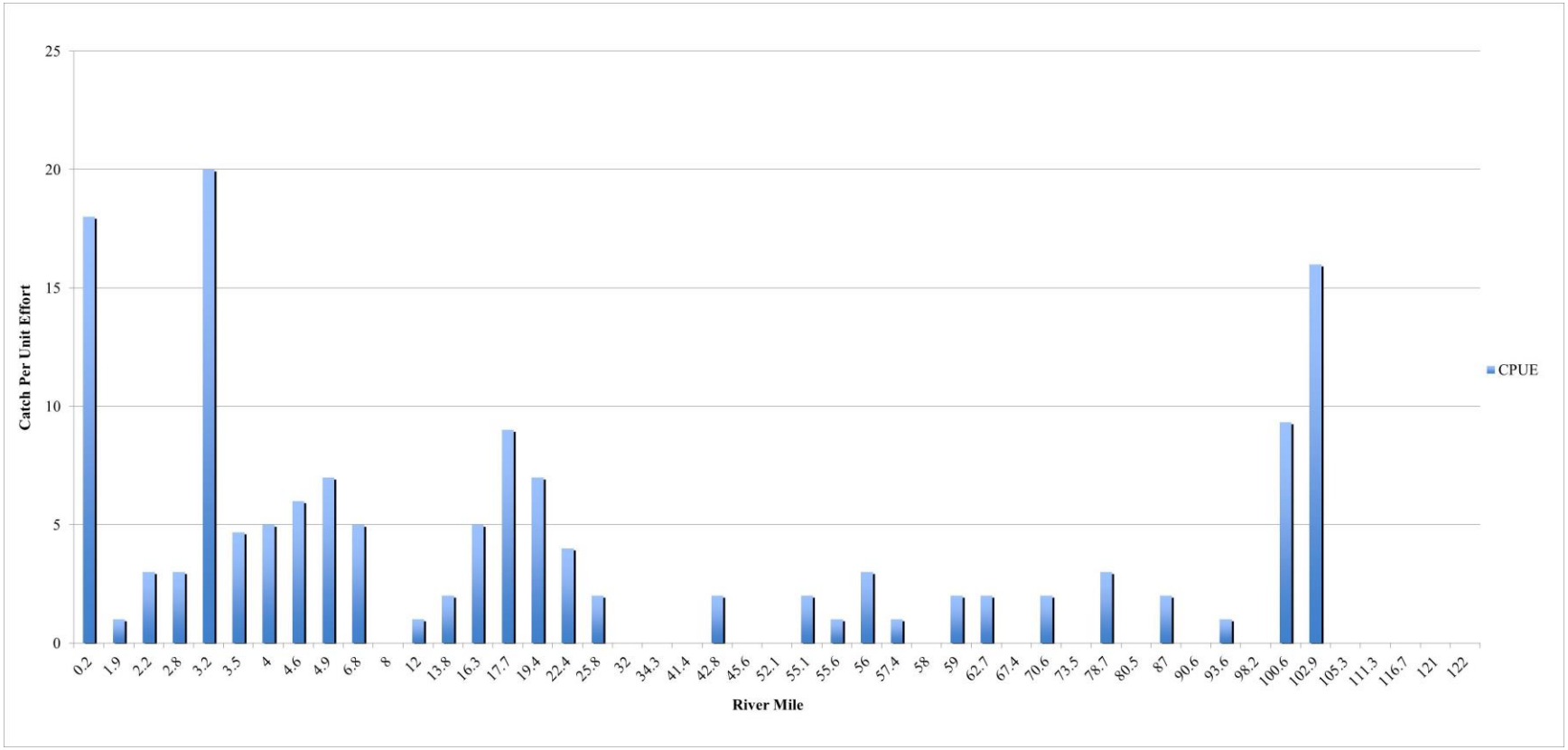

Figure 4. Catch Per Unit Effort (CPUE) at 57 sites in the Buffalo River (2012-2013). Includes live and fresh dead mussels

Appendix C

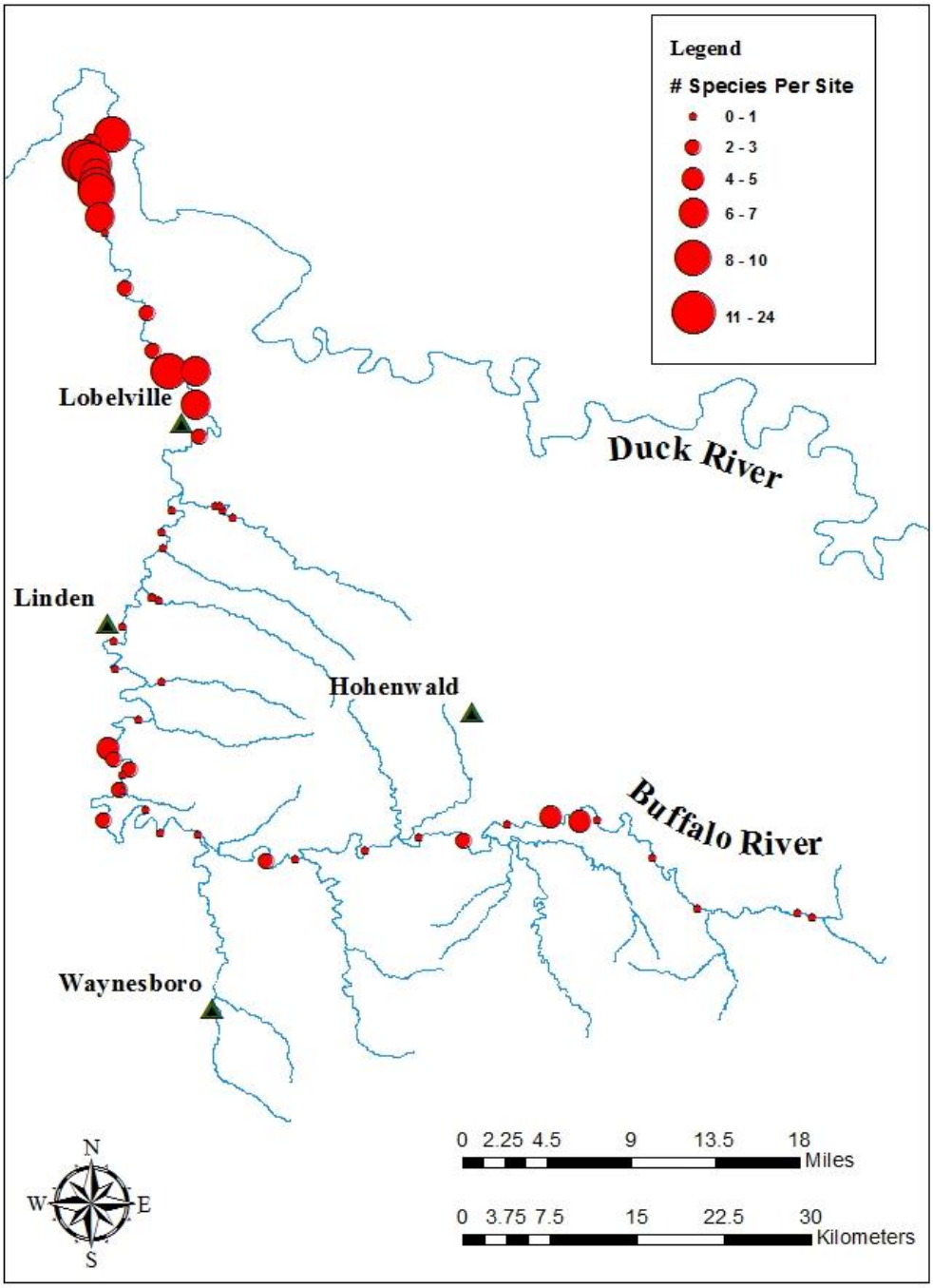

Figure 5. Proportional symbol map representing number of species found per site in the Buffalo River drainage, Tennessee.

Appendix D: Length frequency histograms of selected mussels recorded during qualitative sampling, 2012-2013.

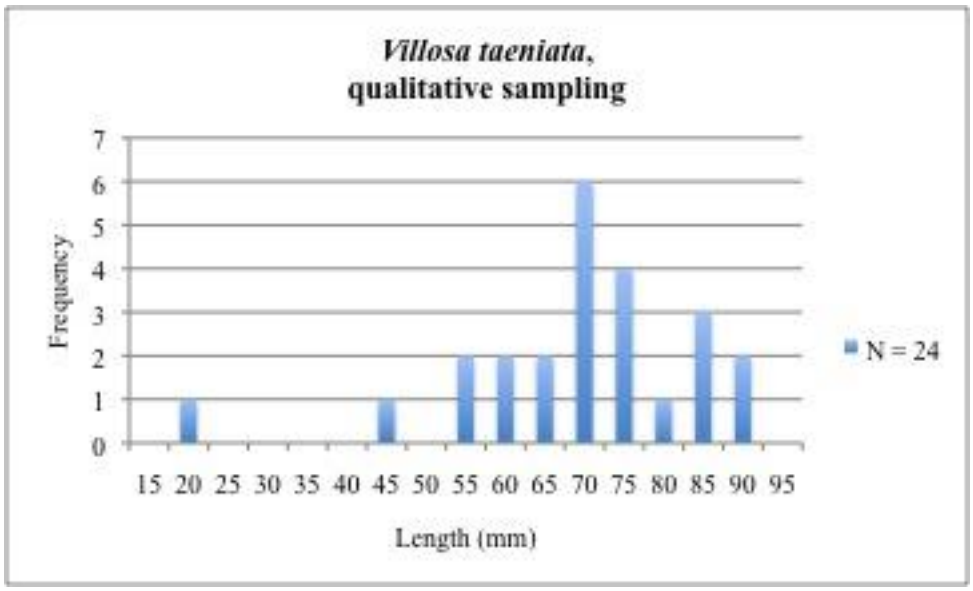

Figure 6. Length frequency of *Villosa taeniata* (2012-2013).

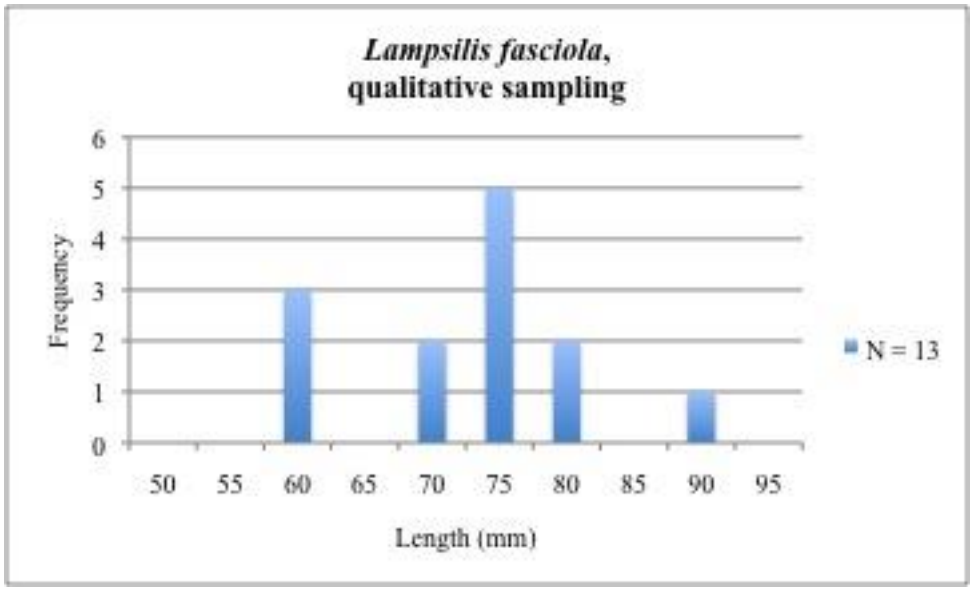

Figure 7. Length frequency of *Lampsilis fasciola* (2012-2013).

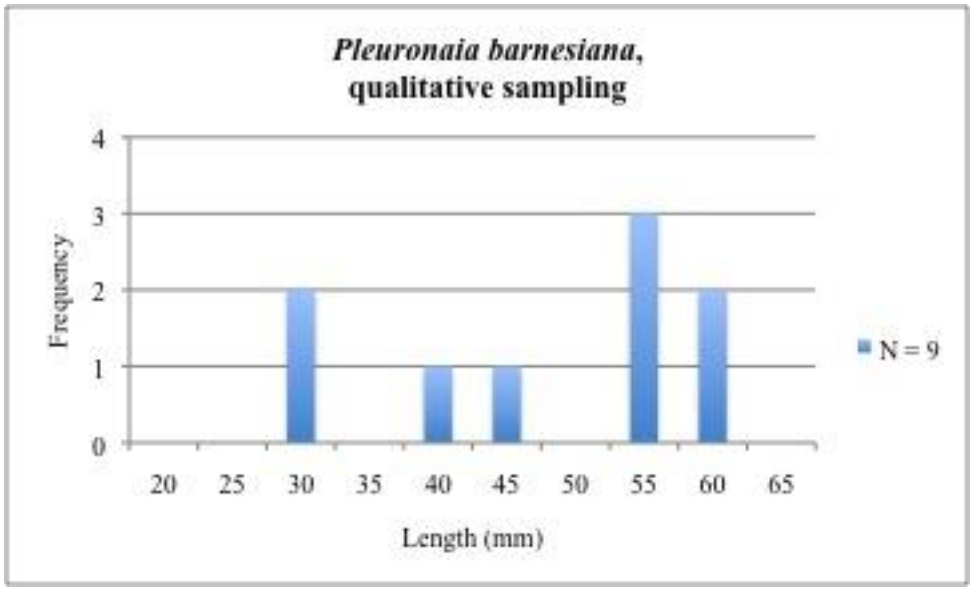

Figure 8. Length frequency of *Pleuronaia barnesiana* (2012-2013).

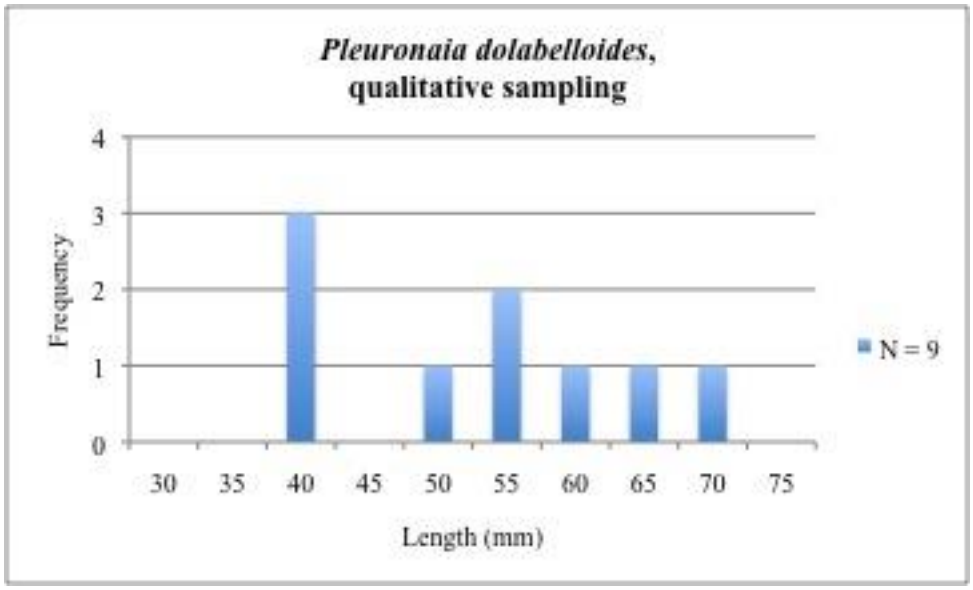

Figure 9. Length frequency of *Pleuronaia dolabelloides* (2012-2013.

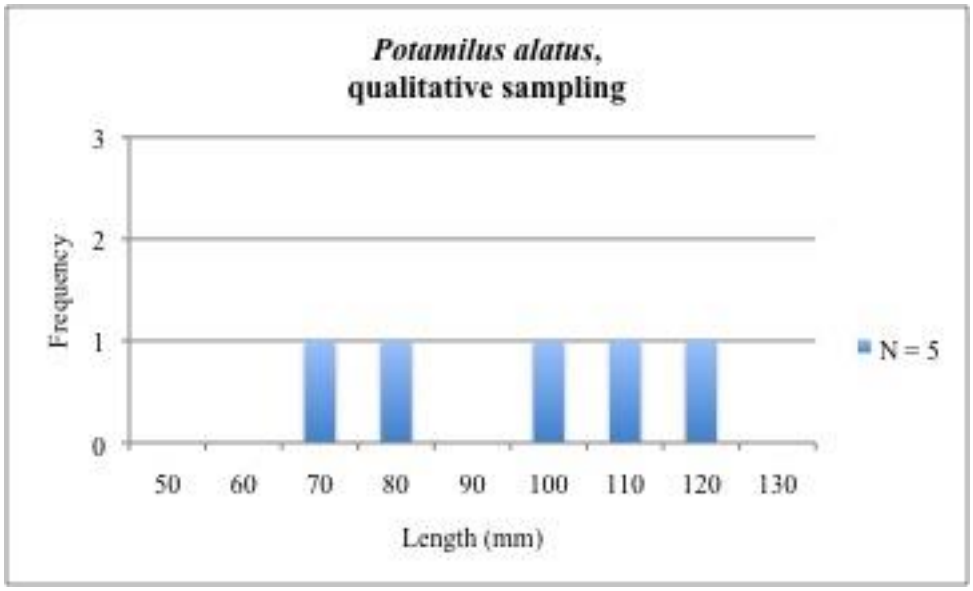

Figure 10. Length frequency of *Potamilus alatus* (2012-2013).

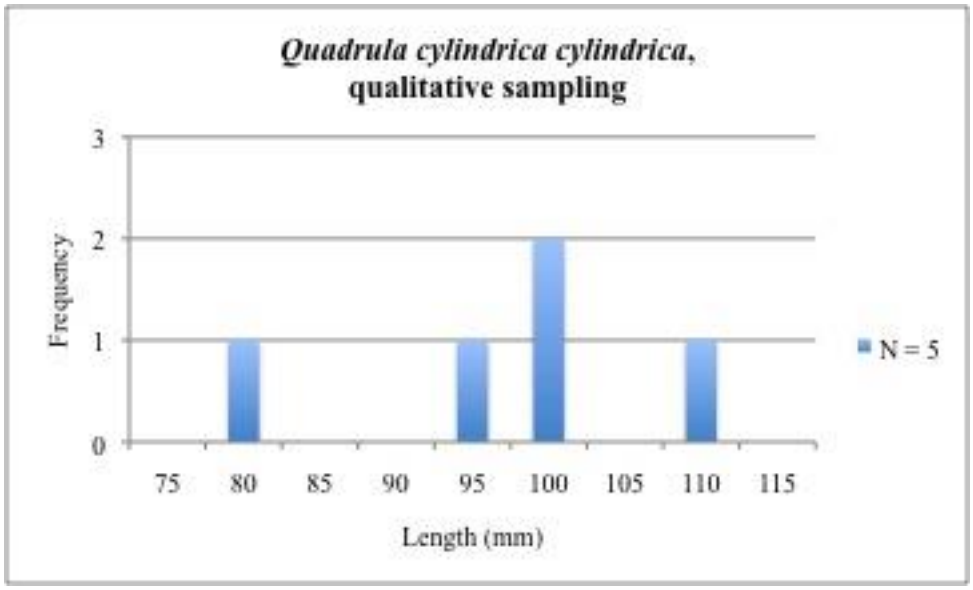

Figure 11. Length frequency of *Quadrula cylindrica cylindrica* (2012-2013).

Appendix E: Length frequency histograms of selected mussels recorded during quantitative sampling, 2012-2013.

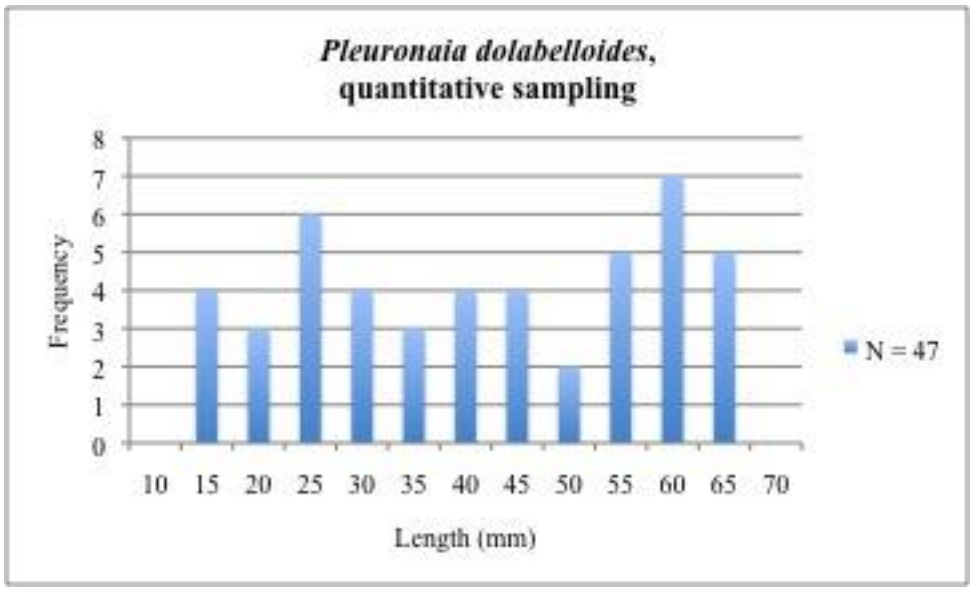

Figure 12. Length frequency of *Pleuronaia dolabelloides* at BRM 3.2.

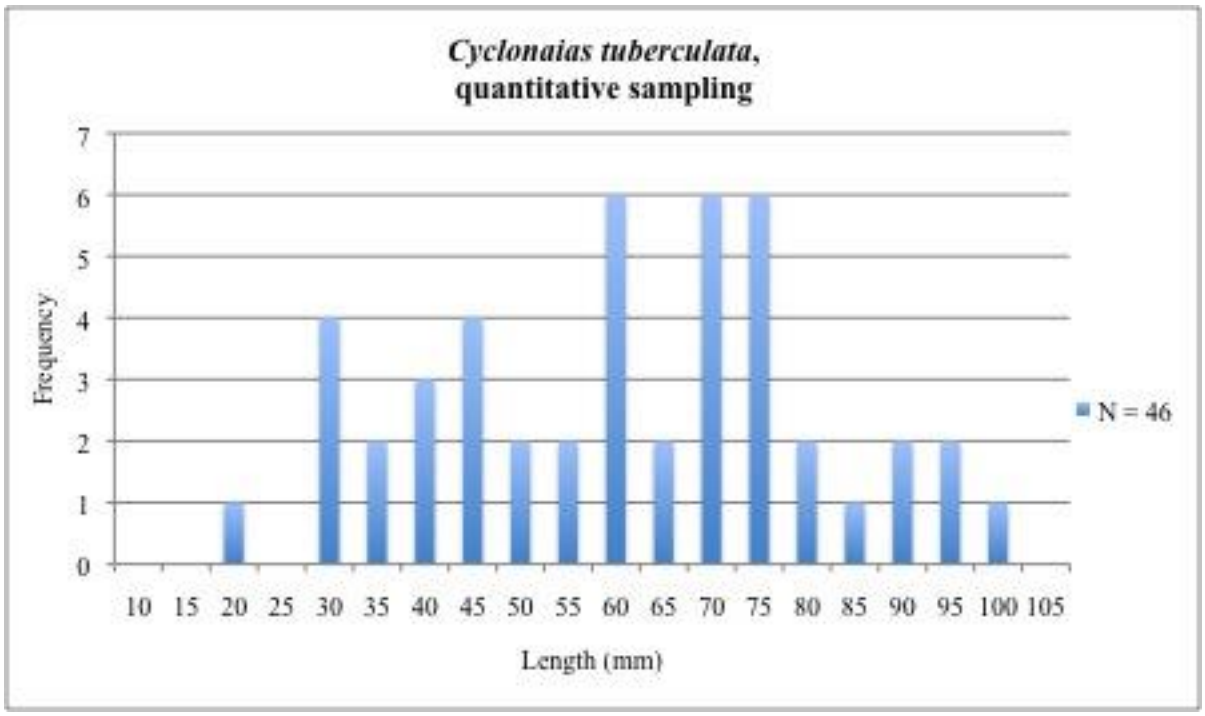

Figure 13. Length frequency of *Cyclonaias tuberculata* at BRM 3.2

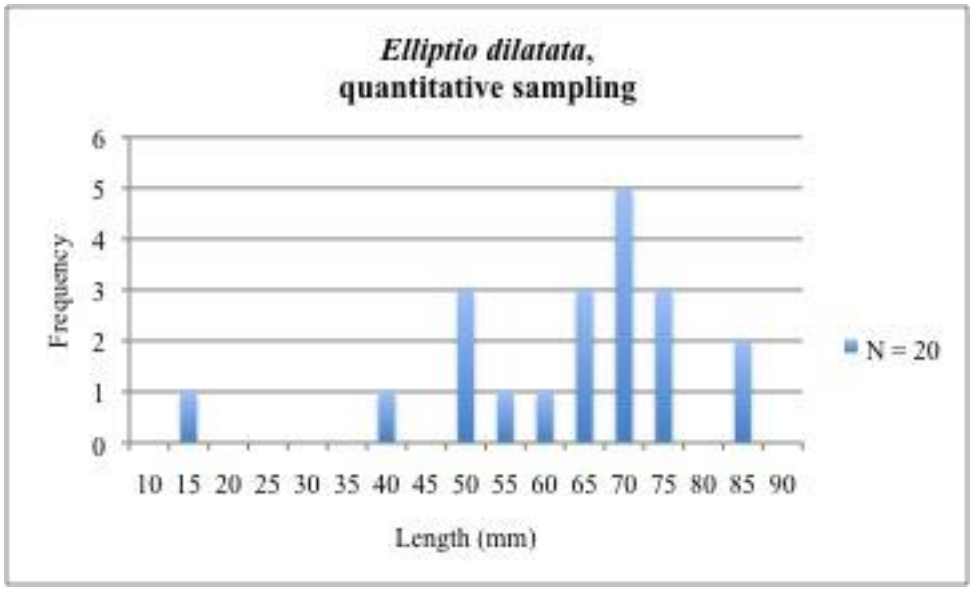

Figure 14. Length frequency of *Elliptio dilatata* at BRM 3.2.

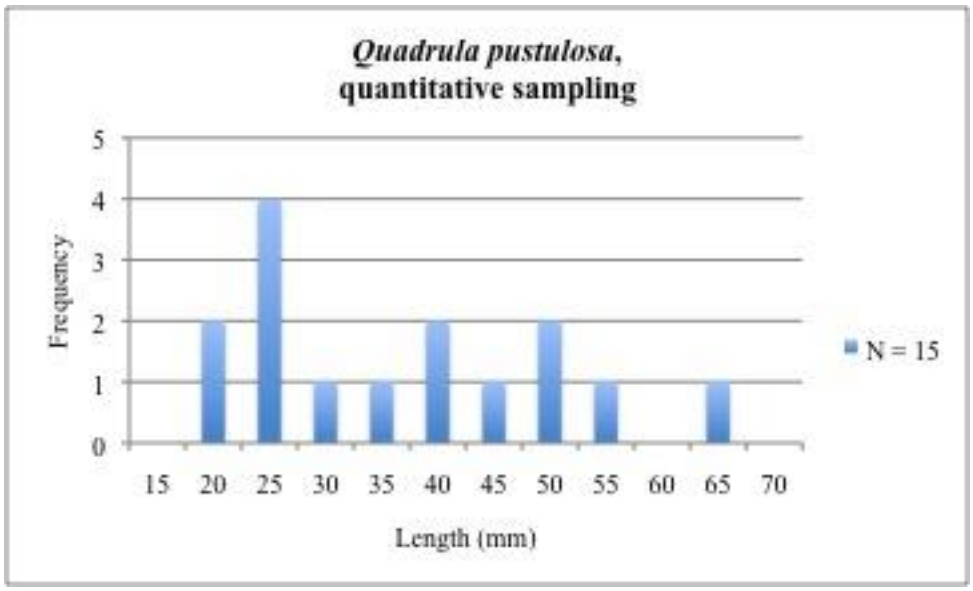

Figure 15. Length frequency of *Quadrula pustulosa* at BRM 3.2.

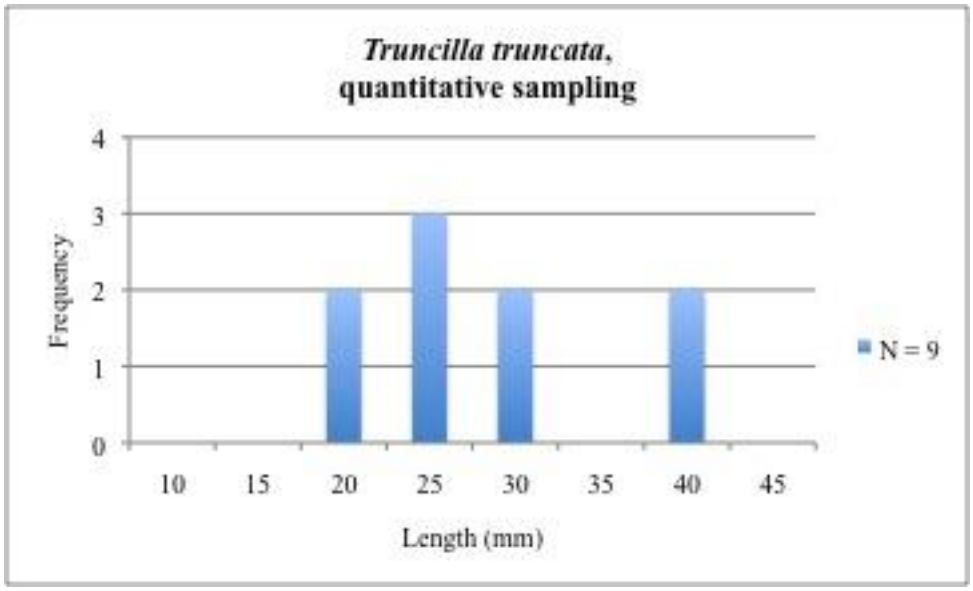

Figure 16. Length frequency of *Truncilla truncata* at BRM 3.2.

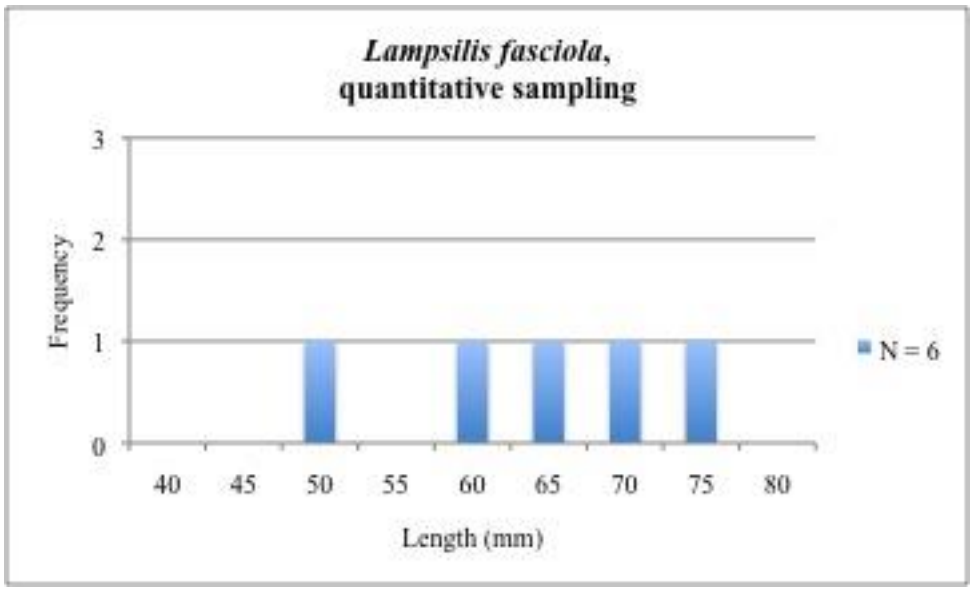

Figure 17. Length frequency of *Lampsilis fasciola* at BRM 3.2.

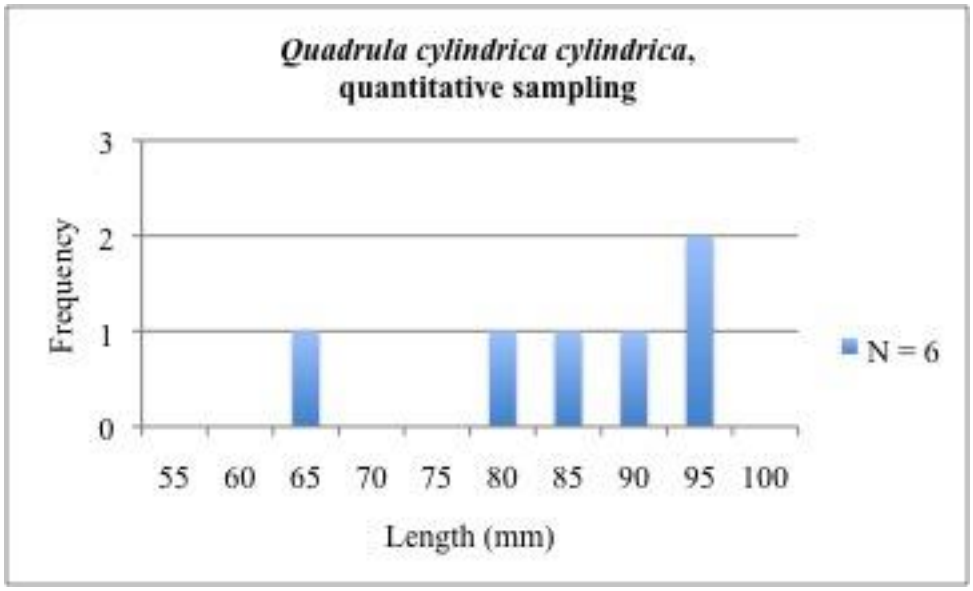

Figure 18. Length frequency of *Quadrula cylindrica cylindrica* at BRM 3.2.

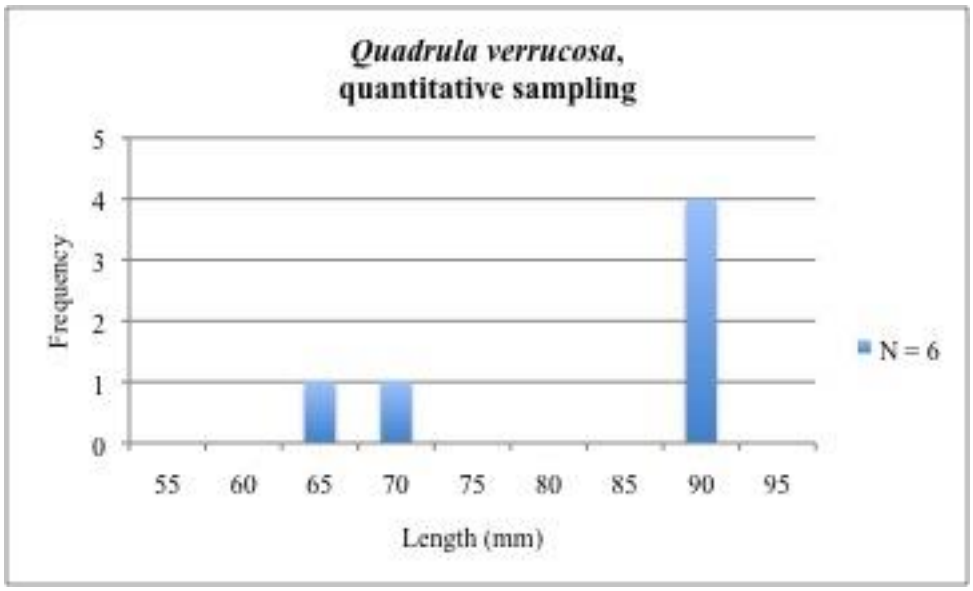

Figure 19. Length frequency of *Quadrula verrucosa* at BRM 3.2.

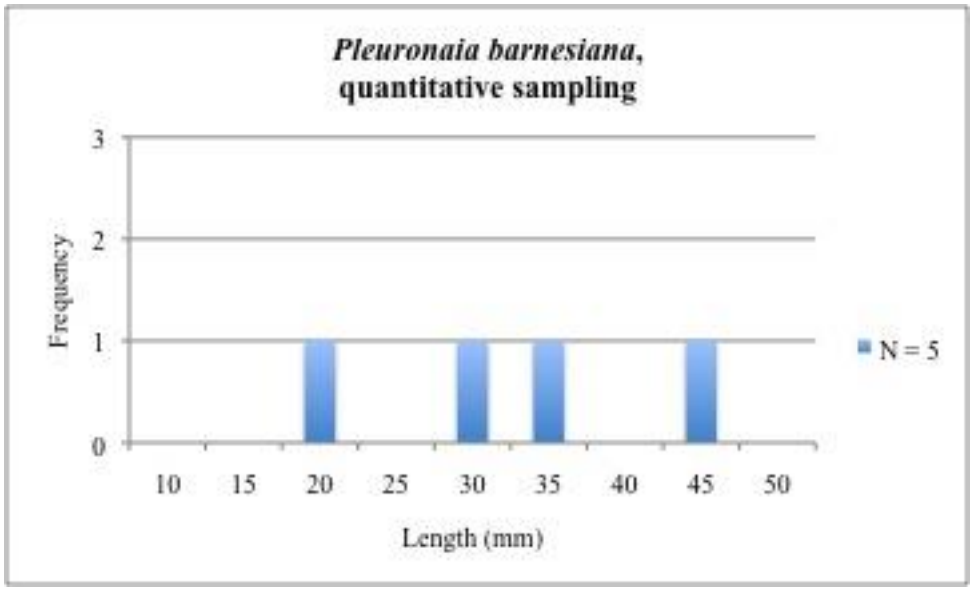

Figure 20. Length frequency of *Pleuronaia barnesiana* at BRM 3.2.

VITA

Matthew Philip Reed is originally from Joelton in Davidson County, Tennessee. After graduating high school in May 2008, he enrolled at the University of Tennessee, Knoxville. While there, he earned a Bachelor of Arts degree in Communication Studies and a Minor in Wildlife and Fisheries Science. In July 2012, he was accepted into the graduate program of Forestry, Wildlife and Fisheries at the University of Tennessee, Knoxville, where his thesis research focused on freshwater mussels of the Buffalo River drainage, Tennessee.

Matthew has worked as Collections Manager of Malacology in McClung Museum's freshwater mollusk research collection for four years. During that time, he actively participated with and guided interdepartmental research projects focused on freshwater mussels of the Southeastern United States. As a graduate student, he worked as a field and research assistant for the University of Tennessee Fisheries Laboratory, as well as a teaching assistant under Dr. Michael McKinney in the department of Earth and Planetary Sciences. Outside of his work at the University of Tennessee, Matthew also worked as a biological field technician for Dinkins Biological Consulting, LLC, and Conservation Fisheries, Inc.