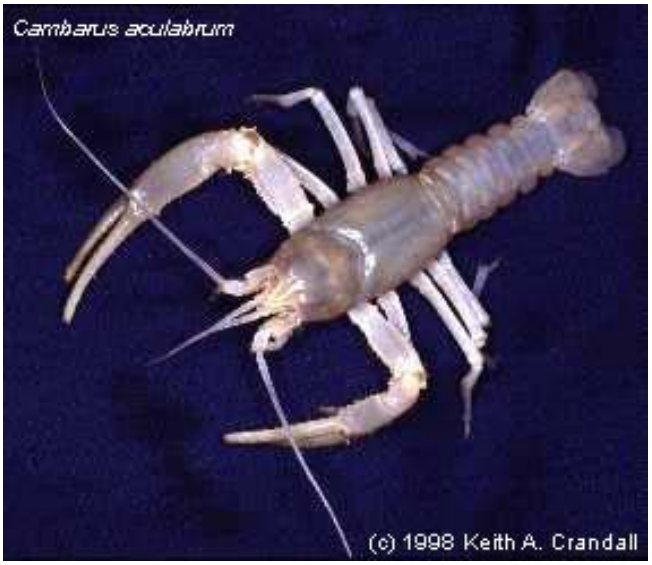
Benton County Cave Crayfish
(*Cambarus aculabrum* Hobbs and Brown 1987)



5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Southeast Region
Arkansas Ecological Services Field Office
Conway, Arkansas

5-Year Review
Benton County Cave Crayfish (*Cambarus aculabrum* Hobbs and Brown 1987)

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Region – Erin Rivenbark, Southeast Region, (706) 613-9493; Nikki Lamp, Southeast Region, (404) 679-7118

Lead Field Office - Chris Davidson, Arkansas Ecological Services Field Office, (501) 513-4481

Cooperating Field Office – None (Arkansas endemic)

Cooperating Regional Office- None (Arkansas endemic)

1.2 Methodology used to complete the review:

This review was completed by the U.S. Fish and Wildlife Service (Service) Arkansas Field Office in coordination with the Arkansas Natural Heritage Commission, Arkansas Game and Fish Commission, and The Nature Conservancy. Literature and documents were researched and reviewed as one component of this evaluation, although limited literature exists on this species. Recommendations resulting from this review are a result of the limited literature review, understanding ongoing conservation actions, input and suggestions from partners involved in conservation efforts, and the reviewers' expertise on this species. Comments and suggestions regarding the five-year review were received from cave crayfish conservation partners listed in the peer review section of this document (Appendix A). No part of the review was contracted to an outside party.

1.3 Background:

1.3.1 Federal Register Notice citation announcing initiation of this review:

73 FR 43947 (July 29, 2008 - Endangered and Threatened Wildlife and Plants; 5-Year Status Review of 20 Southeastern Species).

1.3.2 Species Status:

Stable (2011 Recovery Data Call). Fiscal Year 2009 population levels were among the largest surveyed to date. Continued on-the-ground recharge conservation efforts are showing success in protecting cave recharge zones as evidenced by private landowner partnerships and population status.

1.3.3 Listing History

Original Listing
FR Notice: 58 FR 25742
Date Listed: April 27, 1993
Entity Listed: *Cambarus aculabrum*

Classification: Endangered

1.3.4 Associated rulemakings: None.

1.3.5 Review History:

USFWS Recovery Data Call: 2000-2011

Graening, G.O. and A.V. Brown. 2000. Status survey of aquatic cave fauna in Arkansas. A final report submitted to Arkansas Game and Fish Commission. Arkansas Water Resources Center Publication No. MSC-286, Fayetteville, Arkansas.

Graening, G.O., M.E. Slay, A.V. Brown, J.B. Koppelman. 2006. Status and distribution of the endangered Benton County cave crayfish, *Cambarus aculabrum* (Decapoda: Cambaridae). Southwestern Naturalist 51(3):376-439.

1.3.6 Species' Recovery Priority Number at start of 5-year review: 5 (species faces a high degree of threat and low recovery potential)

1.3.7 Recovery Plan or Outline
Name of Plan: Recovery Plan for the Cave Crayfish (*Cambarus aculabrum*)
Date issued: October 30, 1996

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) Policy?
Species is an invertebrate. Therefore, DPS policy is not applicable.

2.2 Recovery Plan and Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measureable criteria? Yes.

2.2.2 Adequacy of recovery criteria.

2.2.2.1Do the recovery criteria reflect the best available and most up-to date information on the species biology and its habitat? Yes.

2.2.2.2Are all 5 listing factors that are relevant to the species addressed in the recovery criteria? Yes.

Is there new information to consider regarding existing or new threats? Yes. Conversion of land for urban development has increased and threatens groundwater within the known recharge areas. Cave gate vandalism continues to be problematic. Direct trampling of species inadvertently during trespassing associated with recreational caving

activities at Logan Cave National Wildlife Refuge (NWR) and Bear Hollow Cave was documented in recent years.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:

C. aculabrum can be considered for reclassification (downlisting) from endangered to threatened when the two known populations are: 1) self-sustaining (as indicated by monitoring data to be reproducing and stable or increasing in size), 2) protected from trespass, and 3) protected from water quality degradation for a period of not less than 10 years. The recovery plan does not address delisting criteria. The criteria for reclassification have not been met as discussed below.

Recovery Task 1.1. Develop and implement a protection and management plan for Bear Hollow Cave: The Nature Conservancy (TNC) currently owns 6.93 acres at Bear Hollow Cave including the cave entrance, thus providing perpetual ownership protection. A cave gate is in place at Bear Hollow, but vandalism to the cave gate and trespass on the property and in the cave continue to be an ongoing problem. The recharge area ownership consists of TNC, The Bella Vista Property Owners Association, and private landowners. TNC (2001) developed a conservation plan for the cave and its recharge area in the Bella Vista Village area. The conservation plan identifies the following threats:

1. Incompatible chemical use/disposal;
2. Hazardous material spill;
3. Incompatible wastewater treatment (individual and municipal);
4. Incompatible livestock practices;
5. Limestone quarrying;
6. Incompatible recreational and scientific access/vandalism; and
7. Incompatible forestry practices.

The conservation plan identifies strategies to minimize and/or alleviate the aforementioned threats. However, there are no long-term protection/management agreements in place to provide water quality protection within the recharge area at a level necessary to minimize and/or alleviate the following stressors associated with the aforementioned threats:

1. Groundwater contamination (e.g., pesticides, heavy metals [particularly lead], increased nutrients, reduced dissolved oxygen, increased sediment loads, altered pH);
2. Hydrologic alteration (e.g., quarrying and construction activities that redirect water or lessen water holding capacity of the aquifer system, decreased filtering ability of the landscape, altered flow rates); and
3. Trampling associated with vandalism and trespassing.

TNC is developing a Cave Safe Harbor Agreement that would cover this area (and other important caves and recharge areas in northwest Arkansas). The goal

of this agreement is to provide a tool to implement long-term protection, technical assistance, regulatory assurances, and other incentives to encourage private landowner participation in the species recovery.

Recovery Task 1.2: Develop and implement a management plan for Logan Cave NWR: The Service developed a Comprehensive Conservation Plan (CCP) for Logan Cave NWR (USFWS 2008), and it is currently undergoing a biological review (T. Edwards, 2010, pers. comm.). This plan covers the 123-acre refuge and provides general conservation strategies to aid in recovery of *C. aculabrum*. The management plan lacks specific management strategies (e.g., best management practices to protect water quality in the recharge area) to ensure long-term survival and recovery of the species. There also is no guarantee of funds to implement conservation strategies within the refuge boundaries and the recharge area. There are no long-term protection/management plans in place to provide water quality protection throughout the entire recharge area.

Recovery Task 1.3: Construct and maintain cave gates, fences, signs, and other security devices needed for protection: There are cave gates and "no trespassing" signs in place at Logan and Bear Hollow Caves. However, trespassing and vandalism continues to be an ongoing problem. Installation of remote surveillance systems has not proven effective at identifying people responsible for cave gate and sign vandalism and trespass. New surveillance efforts are under consideration to help prevent future vandalism and trespass.

Recovery Task 1.4: Monitor cave trespass and involve law enforcement agencies in protecting *C. aculabrum*: Monitoring cave trespass and involving law enforcement agencies in the protection of *C. aculabrum* is ongoing, but cannot be considered successful at this point due to continued vandalism and trespass problems and the inability to identify responsible individuals and subsequently enforce ESA prohibitions and trespass laws.

Recovery Task 1.5: Ensure recharge protection of both Logan and Bear Hollow Caves: Logan and Bear Hollow Cave recharge areas have been delineated, but long term protection may be difficult to achieve due to rapidly expanding urbanization in northwest Arkansas. At this point, long term protection through development and implementation of private landowner conservation plans has not been fully achieved in the recharge areas. Plans still need to be developed for the majority of landowners and developers to identify and reduce ground water pollution.

Recovery Task 2.1 – 2.4: Educate public on sensitivity of groundwater and fauna to pollution: Extensive public education has been ongoing in the recharge areas with area schools, city councils, developers, non-governmental organizations, recreational cavers, and many other miscellaneous groups and individuals. This activity is considered ongoing.

Recovery Task 3.1: Monitor cave crayfish populations: Bi-annual ocular surveys are ongoing in Bear Hollow and Logan Caves. Based on a limited number of

individuals observed and consistent survey results, populations appear stable. Survey methodology incorporates techniques to minimize turbidity and coincides with Ozark cavefish surveys.

Recovery Task 3.2: Gather baseline habitat and water quality data: Water quality monitoring in each cave system is ongoing. No quantitative baseline habitat assessment has been conducted to date.

Recovery Task 4.1 – 4.2: Search for additional populations: Since listing, two additional populations (Elm Springs and Old Pendergrass) have been identified through continual cave surveys and citizen reports in northwest Arkansas. This activity is ongoing as new caves are identified or known caves resurveyed. Potential to find undiscovered *C. aculabrum* populations still exists.

Recovery Task 5: Study species' biology: Very little is known about *C. aculabrum* life history and ecology. Life history and ecology studies have not been conducted due to the imminent harm that such studies pose to a cryptic species with very low population numbers. Males are reproductively active during October – February (Hobbs and Brown 1987). No females carrying eggs and young have been observed during surveys. The species is probably an opportunistic feeder foraging on organic materials such as plant and animal material and detritus that enters the cave stream.

Recovery Task 6: Monitor and study troglophilic and epigeal species: No studies have been conducted to determine and/or monitor troglophilic (cave-dwelling) and epigeal (living on soil surface) species and their effects, beneficial or adverse, on *C. aculabrum.*

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

Cambarus aculabrum description and taxonomy is described in the Recovery Plan (USFWS 1996). No new information pertaining to the species taxonomy, life history or ecology is available since publication of the Recovery Plan.

At listing, *C. aculabrum* was known from two cave streams in Benton County, Arkansas. The type locality, Logan Cave, is a dendritic stream channel cave located in the Mississippian cherty-limestone, Boone Formation of the Springfield Plateau (Hobbs and Brown 1987). The stream is approximately one kilometer (km) (4,000 feet [ft]) in length with a recharge area of 30.1 km^2 (11.6 square miles [mi]). The entire recharge area minus 123 acres, which includes the cave entrances, is privately owned (Aley and Aley 1987). The Service manages the 123-acre tract under its NWR system (Logan Cave NWR).

Graening et al. (2006) summarize the range wide status and distribution of *C. aculabrum.* Logan Cave has been surveyed 21 times from 1986 – 2006, but only seven of these surveys covered the entire accessible portions of the cave stream.

Counts range from 1 – 47 individuals, with number of individuals observed ranging from 20 – 47 since 2000 (entire accessible stream habitat was not surveyed in 2004 when 20 individuals were observed). The most recent survey (January 22, 2009) documented 43 individuals in Logan Cave (M. Slay 2010, pers. comm.).

Bear Hollow Cave, the second location known at listing, is located approximately 38 km (23 mi) from Logan Cave. The stream system within Bear Hollow Cave is approximately 200 meters (m) (660 ft) in length. Aley and Aley (1998) delineated the recharge area for Bear Hollow Cave.

Bear Hollow Cave has been surveyed 13 times from 1986 – 2006, but only 10 of these surveys covered the entire accessible portions of the cave stream. Counts range from 1 – 9 individuals, with number of individuals observed ranging from 5 – 9 since 2000 when the entire accessible stream habitat was surveyed. The most recent survey (April 29, 2009) recorded the highest numbers to date, documenting 13 individuals.

Two new potential *C. aculabrum* populations have been identified since listing; Elm Springs and Old Pendergrass. Both populations have been confirmed as *C. aculabrum* through genetic analysis (Graening et al. 2006).

One *C. aculabrum* individual was observed in a desiccating pool (Farris Sink Point) of Brush Creek (Elm Springs, Washington County, Arkansas) after being expelled from the sub-surface habitat during a flood event in July, 2004. The one individual observed from this site was a 3.8 cm long female (Graening et al. 2006). Aley and Slay (2006) delineated the groundwater recharge area and mapped vulnerability for *C. aculabrum* at Elm Springs. Groundwater tracing data demonstrate that the most important habitat for *C. aculabrum* extends from Farris Sink Point down gradient to the cluster of five springs on the Hays' property. Suitable habitat also extends up gradient (generally southward) from the Farris Sink Point for some distance (Aley and Slay 2006). There is no surface (cave) entrance to Elm Springs, thus future population surveys and monitoring are not possible (D. Kampwerth, pers. comm.).

In Old Pendergrass Cave (Little Sugar Creek watershed, Benton County, Arkansas), two individuals have been observed in the stream at the rear of the cave. A female was observed in December, 1999, and a male in July, 2004. Aley and Slay (2007) delineated the recharge area and mapped vulnerability for *C. aculabrum* in the Old Pendergrass Cave system, including portions down gradient of the cave. Old Pendergrass Cave has been surveyed periodically, but is difficult to time surveys; survey areas are only accessible after high flow events.

Graening (2002, 2005) provides the first analysis of trophic structure of five Ozark cave streams, including Bear Hollow and Logan Caves. Graening (2000) and Graening and Brown (2003) hypothesized that three trophic levels are normal for cave stream food webs: 1) a food base of benthic detritus; 2) a guild of invertebrate consumers such as isopods, crayfish, and amphipods; and 3) and

predators (fish). This hypothesis was further supported by Graening (2002, 2005). Fine benthic organic matter in sediments appears to sustain crustacean detritivores such as *C. aculabrum* (Graening 2005).

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

It is difficult to ascertain what is occurring underground and the exact status of this species. Given an understanding of the functionality of the karst landscape in which this and the other sites occur, the best indicator of population viability likely is the landscape above and the threats posed by land management activities.

Environmental water quality sampling of Bear Hollow and Logan Cave streams produced evidence of fecal coliform bacteria contamination and elevated levels of dissolved nutrients and metals in water, cave sediment, and tissues of cave animals. The study however failed to document any direct effects of these pollutants upon the ecosystems, but the pollutants are present and remain a constant stress upon *C. aculabrum*, which is adapted to oligotrophic, pristine groundwater habitats. Fine benthic organic matter in sediments appears to sustain crustacean detritivores such as *C. aculabrum* (Graening 2005). Heavy metals may accumulate in clastic (grain-sized pieces of eroded rock) sediments that contain numerous binding sites. Thus, Graening (2005) recommends that sediment quality and mass flux (sediment budgeting) monitoring continue due to intensive land conversion activities in these recharge areas.

In 1968, 59 percent of the Logan Cave recharge area was forested; this had decreased to 43 percent by 1987. By 2008, the only forested areas are along creek bottoms or ridge tops where it is too steep for livestock or poultry operations (Aley and Aley 1987; USFWS 2008). Two major land use activities occur in the Logan Cave recharge area: residential and commercial development and agriculture. Problems associated with these land uses include elevated nutrient concentrations, pesticides, and varied contaminants yielded from storm water runoff (Aley and Aley 1987; USFWS 2008). Numerous cattle, swine, and poultry farms operate within the recharge area and produce substantial quantities of animal waste. Land application of animal waste is commonly used as fertilizer to enhance pasture production. Leaks and spills associated with increased road density in the recharge area increases the likelihood of water quality contaminants entering the cave system. A substantial amount of groundwater contamination from residential and commercial development occurs from inadequate sewage disposal systems. In addition some

wastewater compounds and other contaminants were identified from Logan Cave in a recent study (Bidwell et al. 2010).

Threats to habitat in Bear Hollow Cave include contaminants from storm water runoff (incompatible chemical use/disposal, highways, and leaks and spills), excessive nutrient influx from residential septic systems and agriculture operations, physical alteration from mining operations (e.g., limestone quarries), resulting in sediment transport into karst conduits and leachates from waste products, vandalism, and hydrologic alteration from land clearing and conversion activities. Within the Bear Hollow Cave recharge area most of the houses are in the Bella Vista Development, a large suburban development that relies almost exclusively on septic field systems. Lead concentrations in Bear Hollow Cave stream system are above the Arkansas acute and chronic concentration criteria thresholds for aquatic life. The effects of elevated lead concentrations to *C. aculabrum* are unknown.

Substantial urbanization and commercial development is occurring in the Elm Springs recharge area (Aley and Slay 2006). Lack of or insufficient riparian buffers along streams in the recharge area contribute to the introduction of sediment and other water-borne contaminants into the groundwater system supporting *C. aculabrum*. The recharge area is crossed by approximately 23,000 feet of Arkansas Highways 112 and 412. Storm water runoff and water contaminants derived from highway leaks and spills may adversely affect water quality in the recharge area (Aley and Slay 2006).

Like the Bear Hollow Cave recharge area, the vast majority of the Old Pendergrass Cave recharge area is in Bella Vista, which is a large suburban development that relies almost exclusively on septic field systems. Such systems in karst areas routinely serve to introduce contaminants into the groundwater system. The hydrology of the area also has been substantially altered by the construction of Loch Lomond. This lake has a surface area at normal pool of 477 acres and a drainage area of 8,394 acres. The dam for the lake was closed on April 24, 1981. The dam is located about two miles southwest of Old Pendergrass Cave. Lands outside of the Bella Vista development area identified as being in private ownership are generally used for permanent pasture with some woodland (Aley and Slay 2007).

Land vulnerability mapping was conducted for the Old Pendergrass Cave recharge area (Aley and Slay 2007). Of the 12,270 acres (19.2 square miles) in the recharge area, approximately 89 percent (17 square miles) is in the moderate vulnerability category. Approximately 10 percent (2 square miles), divided equally, falls into the low and high vulnerability categories, with approximately 1 percent (0.14 square mile) classified as extremely high. Within the Old Pendergrass Cave recharge area most of the houses in the Bella Vista Development are located on moderate

vulnerability lands. A large golf course exists on high vulnerability lands in Gordon Hollow that are within the delineated recharge area for Old Pendergrass Cave. Potential water quality issues associated with management of the golf course include increased nutrients and pesticides. There are a number of poultry houses and a large confined swine operation in the southern part of the recharge area outside of the Bella Vista development. There are approximately 43,400 feet of Arkansas state highways in or immediately adjacent to the recharge area for Old Pendergrass Cave. Problems associated with these land uses include elevated nutrient concentrations, pesticides, and varied contaminants yielded from storm water runoff (Aley and Slay 2007).

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Due to permit restrictions on collection of individuals, overutilization via removal of individuals for scientific and educational purposes is no longer considered a threat. Trampling of *C. aculabrum* has been documented and is considered a continuing threat to this species. Cave gates and fence have been placed on Logan (gate and fence) and Bear Hollow (gate only) Caves, but vandalism and trespass continue to be a problem. Both caves have had unauthorized entries, increasing the risk for trampling. Inadvertent trampling is currently thought to be a minimal threat. There is no surface access to Elm Springs, thus overutilization is not considered a threat at that location. There is no cave gate or fence at Old Pendergrass Cave, but difficulty accessing the cave via the entrance serves as a natural limiting factor. While Old Pendergrass Cave is posted “no trespassing”, trespass and vandalism are still possible. However, overutilization is not currently considered a threat at Old Pendergrass Cave.

2.3.2.3 Disease or predation:

While disease threats are unknown, cave species’ endemicity suggests that there is potential for transport of unknown parasites or diseases from cave to cave by researchers or recreational cavers. It is a policy that all cave gear must be cleaned and decontaminated before biannual surveys. There is one documented occasion inside Logan Cave of a banded sculpin (*Cottus carolinae*) consuming *C. aculabrum* (Brown et al. 1994). Numerous surface crayfish and fish enter these systems as well as small mammals, so predation is likely, but is believed minimal and not a threat to continued existence of the populations.

2.3.2.4 Inadequacy of existing regulatory mechanisms:

While surface streams have water quality standards that are monitored and enforced, groundwater generally does not. Existing regulatory mechanisms for the protection of groundwater resources are limited. Progress is being made by the Arkansas Natural Resource Commission and the Arkansas Department of Environmental Quality (ADEQ) for development of standards for groundwater quantity and quality. ADEQ supports groundwater protection strategies by incorporating coordination of permit reviews and Service comments prior to the issuance of any permits. They conduct groundwater quality monitoring throughout the state, but cave crayfish sites are not included in their scheduled sampling regime.

Arkansas enacted legislation, whereby land application of poultry litter must be conducted under an approved nutrient management plan. That plan is based on soil and vegetative communities present, and recommends distances from waterways where litter should be applied. As enforcement is limited and water quality in caves and wells show increases in nutrients and metals, it appears adherence to or success of these plans is limited.

Agencies are requiring storm water management plans under the Environmental Protection Agency's (EPA) MS4 phase 2 regulations whereby development activities greater than two acres in size must develop a storm water management plan. The EPA has regulations and standards outlining water quality conditions for groundwater based on human health standards. Regulations and management guidance necessary to protect groundwater from non-point source pollution do not exist. The Clean Water Act has improved water quality in many locations. However, water quality threats are typically non-point source derived and difficult to regulate.

In general, regulations are not specific enough to provide adequate protection to *C. aculabrum*, and enforcement of existing regulations is understaffed.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

No other natural or man-made factors have been identified as threats to the conservation and continued existence of *C. aculabrum*.

2.4 Synthesis

C. aculabrum occurs with broader distribution than originally described and although population numbers fluctuate widely between surveys, they appear stable. However, direct enumeration of populations does not assure that

populations are in fact stable due to the extreme difficulty of conducting surveys and variable numbers found during these surveys. As such, land management and water quality studies within the delineated and predicted recharge zones serve as predictors of population viability. Threats associated with development and non-point source pollution within the delineated recharge areas have increased since listing and development of the recovery plan. Vandalism and trespass at some cave locations continue to be a problem affecting this species. The recovery plan criteria for reclassifying this species from endangered to threatened have not been met. In addition, some threats to the species have increased. Therefore, this species should remain listed as endangered.

Additional work should be focused on increased coordination with private landowners, and city, county, and Arkansas State Highway and Transportation Department (AHTD) officials, thereby ensuring their knowledge of site sensitivity and building cooperative management strategies for conservation of groundwater resources.

3.0 RESULTS

3.1 Recommended Classification

_____ Downlist to Threatened

_____ Uplist to Endangered

_____ Delist (indicate reasons for delisting per 50 CFR 424.11):

_____ Extinction

_____ Recovery

_____ Original data for classification in error

____X__ No change needed

3.2 New Recovery Priority Number: Not necessary.

3.3 Listing and Reclassification Priority Number: Not necessary.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The following priority actions should be undertaken: 1) continue efforts to prevent human disturbance to cave systems containing *C. aculabrum* through the use of outreach, signage, surveillance, and gating, 2) continue to establish partnerships with private landowners, local businesses, and city and county officials, 3) develop a hazardous materials spill action plan for implementation by local responders and AHTD, 4) continue searching for additional populations, 5) establish a water and sediment quality monitoring program at currently known sites, 6) conduct recharge delineations if new locations are identified, 7) continue efforts to purchase conservation easements or acquire lands within recharge zones, 8) continue biannual monitoring efforts, and 9) finalize and begin implementation of the Cave Safe Harbor program for northwest Arkansas.

5.0 REFERENCES

Aley, T. and C. Aley. 1987. Water quality protection studies, Logan Cave, Arkansas. Ozark Underground Laboratory, Protem, Missouri.

Aley, T. and C. Aley. 1998. Recharge area study: Bear Hollow Cave, Benton County, Arkansas. Ozark Underground Laboratory, Protem, Missouri. 60 pp. + appendices.

Aley, T. and M. Slay. 2006. Groundwater recharge area delineation and vulnerability mapping for a population of *Cambarus aculabrum*, a cave crayfish, near Elm Springs, Arkansas. Ozark Underground Laboratory, Protem, Missouri. 41 pp.

Aley, T. and M. Slay. 2007. Groundwater recharge area delineation and vulnerability mapping for Old Pendergrass Cave and an associated population of *Cambarus aculabrum*, the Benton Cave Crayfish, Benton County, Arkansas. Ozark Underground Laboratory, Protem, Missouri. 29 pp. + appendices.

Bidwell, J. R., C. Becker, S. Hensley, R. Stark, and M.T. Meyer. 2010. Occurrence of organic wastewater and other contaminants in cave streams in northeastern Oklahoma and northwestern Arkansas. Archives of Environmental Contamination and Toxicology 58(2): 286-298.

Brown, A.V., W.K. Pierson, and K.B. Brown. 1994. Organic carbon resources and the payoff-risk relationship in cave ecosystems. Second International Conf. on Ground Water. U.S. Env. Prot. Ag. pp. 67-76.

Graening, G.O. 2000. Ecosystem dynamics of an Ozark cave. Ph.D. Dissertation, University of Arkansas, Fayetteville, Arkansas. 98 pp.

Graening, G.O. 2002. Trophic dynamics and pollution effects in Ozark cave streams containing endangered species. Unpublished report submitted to the U.S. Fish and Wildlife Service, Arkansas Ecological Services Field Office. 20 pp + appendices.

Graening, G.O. 2005. Trophic structure of Ozark cave streams containing endangered species. Oceanological and Hydrobiological Studies 34(3):3-17.

Graening, G.O. and A.V. Brown. 2000. Status survey of aquatic cave fauna in Arkansas. Arkansas Water Resources Center. Publication No. MSC-286. 41 pp.

Graening, G.O. and A.V. Brown. 2003. Ecosystem dynamics and pollution effects in an Ozark cave stream. Journal of the American Water Resources Association 39(6):1497-1507.

Graening, G.O., M.E. Slay, A.V. Brown, and J.B. Koppelman. 2006. Status and distribution of the endangered Benton Cave Crayfish, *Cambarus aculabrum* (Decapoda: Cambaridae). SW Naturalist 51(3):376-381.

Hobbs, H.H. and A.V. Brown. 1987. A new troglobitic crayfish from northwestern Arkansas (Decapoda: Cambaridae). Proc. Biol. Soc. Wash. 100(4):1041-1048.

The Nature Conservancy. 2001. Bella Vista Cave complex site conservation plan. The Nature Conservancy, Greenland, Arkansas. 24 pp.

U.S. Fish and Wildlife Service. 1996. Recovery plan for the cave crayfish (*Cambarus aculabrum*). U.S. Fish and Wildlife Service. Atlanta, Georgia. 36 pp.

U.S. Fish and Wildlife Service. 2008. Logan Cave National Wildlife Refuge comprehensive conservation plan. U.S. Fish and Wildlife Service, Atlanta, Georgia. 96 pp.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Benton County Cave Crayfish (*Cambarus aculabrum)*

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__X__ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: Not applicable.

Review Conducted By: Chris Davidson, Arkansas Ecological Services Field Office

FIELD OFFICE APPROVAL, Lead Field Supervisor, Fish and Wildlife Service

Approve _____ Date 03 /15/2013

REGIONAL OFFICE APPROVAL:

Lead Regional Director, Fish and Wildlife Service

for

Approve _____ Date 5/10/13

APPENDIX A: Summary of peer review for the 5-year review of **Benton County Cave Crayfish (*Cambarus aculabrum)***

Reviewers:

Internal

Erin Leone, Fish and Wildlife Biologist
U.S. Fish and Wildlife Service

External

Brain Wagner, Nongame Aquatics Biologist
Arkansas Game and Fish Commission

Douglas Fletcher, Chief of Stewardship (did not provide comments)
Arkansas Natural Heritage Commission

Mike Slay, Karst Ecologist
The Nature Conservancy – Arkansas Field Office

A. Peer Review Method: A draft copy of this 5-year review was sent to the above knowledgeable individuals for their review and comment. These biologists were selected based on their current active involvement with Benton County Cave Crayfish conservation efforts and/or knowledge with this fish.

B. Peer Review Charge: Reviewers were charged with providing a review of the document including any other comments and/or additions appropriate to include. We did not ask peer reviewers to evaluate our status recommendation.

C. Summary of Peer Review Comments/Report: Reviewers responded verbally and/or by email. All reviewers thought the information in the draft 5-year review of Benton County Cave Crayfish provided to them was accurate. They did provide some additional references and recommendations that were incorporated into the 5-year review as appropriate.

D. Response to Peer Review: Recommendations from the reviewers were included in the document. These consisted primarily of references to new surveys, additional information about the species' status, and recommendations for future actions.