OCCURRENCE OF THE RAYED CREEKSHELL, *ANODONTOIDES RADIATUS*, IN THE MISSISSIPPI RIVER BASIN: IMPLICATIONS FOR CONSERVATION AND BIOGEOGRAPHY

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ABSTRACT - We document the occurrence of the rayed creekshell (*Anodontoides radiatus* Conrad), a freshwater mussel (Unionidae), at eight sites in the upper Yazoo River drainage (lower Mississippi River Basin) in northern Mississippi. Previously, *A. radiatus* was thought to be restricted to Gulf Coast drainages as far west only as the Tickfaw River system (Lake Pontchartrain Basin), Louisiana. The eight populations reported herein represent the only known occurrences of this species in the Mississippi River Basin. This distributional pattern, along with distributions of other aquatic organisms, suggests that headwater stream capture events occurred historically between lower Mississippi River Basin tributaries and the upper Tombigbee River drainage (Mobile Basin). Because *A. radiatus* is a rare species, considered imperiled throughout its range, the discovery of eight additional populations and the extension of its known range are of significance to its conservation.

INTRODUCTION

The distribution and biogeography of the freshwater mussel fauna of the lower Mississippi River Basin (defined as the Mississippi River and its tributaries from the mouth of the Ohio River to the Gulf of Mexico within the Mississippi Embayment Ecoregion and Gulf Coastal Plain) (Abell et al. 2000, Robison 1986) is less well-known than that of most of eastern North America. Extensive surveys of most drainages in this region were not conducted until the 1980s, and most of these focused on large river habitats (e.g., Cooper and Johnson 1980, Hartfield and Rummel 1985, Manning 1989, Miller et al. 1992). The mussel fauna of small streams in this region remains poorly known.

The rayed creekshell, *Anodontoides radiatus* (Conrad), is a little-known freshwater bivalve of the family Unionidae. Previously, *A. radiatus* was believed to be restricted to eastern Gulf Slope drainages from the Tickfaw River system in Louisiana (Lake Pontchartrain Ba-

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sin), east to the Apalachicola Basin in Alabama, Georgia, and Florida (Johnson 1967, Williams and Butler 1994). This species is found most frequently in small to medium-sized creeks but occurs only sporadically throughout its range (Brim Box and Williams 2000, Clench and Turner 1956, Williams and Butler 1994). Its sporadic occurrence may be due either to rarity or a lack of collecting effort in small, headwater streams (Williams and Butler 1994). Because of evidence of population declines in some areas and uncertainty regarding its conservation status in others, *A. radiatus* is considered a species of special concern by the American Fisheries Society (Williams et al. 1993).

We report the collection of *A. radiatus* at eight sites in the upper Yazoo River drainage (lower Mississippi River Basin) in northern Mississippi and provide information about the habitat and mussel species assemblages at these sites. We discuss the implications of this discovery for biogeography and aquatic conservation in this region.

METHODS

From 1993 to 2001, we surveyed for freshwater mussels at 135 sites in the upper Yazoo, Wolf, and Hatchie river drainages in Benton, Lafayette, Marshall, Panola, Tippah, Union, and Yalobusha counties, north-central Mississippi. A large portion of this area lies within or near the proclamation boundaries of the Holly Springs National Forest. The ecoregion is classified as the Northern Loessial Hills Subsection of the Coastal Plain Middle Section within the Southeastern Mixed Forest Province (Keys et al. 1995). Topography consists of irregular low hills (200-m maximum relief) dissected by a well-developed, dendritic drainage system with flat, often broad, floodplains adjacent to large creeks and rivers (Warren et al. 2002). Sample sites were located on streams of varied sizes (0.4-4002.0 km^2 drainage area), small watershed impoundments, and one large mainstem reservoir (Sardis Reservoir, Little Tallahatchie River), but most sites were streams fifth order or smaller (0.4-152.0 km^2 drainage area). Stream substrate is predominantly sand or silty sand with accumulations of finer material in depositional areas.

At most sites, the length of stream sampled was at least 20 times the average width of the stream, so that sampling effort was approximately proportional to stream size (Warren et al. 2002). Minimum sample distance was 80 m for streams less than 4-m average width. We searched shorelines and streambeds, and all living and dead mussels were bagged and returned to the laboratory for identification. Most

living mussels were returned to the site alive. We sampled for living mussels by feeling along the bottom and sifting through the substrate with our fingers and by looking for mussel trails and siphons in the streambed. At some large stream sites and impoundments, we used snorkeling or SCUBA.

Positive identification was made using shell pigmentation patterns, shell shape, and hinge tooth structure as described by Brim Box and Williams (2000), Clench and Turner (1956), and Johnson (1967). Voucher specimens are deposited at the Mississippi Museum of Natural Science, Jackson, Mississippi, and the University of Alabama, Tuscaloosa, Alabama.

RESULTS

We found unionid mussels at 53 (39%) of the surveyed sites. We found *A. radiatus* at eight sites (6% of total sites; 15% of sites with mussels) in seven streams (Table 1) yielding a total of 19 individuals (7 live, 12 dead shells). Populations were found in three major river systems within the upper Yazoo River drainage: the Little Tallahatchie River, Tippah River, and Yocona River (Fig. 1).

Our specimens closely resembled published descriptions of *A. radiatus* from elsewhere in its range (Brim Box and Williams 2000, Clench and Turner 1956, Johnson, 1967). Shells of all specimens were thin with bright green rays of varying widths over the entire surface of the shell. Shell outlines were elliptical with slightly pointed posterior ends and were not biangulate. Pseudocardinal teeth were present but rudimentary and slightly laminate; lateral teeth were absent. These characters readily separate *A. radiatus* from the cylindrical papershell, *A. ferrusacianus* (I. Lea), as well as *Strophitus* spp. and *Villosa* spp., all of which may superficially resemble *A. radiatus* (Brim Box and Williams 2000, Johnson 1967). Shell lengths ranged from 37-79 mm (mean = 56 mm).

Streams supporting *A. radiatus* were small to medium-sized creeks of second to fourth order (Table 1). Seven sites were not channelized, and one site (Cypress Creek) was channelized. Sites were non-incised to moderately incised due to head-cutting likely initiated by channelization further downstream (average bank height at all sites ranged from less than 2 m to 5 m). Substrate at all sites was primarily sand or silty sand with low to moderate amounts of in-stream woody debris. At all eight sites, *A. radiatus* occurred in bivalve assemblages consisting of 2-5 other species (Table 1).

DISCUSSION

Anodontoides radiatus is a rare mussel of sporadic distribution in the upper Yazoo River drainage. The populations we documented represent

Table 1. Collection sites of the rayed creekshell (*Anodontoides radiatus*) and associated bivalve fauna in the upper Yazoo River drainage, Mississippi River Basin, northern Mississippi. Number of live individuals or freshly-dead shells (FD) refers to *A. radiatus*.

Stream Site	Associated Bivalve Species
Cypress Creek (Little Tallahatchie River system) at SR 30 bridge, 6.9 km SW of Etta, 23.0 km ENE of Oxford. T7S, R1W, Sec 27, Lafayette Co., MS (34°26'N, 89°17'W). 7 March 2001. Fourth order. 3 Live.	*Corbicula fluminea* *Lampsilis siliquoidea* *Toxolasma texasensis* *Villosa lienosa*
East Cypress Creek (Little Tallahatchie River system) downstream of Goolsby Lake, at CR 252 bridge, 20.7 km E of Oxford. T8S, R1W, Sec 15, Lafayette Co., MS (34°22'N, 89°17'W). 15 July 2000. Second order. 1 FD.	*Lampsilis siliquoidea* *Pyganodon grandis* *Toxolasma texasensis* *Villosa lienosa*
Mitchell Creek (Little Tallahatchie River system) at SR 30 bridge, 4.5 km NW of Enterprise, 18.0 km W of New Albany. T7S, R1E, Sec 9, Union Co., MS (34°28'N, 89°12'W). 3 November 2000. Third order. 1 FD.	*Corbicula fluminea* *Villosa lienosa*
Puskus Creek (Little Tallahatchie River system) 0.5 km upstream from head of Puskus Lake, 12.5 km WSW of Etta, 16.5 km NE of Oxford. T7S, R2W, Sec 25, Lafayette Co., Mississippi (34°26'N, 89°22'W). 19 August 2000. Fourth order. 4 FD.	*Corbicula fluminea* *Fusconaia flava* *Lampsilis siliquoidea* *Toxolasma texasensis* *Villosa lienosa*
Puskus Creek (Little Tallahatchie River system) 0.75 km downstream from mouth of Bay Springs Branch, 14.0 km WSW of Etta, 15.0 km NE of Oxford. T7S, R2W, Sec 35, Lafayette Co., Mississippi (34°26'N, 89°22'W). 19 August 2000. Fourth order. 2 Live.	*Corbicula fluminea* *Lampsilis siliquoidea* *Pyganodon grandis*
Shelby Creek (Tippah River system) at SR 4 bridge, 13.8 km SE of Ashland, 14.4 km W of Ripley. T4S, R2E, Sec 9, Benton Co., MS (34°45'N, 89°09'W). 25 May 2001. Third order. 4 FD.	*Corbicula fluminea* *Potamilus purpuratus* *Villosa lienosa*
Yellow Rabbit Creek (Tippah River system) at CR 649 bridge, 6.8 km ESE of Ashland, 16.4 km WNW of Ripley. T3S, R2E, Sec 16/17, Benton Co., MS (34°49'N, 89°06'W). 21 July 1999, 23 July 2000. Third order. 2 FD.	*Lampsilis siliquoidea* *Villosa lienosa*
Otoucalafa Creek (Yocona River system) at crossing of unnamed dirt road 0.8 km S of Jct of SR 9W and SR 315 in Paris, 22.5 km S of Oxford. T10S, R2W/3W, Sec 36/31, Lafayette Co., MS (34°10'N, 89°27'W). 23 June 1993. Third order. 2 Live.	*Toxolasma texasensis* *Villosa lienosa*

the only known occurrence of this species in the Mississippi River Basin. The freshwater mussel fauna of the lower Mississippi River Basin is composed mostly of species distributed widely in the eastern and central United States and includes only one known endemic species, the Louisiana pearlshell, *Margaritifera hembeli* (Conrad) in the lower Red River drainage of Louisiana (Smith 1988). By contrast, the mussel faunas of most eastern Gulf Slope drainages are characterized by a high degree of endemism (Brim Box and Williams 2000, Clench and Turner 1956, van der Schalie 1940). The presence of *A. radiatus*, a species characteristic of eastern Gulf Slope drainages, in the lower Mississippi River Basin is unusual.

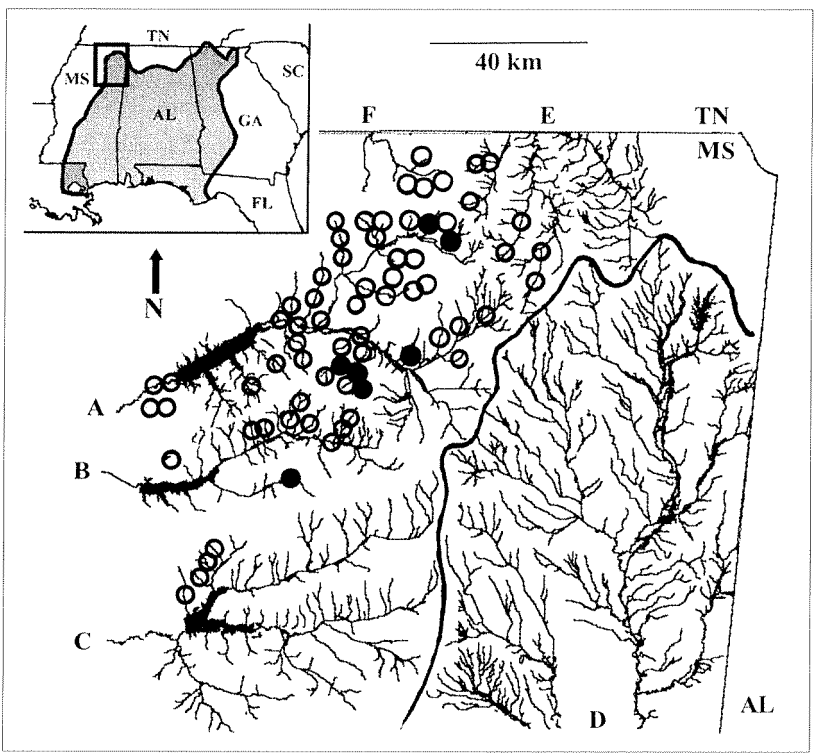

Figure 1. Distribution of *Anodontoides radiatus* in northern Mississippi river drainages. Closed circles indicate occurrence of *A. radiatus*; open circles indicate sampling sites where *A. radiatus* was not found. The curved line on the detailed map delimits the northwestern edge of the previously known range from newly discovered populations in drainages of northern Mississippi. Shaded area in inset indicates the previously known range of *A. radiatus*; the box within the inset (northern Mississippi) shows the area encompassed by the detailed map. Major river systems are labeled as: A – Little Tallahatchie River; B – Yocona River; C – Yalobusha River; D – Tombigbee River; E – Hatchie River; F – Wolf River.

Introduction by humans could explain the apparently isolated occurrence of this species in the upper Yazoo River drainage. However, the populations we documented are distributed among three geographically separated river systems within the upper Yazoo River drainage (Tippah, Little Tallahatchie, and Yocona rivers). If introduced, multiple introductions by humans would have been necessary to establish the species in this region, a scenario we view as improbable. It is more likely that vicariance events, such as stream captures, led to establishment of *A. radiatus* in the upper Yazoo River drainage.

The Yazoo, Hatchie, Wolf (all lower Mississippi River Basin), and Tombigbee (Mobile Basin) rivers have close and often interdigitating headwaters in the area where we discovered *A. radiatus* (see Figure 1). Populations of *A. radiatus* in the western Tombigbee River drainage (unpubl. data, W. Haag and M. Warren) may have been the source for populations in the upper Yazoo drainage. In this region, five other species of primarily small-stream organisms show distributional patterns and phylogenetic relationships that support the hypothesis of stream capture between these drainages. The orangefin shiner (*Notropis ammophilus* Suttkus and Boschung) and Yazoo shiner (*Notropis rafinesquei* Suttkus) are sister species (Raley and Wood 1991) that share an ancestral history involving the lower Mississippi and Mobile basins. The orangefin shiner is widespread in the Mobile Basin, including the western Tombigbee drainage (Mettee et al. 1996), but occurs in the lower Mississippi Basin only as disjunct populations in the eastern-most Yazoo drainage (Skuna River system) and the Hatchie River drainage (Suttkus 1991). Its sister species, the Yazoo shiner, is endemic to the upper Yazoo River drainage. The Yazoo darter (*Etheostoma raneyi* Suttkus and Bart), restricted to the upper Yazoo River drainage, is a close relative of the Tombigbee darter (*E. lachneri* Suttkus and Bailey), a species widespread in the Tombigbee drainage (Suttkus et al. 1994). The crayfish *Orconectes chickasawae* (Cooper and Hobbs) was, until recently, thought to be confined to western tributaries of the upper Tombigbee River (Cooper and Hobbs 1980); recent surveys have revealed that this species (or an undescribed but close relative) is also widespread in the upper Tallahatchie and Yocona rivers (unpubl. data, Warren and Haag; pers. comm., C. Taylor, Illinois Natural History Survey). The southern rainbow mussel, *Villosa vibex* (Conrad), is widespread in eastern Gulf Coast drainages (Williams and Butler 1994), but occurs in the Mississippi Basin only in the upper Hatchie River (Manning 1989) and the adjacent Wolf River system (Kesler et al. 2001) in Tennessee. These examples support the hypothesis that multiple stream capture events have occurred between Tombigbee and lower

Mississippi river tributaries and can explain the presence of disjunct populations of *A. radiatus* in the upper Yazoo River drainage. Further surveys of headwater streams in the Hatchie, Yalobusha, and Big Black river systems near the western divide of the Tombigbee drainage may reveal additional populations of *A. radiatus* in the lower Mississippi Basin.

Because of the small number of known occurrences, the discovery of eight additional populations of *A. radiatus* in a river basin from which it was previously unknown is significant from a conservation perspective. Although historical records indicate sporadic occurrence across a broad geographic region, recent survey results depict a species persisting in small, isolated populations across a few, widely scattered tributaries. In the Apalachicola River Basin, recent surveys at 324 sites documented a dramatic decline relative to the historical distribution, and the species now persists in only two widely separated localities (upper Flint and middle Chattahoochee rivers) (Brim Box and Williams 2000). In the Escambia-Conecuh River drainage, *A. radiatus* was found at only two sites despite searches in many headwater streams (unpubl. data, S. McGregor, Tuscaloosa, AL). In the Mobile Basin, *A. radiatus* may be most common in the middle Tombigbee River drainage where it is known from at least eight streams (unpubl. data, S. McGregor, Tuscaloosa, AL, unpubl. data, W. Haag and M. Warren). Elsewhere in the Mobile Basin, the species occurs only sporadically (McGregor et al. 1999). Similarly, populations in the upper Yazoo drainage are small, widely scattered, and occur at few sites. These range-wide results indicate that the apparent rarity of *A. radiatus* is real and not an artifact of inadequate collecting in suitable habitats.

We found *A. radiatus* only in association with other mussel species and mostly in streams minimally affected by channelization. The one channelized stream that supported *A. radiatus* (Cypress Creek) was straightened approximately 40 years ago and shows modest recovery in bank stability and fish species composition (Warren et al. 2002). Streams of the lower Mississippi River Basin often flow through areas of highly erodible soils, lack hard substrates, and are destabilized easily by stream channelization and subsequent stream incision (Hartfield 1993, Schumm et al. 1984). Extensive stream channelization was conducted in the upper Yazoo, upper Hatchie, and upper Tombigbee drainages, and because of the lack of stable substrates (Strayer 1999, Vannote and Minshall 1982), dense, species-rich mussel assemblages are uncommon in the region (Hartfield 1993; unpubl. data, W. Haag and M. Warren). The richest assemblages are found mostly in streams in which soft substrates are stabilized by the pres-

ence of in-stream wood, aquatic vegetation, and riparian vegetation (Hartfield and Ebert 1986). Land management practices likely to ensure survival of *A. radiatus* in this region and elsewhere in its range are those that will restore and protect the integrity of stream corridors. Because the populations we discovered are near or within the proclamation boundaries of the Holly Springs National Forest, federally mandated management practices on these public lands may have positive effects on the viability of the species in this region.

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