

## NOTES

STATUS AND DISTRIBUTION OF THE ENDANGERED BENTON CAVE  
CRAYFISH, *CAMBARUS ACULABRUM* (DECAPODA: CAMBARIDAE)

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**ABSTRACT**—We present the first summary of the status and distribution of the Benton cave crayfish (*Cambarus aculabrum*). The range of this endangered crayfish is limited to 4 sites globally (3 in Benton County and 1 in Washington County, Arkansas). The identity of the species at these 4 sites is based upon morphological and genetic studies. The identities of cave crayfish inhabiting 2 additional Benton County sites remain undetermined. The current population census is 40 individuals. Threats to the species are analyzed, and subsequent conservation measures recommended. Habitat degradation remains a threat to the species, especially for water quality. Analyses from 1983 to 2002 document nutrient pollution of the subterranean stream habitats, originating from sources such as septic system discharge and run-off from confined animal feeding operations.

**RESUMEN**—Presentamos el primer resumen del estado actual y la distribución del cangrejo *Cambarus aculabrum*. El rango de esta especie en peligro de extinción está limitado a 4 sitios totales (3 en el condado de Benton y 1 en el condado de Washington, Arkansas). La identidad de la especie en estos cuatro sitios se basa en estudios morfológicos y genéticos. Las identidades de individuos habitando dos localidades adicionales en el condado de Benton permanecen sin determinar. El censo actual de la población es de 40 individuos. Amenazas a la población son analizadas y medidas para la conservación de la especie son recomendadas. La degradación del hábitat continúa siendo una amenaza a la especie, especialmente la calidad del agua. Análisis de 1983 al 2002 documentan la contaminación de nutrientes en las corrientes subterráneas, que se originan en descargas de sistemas sépticos y desechos líquidos de operaciones de alimentación de animales en cautiverio.

The Benton cave crayfish, *Cambarus aculabrum*, is physiologically and morphologically adapted to groundwater environments (a stygobite), and is limited to 4 sites globally in Benton and Washington counties, Arkansas (Logan Cave, Bear Hollow Cave, Old Pendergrass Cave, and a site on Brush Creek). Other than its description (Hobbs and Brown, 1987), the Benton cave crayfish lacks any formal study. Because of its rarity and susceptibility to extinction, it was designated endangered by the United States Fish and Wildlife Service (USFWS, 1993) and by the International Union for the Conservation of Nature and Natural Resources (2004), and is considered crit-

ically imperiled by the U.S. Natural Heritage Network (NatureServe, 2006). The *Cambarus aculabrum* Recovery Plan (USFWS, 1996) detailed historical threats to the species and actions needed for the recovery and delisting of the species. This study summarizes current threats and all recovery activities to date.

The recovery plan cited the following factors causing the decline of the species: habitat destruction, disturbance by cavers or trespassers, specimen collection, low reproductive potential, and competition and predation by non-stygobitic species. Habitat degradation from groundwater pollution—the primary reason for federal listing of the species—remains a se-

rious threat to the Benton cave crayfish. Water quality analyses performed by Willis (1984), Means (1993), and Graening (2005) for recovery objectives (hereafter, objectives) 3.2 and 3.3 indicated that organic pollutants were present in the groundwater basins of both Logan Cave and Bear Hollow Cave. Mean concentrations of nitrate, phosphorous, and fecal bacteria consistently equaled or exceeded those of regional surface waters monitored by the National Water Quality Assessment Program for the Springfield Plateau Aquifer (Davis and Bell, 1998). The Logan Cave groundwater recharge zone is approximately 3,015 total hectares, with 86% of the zone rated as highly vulnerable to surface pollutants (Aley and Aley, 1987, unpubl. report to Arkansas Game and Fish Commission [AGFC] and USFWS). Within this recharge zone, there were over 100 confined animal feeding operations (poultry and swine) and cattle ranching operations, as well as at least 60 residences on septic systems. This recharge zone, as well as the Brush Creek habitat, are situated within the Illinois River watershed, which was designated an impaired water body by the State of Arkansas under Section 303(d) of the federal Clean Water Act (40 CFR 130.7) because of flow alterations, organic enrichment, low dissolved oxygen, siltation, and metals concentrations. The Bear Hollow Cave groundwater recharge zone is smaller (896 hectares), with 36% of the zone rated as highly vulnerable, and contained at least 200 residences on septic systems and 2 confined animal feeding operations (Aley and Aley, 1998, unpubl. report to AGFC). Old Pendergrass Cave lies within the Elk River watershed, which was designated an impaired waterbody by Arkansas because of excessive nutrient loading.

The recovery plan cited human disturbance as a reason for decline, and historically, Bear Hollow Cave and Logan Cave were both popular recreational destinations. Vandalism and trespass continue to be serious management issues at both sites, even after the erection of steel channel cave gates. Because stygobitic crayfish use interstitial habitats for refuge and for foraging, human traffic upon the cobble substrate in subterranean streams is known to cause inadvertent mortality by trampling (e.g., Weingartner, 1977). We found a Benton cave crayfish trampled on 7 December 2000 in Bear Hollow Cave (USFWS Case File #2001400370)

after vandals had breached the cave gate and walked through the cave stream. Ironically, this species could also be trampled during official censusing because the majority of the aquatic habitat in Bear Hollow Cave is a narrow stream canyon that serves as both habitat for the crayfish and the only pedestrian route. To circumvent this mortality factor, a fixed line was bolted to a canyon ledge 3 m above the stream with the assistance of members of the Association for Arkansas Cave Studies in 2001. This rope traverse allows the aquatic habitat to be censused safely and more accurately by the elimination of pedestrian-generated turbidity.

Another historical threat to this species is overcollection; 7 crayfish were collected out of the censused population of 17 for taxonomic description (Hobbs and Brown, 1987). While this was an important mortality factor in the 1980s, scientific collection has ceased, and no amateur collection has been reported. The severe penalties for unauthorized collection under the U.S. Endangered Species Act of 1973 (ESA), as amended, probably have discouraged collection since federal listing of the species in 1993.

A natural mortality factor is expulsion from the subterranean habitat by flooding during storm events. In both Logan Cave and Bear Hollow Cave, rapid recharge of their groundwater basins by infiltration of precipitation results in dramatic increases in subterranean stream velocity and volume. In December 1999, GOG noticed one Benton cave crayfish in the fishpond outside of, and downstream from, Logan Cave after a flooding event; because numerous predators exist outside the cave, the crayfish was transferred back to the cave. A Benton cave crayfish also was observed downstream of Logan Cave in 1993 (Herbert, 1994) and another in 1995 (Brown, 1996). A Benton cave crayfish also was found outside of Bear Hollow Cave; the adjacent landowner and cave monitor, S. Green, reported the species surfacing from a resurgent spring on his Missouri property after a flood event; because of this account, and because 58% of the Bear Hollow Cave recharge zone lies within Missouri (Aley and Aley, 1998, unpubl. report to AGFC), we included the watershed of Pea Ridge Hollow, McDonald County, Missouri, in our current understanding of the range of this species. We do not believe that Benton cave crayfish

TABLE 1—Census summary of *Cambarus aculabrum*, listing date of census, number of crayfish sighted, and surveyors (data from Hobbs and Brown, 1987; Brown, 1996; USFWS, 1996; S. Todd, pers. comm., 2001; L. Willis, pers. comm., 2002; B. Wagner, pers. comm., 2004; and this study). Count with an asterisk denotes that a particular census did not cover the entire accessible portions of the cave stream habitat.

Cave and date	Count	Surveyors
Bear Hollow Cave		
23 December 1985	6	S. Todd
31 December 1985	7	S. Todd, L. Willis
11 June 1986	*1	S. Todd, J. Stewart
1987	9	S. Todd, L. Willis
1990	1	USFWS
1995	4	USFWS
30 October 1999	9	GOG, T. Snell, L. Moritz
6 November 2000	5	GOG, T. Snell
7 December 2000	7	MES, GOG
19 August 2001	*2	GOG, MES
22 October 2001	*5	GOG, G. J. Graening
23 February 2004	9	MES, B. Wagner, D. Kampwerth
8 February 2006	6	MES, B. Wagner, E. Inlander, M. Kottmyer
Logan Cave		
9 October 1986	*1	S. Todd, G. Maher
25 February 1987	8	S. Todd, J. Stewart
7 November 1990	10	S. Todd, D. Bowman
10 March 1991	*7	M. Means, D. Bowman
23 October 1994	*18	Z. Brown et al.
13 November 1994	*10	Z. Brown et al.
18 December 1994	*7	Z. Brown et al.
26 January 1995	*8	Z. Brown et al.
21 March 1995	*12	Z. Brown et al.
25 May 1995	*10	Z. Brown et al.
19 June 1995	*16	Z. Brown et al.
20 July 1995	*21	Z. Brown et al.
8 August 1995	*11	Z. Brown et al.
9 September 1995	*13	Z. Brown et al.
25 February 1996	*13	Z. Brown et al.
31 December 1999	24	GOG, L. Willis
21 November 2000	42	AVB, GOG, MES, S. Hensley, L. Willis
13 February 2002	47	GOG, MES, AVB, T. Snell, D. Kampwerth
22 January 2003	38	GOG, MES, D. Kampwerth
24 March 2004	*20	B. Wagner, D. Kampwerth
6 February 2006	31	MES, D. Fletcher, D. Kampwerth

can persist outside of the subterranean habitat because of predation and competition pressures—factors cited in the decline of the species (USFWS, 1996). Banded sculpin (*Cottus carolinae*) have consumed this crayfish on at least one occasion inside Logan Cave (Brown et al., 1994).

We have conducted regular censuses of the Benton cave crayfish (objective 3.1), and all known census data are summarized in Table 1, including our most recent counts, as well as

historical, often incomplete, censuses during which all accessible habitat was not surveyed. Our censuses and collections of crayfish were performed under USFWS Recovery Permits PRT-834518, TE834518-1,2,3, and 43590-HLB-3-01, Arkansas Natural Heritage Commission Permit S-NHCC-99-005, and AGFC Permits 1082 and 1476. Voucher specimens will be deposited at the National Museum of Natural History—Smithsonian Institute. Visual censuses of crayfish were performed using headlamps

and diving lights. One to 3 surveyors moved slowly upstream, counted crayfish in all accessible aquatic habitats, and used snorkeling gear where necessary. In addition to the authors, surveyors were S. Todd (AGFC), L. Willis (Virginia Department of Environmental Quality), B. Wagner (AGFC), T. Snell (The Nature Conservancy), L. Moritz (National Speleological Society, Boston Mountain Grotto), G. J. Graening (Brown and Caldwell, Inc.), and D. Kampwerth (USFWS). To ensure some level of standardization in census, at least one surveyor from a previous census was present in each subsequent census. The current total observed population size is 40 individuals, based upon the latest complete visual census of Bear Hollow Cave ( $n = 6$ ), Logan Cave (31), Old Pendergrass Cave (2), and the Brush Creek pool (1). The maximum historical count is 56 for the species (47 in Logan Cave and 9 in Bear Hollow Cave), irrespective of date.

Four additional sites in northwestern Arkansas harboring stygobitic crayfish populations were investigated (objective 4) (Fig. 1). In Old Pendergrass Cave (Little Sugar Creek watershed, Benton County, Arkansas), a female *Cambarus* was sighted on 10 December 1999 by GOG and MES, and one male collected by MES and C. Brickey (National Speleological Society) on 11 July 2004. Another crayfish was observed in a desiccating pool of Brush Creek (Elm Springs, Washington County, Arkansas) after being expelled from the hyporheos during a flood event. This 3.8-cm-long female was collected by MES on 7 July 2004. A walking leg (pereopod) was removed from both specimens and stored in a preservative of 75% ethanol and 10% 0.5M EDTA. An approximately 501-base-pair (bp) region of the 16S ribosomal DNA (rDNA) from the mitochondrial genome was amplified and sequenced (ABI 3700 sequencer with M13 primers) by JBK. Pairwise sequence differences among specimens from the 2 established habitats and from the 2 new habitats ranged from 0 to 4 (0.8%) for the 501 bases. The Brush Creek specimen was identical to a specimen from Bear Hollow Cave, and the Old Pendergrass Cave specimen was only 3 or 4 bases different from all samples of *C. aculabrum*. Therefore, both of the new habitats are considered to represent additional sites for *C. aculabrum*.

Additional populations of crayfish exist near

these 4 known sites. In Rootville Cave (Spavinaw Creek watershed, Benton County, Arkansas), several stygobitic crayfish of the genus *Cambarus* have been observed by the authors in 1999 and 2000, and previously by cavers of the Association for Arkansas Cave Studies, Inc. (unpubl. data). During a hydrogeological study of a cistern on Spanker Creek, Benton County, Arkansas, V. Brahana (University of Arkansas) observed 11 stygobitic crayfish in 1997; J. Johnson and G. Adams (University of Arkansas) confirmed the crayfish to be of the genus *Cambarus*, but could not make a specific determination before the landowner killed all of the accessible individuals out of concern for incurring liability under the ESA. Future, non-lethal tissue sampling and genetic testing will be performed upon these populations to determine their taxonomic identities.

The primary conservation activity for the Benton cave crayfish has been land protection (objective 1.5). The USFWS purchased 49.6 hectares containing the cave entrances and created Logan Cave National Wildlife Refuge in 1989. A cave gate was installed in 1998 by USFWS and Tulsa Regional Grotto, National Speleological Society (objective 1.3). With funding from USFWS, The Nature Conservancy is implementing a voluntary program to upgrade septic systems in the Logan Cave recharge zone to reduce nutrient loading of the aquifer. The pilot project at the Evans Family property involved the retrofitting of an old concrete septic tank system with a recirculating, aerobic digestion, trickle filter (Orenco Systems, Inc., Sutherlin, Oregon) and fiberglass septic tank, which should dramatically reduce nutrient and bacteria concentrations in the effluent.

The Cooper Family donated 1.7 ha of land containing the entrance of Bear Hollow Cave in 1998 to The Nature Conservancy, establishing the Bear Hollow Natural Area. A cooperative clean-up of illegal refuse dumps within the recharge zone was performed by The Nature Conservancy (T. Snell), Bella Vista Village, and the Benton County Sheriff's Department between 1993 and 2000. A cave gate was installed in the early 1990s by AGFC (objective 1.3), and USFWS continues to fund a gate repair and security program (objective 1.4). Cooper Realty Investments donated the entrance and surrounding land (4.1 ha) of Old Pendergrass

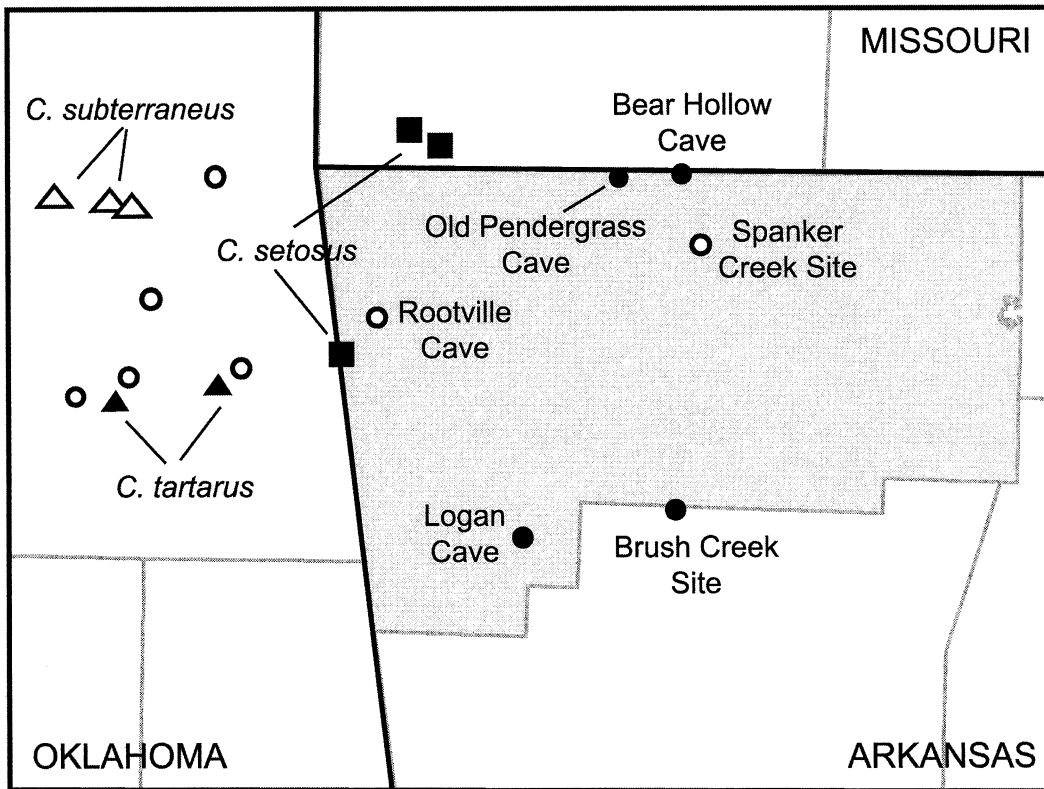
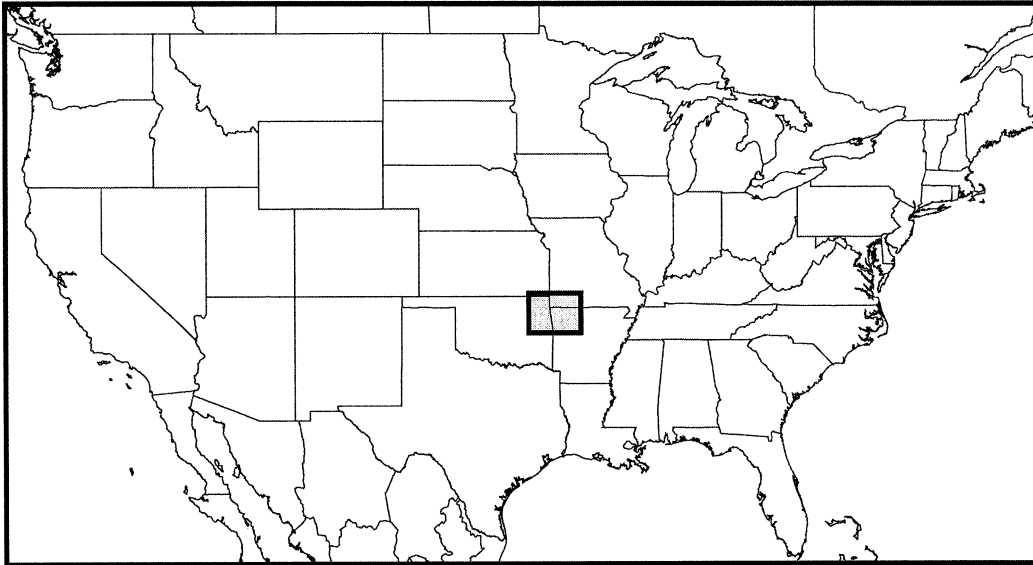


FIG. 1.—Distribution of *Cambarus aculabrum* in Arkansas within USA (upper map) and in relation to other stygobitic crayfish (lower map). Benton County, Arkansas, is denoted with gray shading and adjacent counties with gray lines, and black lines indicate state boundaries; black circles indicate current sites of *C. aculabrum* occurrence; white circles indicate unidentified crayfish populations; squares indicate the nearest (but not all) sites of *C. setosus*; and triangles identify sites for *C. subterraneus* and *C. tartarus*.

Cave to The Nature Conservancy, establishing the Camden Hollow Natural Area. The Nature Conservancy has begun a reforestation effort of its recharge zone. Site conservation and management plans for all 4 caves were developed by The Nature Conservancy (objectives 1.1 and 1.2). Public outreach and education regarding groundwater pollution and the value of ESA-listed species (objective 2) have not been implemented.

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