Alabama Cave Shrimp
(*Palaemonias alabamae*)

Status Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
South Atlantic-Gulf Region
Alabama Ecological Services Field Office
Daphne, Alabama

September 2022

STATUS REVIEW

Alabama cave shrimp
(*Palaemonias alabamae*)

GENERAL INFORMATION

Current Classification: Endangered

Lead Field Office: Alabama, Ecological Services Field Office: Jennifer Grunewald, 251-424-0635.

Reviewers: Alabama, Ecological Services: Scott Lamont, 251-395-2353

Lead Regional Office: Southeast Region, Carrie Straight, (404) 679-7226.

Date of original listing: September 7, 1988 (53 FR 34696)

Methodology used to complete the review: In accordance with section 4(c)(2) of the Endangered Species Act of 1973, as amended (Act), the purpose of a status review is to assess each threatened species or endangered species to determine whether its status has changed and if it should be classified differently or removed from the Lists of Threatened and Endangered Wildlife and Plants (50 CFR 424.11). The U.S. Fish and Wildlife Service (Service) evaluated the biology, habitat, and threats of the Alabama cave shrimp (*Palaemonias alabamae*), hereafter referred to as cave shrimp to inform this status review.

We announced initiation of this review in the Federal Register on July 14, 2021 (86 FR 37178) with a 60-day comment period. We received no public comments during the open period. The primary sources of information used in this analysis were the species' recovery plan (Service 1997), recovery plan amendment (2019), the recent five-year review (Service 2016), recent studies of the species, peer-reviewed reports, agency reports, unpublished survey data and reports, and personal communication with recognized experts. This review was completed by the U.S. Fish and Wildlife Service, Alabama Ecological Services Field Office (AFO), Daphne, Alabama. All literature and documents used for this review are on file at the AFO. All recommendations resulting from this review are the result of thoroughly reviewing the best available information on the Alabama cave shrimp.

FR Notice citation announcing the species is under active review:
July 14, 2021 (86 FR 37178)

Species' Recovery Priority Number at start of 5-year review (48 FR 43098): 5
Palaemonias alabamae is a species with a high degree of threat and a low recovery potential.

Review History:

Five-year Review: August 29, 2006 – No change in status was recommended

Recovery Plan: September 4, 1997

Five-year Review: January 11, 2016 – No change in status was recommended

Recovery Plan Amendment: September 25, 2019

REVIEW ANALYSIS

Listed Entity

Taxonomy and nomenclature
We are not aware of any changes to the taxonomy of this entity, and the Alabama cave shrimp is still considered valid by the Service.

Distinct Population Segment (DPS):
The Act defines species as including any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate wildlife. Because this species is not a vertebrate the Service's 1996 DPS Policy does not apply.

Recovery Criteria

Recovery Plan
Alabama cave shrimp (*Palaemonias alabamae*) Recovery Plan, September 4, 1997.

Amended Recovery Plan for the Alabama cave shrimp (*Palaemonias alabamae*), September 25, 2019.

Recovery plans are not regulatory documents and are intended to provide guidance to the Service, States, and other partners on methods of minimizing threats to listed species and on criteria that may be used to determine when recovery is achieved. If the recovery criteria defined in the plan are still valid, meeting recovery criteria can indicate that the species no longer requires protections under the Act. However, when recommending whether a listed species should be delisted, the Service must apply the factors in section 4(a) of the Act (84 FR 45020).

The Recovery Plan (Service 1997) establishes that the Alabama cave shrimp could be considered for delisting when the following criteria are met:

> Criterion 1. A minimum of five (5) populations in five distinct groundwater systems (determined by hydrologic studies that can distinguish different systems), show a stable or increasing trend, evidenced by natural recruitment, and multiple size classes (addresses Factors A, C, and E).

Criterion 2. Threats have been addressed and/or managed to the extent that the species will remain viable into the foreseeable future (addresses Factors A and E).

Criterion 3. A minimum of three (3) populations occur in groundwater systems protected via a conservation mechanism (addresses Factors A and E).

The Service believes these criteria are appropriate and relevant; however, no criteria have currently been met.

Biology and Habitat Summary

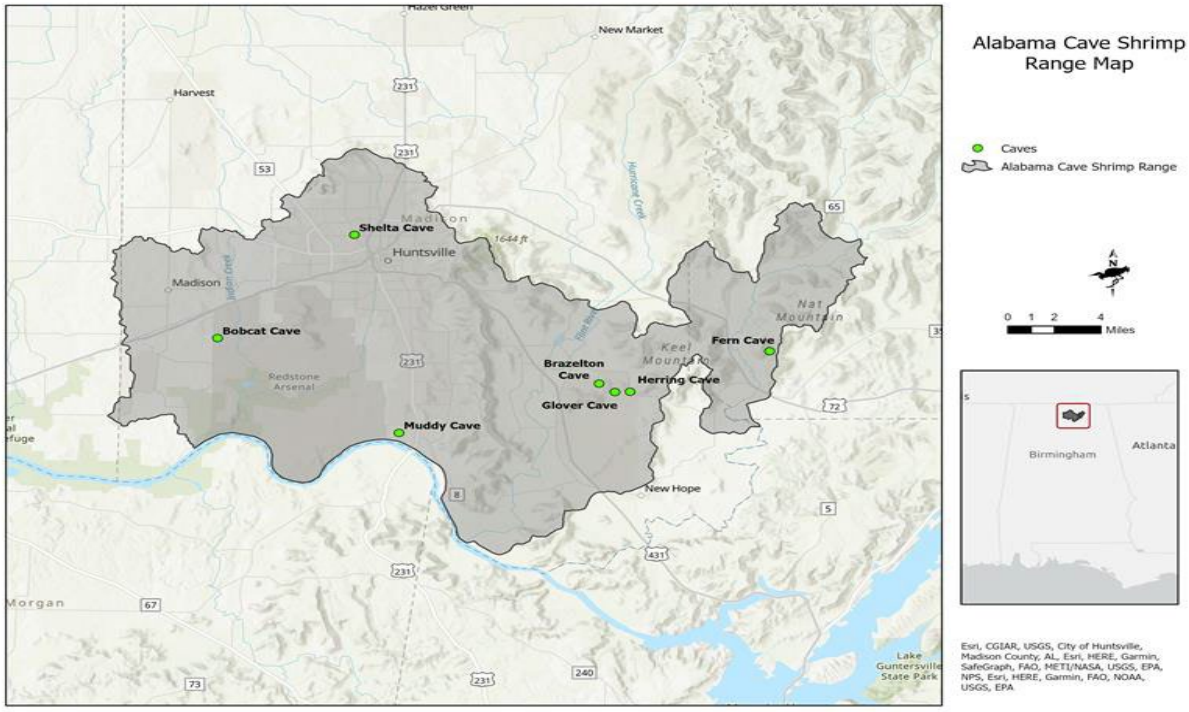

Figure 1. Alabama cave shrimp locations – Madison and Jackson counties Alabama.

A detailed review of the species' biology and habitat information can be found in the previous 5-year status review of this species (Service 2016). Since the previous 5-year review, the cave shrimp has been discovered in Fern Cave (Jackson County, Alabama). This discovery occurred in 2018. A summary of current information is provided below.

The Alabama cave shrimp is an albinistic troglobitic (cave-dwelling) shrimp known to be found in cave systems in Madison and Jackson counties in Alabama (Figure 1). The cave shrimp was first collected in Shelta Cave in 1958 (Cooper 1975); but has not been seen there since the early 1970s. A second population of cave shrimp was discovered in Bobcat Cave in 1973. Populations of cave shrimp have also been discovered in Hering/Glover (1991), Brazelton Cave (1994) (Rheams et al. 1994), Muddy Cave (2005) (Kuhajda, pers. comm. 2006), and Fern Cave (2018) (Niemiller et al. 2019). Until 2018 the total range of the species previously extended approximately 20 km (12 miles) east-southeast across the Flint River and the Huntsville, Green, and Monte Sano mountains and southward to near the Tennessee River (McGregor et al. 1994),

but with the discovery of four cave shrimp in Fern Cave, its known distribution has been expanded into the Lower Paint Rock River watershed (Niemiller et al. 2019; Figure 1).

Shelta Cave

Shelta Cave was considered the most diverse cave community in the southeastern U.S., but development in the 1960's as well as concerns about youths entering the cave began to affect the biodiversity of this cave system (Elliott 2017). After the cave was gated in 1968, a colony of gray bats (*Myotis grisescens*) disappeared (Elliott 2017). The loss of bat guano (a source of nutrients within the cave and food for crayfish) in the cave likely contributed to the decline of endemic cave crayfishes there (Elliott 2000), and may have negatively impacted other cave dwelling species, to include cave shrimp, since the last sighting in Shelta Cave was in 1973 (Cooper 2010). Additionally, water samples taken in Shelta Cave in 1987 indicated that the aquifer had become contaminated by cadmium, heptachlor epoxide, and dieldrin (J. French, in litt. 1987). Anomalous levels of cadmium, almost five times the drinking water standards, were reported and possibly originated from industrial or municipal origin. Both heptachlor epoxide and dieldrin can originate from the degradation of chemicals used for termite control. The two pesticides are extremely toxic to aquatic life and, along with cadmium, present a danger of bioaccumulation in the food web.

Bobcat Cave

Bobcat Cave is located on Redstone Arsenal (RSA), an Army installation near Huntsville, Alabama. Bobcat Cave has been visited by researchers over the years and has been monitored monthly from 1990 to the present by the Geological Survey of Alabama (Bearden, et al. 2019; Table 1). While Bobcat Cave continues to contain a viable population of cave shrimp, with sightings as recent as 2019 (Niemiller et al. 2019), continued urban growth in the Huntsville area, as well as, emerging missions and infrastructure projects on RSA continue to make the cave shrimp, within Bobcat Cave, vulnerable to contamination from surface runoff that may infiltrate the groundwater supply and feeds water within Bobcat Cave.

While a number of groundwater studies have been conducted to determine hydrologic patterns between the east and west side of Indian Creek, the research is not conclusive, and questions remain about deep groundwater flow regimes and connections from these surface water areas and impacts to the Bobcat Cave ecosystem. PELA GeoEnvironmental completed an isotope and dye trace study in 2019 suggesting recharge of Bobcat Cave is meteoric, originating from rainfall directly into the cave or shallow groundwater in the recharge area around the cave (PELA GeoEnivronmental 2019). That said, the same researchers stated that dye results indicated that Indian Creek does not serve as an "absolute barrier" to the westward movement of groundwater as dye was detected dispersing across Indian Creek on three occasions (PELA GeoEnvironmental 2019). A recently proposed project to construct a new on/off ramp from I-565 to a new gate entering the installation, as well as widening Zierdt Road, are examples of infrastructure development that could potentially threaten the cave shrimp. In 2019, the Geological Survey of Alabama (GSA) conducted a four-year study to monitor the cave shrimp and report on its life history and population trends, as well as, monitor water-quality and water-level trends in Bobcat and Matthews caves on RSA (Bearden 2019). Results indicated that water-

quality conditions within Bobcat Cave are stable, but that Matthews continues to show effects of urban contaminant runoff (Bearden 2019).

While the Ecologically Sensitive Area around Bobcat Cave remains in place, in 2022, RSA reduced the size of the Groundwater Protection Buffer Zone (GPBZ). After consulting with the Service under Section 7 of the Act, it was determined reducing the GPBZ from approximately 5,500 acres down to 1,900 acres would not adversely affect the cave shrimp on RSA, and monitoring would continue (Service 2022).

Because questions about groundwater flow remain and because changes in surface runoff could have negative impacts on cave ecosystems, it is critical to be cautious as new infrastructure projects continue to appear on and around RSA. The population of cave shrimp within Bobcat Cave is stable; but continues to be threatened by growth and development in the area.

Hering-Glover-Brazelton Cave System

Hering-Glover-Brazelton (HGB) caves are a series of hydrologically connected caves and considered one cave system (Service 2016). Similar to other caves where the cave shrimp is found, locations where cave shrimp have been observed are inaccessible during high-water periods however, Alabama cave shrimp were observed in Hering Cave between 2018-2019 (Niemiller et al. 2019).

Muddy Cave

Near the Tennessee River southwest of Huntsville, Muddy Cave had been visited by researchers on several occasions without reliable cave shrimp observations (Kuhajda 2004; Service 2016). Population dynamics of the cave shrimp are unknown; however, some caves, such as Muddy Cave where very few shrimp have ever been observed, may represent sinks that are periodically extirpated but recolonized from currently unknown or inaccessible source populations (Niemiller et al. 2019). Alabama cave shrimp were last observed in Muddy Cave in 2012 and the current status of the population is unknown (Niemiller et al. 2019).

Fern Cave

Between 2018-2019, the Alabama cave shrimp was discovered in Fern Cave (Niemiller et al. 2019). Four shrimp were seen in August 2018 and two shrimp were observed in July 2019. Although this discovery adds a fifth location for known cave shrimp populations, further research regarding reproduction and recruitment is needed to confirm if all sites contain viable populations. That said, this discovery is the first new locality since 2005 in Muddy Cave and suggests that the cave shrimp may be found in other cave systems in the Paint Rock watershed and potentially along the Tennessee River (Niemiller et al. 2019).

In Fern Cave, cave shrimp were observed in the isolated pool perched above the main stream but also in a shallow pool in the main stream. Based on observations of mud stains and debris on passage walls, water levels in the passage where cave shrimp were observed can fluctuate at least 3 m (9.5 ft) above the water levels observed during our 2018 and 2019 surveys. In those instances, the pool where cave shrimp were observed is hydrologically connected with the main stream.

Genetic analysis was performed and individuals were compared to previously analyzed specimens. Molecular analysis confirmed that the Fern Cave population was closely related to other populations of *P. alabamae* in Madison County (i.e., Hering and Bobcat caves), with 0.4–0.6% uncorrected sequence divergence at the 16S locus between Fern Cave and these two caves (Niemiller et al 2019). According to Niemiller, this is suggestive of limited connectivity between the two sites although additional genetic work is required to better assess genetic diversity within and among Alabama cave shrimp populations (Niemiller, pers. comm. 2023).

Table 1. Confirmed occurrences of *Palaemonias alabamae* in Alabama (Niemiller et al. 2019).

Cave	County	Watershed	First observed	Last observed
Shelta Cave	Madison	Indian Creek	1958	1973
Bobcat Cave	Madison	Indian Creek	1973	2019
Hering Cave	Madison	Lower Flint River	1991	2018
Glover Cave	Madison	Lower Flint River	1991	1998
Brazelton Cave	Madison	Lower Flint River	1991	1998
Muddy Cave	Madison	Tennessee River-Wheeler Lake	2005	2012
Fern Cave	Jackson	Lower Paint Rock	2018	2019

Threats (Five-Factor Analysis) Summary

A detailed review of the species' threats can be found in the 2016 Alabama cave shrimp 5-year status review (Service 2016). The status of a species is determined from an assessment of factors specified in section 4 (a)(1) of the Act.

Factor A: the present or threatened destruction, modification, or curtailment of its habitat or range.

Groundwater contamination is likely the greatest threat to the cave shrimp populations (Service 2016). The Mississippian carbonate aquifer, where caves that support the cave shrimp are found, are susceptible to contamination due to the shallow groundwater depth, moderately well to well-drained soils, soils with low organic content, and rapid contaminant transport through the karst groundwater flow system (U.S. Geological Survey 2002). Additionally, urbanization of areas surrounding Shelta and Bobcat caves, and development in the recharge area of the HGB system, may cause contamination of the aquifers containing Alabama cave shrimp (Rheams et al. 1994). Population growth, irrigation, as well as urban and industrial development can lead to lowering of the water table, alteration of drainage and hydrological patterns, and acute and chronic water quality issues.

Factor B: overutilization from commercial, recreational, scientific, or educational purposes.

We have no evidence that overutilization for commercial, recreational, scientific, or educational

purposes are currently a threat to the species. Scientific collecting, which has not involved lethal take, is controlled by the State of Alabama.

Factor C: disease or predation

Little is known about the life cycle or habitat requirements of the cave shrimp (Service 1997). While predation likely occurs, we do not know the specific details of the food webs in these cave systems. There is no evidence to suggest that disease and predation pose a threat to the species at-this-time.

Factor D: the inadequacy of existing regulatory mechanisms.

The cave shrimp and its habitats are afforded some protection through various federal and state laws. Through Section 7 and 9 of the Act and by Code of Alabama §§ 220-2-92, it is unlawful to take or attempt to take, capture, or kill the cave shrimp. However, oversight or enforcement would be minimal because of the locations where this species is found. The species is also afforded some protection from water quality and habitat degradation under the Clean Water Act of 1972 (33 U.S.C. 1251 et seq.) and the Alabama Water Pollution Control Act, as amended, 1975 (Code of Alabama, §§ 22-22-1 to 22-22-14). However, the recent Clean Water Rule defining the waters of the United States (80 FR 37054, June 29, 2015) excludes groundwater. Ground water allocation for Alabama is based on reasonable use, and there exists no preference for groundwater allocation in Alabama for different water uses such as domestic, agricultural, industrial, or mining at a rate of 100,000 gallons or more per day (Sanjaya 2005). Because of this, landowners may extract water on private land from the same aquifer systems that supplies the habitat for the cave shrimp. Additionally, the inconsistency in implementation of Clean Water Act regulations and other best management practices, and existing regulatory mechanisms in Alabama, are still inadequate.

Conservation measures include: property owners at Shelta (National Speleological Society (NSS)) and Bobcat caves have gated entrances and limited access, the Environmental Protection Agency (EPA) has restricted the use of heptachlor epoxide and banned the use of 11 dieldrin, both of which are presumably lethal to the cave shrimp. EPA County bulletins prescribe buffers for certain current-use pesticides, which may also be helpful. Shelta Cave is owned by the NSS and a perimeter fence has been installed to exclude unauthorized visitors. Bobcat Cave is owned by RSA and admittance is controlled. The entrances to the HGB caves are located on private lands and are currently unprotected. The entrance to Muddy Cave is owned by the North Alabama Land Trust and is operated by the Southeastern Cave Conservation, Inc.

Factor E: other natural or manmade factors

Numerous natural and manmade factors could affect the continued existence of the cave shrimp. This highly endemic species with an extremely localized range makes cave shrimp populations vulnerable to extirpation from catastrophic events, such as toxic spills, changes in flow regime, and changes in aquifer recharge due to pumping for public water supply or irrigation. Additionally, although more research will need to be conducted in this area, concerns from climate change on flow rates/flood cycles could be a concern.

Synthesis

The Alabama cave shrimp is an albinistic troglobitic shrimp known to be found in cave systems in Madison and Jackson counties in Alabama. Little is known about the life cycle or habitat requirements of the cave shrimp and this highly endemic species continues to be threatened by rapid population growth as well as urban and industrial development.

Many of the studies conducted over the past 30 years have advanced our understanding of surface/groundwater interactions, as well as how precipitation relates to the timing and magnitude of waters being delivered to caves. However, the cave environment is extremely dynamic and more research is needed to better understand the quality of water in caves and how and when it is delivered. At the time of this review, cave shrimp have been found in five locations, however, no sightings have occurred in Shelta Cave since the 1970's.

The Alabama cave shrimp remains extremely rare throughout its range and is in danger of extinction. Despite confirmed populations in Madison and Jackson counties, Alabama, and the potential to find other locations, threats to the species survival are on-going. Therefore, we believe the species continues to meet the definition of endangered under the Act.

RECOMMENDED FUTURE ACTIVITIES

A detailed discussion of recovery actions and criteria are presented in the Recovery Plan (Service 1997) and Alabama Cave Shrimp Recovery Plan Amendment (Service 2019). During the course of this status review new and/or targeted potential recovery activities were identified and are included below.

Recovery Activities

1. The Service should continue working with landowners to protect Alabama cave shrimp populations, their groundwater habitat, and surrounding recharge zones.

2. Assess the suitability of re-introductions of Alabama cave shrimp into Shelta Cave.

Monitoring and Research Activities

1. Population monitoring should be conducted to assess the response of the Alabama cave shrimp to continued threats, determine the current population size and viability, and determine other biological relationships within the known cave ecosystems where the Alabama cave shrimp is found.

2. Continue water quality monitoring within Bobcat Cave.

3. Additional studies should be conducted to determine if other populations of the Alabama cave shrimp exist in other locations. This could be accomplished utilizing traditional methods, eDNA monitoring, or other novel methods not yet considered.

4. Additional studies of the recharge area surrounding caves where the Alabama cave shrimp is known to occur should be conducted to get an updated understanding of current hydrological conditions and how groundwater impacts karst environments.

5. Conduct life history and other needed research such as assessment of genetic diversity within and among populations.

6. Conduct hydrologic studies to determine if Muddy and Bobcat caves are in separate groundwater recharge systems.

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Personal Communication

Dr. Bernard Kuhajda, University of Alabama. 2006. Re: Muddy Cave cave shrimp genetics. Email confirming that Muddy Cave cave shrimp is genetically identical or nearly so to shrimp found in Bobcat and the Hering/Glover/Brazelton cave system, based on the cytochrome oxidase mitochondrial gene.

Gheorghe Ponta, Geological Survey of Alabama. 2023. Re: Discussion about HGB and Fern cave system connectivity.

Dr. Matthew L. Niemiller, The University of Alabama in Huntsville. 2023. Re. Alabama cave shrimp genetics question.

RESULTS / SIGNATURES

U.S. Fish and Wildlife Service
Status Review of Alabama cave shrimp (*Palaemonias alabamae*)

Status Recommendation:

On the basis of this review, we recommend the following status for this species. A 5-year review presents a recommendation of the species status. Any change to the status requires a separate rulemaking process that includes public review and comment, as defined in the Act.

____ Downlist to Threatened
____ Delist:
____ *The species is extinct*
____ *The species does not meet the definition of an endangered or threatened species*
____ *The listed entity does not meet the statutory definition of a species*
_X_ No change needed

FIELD OFFICE APPROVAL:

Field Supervisor, Alabama Ecological Services Field Office, Fish and Wildlife Service

Approve WILLIAM PEARSON Digitally signed by WILLIAM PEARSON Date: 2023.05.24 12:22:00 -05'00'