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Authors: Ellwanger, Robert J., and Wagner, Matthew D.

Source: Freshwater Mollusk Biology and Conservation, 25(2) : 62-73

Published By: Freshwater Mollusk Conservation Society

URL: https://doi.org/10.31931/fmbc-d-21-00006

Freshwater Mollusk Biology and Conservation 25:62–73, 2022

DOI:10.31931/fmbc-d-21-00006

REGULAR ARTICLE

DISTRIBUTION AND STATUS OF FRESHWATER MUSSELS IN THE BEAR CREEK WATERSHED, MISSISSIPPI

Robert J. Ellwanger[1]* and Matthew D. Wagner[2]

[1] *Mississippi Department of Wildlife, Fisheries, and Parks, Mississippi Museum of Natural Science, Jackson, MS 39202 USA*

[2] *U.S. Fish and Wildlife Service, Ecological Services Field Office, Jackson, MS 39213 USA*

ABSTRACT

Bear Creek is a tributary of the Tennessee River in northwestern Alabama and northeastern Mississippi. The watershed supports a diverse freshwater mussel assemblage including several species of conservation concern. We conducted a mussel survey at 55 sites in the Mississippi portions of Bear Creek and its largest tributary, Cedar Creek, during September and October 2020. We found a total of 30 species, of which 25 were represented by live individuals. The invasive Asian Clam, *Corbicula fluminea*, was widespread in the watershed, but we found no evidence of Zebra Mussel, *Dreissena polymorpha*. Notable species found live included two federally endangered species, Cumberlandian Combshell, *Epioblasma brevidens* and Slabside Pearlymussel, *Pleuronaia dolabelloides*; one federally threatened species, Rabbitsfoot, *Theliderma cylindrica*; and two state endangered species. In addition, we report the first documented occurrence of the Mountain Creekshell, *Villosa vanuxemensis*, in Mississippi. Mussel abundance and species richness were low at most sites in the watershed, but the upper portion of Bear Creek had the highest mussel abundance and species richness. We compare our results with previous surveys in the watershed and discuss conservation issues pertinent to the Bear Creek mussel fauna.

KEY WORDS: Unionidae, threatened, survey, Tennessee River system

INTRODUCTION

Bear Creek is a major tributary within the Tennessee River system that supports one of the most diverse freshwater mussel faunas on Earth (Haag 2012). The Bear Creek watershed covers approximately 2,450 km^2 in northwestern Alabama and northeastern Mississippi. Bear Creek flows 219 km from its headwaters to its confluence with the Tennessee River. In Mississippi, Bear Creek flows approximately 44 km through Itawamba and Tishomingo counties and converges with Cedar Creek, a major tributary, at the Alabama–Mississippi border (Fig. 1). Although it retains a diverse mussel fauna, Bear Creek historically contained several species that now appear to be extirpated, and the fauna in general may have declined (McGregor and Garner 2004). The causes of mussel declines and species loss in Bear Creek are unknown, but the watershed has experienced a wide range of anthropogenic modifications.

*Corresponding Author: robert.ellwanger@mmns.ms.gov

The upper portion of the Bear Creek watershed in Alabama is impounded by four Tennessee Valley Authority (TVA) dams constructed between 1969 and 1979 for flood control and recreation. These include two dams on Bear Creek, one on Little Bear Creek, and one on Cedar Creek. As Bear Creek enters Mississippi, two separate elevated channelized sections run alongside the sinuous original channel. These channelized sections were constructed in 1973 by TVA as overflow channels to alleviate flooding and reduce bank erosion during high-flow events. A grade-control structure is present at the head of both sections and consists of about 50 m of large riprap that slowly drops in elevation until it reaches the channelized streambed. Both sections hold water during low flow but are stagnant and do not provide suitable mussel habitat. After leaving Mississippi, Bear Creek flows back into Alabama where the lower 30 km of Bear Creek are inundated by the backwaters of Pickwick Reservoir, which was constructed in 1938 (McGregor and Garner 2004).

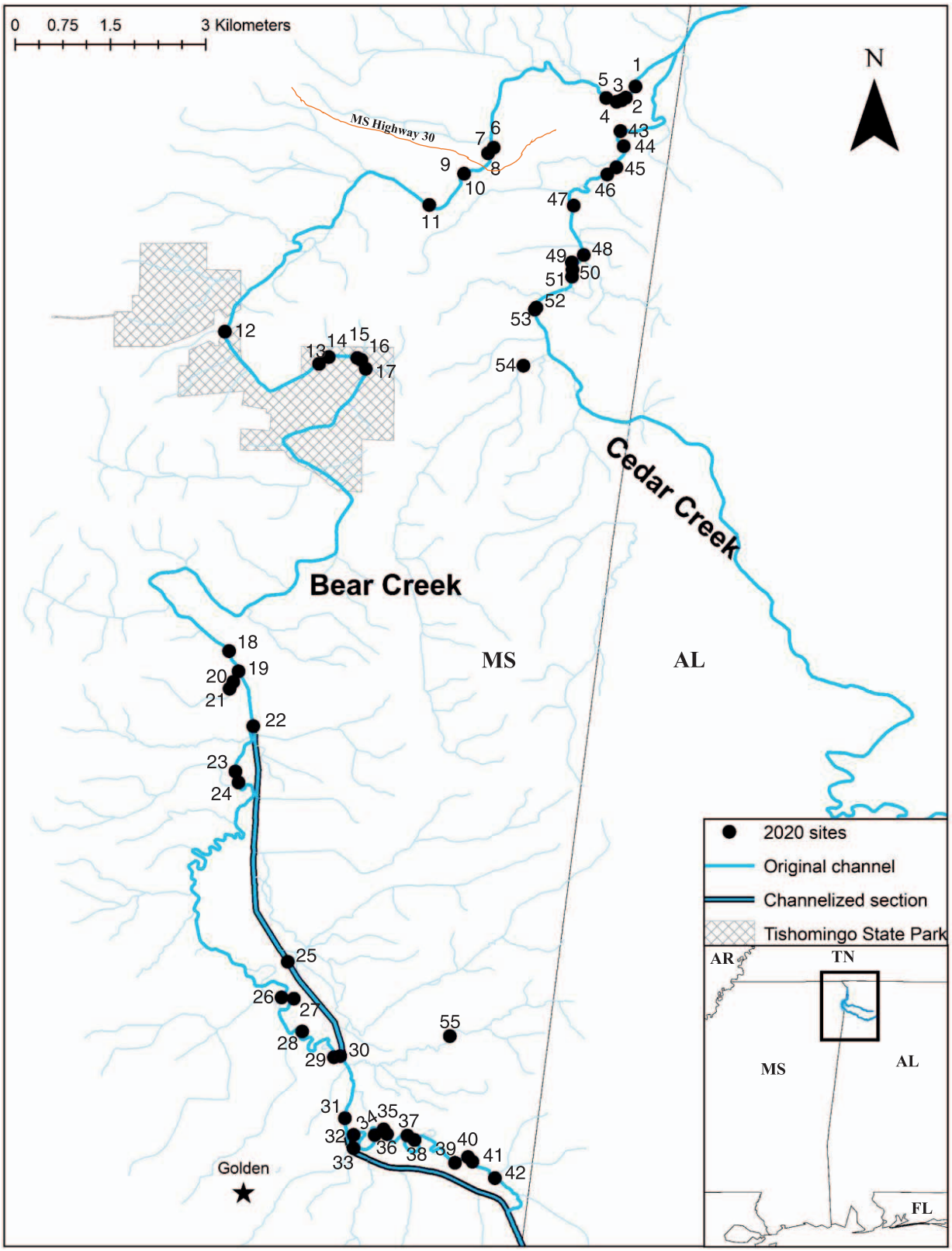

Figure 1. Map of the Bear Creek watershed in Mississippi showing sites sampled for mussels in 2020.

Table 1. Mussel species documented in the Bear Creek watershed, Alabama and Mississippi. MMNS = Mississippi Museum of Natural Science, Jackson, MS. L = live individuals reported; FD = freshly dead shells only; L/FD = live individuals or freshly dead shells reported, but not differentiated; R = relic shells only; X = species present but condition not reported; — = species not reported. All records reported by MMNS and this study are from Mississippi. Records reported by other studies from Mississippi are indicated by an asterisk (*), and their condition (if reported) is given in parentheses.

Species	Ortmann (1925)	Isom and Yokely (1968)	McGregor and Garner 1995-2000 (2004)	MMNS 1999-2008	MMNS 2009-2018	This Study (2020)
Unionids						
Actinonaias pectorosa (Conrad, 1834)	X	—	—	—	—	—
Alasmidonta marginata (Lea, 1858)	X	—	—	—	—	—
Amblema plicata (Say, 1817)	X	X	L/FD(R*)	L	—	L
Arcidens confragosus (Say, 1829)	—	—	L/FD	FD	—	L
Cyclonaias pustulosa (Lea, 1831)	X	X	L/FD(L/FD*)	L	R	L
Cyclonaias tuberculata (Rafinesque, 1820), SE[a]	—	—	L/FD(R*)	L	—	L
Ellipsaria lineolata (Rafinesque, 1820)	—	X	L/FD(R*)	L	—	R
Elliptio crassidens (Lamarck, 1819)	—	X	L/FD(R*)	L	R	L
Epioblasma brevidens (Lea, 1831), SE, FE	—	X	L/FD	FD	L	L
Epioblasma capsaeformis (Lea, 1834), FE	X	—	—	—	—	—
Epioblasma triquetra (Rafinesque, 1820), SE, FE	X*	—	—	—	—	—
Epioblasma turgidula (Lea, 1858), FE	X	—	—	—	—	—
Fusconaia cuneolus (Lea, 1840), FE	X	—	—	—	—	—
Lampsilis abrupta (Say, 1831), FE	—	—	L/FD	—	—	—
Lampsilis fasciola Rafinesque, 1820	X	X	L/FD	FD	FD	L
Lampsilis ovata (Say, 1817)	X	X	L/FD(R*)	L	L	L
Lampsilis teres (Rafinesque, 1820)	—	—	—	—	FD	L
Lampsilis virescens (Lea, 1858), FE	X	—	—	—	—	—
Lasmigona complanata (Barnes, 1823)	—	—	L/FD	L	—	L
Lasmigona costata (Rafinesque, 1820), SE	X	—	L/FD	R	—	L
Ligumia recta (Lamarck, 1819), SE	—	X	L/FD(R*)	L	—	L
Megalonaias nervosa (Rafinesque, 1820)	—	X	L/FD(L/FD*)	L	R	L
Obliquaria reflexa Rafinesque, 1820	—	X	L/FD(L/FD*)	FD	—	L
Obovaria subrotunda (Rafinesque, 1820), SE, FC	X	—	—	—	—	—
Pleurobema oviforme (Conrad, 1834)	X	—	R	—	—	—
Pleuronaia barnesiana (Lea, 1838), FC	X	X*	—	—	—	—
Pleuronaia dolabelloides (Lea, 1840), SE, FE	—	—	L/FD	L	L	L
Potamilus alatus (Say, 1817)	—	X	L/FD(L/FD*)	L	L	L
Potamilus ohiensis (Rafinesque, 1820)	—	—	FD	—	—	—
Potamilus fragilis (Rafinesque, 1820)	—	X	L/FD(R*)	L	—	L
Ptychobranchus fasciolaris (Rafinesque, 1820), SE	X	—	L/FD(R*)	L	—	FD
Pyganodon grandis (Say, 1829)	—	—	L/FD(R*)	—	—	R
Quadrula apiculata (Say, 1829)	X	—	L/FD	FD	R	—
Quadrula quadrula (Rafinesque, 1820)	—	—	L/FD(R*)	L	R	L
Reginaia ebenus (Lea, 1831)	—	—	L/FD	FD	—	L
Strophitus undulatus (Say, 1817)	—	—	(R*)	FD	—	L
Theliderma cylindrica (Say, 1817), SE, FT	X	X	L/FD	L	R	L
Toxolasma lividum Rafinesque, 1831	X	—	—	—	—	—
Toxolasma parvum (Barnes, 1823)	—	—	FD	—	—	—
Tritogonia verrucosa (Rafinesque, 1820)	X	X	L/FD(R*)	L	—	L
Truncilla donaciformis (Lea, 1828)	—	X	L/FD	FD	—	L
Truncilla truncata Rafinesque, 1820	X	X	L/FD	FD	FD	L
Utterbackia imbecillis (Say, 1829)	—	—	L/FD	—	—	FD
Utterbackiana suborbiculata (Say, 1831)	—	—	L/FD	—	—	—
Villosa iris (Lea, 1829)	X	—	—	—	—	—
Villosa vanuxemensis (Lea, 1838)	X	—	L/FD	—	—	FD
Nonnative Bivalves						
Corbicula fluminea (Müller, 1774)	—	—	L	L	L	L
Dreissena polymorpha (Pallas, 1771)	—	—	R	—	—	—

[a]SE = state endangered; FT = federally threatened; FE = federally endangered; FC = candidate for federal listing.

Table 2. Locations of sites surveyed in the Bear Creek watershed, Mississippi in 2020.

Site	Locality	Date	Latitude	Longitude	Time (min)
1*	Bear Creek upstream of Indian Mound	September 8, 2020	34.64549	−88.13305	87
2	Bear Creek upstream of Indian Mound	September 8, 2020	34.64393	−88.13441	138
3	Bear Creek upstream of Indian Mound	September 8, 2020	34.64357	−88.13498	189
4	Bear Creek upstream of Indian Mound	September 8, 2020	34.64333	−88.13574	78
5*	Bear Creek upstream of Indian Mound	September 8, 2020	34.64388	−88.13719	75
6	Bear Creek downstream Highway 30	Septembe 10, 2020	34.63684	−88.15314	200
7	Bear Creek downstream Highway 30	September 10, 2020	34.63605	−88.15393	120
8	Bear Creek downstream Highway 30	September 10, 2020	34.63605	−88.15393	124
9	Bear Creek upstream Highway 30	September 29, 2020	34.63315	−88.15733	69
10	Bear Creek upstream Highway 30	September 29, 2020	34.63315	−88.15733	24
11	Bear Creek upstream Highway 30	September 29, 2020	34.62872	−88.16227	333
12	Bear Creek by Natchez Trace overpass in Tishomingo State Park	September 9, 2020	34.61079	−88.19122	114
13	Bear Creek upstream of Swinging Bridge	September 9, 2020	34.60622	−88.17788	360
14	Bear Creek upstream of Swinging Bridge	September 9, 2020	34.60719	−88.1765	198
15	Bear Creek upstream of Swinging Bridge	September 9, 2020	34.60707	−88.17247	148
16	Bear Creek upstream of Swinging Bridge	September 9, 2020	34.60678	−88.17188	112
17	Bear Creek upstream of Swinging Bridge	September 9, 2020	34.60552	−88.17126	104
18	Bear Creek downstream of Dennis Bridge	September 21, 2020	34.56554	−88.19061	57
19	Bear Creek upstream of Dennis Bridge	September 21, 2020	34.56268	−88.18928	108
20	Bear Creek upstream of Dennis Bridge	September 21, 2020	34.56118	−88.19002	18
21	Bear Creek upstream of Dennis Bridge	September 21, 2020	34.56022	−88.19056	30
22	Bear Creek upstream of Dennis Bridge at mouth of channelized section	September 21, 2020	34.5549	−88.1872	29
23	Bear Creek upstream of Dennis Bridge at powerlines in sinuous section	September 21, 2020	34.54848	−88.18973	33
24	Bear Creek upstream of Dennis Bridge in sinuous section	September 21, 2020	34.54692	−88.18928	87
25	Bear Creek auxiliary channel upstream County Road (CR) 993	September 30, 2020	34.52154	−88.1823	20
26*	Bear Creek upstream CR 993	September 30, 2020	34.51649	−88.18319	16
27	Bear Creek upstream CR 993	September 30, 2020	34.51632	−88.18145	16
28	Bear Creek upstream CR 993	September 30, 2020	34.51167	−88.18027	36
29	Bear Creek downstream of Golden, below grade-control structure in sinuous section	September 17, 2020	34.50803	−88.17579	93
30	Bear Creek downstream of Golden, below grade-control channelized section	September 17, 2020	34.50818	−88.17488	90
31*	Bear Creek downstream of Golden, channelized section	September 17, 2020	34.4994	−88.17423	27
32	Bear Creek upstream of Golden, sinuous section	September 17, 2020	34.49702	−88.17299	17
33	Bear Creek upstream of Golden, channelized section	September 17, 2020	34.49513	−88.17299	51
34	Bear Creek upstream of Golden, sinuous section	September 16, 2020	34.497	−88.16999	210
35	Bear Creek upstream of Golden, sinuous section	September 16, 2020	34.49782	−88.16874	26
36	Bear Creek upstream of Golden, sinuous section	September 16, 2020	34.49713	−88.16825	128
37	Bear Creek upstream of Golden, sinuous section	September 16, 2020	34.49692	−88.16536	134
38	Bear Creek upstream of Golden, sinuous section	October 8, 2020	34.49629	−88.16436	144
39	Bear Creek upstream of Golden, sinuous section	October 8, 2020	34.49307	−88.15862	240
40	Bear Creek upstream of Golden, sinuous section	October 14, 2020	34.49388	−88.15678	270
41	Bear Creek upstream of Golden, sinuous section	October 14, 2020	34.49322	−88.15615	15
42	Bear Creek upstream of Gee Branch, sinuous section	October 14, 2020	34.49089	−88.15297	123
43	Cedar Creek downstream Maudeal Road/CR 98	September 22, 2020	34.63919	−88.13519	72
44	Cedar Creek downstream Maudeal Road/CR 98	September 22, 2020	34.63705	−88.13472	21
45	Cedar Creek downstream Maudeal Road/CR 98	September 22, 2020	34.63405	−88.13575	5
46	Cedar Creek downstream Maudeal Road/CR 98 (beach walk)	September 22, 2020	34.63305	−88.13706	10
47	Cedar Creek at Maudeal Road/CR 98	September 21, 2020	34.62864	−88.14181	48
48*	Cedar Creek upstream Maudeal Road/CR 98	September 22, 2020	34.62165	−88.14039	15
49	Cedar Creek upstream Maudeal Road/CR 98	September 22, 2020	34.62059	−88.14208	27

Table 2, continued.

Site	Locality	Date	Latitude	Longitude	Time (min)
50	Cedar Creek upstream Maudeal Road/CR 98 (beach walk)	September 22, 2020	34.61955	−88.14198	10
51	Cedar Creek upstream Maudeal Road/CR 98	September 22, 2020	34.61857	−88.14206	30
52	Cedar Creek upstream Maudeal Road/CR 98	September 22, 2020	34.61418	−88.14709	27
53	Cedar Creek upstream Maudeal Road/CR 98	September 22, 2020	34.61391	−88.14731	21
54*	Holly Branch on CR 85	September 29, 2020	34.60595	−88.14893	90
55*	Brumley Branch on CR 68	September 29, 2020	34.51102	−88.15936	65

*Previously unsurveyed sites.

Previous surveys documented a total of 46 native mussel species and two invasive bivalves (Zebra Mussel, *Dreissena polymorpha*; Asian Clam, *Corbicula fluminea*) in the entire Bear Creek watershed (Table 1). Thirty-one mussel species and one invasive bivalve (Asian Clam) are reported previously in the Mississippi portion of the watershed (Table 1). These include three federally endangered species (Cumberlandian Combshell, *Epioblasma brevidens*; Snuffbox, *Epioblasma triquetra*; Slabside Pearlymussel, *Pleuronaia dolabelloides*), one candidate for federal listing (Tennessee Pigtoe, *Pleuronaia barnesiana*), and two state endangered species (Purple Wartyback, *Cyclonaias tuberculata*; Kidneyshell, *Ptychobranchus fasciolaris*), all of which are reported from Mississippi only in the Bear Creek watershed (Jones et al. 2021). In addition, one federally threatened species (Rabbitsfoot, *Theliderma cylindrica*) is reported from Bear Creek but is also found elsewhere in Mississippi. Its high diversity, including nine species of conservation concern, demonstrates the regional and global importance of the Bear Creek watershed for mussel conservation.

Previous mussel surveys devoted comparatively little effort to the Mississippi portion of the Bear Creek watershed. For example, McGregor and Garner (2004) surveyed 40 sites in the watershed but only four of those sites were in Mississippi. On the basis of records in a statewide mussel distribution database maintained by the Mississippi Museum of Natural Science (MMNS, Jackson, MS; MMNS Freshwater Invertebrate Collection, https://www.mdwfp.com/museum/seek-study/biological-collections/freshwater-invert/), 58 shell collections were made in Bear Creek in Mississippi between 1966 and 2018. However, most of these collections were made incidentally during fish surveys and were not the result of targeted mussel surveys. The few targeted surveys sampled only one to three sites each year and did not comprehensively cover the system. Excluding incidental collections, no mussel surveys have been conducted in the Mississippi portion of Bear Creek in over 10 yr, and a single, comprehensive survey of this section has never been undertaken. We conducted the first intensive mussel survey of the Mississippi portion of the Bear Creek watershed, including surveys at 55 sites. We report species richness, mussel abundance (as catch per unit effort [CPUE]), and size structure at these sites, and we discuss the conservation applications of our findings.

METHODS

We surveyed 55 sites throughout the Bear Creek watershed in Mississippi (Fig. 1, Table 2). We chose both previously surveyed and unsurveyed sites on the basis of site accessibility and the presence of apparently suitable mussel habitat (riffles or runs with stable, sand/gravel substrate), as well as the presence of shell material. One site was on a small tributary to Cedar Creek, 11 sites were on main-stem Cedar Creek, one site was on a small tributary to Bear Creek, and 42 sites were on main-stem Bear Creek; most main-stem Bear Creek sites were on the original channel, but we surveyed four sites on the channelized sections. Surveys were conducted in September and October 2020.

We searched for live mussels at most sites using a combination of snorkeling and tactile search (grubbing). This was done by lightly disturbing the substrate with our hands to detect partially buried mussels either by touch or by sight. We also searched gravel bars and shorelines for freshly dead and relic shells. We defined freshly dead shells as those having lustrous nacre, and relic shells as those with chalky shells or badly eroded nacre and periostracum, indicating that they had been dead for an extended time. At two sites, 46 and 50, we searched for shells but did not search for live mussels because the habitat did not appear suitable. We established a sampling area at each site on the basis of the extent of suitable mussel habitat. We conducted timed searches for live mussels at each site within the designated sampling area. We determined search time on the basis of amount of available habitat as well as mussel species richness at the site. If initial sampling revealed a high number of species, we searched the site for a longer time. Time began when all searchers entered the water and ended when searching ceased; shell searches were not included in the search time. We counted and measured all live native mussels (length, greatest anterior–posterior dimension, nearest 1 mm). We counted Asian Clams, but we did not measure them. We expressed native mussel abundance and Asian Clam abundance at each site as CPUE (number of live individuals/person-hours search time). We generated length–frequency histograms on the basis of live individuals for species that were represented by 10 or more individuals across all sites. We included freshly dead and relic shells for calculating species richness, but we used live individuals only when calculating CPUE and length–frequency distributions.

Table 3. Results of mussel surveys at 55 sites in the Bear Creek watershed, Mississippi in 2020. Cell entries are catch per unit effort (CPUE, number of live mussels/h), followed by numbers of live individuals encountered (in parentheses). Species that were present but not represented by live individuals are indicated as FD (freshly dead) or R (relic); "—" indicates that a species was not found at the site.

	Site													
	Bear Creek													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Unionids														
Amblema plicata	—	0.4 (1)	R	R	—	—	—	1 (2)	—	—	0.2 (1)	—	—	—
Arcidens confragosus	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cyclonaias pustulosa	—	0.9 (2)	0.6 (2)	—	—	R	R	R	R	—	3.6 (20)	R	0.2 (1)	0.9 (3)
Cyclonaias tuberculata	—	—	—	0.8 (1)	—	R	—	—	—	—	R	—	—	—
Ellipsaria lineolata	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Elliptio crassidens	—	1.7 (4)	1.6 (5)	1.5 (2)	—	R	—	R	—	—	—	R	R	—
Epioblasma brevidens	—	—	0.3 (1)	—	—	—	—	—	—	—	—	—	—	—
Lampsilis fasciola	—	—	—	—	—	—	—	—	R	—	0.2 (1)	R	R	0.3 (1)
Lampsilis ovata	—	0.4 (1)	1 (3)	R	—	R	0.5 (1)	0.5 (1)	R	—	1.6 (9)	0.5 (1)	—	0.9 (3)
Lampsilis teres	—	—	—	—	—	R	—	—	—	—	0.4 (2)	—	—	—
Lasmigona complanata	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lasmigona costata	—	—	—	—	—	—	—	—	—	—	0.2 (1)	—	—	—
Ligumia recta	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Megalonaias nervosa	—	R	3.2 (10)	2.3 (3)	—	—	—	—	—	—	—	0.5 (1)	R	—
Obliquaria reflexa	—	—	—	—	—	R	—	R	—	—	0.2 (1)	—	—	—
Pleuronaia dolabelloides	—	0.4 (1)	0.3 (1)	0.8 (1)	—	—	R	—	—	—	R	—	—	0.3 (1)
Potamilus alatus	—	R	—	R	—	—	—	R	R	—	0.4 (2)	0.5 (1)	—	0.3 (1)
Potamilus fragilis	—	R	—	—	—	R	0.5 (1)	R	FD	—	0.4 (2)	R	—	—
Ptychobranchus fasciolaris	—	—	—	—	—	—	—	—	—	—	R	FD	—	—
Pyganodon grandis	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Quadrula quadrula	—	—	—	—	—	0.6 (2)	2 (4)	1.5 (3)	0.9 (1)	—	2.7 (15)	—	0.5 (3)	0.6 (2)
Reginaia ebenus	—	—	0.6 (2)	—	—	—	R	—	—	—	—	—	—	—
Strophitus undulatus	—	—	—	—	—	—	—	1 (2)	—	—	0.2 (1)	—	—	—
Theliderma cylindrica	—	—	—	0.8 (1)	—	—	0.5 (1)	—	—	—	—	—	—	—
Tritogonia verrucosa	—	—	—	—	—	—	—	—	—	—	0.2 (1)	—	—	—
Truncilla donaciformis	—	—	—	—	—	0.3 (1)	—	R	—	—	—	—	—	—
Truncilla truncata	—	R	—	—	—	R	R	—	—	—	R	—	—	—
Villosa vanuxemensis	—	—	—	—	—	FD	—	—	—	—	—	—	—	—
Utterbackia imbecillis	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nonnative bivalves														
Corbicula fluminea	1.4 (2)	217 (499)	1 (3)	—	—	0.6 (2)	—	—	—	—	0.9 (5)	—	6.7 (40)	R
Number of unionid species	0	4	8	5	0	2	4	4	1	0	12	3	2	6
Total CPUE (all species)[a]	0	3.4	7.6	6.2	0	0.9	3.5	4	0.9	0	10.3	1.5	0.7	3.3

[a]Total CPUE excludes *Corbicula fluminea*.

We collected representative live, freshly dead, or relic shells of each species encountered at each site and deposited them in the MMNS Freshwater Invertebrate Collection.

RESULTS

We documented a total of 30 native mussel species and one invasive bivalve, the Asian Clam (Table 1). We found no live individuals or shells of *D. polymorpha*, which has been found in upper Bear Creek in Alabama and Pickwick Reservoir (McGregor and Garner 2004). We found live individuals of 25 native mussel species and the Asian Clam. The Kidneyshell, Paper Pondshell (*Utterbackia imbecilis*), and Mountain Creekshell (*Villosa vanuxemensis*) were represented only by freshly dead shells, and no live individuals were found. The Butterfly (*Ellipsaria lineolata*) and Giant Floater (*Pyganodon grandis*) each were represented only by a single relic shell.

Average mussel abundance and species richness across all sites were low (mean CPUE = 4.5 live mussels/h; 5.4 native species/site; Table 3). However, mussel abundance and species

Table 3, extended.

Site																			
Bear Creek																			
15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
—	—	R	—	—	—	—	—	—	—	—	—	—	—	—	R	—	R	—	7.7 (27)
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.3 (1)
0.4 (1)	0.5 (1)	R	—	0.6 (1)	—	R	—	—	—	—	—	R	1.7 (1)	3.2 (5)	R	—	R	—	12.9 (45)
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	R	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	R	—	—	—	—	—	—	—	—	—	—	—
0.4 (1)	1.1 (2)	0.6 (1)	-	0.6 (1)	R	R	FD	—	0.7 (1)	—	—	—	—	1.3 (2)	R	—	—	—	—
—	—	—	R	—	—	R	—	—	—	—	—	—	—	R	R	—	—	R	0.3 (1)
—	—	—	—	—	—	—	R	—	—	—	—	—	—	—	R	—	—	—	—
—	—	—	—	—	—	R	—	—	—	—	—	—	—	—	0.7 (1)	—	—	—	0.6 (2)
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	0.5 (1)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4.6 (16)
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.3 (8)
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	R
R	0.5 (1)	R	—	—	—	R	FD	—	2.1 (3)	R	—	3.8 (1)	5 (3)	5.2 (8)	R	—	3.5 (1)	—	2.3 (8)
—	—	—	—	—	—	—	R	—	0.7 (1)	—	—	—	—	R	FD	—	—	—	0.9 (3)
R	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R	-	1.7 (3)	—	—	—	—	—	—	0.7 (1)	R	—	—	1.7 (1)	0.6 (1)	—	—	—	—	0.6 (2)
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	R	—	—	—	—	—	—	0.7 (1)	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	R
—	R	—	—	—	—	—	—	—	0.7 (1)	—	—	—	1.7 (1)	0.6 (1)	—	—	—	—	4.3 (15)
R	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	1.7 (3)	—	0.6 (1)	—	4 (2)	—	5.5 (3)	—	—	48.8 (13)	22.5 (6)	33.3 (20)	0.6 (1)	—	—	—	—	12.6 (44)
2	4	2	0	2	0	0	0	0	6	0	0	1	4	5	1	0	1	0	11
0.8	2.6	2.3	0	1.2	0	0	0	0	5.6	0	0	3.8	10.1	10.9	0.7	0	3.5	0	36.8

richness were distributed unevenly in the watershed. Mussel abundance and species richness were highest in Bear Creek (mean CPUE = 5.6 mussels/h; mean richness = 6.3 species/site). Within Bear Creek, mussel abundance was consistently high only in the section from site 34 to site 42 (mean CPUE = 17.0 mussels/h), which included the four highest CPUE values observed (site 34, 36.8; site 39, 31.9; site 42, 13.4; site 37, 12.5). Species richness also was highest in this section (mean = 10.4 species/site), with the highest values at sites 39 and 40 (each having 17 species). Beyond that section, mussel abundance and species richness were relatively high only at sites 3 and 4 (mean CPUE = 6.9, mean richness = 6.5), site 11 (CPUE = 10.3, richness = 12), site 24 (CPUE = 5.6, richness = 6), and sites 28 and 29 (mean CPUE = 10.5, mean richness = 4.5). CPUE was <4.0/h at all other Bear Creek sites, and few other sites had more than four native species.

Mussel abundance and species richness were low in Cedar Creek (mean CPUE = 0.8/h; mean richness = 3.0 species/site). The highest abundance and species richness in Cedar Creek were observed at sites 43 (CPUE = 4.1) and 44 (8 species), respectively. There was little recent evidence of mussels in the channelized sections of Bear Creek. We found only one live

Table 3, extended.

Site																				
Bear Creek								Cedar Creek											Holly Branch	Brumley Branch
35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
R	1.4 (3)	0.9 (2)	0.8 (2)	0.3 (1)	0.9 (4)	—	1.5 (3)	—	—	R	—	R	—	—	—	—	—	—	—	—
—	—	—	0.4 (1)	2 (8)	0.4 (2)	—	1 (2)	—	—	—	—	—	—	—	—	—	—	—	—	—
R	0.9 (2)	2.7 (6)	1.7 (4)	6.3 (25)	4.2 (19)	—	1.5 (3)	0.8 (1)	R	FD	—	R	—	—	FD	—	—	—	—	—
—	—	—	—	0.3 (1)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	R	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	R	—	0.3 (1)	0.2 (1)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	R	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	0.4 (1)	0.4 (1)	1 (4)	1.6 (7)	4 (1)	1.5 (3)	R	2.9 (1)	—	—	R	—	—	—	2 (1)	R	—	—	—
R	R	0.4 (1)	R	R	R	—	1 (2)	—	R	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	0.3 (1)	0.2 (1)	—	1 (2)	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	1.3 (3)	—	0.7 (3)	—	—	—	R	—	—	R	—	—	R	—	—	—	—	—
—	—	—	0.4 (1)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4.6 (2)	0.9 (2)	7.2 (16)	10.8 (26)	10.3 (41)	7.8 (35)	—	—	—	R	—	—	—	—	—	—	R	—	—	—	—
—	—	—	R	0.5 (2)	—	—	FD	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	R	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2.3 (1)	—	0.9 (2)	0.4 (1)	2 (8)	1.3 (6)	4 (1)	4.9 (10)	2.5 (3)	R	FD	—	—	—	—	R	FD	—	—	—	—
R	R	—	R	0.8 (3)	R	—	FD	—	—	FD	—	R	—	—	—	—	—	—	—	—
—	—	—	—	—	R	—	—	—	R	—	R	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	R	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	R	R	1 (4)	1.6 (7)	—	1 (2)	0.8 (1)	—	—	—	—	—	—	—	—	R	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	FD	0.8 (3)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	0.8 (2)	1.5 (6)	1.1 (5)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	FD	—	—	—	0.2 (1)	—	R	—	—	—	—	—	—	—	—	—	—	—	—	—
R	0.9 (2)	FD	R	4.5 (18)	1.8 (8)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	FD	—	—	—	—	—	—	—	—	—	—
FD	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6.9 (3)	—	4 (9)	R	3.8 (15)	—	—	0.5 (1)	—	—	—	—	—	—	—	—	—	—	—	—	—
2	4	6	9	15	13	2	8	3	1	0	0	0	0	0	0	1	0	0	0	0
6.9	4.1	12.5	17	31.9	22	8	13.4	4.1	2.9	0	0	0	0	0	0	2	0	0	0	0

mussel in these sections (Flutedshell, *Lasmigona costata*, site 30), and only one freshly dead shell (Mapleleaf, *Quadrula quadrula*, site 30). We found relic shells of seven other species in the channelized sections. No live mussels or shells were found at either of the two tributary sites (sites 54 and 55). We found Asian Clams at about half of the Bear Creek sites, but we did not find them in Cedar Creek or the other two tributary sites.

The most abundant and widely distributed native species were Washboard (*Megalonaias nervosa*, mean CPUE = 4.8/h, 153 live individuals, live individuals or shells found at 15 sites), Pimpleback (*Cyclonaias pustulosa*, 2.4/h, 142 individuals, 33 sites), Pink Heelsplitter (*Potamilus alatus*, 2.3/h, 61 individuals, 32 sites), Deertoe (*Truncilla truncata*, 2.1/h, 47 individuals, 15 sites), Mapleleaf (1.2/h, 52 individuals, 21 sites), and Pocketbook (*Lampsilis ovata*, 1.1/h, 46 individuals, 31 sites). All other species occurred at a mean abundance of $\leq$2.0 mussels/h and were found live at $\leq$10 sites.

Federally listed species were uncommon throughout the watershed (Table 3). We found only one live Cumberlandian Combshell (adult male, 36.0 mm length) in the lower section of Bear Creek (site 3), one relic shell at site 21 in Bear Creek,

and one relic juvenile or subadult (23.4 mm length) in Cedar Creek (site 50). We found a single live Slabside Pearlymussel at each of four sites in Bear Creek (sites 2, 3, 4, and 14), and we found single relic shells at sites 7, 11, 34, and 40; all live individuals appeared to be adults (lengths = 52.0–68.0 mm). We found six live Rabbitsfoot among four sites in Bear Creek (sites 4, 7, 24, and 39; lengths = 50.0–96.0 mm), two freshly dead shells (site 38), and a single relic shell (site 17).

State-listed species were similarly uncommon. We found two live Purple Wartyback in Bear Creek (sites 4 and 39, lengths = 85.0 mm and 137.0 mm) and three relic shells (sites 6 and 11). We found no live Kidneyshell, but we found one freshly dead juvenile or subadult in Bear Creek (site 12; 34.5 mm length) and relic shells in Bear Creek (sites 11, 15, and 40) and Cedar Creek (sites 44 and 46).

The Flutedshell, Black Sandshell (*Ligumia recta*), and Mountain Creekshell are proposed for state listing in Mississippi. We found 10 live Flutedshell in Bear Creek (sites 1, 30, 34, 38, and 40) and five relic shells (Bear Creek, site 21; Cedar Creek, sites 44, 47, and 50). We found one live Black Sandshell in Bear Creek (site 38). We found one freshly dead Mountain Creekshell in Bear Creek (site 6), one freshly dead shell in Cedar Creek (site 45), and one relic shell in Bear Creek (site 15).

Most of the 11 species for which we constructed length–frequency histograms were represented by a wide range of sizes, and several species were represented by individuals <50 mm length (Fig. 2). A conspicuous exception was the Elephantear (*Elliptio crassidens*), for which all 13 live individuals were ≥100 mm.

DISCUSSION

We found all species previously reported from the Mississippi section of Bear Creek except Snuffbox, Tennessee Pigtoe, and Southern Mapleleaf (*Quadrula apiculata*). Snuffbox and Tennessee Pigtoe have not been reported from anywhere in the Bear Creek watershed for over 50 yr and likely are extirpated from the system. Southern Mapleleaf recently colonized the lower Tennessee River system, including Bear Creek (Garner and McGregor 2001; McGregor and Garner 2004), and it likely still occurs in the Mississippi section. Notably, we found living individuals of all previously reported species except Butterfly and Giant Floater. Butterfly is predominantly a large-river species, and a large population exists in Pickwick Reservoir (Garner and McGregor 2001); it is likely that a small population exists in the Mississippi portion of Bear Creek. Giant Floater is a stream-size generalist, but it typically occurs in pools or depositional areas (Haag 2012), which we did not sample extensively; it probably occurs at least sparingly in those habitats in Bear Creek.

Our finding of the Mountain Creekshell in Bear Creek is the first report of this species anywhere in Mississippi, but the species was reported previously in the Alabama portion of the watershed (Ortmann 1925; McGregor and Garner 2004). We did not find live Mountain Creekshell, but our finding of two freshly dead shells suggests that a small population exists in the Mississippi portion of the watershed. The Flutedshell previously was reported from the Mississippi portion of Bear Creek only as relic shells (MMNS). Our finding of 10 live individuals confirms the continued existence of this species in the state. Our findings of Mountain Creekshell and Flutedshell prompted consideration of both species for listing as state endangered in Mississippi because of their apparently small population size and restricted range in the state.

Paper Pondshell was the only other species we found that had not been reported previously in the Mississippi portion of Bear Creek. We found only freshly dead shells of this species, but like the Giant Floater, it typically occurs in depositional areas and a population probably occurs in the Mississippi portion of Bear Creek. The Yellow Sandshell (*Lampsilis teres*) was reported previously from the Mississippi portion of Bear Creek only as freshly dead or relic shells (MMNS), and it was not reported previously from the Alabama portion; our collections represent the first findings of live individuals in the watershed. The Ebonyshell (*Reginaia ebenus*) was previously known from Bear Creek in Mississippi by a single freshly dead shell (MMNS), but our records of two live individuals confirm the species' presence and suggest that it is moving upstream in the system (see McGregor and Garner 2004).

Length–frequency distributions of most of the more common species showed individuals of a wide range of sizes, which suggests that at least some recruitment is occurring for these species. The only exception was the Elephantear, which was represented only by large individuals. Elephantear populations in other areas are similarly dominated by large individuals and show no evidence of recent recruitment, potentially due to restriction of movement of their host fishes (herrings, *Alosa* spp.) by dams (Haag 2012). We were unable to assess recent recruitment for federally endangered or threatened species because of our low sample sizes for these species. However, Rabbitsfoot was represented by a wide range of sizes (lengths = 50.0–96.0 mm), suggesting the presence of several age classes.

The continued survival of most previously reported species and the presence of recent recruitment suggests that mussel populations in the Mississippi portion of the Bear Creek watershed have been relatively stable since the 1995–2000 survey of McGregor and Garner (2004). However, our study is the first to provide quantitative estimates of mussel abundance, so it is impossible to make inferences about changes in mussel abundance during the last 25 yr. It seems clear that major changes occurred in the Bear Creek fauna before the McGregor and Garner (2004) study. In addition to Snuffbox and Tennessee Pigtoe, nine other species had disappeared from the stream by that time. Although we have no information about historical mussel abundance, the overall low abundance we observed at most sites suggests that the stream continues to be negatively affected by some factor or has not recovered from previous anthropogenic insults.

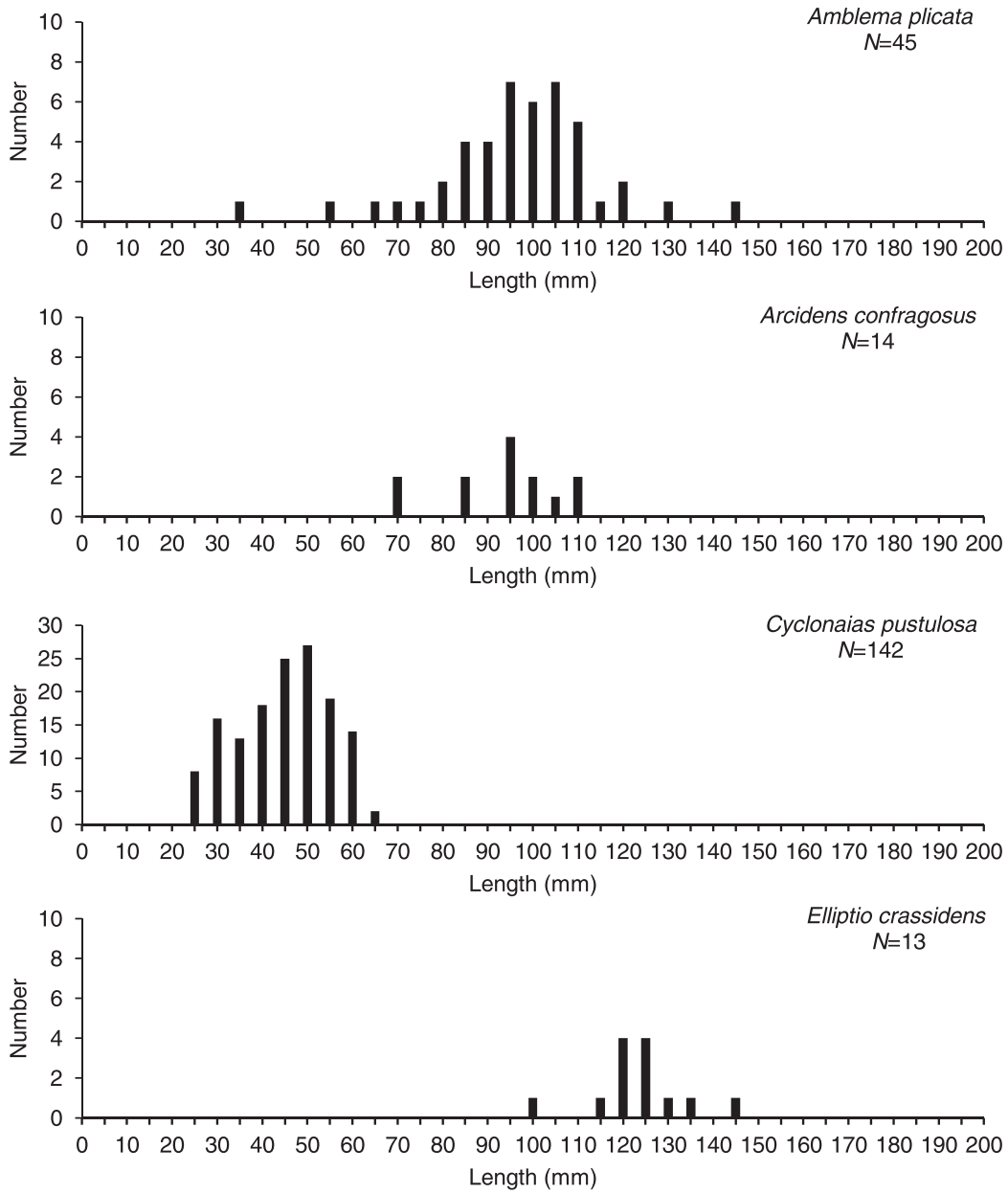

Figure 2. Length frequency histograms for 11 mussel species in the Bear Creek watershed, Mississippi in 2020. Sample sizes (*N*) represent all live individuals collected throughout the watershed.

The reasons for species loss and the currently low mussel abundance in Bear Creek are unknown. McGregor and Garner (2004) proposed that altered flow regimes caused by TVA reservoirs in the upper watershed have negatively affected the mussel fauna. TVA initiated minimum flows from these reservoirs in 2007 to improve aquatic habitats in the system (USFWS 2006), but we are unable to assess potential effects of this action because of the absence of previous estimates of mussel abundance. Stream habitats in the Bear Creek watershed have been degraded in other ways, including channelization and channel alteration, loss of riparian vegetation, and bank erosion, but the effect of these factors on the mussel fauna is unknown.

Bear Creek continues to support a diverse and important mussel fauna. Bear Creek represents the approximate downstream extent of the endemic mussel fauna of the Tennessee River system (Haag 2012), and it is distant from other populations of endemic species in the system. For example, the Bear Creek population of Cumberlandian Combshell is separated from the nearest surviving population by 748 river km and numerous dams (Gladstone et al. 2022). This isolation illustrates the biogeographic importance of Bear Creek, as well as its vulnerability to stochastic effects. The results from our comprehensive survey of Bear Creek, including the first estimates of mussel abundance in the system, will be important

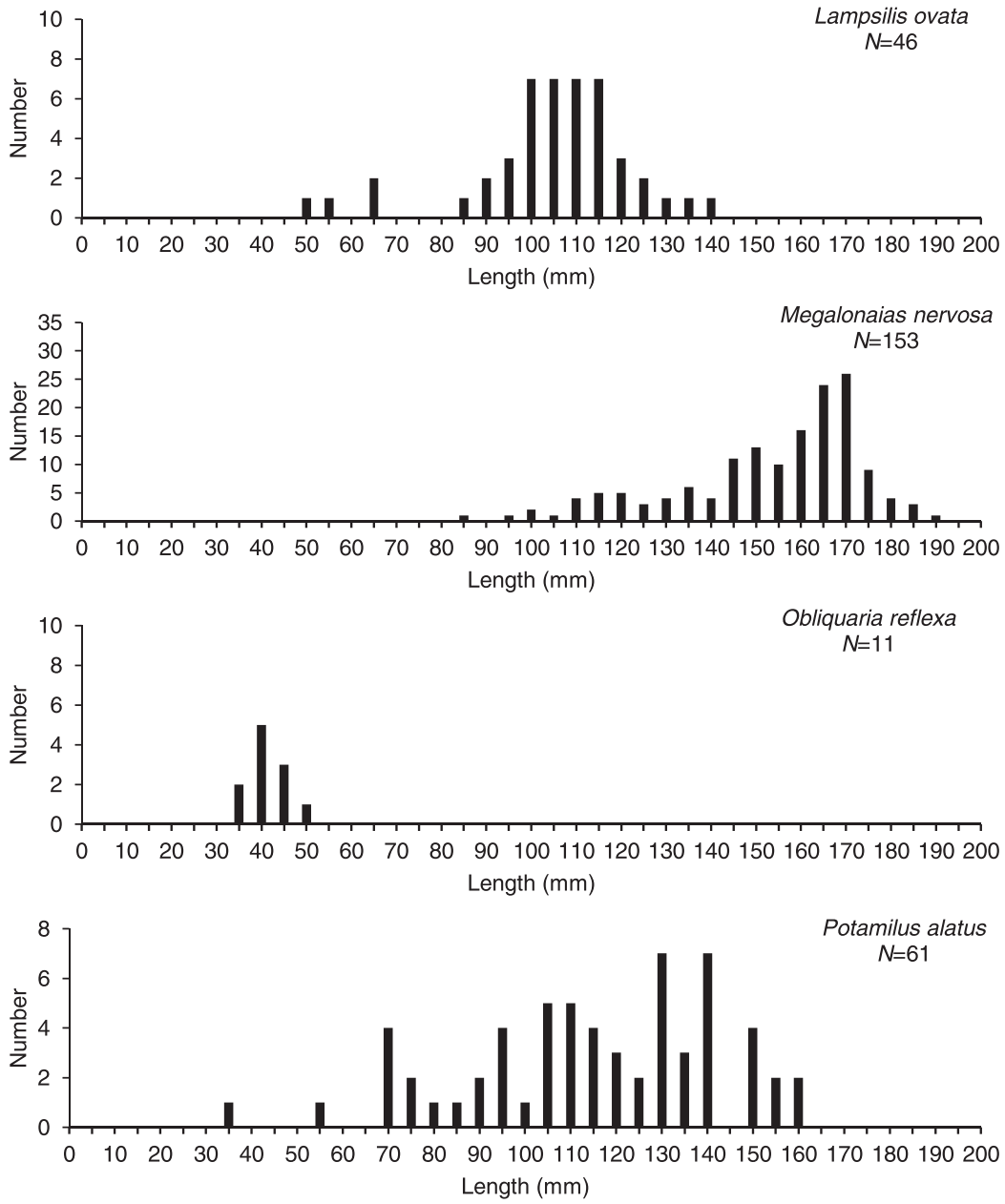

Figure 2, continued.

for monitoring the fauna and assessing the effects of future conservation actions.

ACKNOWLEDGMENTS

We thank Jacob Moore with the Private John Allen National Fish Hatchery, Dustin Rodgers with Mississippi Department of Wildlife, Fisheries, and Parks, and Ian Hurst with Mississippi State University for help with field surveys. For help with species identification, we thank Scott Peyton with the MMNS, Paul Hartfield with the U.S. Fish and Wildlife Service, Jeff Garner with Alabama Department of Conservation of Natural Resources, Robert L. Jones, and Jim Williams. We thank Wendell Haag for the extensive edits and technical guidance provided during the preparation of this manuscript. This project was funded by the U.S. Fish and Wildlife Service through a cooperative agreement under Section 6 of the Endangered Species Act with the Mississippi Department of Wildlife, Fisheries, and Parks (award MS-E-F20AP00074).

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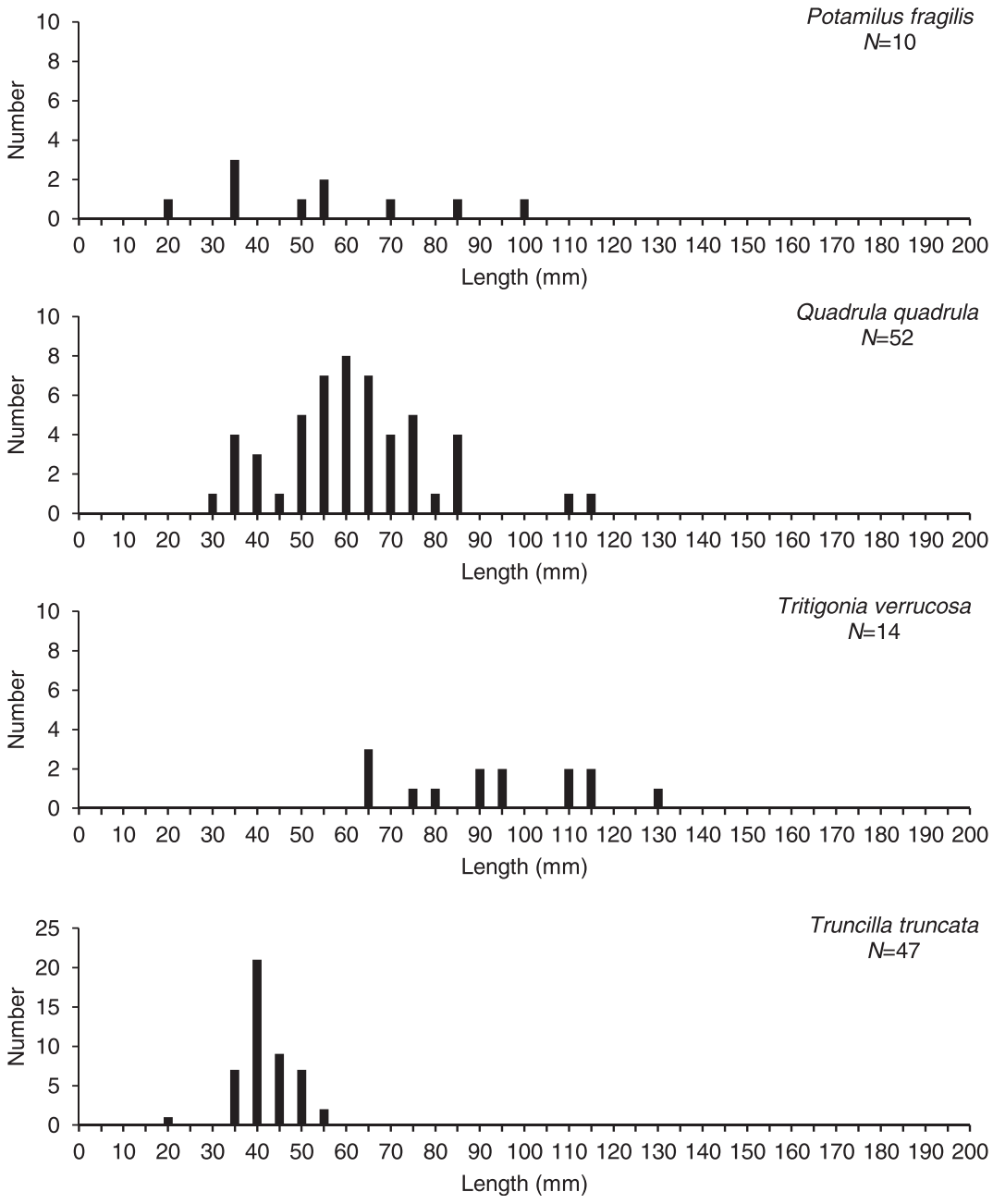

Figure 2, continued.

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