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REGULAR ARTICLE

A SURVEY OF THE FRESHWATER MUSSELS (MOLLUSCA: BIVALVIA: UNIONIDA) OF THE UPPER BARREN RIVER SYSTEM, TENNESSEE

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ABSTRACT

The freshwater mussel fauna of the Barren River system in Kentucky is well documented, but information on mussel occurrence in the Tennessee portion of the system was lacking. We conducted mussel surveys at 56 sites in 22 streams in the Barren River system in Tennessee. We found six species at 14 sites: *Alasmidonta viridis* (Slippershell), *Fusconaia flava* (Wabash Pigtoe), *Lampsilis cardium* (Plain Pocketbook), *Lampsilis siliquoidea* (Fatmucket), *Pyganodon grandis* (Giant Floater), and *Villosa ortmanni* (Kentucky Creekshell). Our records of *V. ortmanni* are the first reports of this species from Tennessee, and our records of *L. siliquoidea* considerably expand the known range of that species in the state. We found live or freshly dead *V. ortmanni* at five sites, and at least two sites supported relatively large populations with evidence of recent recruitment. These observations represent important information for the conservation of this imperiled species. Overall, mussel populations in the Barren River system of Tennessee were small and scattered, which may be due, in part, to the lower mussel abundance typical of headwater streams. However, the occurrence of widespread mussel declines in this region suggests that human factors may have further reduced mussel abundance.

KEY WORDS: Barren River, mussel records, Tennessee, headwaters, *Villosa ortmanni*, *Alasmidonta viridis*, *Lampsilis siliquoidea*

INTRODUCTION

The Barren River drains approximately 4,302 km^2 and is the largest tributary of the Green River (Fig. 1). The Green River joins the Ohio River south of Evansville, Indiana, and drains a greater percentage of Kentucky's land area than any other river system in the state (Burr and Warren 1986). The upper Barren River system is the only portion of the Green River drainage in Tennessee and drains 1,119 km^2 in that state. The Green River drainage supports high fish and mussel species richness, including eight endemic fishes and, potentially, one endemic mussel species (*Villosa ortmanni*; Haag and Cicerello 2016). The fish fauna of the Barren River system, including the Tennessee portion, is well known (Burr and Warren 1986; Etnier and Starnes 1993; Ceas and Page 1997). The mussel fauna of the Kentucky portion of the Barren River system is similarly well documented (Haag and Cicerello 2016), but the fauna of the Tennessee portion is largely unknown. No mussel records exist in the databases of the Tennessee Department of Environment and Conservation (TDEC) (D. Withers, TDEC, personal communication), Tennessee Wildlife Resources Agency (D. Hubbs, Tennessee Wildlife Resources Agency, personal communication), and Tennessee Valley Authority (T. Amacker, Tennessee Valley Authority, personal communication). Parmalee and Bogan (1998) provided no Tennessee mussel records from the Barren River system and did not mention it in their discussion of river systems of the state even though it appeared on two state

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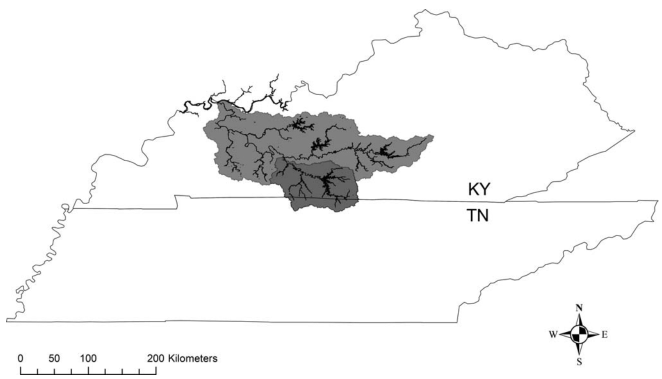


Figure 1. Location of the Barren River system within the Green River drainage, Kentucky and Tennessee, USA (Barren River system in dark shade, Green River system in light shade).

drainage maps. Finally, there are no specimens from the Tennessee portion of the Barren River system in any of the mollusk collections we contacted (North Carolina Museum of Natural Sciences, Carnegie Museum of Natural History, University of Michigan Museum of Zoology, Florida Museum of Natural History, University of Tennessee McClung Museum of Natural History and Culture [MMNHC], The Ohio State University Museum of Biological Diversity, and Harvard University Museum of Comparative Zoology). Several Barren River tributaries in Tennessee are of substantial size, suggesting that the lack of mussel records is due to lack of sampling.

We conducted a comprehensive mussel survey of the Tennessee portion of the Barren River system from December 2016 to May 2019. We discuss how our results expand our knowledge of mussel distribution in this region and contribute to conservation efforts for the Green River drainage mussel fauna.

METHODS

Study Area

The Barren River system in Tennessee lies in Sumner, Macon, and Clay counties, and includes 906 km of streams and 18 ha of impoundments (TDEC 2007; Fig. 1). On the western side of the system in Tennessee, the largest tributaries are West Fork Drakes Creek, Middle Fork Drakes Creek, and Trammel Creek, which converge in Kentucky to form Drakes Creek, the largest tributary of the Barren River. On the eastern side of the system in Tennessee the largest tributaries are Long Creek, Salt Lick Creek, Long Fork, and Line Creek, all of which ultimately flow into the upper Barren River. Streams in the Barren River system in Tennessee are on the Eastern Highland Rim or Western Pennyroyal Karst subunits of the Interior Low Plateaus physiographic province. Streams in this area are upland in character and flow over sand, gravel, and bedrock substrates.

The Barren River system in Tennessee is largely rural and undeveloped. The largest municipality (Portland) has fewer than 12,000 people (US Census Bureau 2020). Land use in the Tennessee portion of the system is 50.2% forest (deciduous, evergreen, and mixed), 23.8% developed and barren land, 21.1% hay pasture and herbaceous, 1.9% cultivated crops,

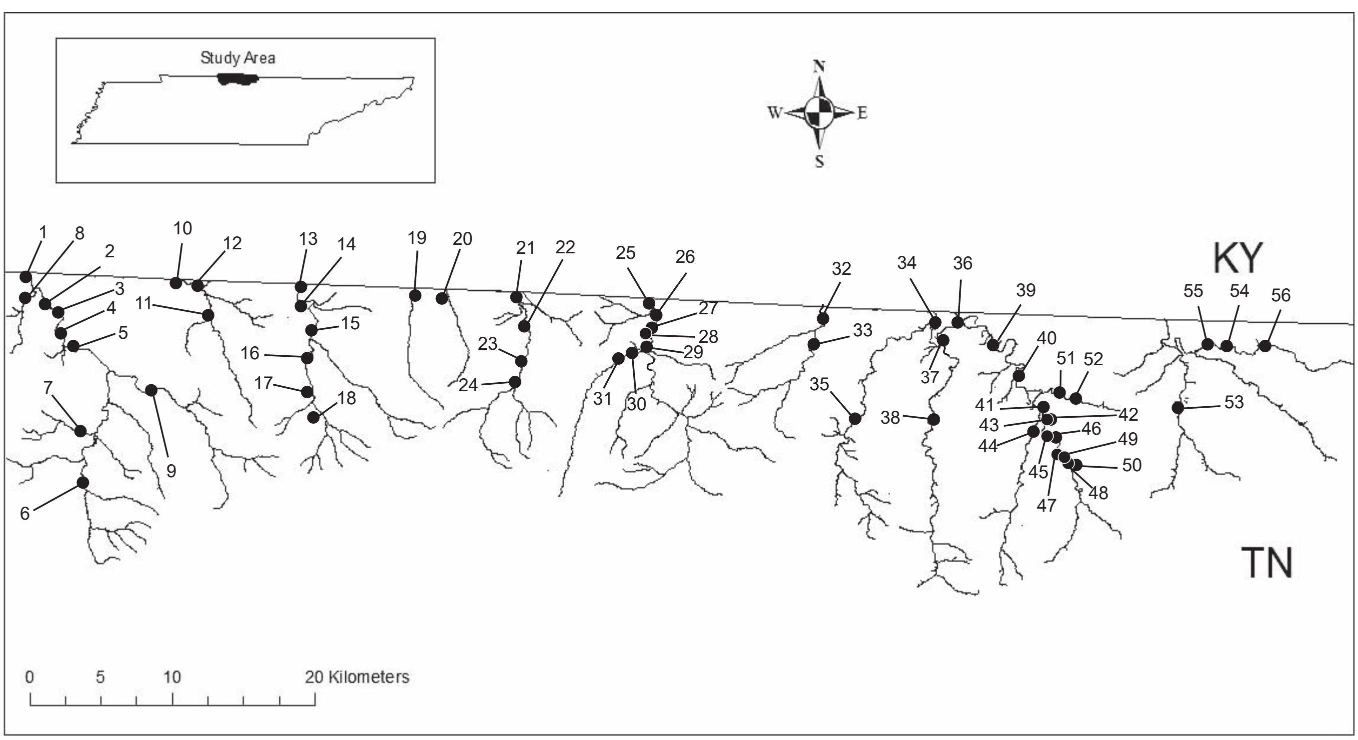


Figure 2. Mussel sampling sites in the Barren River system, Tennessee. Inset map shows the Barren River system in Tennessee (shaded).

Table 1. Mussel survey sites in the Barren River system, Tennessee.

Site	Stream	Location	County	Coordinates	Date	Stream Order
1	West Fork Drakes Creek	Coker Ford Road	Sumner	36.64760, 86.50632	December 13, 2016	3
2	West Fork Drakes Creek	Rapids Road	Sumner	36.63122, 86.49150	December 13, 2016	3
3	West Fork Drakes Creek	State Route 259	Sumner	36.62369, 86.48972	December 13, 2016	3
4	West Fork Drakes Creek	Below Denning Ford Road	Sumner	36.60750, 86.47914	December 13, 2016 December 1, 2017	3
5	West Fork Drakes Creek	Above Denning Ford Road	Sumner	36.60673, 86.46865	December 1, 2017	3
6	West Fork Drakes Creek	Railroad Lane	Sumner	36.50152, 86.46963	December 13, 2016	3
7	West Fork Drakes Creek	Butler Bridge Road	Sumner	36.55553, 86.46758	December 16, 2016	3
8	Grace Creek	500 m upstream of mouth	Sumner	36.64297, 86.50388	December 13, 2016	1
9	Caney Fork Creek	State Route 52	Sumner	36.58240, 86.41974	December 16, 2016	3
10	Sulfur Fork	North Jones Road	Sumner	36.64780, 86.40761	May 17, 2019	2
11	Sulfur Fork	Gregory Road	Sumner	36.62643, 86.39260	December 14, 2016	2
12	Sulfur Fork	Absher Branch Road	Sumner	36.63798, 86.39447	December 14, 2016	2
13	Middle Fork Drakes Creek	State line	Sumner	36.64781, 86.33271	May 16, 2019	3
14	Middle Fork Drakes Creek	Hershel Lyles Road	Sumner	36.63608, 86.32859	December 14, 2016	3
15	Middle Fork Drakes Creek	Confluence w/Dutch Creek	Sumner	36.61704, 86.33000	December 14, 2016	3
16	Middle Fork Drakes Creek	Keen Hollow Road	Sumner	36.60292, 86.32947	December 14, 2016	3
17	Middle Fork Drakes Creek	Haskell Akin Road	Sumner	36.58310, 86.32889	December 14, 2016	3
18	Middle Fork Drakes Creek	State Route 52	Sumner	36.56636, 86.32060	December 14, 2016	3
19	Little Trammel Creek	Old U.S. 31E (State Route 174)	Sumner	36.63788, 86.26626	December 16, 2016	3
20	Garrett Creek	John Beasely Road	Sumner	36.63686, 86.24210	May 16, 2019	2
21	Trammel Creek	State line	Macon	36.63861, 86.19751	May 16, 2019	3
22	Trammel Creek	Buck Haynes Road	Macon	36.62149, 86.19234	December 15, 2016	3
23	Trammel Creek	Hawkins Road	Macon	36.60054, 86.19722	December 15, 2016	3
24	Trammel Creek	Sister Hollow Road	Macon	36.58633, 86.20043	December 16, 2016	3
25	Long Creek	State Line	Macon	36.63479, 86.11480	May 16, 2019	3
26	Long Creek	Hanestown Road	Macon	36.62362, 86.11152	December 15, 2016	3
27	Unnamed tributary to Long Creek	Negro Hollow	Macon	36.62118, 86.10926	May 16, 2019	1
28	Long Creek	Adjacent to Clifty Road	Macon	36.61881, 86.11500	December 15, 2016	3
29	Long Creek	Adjacent to Clifty Road	Macon	36.61131, 86.11568	December 15, 2016	3
30	Long Creek	Shiloh Road	Macon	36.60717, 86.11895	December 15, 2016	3
31	West Fork Long Creek	Shiloh Road	Macon	36.60681, 86.12221	December 15, 2016	2
32	Puncheon Creek	Green Valley Road	Macon	36.62828, 86.00595	May 16, 2017	3
33	Puncheon Creek	Puncheon Creek Road	Macon	36.61174, 86.01224	November 30, 2017	3
34	White Oak Creek	Cook Road	Macon	36.62254, 85.93653	November 30, 2017	3
35	White Oak Creek	Coley Road	Macon	36.56656, 85.98312	November 30, 2017	3
36	Long Fork	Hagan Circle	Macon	36.62209, 85.92411	May 17, 2019	3
37	Long Fork	Wilson Road	Macon	36.61519, 85.92942	November 30, 2017	3

Table 1, continued.

Site	Stream	Location	County	Coordinates	Date	Stream Order
38	Long Fork	Spring Hollow Road	Macon	36.56791, 85.93932	November 30, 2017	2
39	Saltlick Creek	Pitcock Road	Macon	36.61074, 85.89944	November 29, 2017	3
40	Saltlick Creek	Parkhurst Road	Macon	36.59100, 85.88032	November 29, 2017	3
41	Saltlick Creek	1.1 km W of Bethany Cemetery	Macon	36.56933, 85.86982	May 17, 2019	3
42	Unnamed tributary to Saltlick Creek	1.1 km WSW of Bethany Cemetery	Macon	36.56657, 85.86944	May 17, 2019	1
43	Saltlick Creek	Above confluence with Long Hungry Creek	Macon	36.56492, 85.86948	May 17, 2019	2
44	Long Hungry Creek	Above confluence with Saltlick Creek	Macon	36.56477, 85.87075	May 17, 2019	2
45	Saltlick Creek	3.1 km SE of Sunrise	Macon	36.55566, 85.86714	May 17, 2019	2
46	Saltlick Creek	Maxie Bluff Road	Macon	36.55170, 85.85699	November 29, 2017	2
47	Saltlick Creek	Red Boiling Springs	Macon	36.54040, 85.85042	November 29, 2017	2
48	Saltlick Creek	Below old dam site	Macon	36.54431, 85.85877	November 29, 2017	2
49	Saltlick Creek	Old Lake Road to old dam site	Macon	36.54205, 85.85469	November 30, 2017	2
50	Unnamed spring	Red Boiling Springs	Macon	36.53888, 85.84972	November 29, 2017	1
51	Little Saltlick Creek	Sutton Road	Macon	36.58147, 85.85700	November 29, 2017	1
52	Unnamed tributary to Little Saltlick Creek	Sutton Road	Macon	36.58219, 85.85346	November 29, 2017	1
53	Trace Creek	State Route 52	Clay	36.57592, 85.78019	November 30, 2017	2
54	Line Creek	Copars-York Road	Clay	36.60908, 85.75448	November 28, 2017	2
55	Line Creek	Homer-Bray Road	Clay	36.60930, 85.76675	November 28, 2017	2
56	Line Creek	Adj. to Line Creek Road	Clay	36.60880, 85.73158	November 28, 2017	2

Table 2. Mussels found in the Barren River system, Tennessee, 2016–19. Cell entries are the combined number of live and freshly dead mussels or the number of relic shells (in parentheses). Totals do not include unidentifiable shell fragments or *Corbicula fluminea*, which is reported only as present (P) or not present (NP). See Table 1 for site specifications.

Species	Site																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Alasmidonta viridis																								
Fusconaia flava		(1)																						
Lampsilis cardium		1																						
Lampsilis siliquoidea	(1)	1 (3)	(1)				(1)						24	1										
Pyganodon grandis																								
Villosa ortmanni				1 (1)																				
Unidentifiable unionid shell fragments		(1)					(1)																	
Corbicula fluminea	P	P	P	P	P	NP	P	NP	NP	NP	NP	NP	P	NP	NP	NP	NP	NP	NP	NP	P	NP	NP	NP
Total no. of species	1	3	1	1	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Total no. of individuals	(1)	1 (5)	(1)	1 (1)	0	0	(1)	0	0	0	0	0	24	1	0	0	0	0	0	0	0	0	0	0

1.9% shrub/scrub, and 0.8% wetlands (open water, woody, and herbaceous) (Yang et al. 2018). Despite the undeveloped nature of the system, a number of major tributaries of the Barren River system in Tennessee are considered impaired due to siltation, habitat degradation, or poor water quality associated with point and nonpoint discharges (TDEC 2007). These include Big Trammel Creek, Little Trammel Creek, Long Creek, Long Fork, West Fork Drakes Creek, Middle Fork Drakes Creek, Salt Lick Creek, Trace Creek, Town Creek, and West Fork Long Creek. A widespread problem in the Barren River system of Tennessee is illegal gravel dredging, which is widespread because of the area's relative remoteness and the abundance of gravel substrate in the larger streams (TDEC 2007).

Mussel Surveys

We conducted mussel surveys at 56 sites on 22 streams from December 2016 to May 2019 (Fig. 2 and Table 1). Sample sites were selected based on access, stream position, distance to other sample sites, and presence of suitable mussel habitat, such as shallow riffles and runs with gravel and cobble substrates. At each site, we conducted qualitative visual and tactile searches for live mussels, and we searched shorelines, gravel bars, and submerged vegetation for stranded live mussels and shells. We spent at least 1 person-h at each site except at sites where the habitat was extremely degraded or the water quality was obviously compromised. Longer search times were used at sites where live mussels or freshly dead shells were found. At some sites, we used a rake to disturb the top few centimeters of substrate. We sampled upstream of bridges, fords, and culverts to examine reaches unaffected by those structures. Live mussels were identified to species, measured (anterior to posterior length, nearest 1 mm), counted, and reinserted into the substrate. Freshly dead shells (tissue remaining, shiny nacre) and relic shells (chalky nacre, weathered periostracum) were identified, counted, and cataloged at MMNHC. At each site, we also recorded presence or absence of the invasive species *Corbicula fluminea* (Asian Clam). Our nomenclature follows Williams et al. (2017).

RESULTS

We found live mussels, freshly dead shells, or relic shells at 14 sites; only relic shells were found at four sites (Table 2). Mussels were found in nine third-order streams and in five second-order streams; no first-order streams yielded evidence of mussel occurrence. We found a total of six mussel species, but only five were represented by live individuals or freshly dead shells, and only one to three species were observed at each site. Live mussels were generally uncommon and represented by only one to three individuals at most sites. Exceptions were site 13 (Middle Fork Drakes Creek), where 24 individuals of *Lampsilis siliquoidea* were found, and sites 45 and 46 (Saltlick Creek), where *V. ortmanni* was represented by nine individuals at each site. *Corbicula fluminea* was present at 25 sites, including all but two of the sites with mussels (Table 2). Live *Corbicula* were uncommon at all sites.

Alasmidonta viridis, *L. siliquoidea*, and *V. ortmanni* were the most widespread species in the system, each present at five to six sites (Table 2). *Alasmidonta viridis* was represented by adults only; no juvenile individuals were found (Fig. 3). *Lampsilis siliquoidea* was represented by a range of sizes, but no juveniles were found. *Villosa ortmanni* was represented by a range of sizes and included small individuals indicative of recent recruitment (Fig. 3). Three species were found at a single site and represented by single individuals: *Fusconaia flava*, *Lampsilis cardium*, and *Pyganodon grandis*; *F. flava* was represented only by a single relic shell at site 2 (West Fork Drakes Creek). In addition, we found two freshly dead *L. fasciola* at one site in Middle Fork Drakes Creek a few hundred meters downstream of the Kentucky state line, but we

Table 2, extended.

Site																																
25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	53	54	55	56
																(1)				1	3 (1)		1							(1)	2	
	1																															
																2 (2)				9	9		2									
NP	NP	NP	NP	NP	NP	NP	NP	NP	P	P	P	NP	P	P	P	P	P	P	P	P	P	NP	P	P	NP	NP	NP	NP	NP	P	P	P
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	2	0	2	0	0	0	0	0	0	1	1	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2 (3)	0	0	0	10	12 (1)	0	3	0	0	0	0	0	0	(1)	2	0

could not confirm its occurrence in the Tennessee portion of the Barren River system.

DISCUSSION

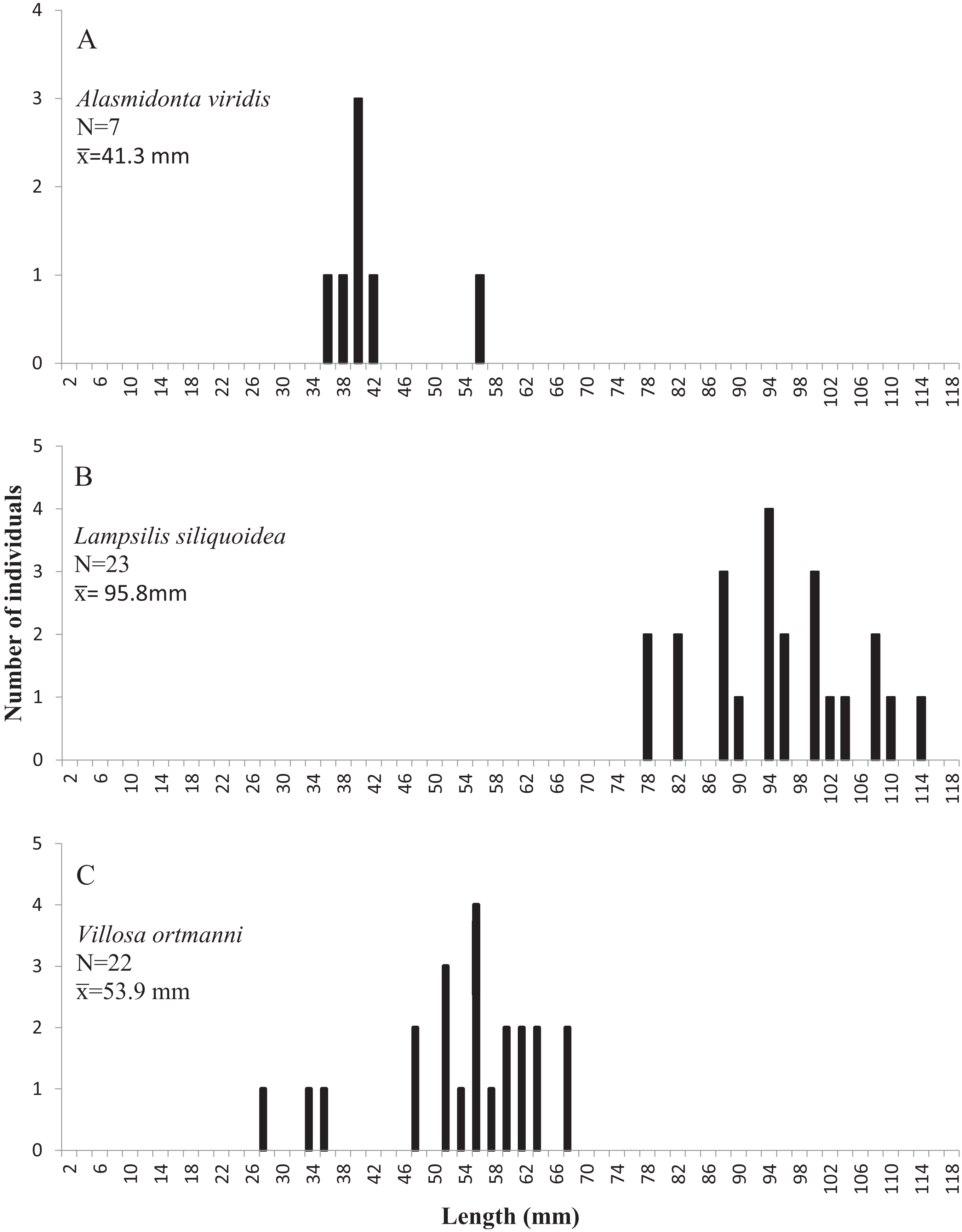
The Barren River system in Tennessee supports a limited mussel fauna typical of headwater streams in the Green River system and elsewhere in the Ohio River basin. *Alasmidonta viridis* and *L. siliquoidea* are characteristic headwater species throughout much of this region, and *P. grandis* is a stream-size generalist that is often common in small streams (Parmalee and Bogan 1998; Watters et al. 2009; Haag and Cicerello 2016). *Lampsilis cardium* and *F. flava* also occur in a wide variety of habitats, but neither species typically occurs far into the headwaters (Haag and Cicerello 2016). We found both of these species only in a larger stream (West Fork Drakes Creek), about 3 stream km upstream of the Kentucky state line. *Lampsilis fasciola* is widely distributed in the Barren River system in Kentucky and also may occur in the lower reaches of Barren River tributaries in Tennessee, but we could not confirm its presence.

Villosa ortmanni traditionally is considered endemic to the upper Green River drainage, but there is uncertainty about its relationship to *Villosa vanuxemensis* in the adjacent Red River system (Cumberland River drainage; Kuehnl 2009; Haag and Cicerello 2016); until that issue is resolved, we follow the traditional view of this species as endemic to the Green River drainage. *Villosa ortmanni* occurs in a wide variety of stream habitats from the mainstem Green River to small streams, but it is a characteristic species of headwaters, particularly spring runs, where it may be the only species present (Haag and Cicerello 2016). Along with *A. viridis*, *V. ortmanni* was the only species we found in second-order streams. Prior to our study, *V. ortmanni* was considered endemic to Kentucky (Haag and Cicerello 2016).

Tennessee has the second-highest number of mussel species in the USA, behind Alabama (Parmalee and Bogan 1998, Williams et al. 2008). Our discovery of *V. ortmanni* in the Barren River system of Tennessee brings the total number of recognized species in the state to 140 (G. Dinkins, personal observation). This is the first new record of a previously recognized species from Tennessee since reports of *L. siliquoidea* in 1985 and 1994 (MMNHC; Kesler and Manning 1996). Prior to our study, *L. siliquoidea* was reported in Tennessee only from direct tributaries of the Mississippi River (Reelfoot Lake and Wolf River), and our records of that species are the first from the Ohio River basin in Tennessee. In addition, our study provides the first mussel records of any species from the Barren River system in Tennessee.

In part, the scarcity of mussels in the upper Barren River system may be a natural feature of these headwater streams, where mussel abundance typically is lower than it is in larger streams (Haag 2012). However, the extremely low abundance we observed may be a result of human factors that have further reduced mussel populations. Entire mussel assemblages have nearly disappeared from much of the Barren River system and from many other upland streams in the southeastern USA, but the reasons for these disappearances are unknown (Irwin 2018; Reed et al. 2019; Haag 2019). The upper Barren River system is now isolated by Barren River Reservoir in Kentucky, which hinders mussel dispersal and gene flow. We observed several sources of stream degradation including illegal gravel mining (West Fork Drakes Creek, Middle Fork Drakes Creek, Long Creek, Trace Creek), channelization (Salt Lick Creek, Line Creek), and brine discharge from abandoned gas wells (Little Salt Lick Creek, Middle Fork Drakes Creek), but we have no information about the extent of these impacts or their effects on water quality or mussels in the Barren River system.

Our discovery of additional populations of *V. ortmanni* is important from a conservation perspective, regardless of this species' taxonomic status. The species was once widespread and common in the Green River drainage, but it has declined


A
Alasmidonta viridis
N=7
x̄=41.3 mm
B
Lampsilis siliquoidea
N=23
x̄= 95.8mm
C
Villosa ortmanni
N=22
x̄=53.9 mm
Number of individuals
Length (mm)
0
1
2
3
4
5
2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82 86 90 94 98 102 106 110 114 118

dramatically in the last 30 yr and now survives in only a few small populations; populations of *V. vanuxemensis* in the adjacent Red River system have declined similarly (Haag and Cicerello 2016; M. Compton, Office of Kentucky Nature Preserves, personal communication). In 2010, the Center for Biological Diversity petitioned the U.S. Fish and Wildlife Service to include *V. ortmanni* on the federal list of endangered species. Our findings considerably expand the known range of this species, and at least two of the sites we surveyed supported relatively large populations with evidence of recent recruitment.

With the exception of *V. ortmanni*, all of the mussel species we observed remain widespread and common in at least some parts of their ranges, but enigmatic mussel declines in the Barren River system and elsewhere threaten the survival of even widespread species. Headwater streams provide unique aquatic habitats but are vulnerable to a wide range of human impacts (Downing et al. 2012; Wohl 2017). Approximately 12,000 m of a tributary to Line Creek is being restored as part of the Tennessee Stream Mitigation Program (T. Dinkins, Stantec Consulting Services, Inc., personal communication). Efforts such as this are necessary to improve and ensure the health of headwater streams and the mussel assemblages they support.

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Figure 3. Length frequency distributions of live and freshly dead (a) *Alasmidonta viridis* in Salt Lick and Line creeks, (b) *Lampsilis siliquoidea* in West Fork Drakes and Middle Fork Drakes creeks, and (c) *Villosa ortmanni* in Salt Lick and West Fork Drakes creeks, Barren River system, Tennessee. Sample size (N) and mean length ($\bar{x}$) is provided for each species.