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REGULAR ARTICLE

A SURVEY OF THE FRESHWATER MUSSELS (MOLLUSCA: BIVALVIA: UNIONIDA) OF THE NIANGUA RIVER BASIN, MISSOURI

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ABSTRACT

During 2007 and 2008, we surveyed freshwater mussels with timed searches at 35 sites in the Niangua River basin, an Osage River tributary in west-central Missouri. Our objective was to determine the distribution, species richness, and abundance of freshwater mussels in the basin. We observed a total of 714 live individuals from 20 species, including the Missouri endemic and species of conservation concern *Lampsilis brittsi*. The mean catch per unit effort (live mussels/person-hour) was 12 with values ranging from 0 to 144. *Eurynia dilatata* was the most abundant species (387 individuals observed, relative abundance = 54.2%), but all other species were present at much lower numbers. *Eurynia dilatata* and *Venustaconcha ellipsiformis* were the most commonly encountered species, both occurring at 24 sites. Our observation of 20 species is lower than historical richness in the basin (32 species), and nearly all species were formerly more widely distributed in the basin based on the occurrence of weathered and subfossil shells. Together with low catch per unit effort at most sites, these data suggest a sharp decline in mussel populations throughout the basin over the last few decades. This decline is cause for concern, but the causes are unknown.

KEY WORDS: freshwater mussel, Unionida, survey, Missouri

INTRODUCTION

The freshwater mussel fauna of Missouri is diverse but imperiled. Of the 69 species documented or reported from Missouri, 30 are Missouri species of conservation concern (SOCC), having state rankings of S1 (critically imperiled), S2 (imperiled), or S3 (vulnerable). Most of these SOCC are critically imperiled, and 15 are considered either state or federally endangered or threatened (McMurray et al. 2012; MDC 2018). Understanding the distribution, abundance, and diversity of mussels is crucial to the conservation of this ecologically important fauna (Haag and Williams 2014; FMCS 2016).

The Niangua River basin is part of the Upper Mississippi faunal province (Haag 2012). Thirty-two mussel species, including 5 Missouri SOCC and 1 federally and state endangered species (*Epioblasma triquetra*), are reported historically from the Niangua River basin (Table 1). *Cyprogenia aberti* is reported from the basin by 1 study (Schulz 2001), but its limited distribution in Missouri makes it likely that this record is erroneous (Oesch 1995; McMurray et al. 2012). The reports of *Ptychobranchus occidentalis* (Oesch 1995; Schulz 2001) are also doubtful based on its known distribution in Missouri (see also Hutson and Barnhart 2004).

Previous survey efforts in the Niangua River basin from 1915 to 2003 (Table 1) had limited geographic coverage, and the basin has never been systematically or quantitatively surveyed. Utterback (1915–1916) reported 3 species from a single location in the now impounded portion of the Niangua River in Lake of the Ozarks but did not report sampling effort or species abundances. Oesch (1995) reported 18 species from a 12 km reach of the Niangua River surveyed in 1969 and 10 species from a single location in the Little Niangua River surveyed in 1978 but did not describe sampling effort or report abundance or condition of the individuals collected. Addition-

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Table 1. Freshwater mussel taxa reported from the Niangua River basin, Missouri.

Species	Utterback (1915–1916)	Oesch (1995)	Schulz (2001)	MDC (Unpubl. Data)	Present survey
Anodontini					
Alasmidonta marginata[A,B]		×	×		
Alasmidonta viridis[B]			×	×	
Lasmigona complanata		×	×	×	×
Lasmigona costata		×	×	×	×
Pyganodon grandis		×	×	×	×
Strophitus undulatus		×	×	×	
Utterbackiana suborbiculata[B]		×	×		
Amblemini					
Amblema plicata		×	×	×	×
Lampsilini					
Actinonaias ligamentina		×	×		×
Ellipsaria lineolata[A]				×	
Epioblasma triquetra[B]		×	×		
Lampsilis brittsi[B]	×	×	×	×	×
Lampsilis cardium		×	×	×	×
Lampsilis siliquoidea		×	×	×	×
Leptodea fragilis		×	×	×	×
Ligumia subrostrata		×	×		
Obliquaria reflexa		×	×	×	×
Potamilus alatus		×	×	×	×
Potamilus ohiensis		×	×		
Toxolasma parvum		×	×		
Truncilla donaciformis		×	×		×
Truncilla truncata		×	×	×	×
Venustaconcha ellipsiformis	×	×	×	×	×
Pleurobemini					
Eurynia dilatata	×	×	×	×	×
Fusconaia flava		×	×	×	×
Pleurobema sintoxia		×	×	×	×
Quadrulini					
Cyclonaias pustulosa		×	×	×	×
Cyclonaias tuberculata		×	×	×	×
Megalonaias nervosa		×	×		
Quadrula quadrula		×	×		
Theliderma metanevra			×		
Tritogonia verrucosa		×	×	×	×
Total native species[C]	3	29	31	21	20

[A]Only shells collected.
[B]Missouri species of conservation concern (MDC 2018).
[C]Excludes questionable taxa.

al species reported by Oesch (1995) were a summary of known collections. Schulz (2001) reported 31 species, but this was a summary of all available records in the basin, and specific collection information was not provided. Ecological Specialists, Inc. (2003) conducted surveys at 12 sites in the Little Niangua River in 2001 and reported 18 species but only 3 live individuals. Our objective was to document the current distribution, diversity, and abundance of mussels throughout the Niangua River basin.

METHODS

Study Area

The Niangua River is a sixth-order tributary of the Osage River, Missouri River basin, in west-central Missouri. The watershed is approximately 2,694 km^2, with the Little Niangua River draining approximately 829 km^2 (Schulz 2001; Sowa et al. 2007). The basin is located in the unglaciated Ozark Aquatic Subregion, which is characterized by older limestone bedrock and higher elevations than surrounding regions. Streams in the subregion tend to be spring influenced and cool and contain limited suspended solids (Sowa et al. 2007). The basin has a diverse fish fauna that includes the Missouri endemic *Percina cymatotaenia* and the endemic and federally threatened *Etheostoma nianguae* (Pflieger 1997; Schulz 2001).

The Niangua River flows north off the Springfield Plateau to its confluence with the Osage River (Fig. 1). The Little Niangua River flows north and east to its confluence with the Niangua River near river km 10. The lower 34 km of the Niangua River and the lower 16 km of the Little Niangua River are inundated by Lake of the Ozarks. Lake Niangua is an approximately 1.5 km^2 private hydropower reservoir that impounds approximately 3.7 km of the Niangua River. Springs are numerous in the basin, with 9 having a mean daily discharge > 0.03 m^3/s, including Bennett Spring (5.1 m^3/s) and Ha Ha Tonka Spring (1.4 m^3/s), the fourth and 12th largest springs, respectively, in Missouri (Schulz 2001). Water in the basin is generally well buffered due to the underlying limestone bedrock and influence of karst (Hauck and Nagel 2003; Owen and Pavlowsky 2011). Historically, the basin consisted of deciduous pine-oak and pine forests intermixed with glades, prairie, and savannah (Sowa et al. 2007). At present, savannahs are reduced in area and the basin is mainly in pasture, with mixed-hardwood forests confined to riparian areas and protected slopes (Nigh and Schroeder 2002).

Field Sampling and Data Analysis

We surveyed mussels with timed tactile or visual searches while wading or snorkeling at 35 sites in the Niangua and Little Niangua rivers in 2007 and 2008 (Fig. 1). Additional tributaries were not surveyed because they either were too small to support substantial mussel faunas or were intermittent. Surveys were conducted during low-flow conditions, usually in summer and autumn. We searched a mean of 1.25 person-hour (person-h)/site (range = 0.4–3.2). We searched all habitats at a site, and search time was roughly equivalent to the amount of available habitat; we searched additional time if live individuals were encountered. Visual and tactile searches tend to oversample large or sculptured individuals and undersample small or buried individuals, but these techniques maximize species richness (Strayer and Smith 2003). We chose survey sites based on the presence of suitable habitat (stable gravel or gravel-sand mixtures, bluff pools) or the presence of shell material on gravel bars and to provide relatively even spatial coverage throughout the basin. Survey sites encompassed approximately 143 km of the Niangua River and approximately 33 km of the Little Niangua River and included areas previously surveyed by Oesch (1995) and Ecological Specialists, Inc. (2003). Shell material was also collected and retained as voucher material in the Missouri Department of Conservation mollusk collection, Columbia. Shell material was classified as fresh dead (FD; intact periostracum and lustrous nacre), weathered dead (WD; intact periostracum but weathered, chalky nacre), or subfossil (SF; shell chalky with no periostracum) following Southwick and Loftus (2003). We made no attempt to quantify the abundance of shell material. Conservation status follows Williams et al. (1993) and MDC (2018); nomenclature follows Williams et al. (2017).

We determined species richness for each site in 2 ways: first, as the total number of species collected live and as FD shell material (Live + FD), and, second, as the total number of species collected live and shell material in any condition (Live + shell). We used the proportional difference in these 2 estimates [1 − (richness Live + FD/richness Live + shell)] to examine apparent recent changes in species richness. We computed relative abundance, catch per unit effort (CPUE, live mussels/person-h), and Shannon Diversity Index (SDI) from live collections only. We calculated SDI with the statistical package MVSP (Multi-Variate Statistical Package, ver. 3.12d, Kovach 1999). We used Mann-Whitney *U*-test in R (version 3.4.2, R Core Team 2017) to test for significant differences between species richness estimates, CPUE, and SDI values from the Little Niangua River and Niangua River.

RESULTS

A total of 714 live individuals representing 20 species were observed (Table 2). Live mussels were not found at 10 sites. Species richness based only on Live + FD shells averaged 2.8 species/site and ranged from 0 to 10. Mean CPUE across all sites was 12.0 live mussels/person-h and ranged from 0.0 to 144.0, but CPUE was > 25.0 live mussels/person-h at only 2 sites (Fig. 2). Site NR20 had the highest species richness (Live + FD) and CPUE. There were no obvious longitudinal patterns in species richness or CPUE (Fig. 2). Species richness and CPUE were highly variable among sites, and estimates of mean values were not significantly different between the Little Niangua River (mean richness/site = 1.9; mean CPUE/site = 1.8) and the Niangua River (mean richness/site = 3.1; mean CPUE/site = 14.9; richness: $U = 95.5$; CPUE: $U = 58.5$; both $P > 0.05$; Mann-Whitney *U*-test). Shannon Diversity Index values were low at all sites and were not significantly different between the Niangua River (mean SDI = 0.8) and Little Niangua River (mean SDI = 0.7; $U = 63$, $P > 0.05$; Mann-Whitney *U*-test).

In contrast to live mussels, shells were found at every site (Table 2) and were usually abundant. Species richness based on Live + shell averaged 6.2 species/site (range = 1–14). Live + shell richness was higher than Live + FD richness at 29 of 35 sites, and the 2 measures were equal at 6 sites; Live + FD richness was not greater than Live + shell richness at any site (Fig. 2). Species richness based on Live + shell was similar in the Little Niangua and Niangua rivers (6.0 and 6.3 species/site, respectively). The apparent proportional decline in species richness averaged 0.5 but was 1.0 at 7 sites and > 0.7 at 15 sites. The mean apparent proportional decline in species richness was 0.51 in the Niangua River and 0.68 in the Little Niangua River, and there was no significant difference between the rivers ($U = 135.5$, $P > 0.05$; Mann-Whitney *U*-test). The total number of occurrences in the basin was greater

Table 2. Results of mussel surveys in the Little Niangua River and Niangua River, Missouri. CPUE = catch per unit effort; SDI = Shannon Diversity Index. Numbers for each species represent the number of live individuals at a site; the presence of shell material is indicated as FD = Fresh Dead; WD = Weathered Dead; and SF = Subfossil. *Corbicula fluminea* presence noted as L (= Live) or shell material.

	Collecting Site														
	Little Niangua River								Niangua River						
Species	8	7	6	5	4	3	2	1	27	26	25	24	23	22	21
Lasmigona complanata								SF							
Lasmigona costata						1								5	
Pyganodon grandis															
Amblema plicata		1		WD	SF	1	SF	WD			WD				
Actinonaias ligamentina											WD			5	
Lampsilis cardium	1	SF	1		FD	13		SF			4	1	WD	4	WD
Lampsilis brittsi							SF		2	18	10	WD	WD	SF	
Lampsilis siliquoidea	1	WD	1	WD	SF	WD		SF					WD	WD	SF
Leptodea fragilis		WD													
Obliquaria reflexa		1													
Potamilus alatus		WD			WD			WD							
Truncilla donaciformis															
Truncilla truncata															
Venustaconcha ellipsiformis		WD	WD		WD	1		1		1	1	WD	WD	7	
Eurynia dilatata	SF		FD		WD			1		2	10	3	WD	189	8
Fusconaia flava	SF	WD			SF			SF			2	WD	WD	67	4
Pleurobema sintoxia		WD			WD		SF					WD			
Cyclonaias pustulosa															
Cyclonaias tuberculata			SF				SF	1						WD	WD
Tritogonia verrucosa							SF	SF						2	
Corbicula fluminea		L	L	L	L	L	L	L		L	L	FD	L	L	L
Species richness (live + shells, any condition)	4	9	5	2	8	5	5	10	1	3	7	7	6	10	5
Live species richness (live + FD shells)	2	2	3	0	1	4	0	3	1	3	5	2	0	7	2
Live total individuals	2	2	2	0	0	16	0	3	2	21	27	4	0	279	12
Person-hours	2.1	1.0	1.5	1.5	1.5	2.0	0.7	1.5	0.7	1.2	1.3	1	1.5	3.2	1.2
CPUE (mussels/person-h)	1.0	2.0	1.3	0.0	0.0	8.0	0.0	2.0	2.9	17.5	20.8	4.0	0.0	87.2	10.0
SDI	0.7	2.0	0.7			0.7		1.1	0.0	0.5	1.3	0.6		0.9	0.6

for Live + shell than Live + FD for all species except *Obliquaria reflexa* and *Truncilla donaciformis*, for which the 2 measures were equal, and the total number of occurrences overall was 2.4× greater for Live + shell (Table 3).

The live mussel fauna was dominated by *Eurynia dilatata*, which was found at 24 sites, with a mean CPUE of 8.7 live mussels/person-h, and representing 54.2% of live mussels (Table 3). *Fusconaia flava* was the second most abundant species (mean CPUE = 2.2 live mussels/person-h; relative abundance = 13.5%) and was observed at 21 sites. Along with *E. dilatata*, *Venustaconcha ellipsiformis* was the most widely distributed species, occurring at 24 sites, followed by *Lampsilis cardium* (22 sites) and *Lampsilis siliquoidea* (20 sites). Ten species had relative abundance values between 1.12 and 6.86%, and the remaining 8 species each had relative abundance values $\leq$ 0.84% (Table 3).

We observed no federal or state endangered or threatened species. One Missouri SOCC, *Lampsilis brittsi*, was observed live at 6 sites (mean CPUE = 1.1 live mussels/person-h), with shell material collected at 5 additional sites. The other SOCC previously reported from the basin were not observed. We did not count *Corbicula fluminea*, but it was abundant live at 24 sites throughout the basin; shell material was observed at 4 additional sites (Table 2). *Dreissena polymorpha* is reported from Lake of the Ozarks, including the downstream impounded reaches of the Niangua River (McMurray et al. 2012) but was not observed during this survey.

DISCUSSION

Historical species richness and faunal composition of the Niangua River basin are generally similar to other streams in

Table 2, extended.

Collecting Site																			
Niangua River																			
20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
																1			WD
1				SF		1													WD
							WD								3	1			WD
				WD	SF										WD	2	6	2	WD
8	5	SF	1	WD	WD	3	WD			WD			WD					WD	WD
4			1	WD	WD	1						SF	WD		WD		1	1	WD
				SF				1		11		7							
3	SF		WD	WD	WD	2	WD									2	2	1	
																7	13		WD
																4	2	1	FD
	SF			SF												4	6	FD	WD
																FD	1		
																4	2	FD	WD
8	1	1	1	SF	1		WD		WD	2	SF		WD	2	WD			SF	
165	1	1	WD	FD	2	4	WD		WD				WD	SF	WD			1	WD
16	1	WD	WD	WD	WD	6	WD			SF			WD		WD		SF		
5						1							WD				SF		WD
																	2	SF	
4			WD	WD													WD		WD
2	1	1		SF															WD
L	L	L	L		L	L	FD	WD	L	L		L	WD	L	L			L	
10	7	5	7	12	7	7	6	1	2	5	1	2	6	2	6	9	12	10	14
10	5	3	3	1	2	7	0	1	0	2	0	1	0	1	1	9	9	7	1
216	9	3	3	0	3	18	0	1	0	13	0	7	0	2	3	25	35	6	0
1.5	0.5	0.4	0.6	1.5	1.3	1.0	1.3	1	1.0	1.0	1.5	1.0	1.0	0.8	1.3	1.5	1.5	1.5	0.8
144.0	18.0	7.5	5.0	0.0	2.3	18.0	0.0	1.0	0.0	13.0	0.0	7.0	0.0	2.5	2.3	16.7	23.3	4.0	0.0
1.0	1.3	1.1	1.1		0.6	1.7		0.0		0.4		0.0		0.0	0.0	1.9	1.8	1.6	

the region. Excluding reported species of doubtful occurrence (see Introduction), the Niangua River basin had a historical mussel fauna of at least 32 species, which is similar to the Pomme de Terre (32 species), Sac (34 species), Marais des Cygnes (40 species), and lower Osage (33 species) rivers (Ecological Specialists, Inc. 2003; Hutson and Barnhart 2004; Angelo et al. 2009). However, we found only 20 live species.

Our survey results suggest a major recent decline in species richness throughout the Niangua River basin. Most species were represented only as WD or SF at many more sites than they were found Live + FD, indicating that they were previously more widely distributed throughout the basin. We do not know the time of death for WD and SF shells and cannot pinpoint when the decline began. Due to the well-buffered water in the Niangua River basin, we would expect shell material to persist on the order of decades, especially for species with thicker shells (Warren and Haag 2005; Strayer and Malcom 2007). We also cannot account for nondetection of live individuals at sites where a species was present only as WD or SF shells (Strayer and Smith 2003). Nevertheless, the consistently higher richness estimates including WD and SF shells at most sites suggests a severe decline in basin-wide richness.

There are few historical survey data from specific sites, but comparison of existing data with ours also supports a recent decline. Oesch (1995) reported 18 species in a 12 km reach of the Niangua River surveyed in 1969 that coincided with 2 of our survey sites (NR8 and NR9; Fig. 1). We observed only 3 species in that same reach, and only 1 was represented by live individuals (*L. brittsi*). Oesch (1995) reported 10 species, including *E. triquetra*, from a single site in the Little Niangua River (our site LN3) in 1978. Ecological Specialists, Inc.

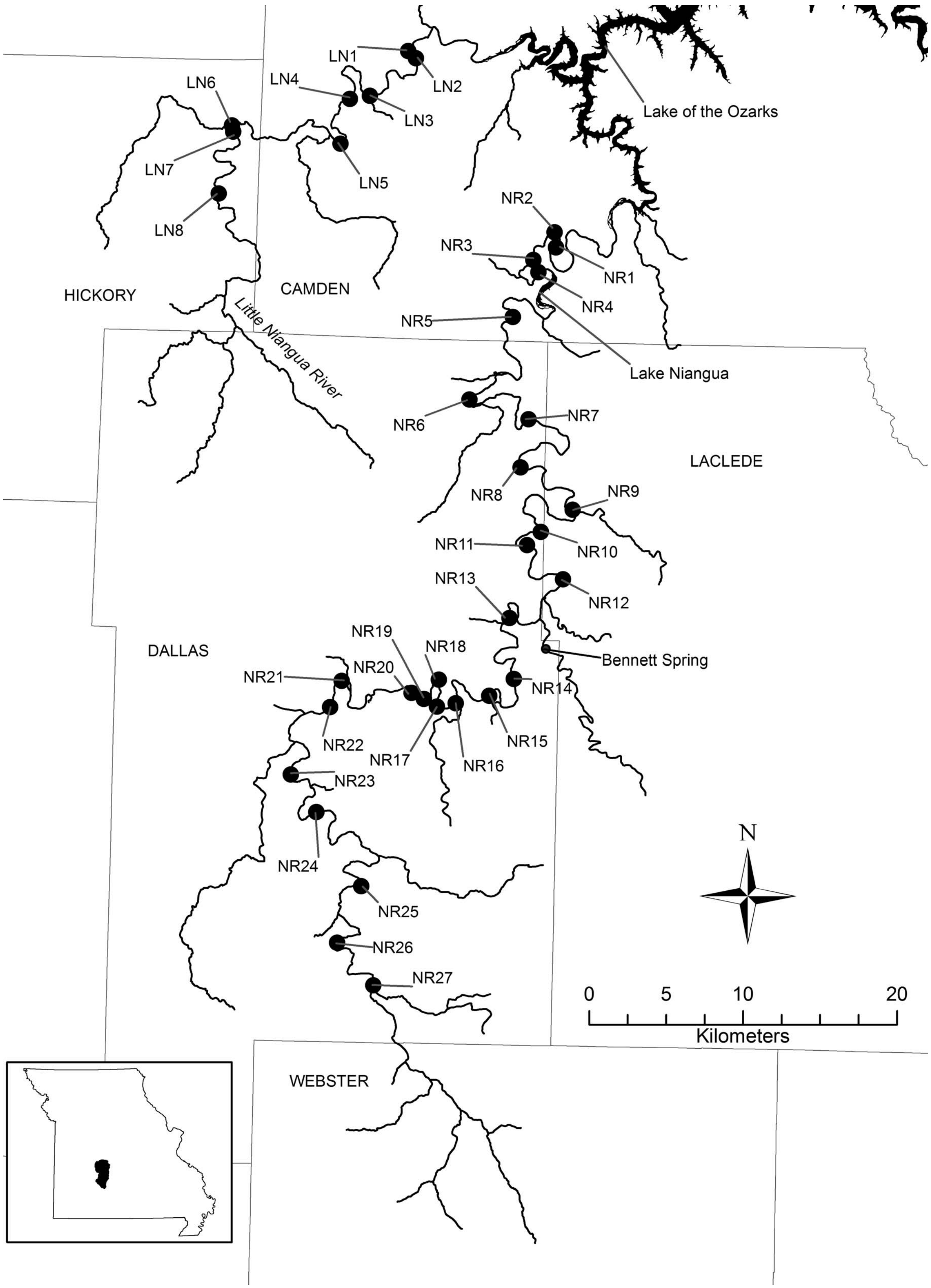

Figure 1. Niangua River Basin freshwater mussel collection sites (2007–2008). Inset shows the location of the basin in Missouri.

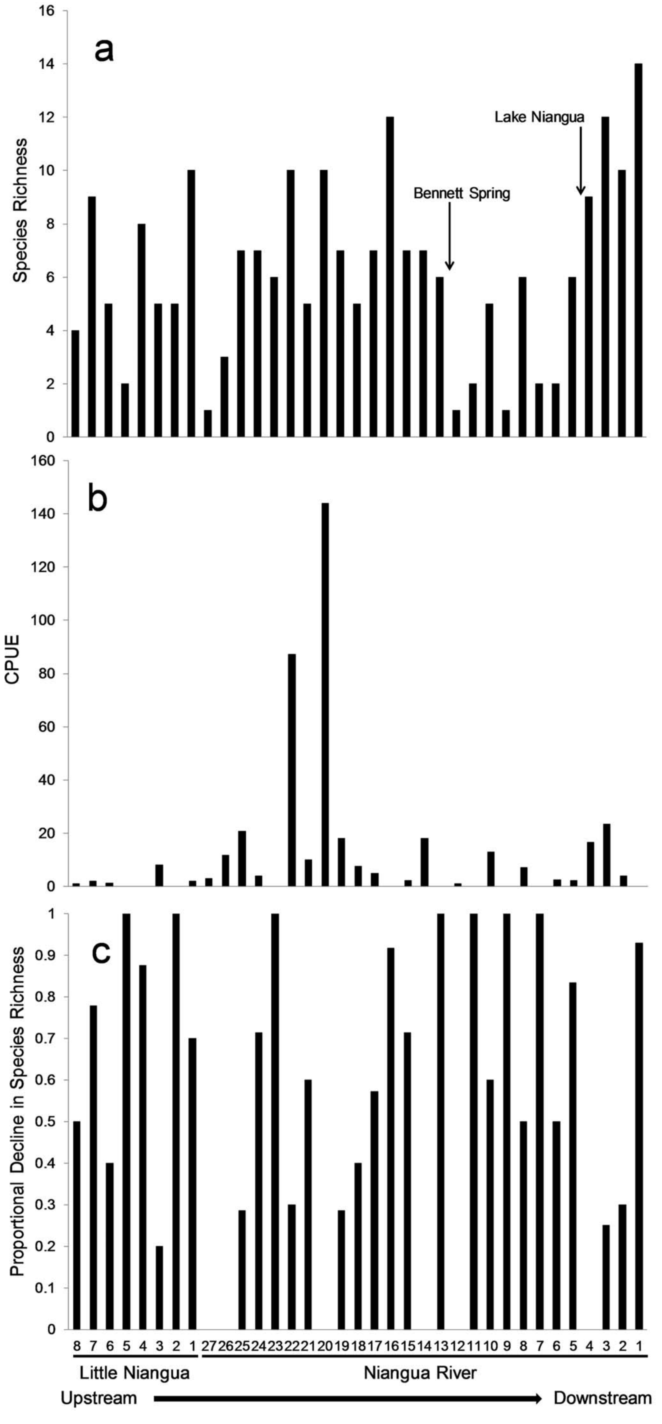

Figure 2. (a) Species richness (Live + shells), (b) catch per unit effort (CPUE, live mussels/person-h), and (c) apparent proportional decline in species richness at 35 sites in the Niangua River basin, Missouri, 2007–2008.

(2003) reported only 3 species (*Cyclonaias tuberculata*, *L. cardium*, and *L. siliquoidea*) as FD shell from that same site, and we observed only 4 live species and 1 species represented only by WD shell. No historical estimates of mussel abundance in the basin are available. However, our estimate of basin-wide mean CPUE (12.0 live mussels/person-h) was considerably lower than that reported from 2 other Osage River basin tributaries (Sac and Pomme de Terre rivers, 89.1 live mussels/person-h; Hutson and Barnhart 2004).

Table 3. Total number collected live, number of occurrences (live [L] + fresh dead [FD], and L + shells, any condition), and relative abundance of live freshwater mussels collected in the Niangua River basin, Missouri.

Species	No. Collected Live	No. Occurrences L + FD	No. Occurrences L + Shell	Relative Abundance (%)
Eurynia dilatata	387	14	24	54.20
Fusconaia flava	96	6	21	13.45
Lampsilis brittsi	49	6	11	6.86
Lampsilis cardium	32	12	22	4.48
Venustaconcha ellipsiformis	27	12	24	3.78
Actinonaias ligamentina	22	5	14	3.08
Leptodea fragilis	20	2	4	2.80
Amblema plicata	12	5	14	1.68
Lampsilis siliquoidea	12	7	20	1.68
Potamilus alatus	10	3	9	1.40
Lasmigona costata	8	4	6	1.12
Obliquaria reflexa	8	5	5	1.12
Pleurobema sintoxia	6	2	9	0.84
Tritogonia verrucosa	6	4	8	0.84
Truncilla truncata	6	3	4	0.84
Cyclonaias tuberculata	5	2	10	0.70
Pyganodon grandis	4	2	4	0.56
Cyclonaias pustulosa	2	1	2	0.28
Lasmigona complanata	1	1	3	0.14
Truncilla donaciformis	1	2	2	0.14

Apart from localized effects of hydropower operations and impoundment, several potential threats are present throughout the watershed (e.g., point source discharges, nonpoint source pollution, gravel mining), but the role of most of these factors in mussel declines is unknown (Schulz 2001; Haag 2012; Haag and Williams 2014), and we have no data on the distribution and magnitude of these potential threats. Lake Niangua could pose a barrier to *Aplodinotus grunniens* movement, the sole known host for *Leptodea fragilis* and *Potamilus alatus*, which could explain the apparent absence of these species upstream of the lake (Haag 2012; Sietman et al. 2018). However, reasons for the apparent assemblage-wide mussel decline throughout the Niangua River basin are unknown.

The Niangua River Basin has a growing threat from *D. polymorpha*, which is well established in Lake of the Ozarks, including the impounded portion of the lower Niangua River (McMurray et al. 2012). With boat traffic upstream to Lake Niangua, there will likely be further infestation of the lower Niangua River. *Corbicula fluminea* can pose a threat to native freshwater mussels in the basin through displacement or competition for juvenile habitat or by producing lethal concentrations of NH_3 during large die-offs (Yeager et al. 2000; Cherry et al. 2005; Cooper et al. 2005), but the importance of this threat is unknown.

Of the 12 previously reported species that we did not observe, some may survive in the Niangua River basin. *Alasmidonta marginata*, *Ellipsaria lineolata*, *Quadrula quadrula*, and *Theliderma metanevra* were reported within the last 10–40 years in the Niangua basin (Oesch 1995; Schulz 2001; MDC unpubl. data) and persist in other Osage River tributaries (Angelo et al. 2009; McMurray et al. 2012). Oesch (1995) reported *Utterbackiana suborbiculata*, *Potamilus ohiensis*, and *Toxolasma parvum* from an impounded portion of the Niangua River (Lake of the Ozarks); we did not survey impounded areas, but these adaptable, widespread species probably continue to occur in impounded portions of the basin. *Alasmidonta viridis*, *Strophitus undulatus*, *Ligumia subrostrata*, *E. triquetra*, and *Megalonaias nervosa* are reported from the basin only prior to 1980 (Oesch 1995; Butler 2007; McMurray 2015) and may be extirpated. With the exception of impoundment-tolerant species, other surviving species are rare in the basin, and most species we detected appeared to be present only as small populations. Our data provide a baseline for future monitoring and investigations of the cause of mussel declines in the Niangua River.

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