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STATUS OF RARE AND ENDANGERED FRESHWATER MUSSELS IN SOUTHEASTERN OKLAHOMA

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ABSTRACT—We reviewed the conservation status of rare and endangered species of mussels in southeastern Oklahoma by completing surveys of 10 long-term monitoring sites on the Kiamichi River and five sites in the Little River. We found extant populations of the Ouachita rock pocketbook, *Arkansia wheeleri*, scaleshell, *Leptodea leptodon*, winged mapleleaf, *Quadrula fragosa*, and rabbitsfoot, *Quadrula cylindrica cylindrica*. This is the first reported documentation of *Q. fragosa* in the Little River. When our data are compared to historic records, populations, particularly of *A. wheeleri* and *Q. cylindrica*, appear to be declining.

RESUMEN—Revisamos el estado de conservación de las especies raras de mejillones y en peligro de extinción en 10 sitios de muestreo a largo plazo en el río Kiamichi y 5 sitios en el río Little en el sureste de Oklahoma. Encontramos poblaciones existentes de *Arkansia wheeleri*, *Leptodea leptodon*, *Quadrula fragosa* y *Quadrula cylindrica cylindrica*. Reportamos por primera vez a *Q. fragosa* en el río Little. Cuando los resultados son comparados con registros históricos, las poblaciones, particularmente de *A. wheeleri* y *Q. cylindrica*, parecen estar disminuyendo.

One of the most critically imperiled freshwater groups in the United States is freshwater mussels (Family Unionidae; Strayer et al., 2004). The United States Fish and Wildlife Service recognizes 12% of native freshwater mussels to be extinct and 23% as threatened or endangered, while the Nature Conservancy considers 68% of native mussels to be at risk (Biggins and Butler, 2000). Mussels are long-lived, iteroparous, and spend a portion of their lives as obligate ectoparasites on a fish host (McMahon and Bogan, 2001). These life-history characteristics have made them particularly susceptible to anthropogenic impacts.

The highest diversity of freshwater mussels occurs in the southeastern United States, which provides habitat for almost 270 of the about 300 North American species (Williams et al., 1993; Neves et al., 1997). Oklahoma, on the periphery of the highest species richness for mussels, is still home to a diverse and speciose assemblage of freshwater mussels with about 55 species in the state. One river basin, the Kiamichi-Little River Basin, supports about 80% of all species of mussels that can be found in Oklahoma (Table 1; D. E. Spooner et al., in litt.). Historically, both of these rivers also have been home to a number of rare and endangered species of mussels including the Ouachita rock pocketbook, *Arkansia wheeleri*, scaleshell, *Leptodea leptodon*, winged mapleleaf, *Quadrula fragosa*, and rabbitsfoot, *Quadrula cylindrica*.

Arkansia wheeleri (syn. *Arcidens wheeleri*) is a federally listed, endangered species whose historical distribution includes the Kiamichi River and Jackfork Creek (a tributary to the Kiamichi River), the Little River, the Ouachita River in Arkansas, and Pine Creek and Sanders Creek in Texas (Martinez, 2004). As of the early 1990s, the most substantial remaining population occurred in the Kiamichi River within a 123-km stretch upstream of Hugo Reservoir (Vaughn and Pyron, 1995; Martinez, 2004; C. C. Vaughn et al., in litt.). Other smaller populations were known to occur in the Little River in Oklahoma and the Ouachita River in Arkansas (Martinez, 2004; C. C. Vaughn, in litt.; C. C. Vaughn et al., in litt.).

Leptodea leptodon, also a federally listed, endangered species, was known historically from 55 rivers across the United States in Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky, Minnesota, Missouri, Ohio, Oklahoma, South Dakota, Tennessee, and Wisconsin (Syzmanski,

TABLE 1—Freshwater species of mussels known from the Kiamichi and Little rivers, Oklahoma (from D. E. Spooner et al., in litt.).

Species	Common name	Kiamichi river	Little river	Federal status	State status
Actinonaias ligamentina	Mucket	X	X		
Amblema plicata	Threeridge	X	X		
Arkansia wheeleri	Ouachita rock pocketbook	X	X	Endangered	Endangered
Ellipsaria lineolata	Butterfly	X	X		
Elliptio dilatata	Spike		X		
Fusconaia flava	Wabash pigtoe	X	X		
Lampsilis cardium	Plain pocketbook	X	X		
Lampsilis satura	Sandbank pocketbook		X		
Lampsilis siliquoidea	Fatmucket	X	X		
Lampsilis teres	Yellow sandshell	X	X		
Lasmigona complanata	White heelsplitter	X	X		
Lasmigona costata	Flutedshell	X	X		
Leptodea fragilis	Fragile papershell	X	X		
Leptodea leptodon	Scaleshell	X		Endangered	Species of special concern
Ligumia subrostrata	Pondmussel	X	X		
Megalonaias nervosa	Washboard	X	X		
Obliquaria reflexa	Threehorn wartyback	X	X		
Obovaria jacksoniana	Southern hickorynut	X			
Plectomerus dombeyanus	Bankclimber		X		
Pleurobema sintoxia	Round pigtoe		X		
Pleurobema rubrum	Pyramid pigtoe	X	X		
Potamilus purpuratus	Bleufer	X	X		
Ptychobranchus occidentalis	Ouachita kidneyshell	X	X		
Pyganodon grandis	Giant floater	X	X		
Quadrula apiculata	Southern mapleleaf		X		
Quadrula fragosa	Winged mapleleaf		X	Endangered	
Quadrula cylindrica	Rabbitsfoot	X			Species of special concern
Quadrula nodulata	Wartyback		X		
Quadrula pustulosa	Pimpleback	X	X		
Quadrula quadrula	Mapleleaf	X	X		
Strophitus undulatus	Creeper	X	X		
Toxolasma parvus	Lilliput	X	X		
Toxolasma texasensis	Texas lilliput		X		
Tritogonia verrucosa	Pistolgrip	X	X		
Truncilla truncata	Deertoe	X	X		
Truncilla donaciformis	Fawnsfoot		X		
Utterbackia imbecillis	Paper pondshell	X			
Villosa arkansasensis	Ouachita creekshell		X		
Villosa iris	Rainbow		X		
Villosa lienosa	Little spectaclecase		X		

1998; Roberts, 2004). Although it always has been considered a rare species, its populations have declined significantly over the past decade such that it has been extirpated from most of its previously known localities. Presently, it is believed to remain in 14 of the original rivers including the Kiamichi River, the Little River, and the Mountain Fork River (a tributary to the Little River; Roberts, 2004; NatureServe, http://www.natureserve.org/explorer/servlet/NatureServe?searchSciOrCommonName=Leptodea+leptodon).

The historical distribution of federally listed, endangered *Q. fragosa* is uncertain because many published records misidentified this species as *Quadrula quadrula*; however, it has been suggested that this species occurred historically throughout the Interior Basin. Currently, the only known viable populations are in the Saint Croix River in Minnesota and Wisconsin, the Bourbeuse River in Missouri, and the Ouachita and Saline rivers in Arkansas (Hornbach et al., 1996; Hove et al., 2003; NatureServe, http://www.natureserve.org/explorer/servlet/NatureServe?searchSciOrCommonName=Quadrula+fragosa&x=7&y=5; C. Davidson and W. R. Posey, pers. comm.).

Quadrula cylindrica cylindrica, although not listed as federally threatened or endangered, has experienced significant population declines across most of its range. This species was found historically in the Great Lakes sub-basin and in the Mississippi River drainage in about 136 rivers across 15 states (R. S. Butler, in litt.; NatureServe, http://www.natureserve.org/explorer/servlet/NatureServe?searchSciOrCommonName=Quadrula+cylindrica+cylindrica). Presently, populations of *Q. cylindrica* are believed to remain in 46 of these streams in 13 states. Most reports on this mussel suggest that it has become rare or extirpated in many regions; however, populations of *Q. cylindrica* in the Little River are considered to be one of the most significant throughout the range of this species. This species is currently under review by the United States Fish and Wildlife Service for possible listing as threatened or endangered (R. S. Butler, in litt.).

Frequent surveys of rare and endangered species are necessary to assess recovery of populations and current and future management practices. During 1990–1992, Vaughn and Pyron (1995) identified and surveyed 10 long-term population monitoring sites for *A. wheeleri* in the Kiamichi River. These sites were all located above a large mainstem impoundment, with four sites above and six sites below a tributary impoundment (Fig. 1). Additionally, during 1993–1995 multiple sites were surveyed along the Little River for *A. wheeleri* (Vaughn and Taylor, 1999; C. C. Vaughn, in litt.). The purpose of the present study was to resurvey the Kiamichi River monitoring sites and survey additional sites in the Little River to determine the status of federally listed and other rare species of mussels in rivers of southeastern Oklahoma.

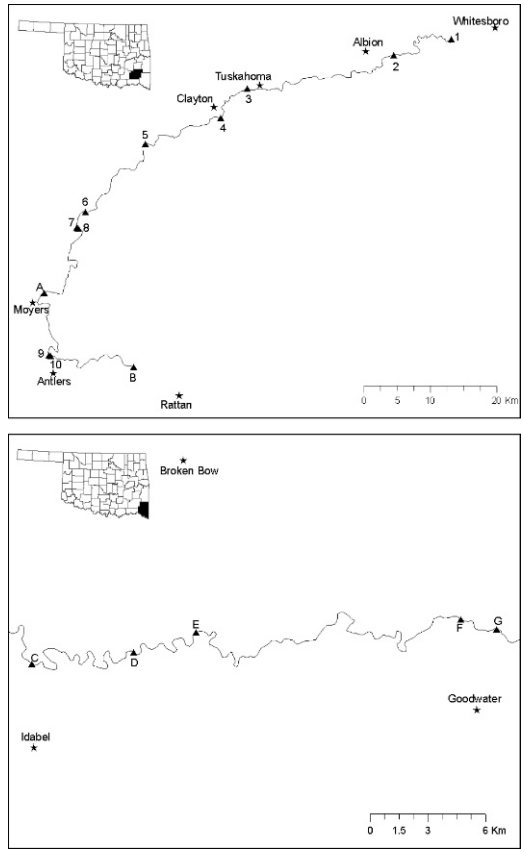

FIG. 1—Sampling sites on the Kiamichi River (top) and Little River (bottom). Monitoring sites established in the 1990s are numbered from upstream to downstream; remaining sites are lettered from upstream to downstream. Towns are indicated by ★.

MATERIALS AND METHODS—During summers of 2003–2005, we surveyed the 10 monitoring sites in the Kiamichi River and 5 additional sites in the Little River that were believed to harbor dense, diverse communi-

ties of mussels (Fig. 1). At each site, we sampled quantitatively with quadrats, followed by qualitative sampling with a timed search (Vaughn et al., 1997; Strayer and Smith, 2003). For each site, we used a stratified-random design and excavated 15 0.25-m^2 quadrats to a depth of about 15 cm. Timed searches consisted of ≥2 h of searching for mussels by hand, snorkel, or SCUBA in deeper areas (>0.75 m). We measured all located endangered species with digital calipers (height, width, length), individually marked each with a Floy® shellfish tag (Floy Tag, Inc., Seattle, Washington) attached with gel-type superglue, and returned mussels to the same location from which they were captured. In beds that were known to have contained *A. wheeleri* in past surveys, we spent additional time searching habitat appropriate for this species (Vaughn and Pyron, 1995) and looking for individuals of *A. wheeleri* that were marked in the early 1990s.

We also canoed a 60-km stretch of the Kiamichi River, between Whitesboro and Moyers, to locate previously unmapped mussel beds and search for rare species of mussels (Fig. 1a). We found mussel beds by conducting visual searches in shallow water and looking for dead shells on the shore. At newly located mussel beds, we recorded universal transverse mercator (UTM) coordinates at each site using a global positioning system (GPS). For most of the newly identified sites, we performed a short timed search (usually 30 min) to obtain a rough estimate of mussel richness. We also searched each new site for potential habitat of *A. wheeleri* so that we might more thoroughly search these sites in the future.

Results—*Arkansia wheeleri*—Historically, *A. wheeleri* was present at 6 of the 10 monitoring sites in the Kiamichi River: sites 1, 2, 3, 5, 6, and 7 (Fig. 1; Vaughn and Pyron, 1995). In our surveys during 2003–2005, we did not find *A. wheeleri* at any of these locations. We found three live *A. wheeleri* at site A, a newly discovered mussel bed near Moyers, Oklahoma (Fig. 1). These individuals (67, 82, and 82 mm) were within the size range of *A. wheeleri* collected in the 1990s (40–100 mm; Vaughn and Pyron, 1995). We also found a relict shell of *A. wheeleri* at a previously unsampled mussel bed located between sites 5 and 6. In 1993, C. C. Vaughn et al. (in litt.) found a live *A. wheeleri* at site B, just upstream of Rattan (Martinez, 2004); we were unable to resample this bed, so the status of this *A. wheeleri* population is unknown.

In the 1990s, *A. wheeleri* was present at site E in the Little River (Martinez, 2004). We did not find *A. wheeleri* at this site in our surveys in 2003–2005. However, we found two individuals (92 and 121 mm) of *A. wheeleri* in the Little River at site F, located <1 km above the confluence of the Mountain Fork River (Fig. 1) on the Little River National Wildlife Refuge where C. C. Vaughn (in litt.) also collected this species historically.

Leptodea leptodon—We found three, fresh dead (i.e., some tissue still attached) shells of *L. leptodon* in the Kiamichi River. One of these shells was at site 2 near Albion, one at site A in the same mussel bed as *A. wheeleri*, and the third at site 10 near Antlers (Fig. 1). One of the shells was small (<5 cm), indicative of either a female or a juvenile.

Quadrula fragosa—We found individuals that genetic analysis confirmed to be *Q. fragosa* (J. Serb, pers. comm.) at sites C, D, E, and F in the Little River. Densities of *Q. fragosa* at each site were 0.13 individuals/m^2 at sites D and E, and 0.53 individuals/m^2 at site F. A single individual was located at site C during our timed search; thus, we do not have a density estimate for this site.

Quadrula cylindrica—We found three substantial populations of *Q. cylindrica* in the Little River at sites D, E, and G, with densities of about 2.4, 1.1, and 0.27 individuals/m^2, respectively. In February of 2006, however, we revisited these sites and found that the population at site D had suffered a large mortality event. We collected >160 fresh dead shells on the bank of this mussel bed; dead individuals spanned the range of sizes for this species from 33 to 103 mm.

Discussion—Extant populations of *A. wheeleri*, *L. leptodon*, and *Q. cylindrica* occur in the Kiamichi and Little rivers. Additionally, this is the first confirmed finding of *Q. fragosa* in Oklahoma. Although it has been suggested that populations of this species exist in the Kiamichi River (P. Mehlhop-Cifelli and E. K. Miller, in litt.; Hove et al., 2003), we have never found this species there in extensive surveys over the past 15 years. Despite finding living individuals of all but *L. leptodon*, we are concerned about the long-term persistence of all of these rare species in southeastern Oklahoma.

In the Kiamichi River, *A. wheeleri* appears to have declined significantly in both number of sites at which it occurs and in abundance. This species tends to be found in the largest, most species-rich mussel beds (Vaughn and Pyron, 1995); however, over the past decade abundance and species richness of mussels have declined throughout the Red River drainage (Vaughn, 2000) and specifically in the Kiamichi River (H. S. Galbraith et al., in litt.). Whatever factors are

impacting mussels in the Kiamichi River seem to have had particularly deleterious effects on *A. wheeleri*. The *A. wheeleri* at the newly discovered bed at site A are under severe threat from human activities. Over the past few years, complete removal of riparian habitat and gravel mining within and above the mussel bed have resulted in mass mortality of mussels at this site.

Although we found individuals of *A. wheeleri* in the Little River at localities that previously were unknown, we also have concerns about this population. The water levels over the site-F mussel bed were extremely low at the time we sampled (8 August 2005), and many other mussels were stranded or dead. Both individuals of *A. wheeleri* that we found in our study were stranded out of water; we replaced them in a deeper portion of the mussel bed that was still under water. These individuals were also large: the extent to which recruitment is occurring in this species is assumed to be low (or nonexistent) given the large size classes and low densities of individuals that we sampled in both the Little River and Kiamichi River.

The three fresh-dead *L. leptodon* we found suggest that this species remains extant in the Kiamichi River; however, over the past 15 years, no one has sampled a living individual to our knowledge. Our collection at site 2 near Albion is the farthest upstream an individual has been found in the Kiamichi River since at least 1987 (Syzmanski, 1998; Roberts, 2004). Again, we are reluctant to suggest that any populations of *L. leptodon* at the site-A mussel bed will survive the current degradation.

We found large, apparently stable, and reproducing populations of *Q. cylindrica* in the Little River, one of the last places in the United States this species is known to be abundant (R. S. Butler, in litt.). We are uncertain of the cause of mortality in this species at site D, but are troubled over the large number of fresh-dead individuals we observed spanning the range of size classes of this species. This die off was apparently species specific as no other species of mussel was found dead in such high abundance. For southeastern Oklahoma, 2005 was the driest year on record, receiving $<50\%$ of the average precipitation (calculated over a 30-year period–Oklahoma Climatological Survey, 2006). High water temperatures (which can exceed 40°C) combined with extensive blooms of filamentous algae may have resulted in extreme physiological stress at site D (D. E. Spooner et al., in litt.), while low water levels may have increased predation pressure at this already shallow bed. Despite the possibility of these factors, we observed no mass mortality prior to November 2005 when the river conditions were most extreme, suggesting the mortality event occurred between November 2005 and February 2006. The Little River is susceptible, however, to inputs of sewage and runoff from poultry plants, which may have been a factor in the mortality of *Q. cylindrica*, although we have no evidence to confirm or refute this hypothesis.

Results of our surveys suggest that, although rare and endangered species of mussels are still present in southeastern Oklahoma, populations in both the Kiamichi and Little rivers are declining. This is troubling information, particularly for *A. wheeleri*, whose global distribution is limited to these two rivers and the Ouachita River in Arkansas. Given the declines in populations of *A. wheeleri* and *Q. cylindrica* and the recent discovery of *Q. fragosa* in this region, it is imperative that further efforts be made to minimize impacts on these already threatened populations. Further construction of reservoirs in this area as recently has been proposed could be detrimental to the remaining populations of both rare and common species of mussels.

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