# Tumbling Creek Cavesnail
## *(Antrobia culveri)*

## 5-Year Review:
## Summary and Evaluation

**February 2014**

**U.S. Fish and Wildlife Service**
**Columbia, Missouri Ecological Services Field Office**
**Columbia, Missouri**

# 5-YEAR REVIEW
Tumbling Creek Cavesnail/*Antrobia culveri*

## 1.0 GENERAL INFORMATION

### 1.1 Reviewers

**U.S. Fish and Wildlife biologists in the offices listed below provided valuable additional information and corrections to a draft of this Review.**

**Lead Regional Office**: Jessica Hogrefe, Midwest Regional Office; 612-713-5346

**Lead Field Office**: Paul McKenzie, Columbia, Missouri Ecological Services Field Office, MO; 573-234-2132, ext. 107

**Cooperating Field Offices**: NA

### 1.2 Methodology used to complete the review:

The U.S. Fish and Wildlife Service's (USFWS) Columbia, Missouri Ecological Services Field Office (Columbia, Missouri Field Office) completed this review. The March 18, 2009, *Federal Register* notice initiating this 5-year review (74 FR 11600), requested new scientific or commercial data and information that may have a bearing on the Tumbling Creek cavesnail (*Antrobia culveri*) classification of endangered. New information considered in this review includes relevant information generated since the 2003 approved recovery plan, published reports in peer-reviewed literature, gray literature (e.g., various state and Federal Aid grant reports, theses and dissertations by graduate students) and data received from various state personnel through personal communication involving electronic mail and letters. All literature and documents used for this review are on file at the USFWS's Columbia, Missouri Field Office. In October 2013, the Columbia, Missouri Field Office solicited peer review of this draft 5-year review from four recognized Tumbling Creek cavesnail experts: Mr. Tom Aley, President and Senior Hydrologist for the Ozark Underground Laboratory, Protem, Missouri; Dr. David Ashley, Missouri Western State University, St. Joseph, Missouri; Mr. Michael Slay, The Nature Conservancy, Fayetteville, Arkansas, and Dr. Julian Lewis, Lewis & Associates LLC-Cave, Karst & Groundwater, Borden, Indiana. We received comments from all peer reviewers and have incorporated their suggestions in this revised document. Additionally, we received input on specific items from cave invertebrate expert Dr. Steve Taylor (Illinois Natural History Survey, Champaign, Illinois) and we have included his recommended suggestions and additions into this document.

### 1.3 Background:

**1.3.1 FR Notice citation announcing initiation of this review:** March 30, 2006 (71 FR 16176): Notice of Endangered and Threatened Wildlife and Plants; 5-Year Review of Five Midwestern Species.

**1.3.2 Listing history**

Emergency Listing
**FR notice:** 66FR 66803
**Date listed:** December 27, 2001
**Entity listed:** Species
**Classification:** Endangered

Original Listing
**FR notice:** 67FR 52879
**Date listed:** August 14, 2002
**Entity listed:** Species
**Classification:** Endangered

**1.3.3 Associated rulemakings**:
Critical Habitat Designation
**FR notice:** 76FR 37663
**Date designated:** June 28, 2011

**1.3.4 Review History**:
No previous formal reviews have been conducted for this species

**1.3.5 Species' Recovery Priority Number at start of 5-year review:**
The recovery priority number for the Tumbling Creek cavesnail is 1; indicative of a species with a high degree of threat but one with a high recovery potential.

**1.3.6 Recovery Plan**
Tumbling Creek Cavesnail Recovery Plan
**Date issued**: September 15, 2003
**Dates of previous revisions, if applicable**: NA

## 2.0 REVIEW ANALYSIS

### 2.1 Application of the 1996 Distinct Population Segment (DPS) policy

**2.1.1 Is the species under review a vertebrate?** No

**2.1.2 Is the species under review listed as a DPS?** N/A

**2.1.4 Is there relevant new information for this species regarding the application of the DPS policy? N/A**

**2.2 Recovery Criteria**

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

**2.2.2 Adequacy of recovery criteria.**

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

**2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?** No. There are new threats that were not identified in either the two listing packages or the approved recovery plan. They are discussed below.

**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**:

The Tumbling Creek cavesnail will be considered for reclassification from endangered to threatened when the following criteria have been met.

**Criterion 1.** The population is stable or increasing for 10 consecutive years with at least 1,500 individuals. The population shall be considered stable when a linear regression analysis of population numbers estimated within a established survey area reveals no significant decline in numbers.

**Criterion 2.** A minimum of 80% of the surface habitat within the recharge area of Tumbling Creek Cave, including a minimum of 75% of all riparian corridors, sinkholes and losing streams, is appropriately managed, restored, rehabilitated, or stabilized through long term, voluntary, land owner agreements, such as stewardship plans, easements, or memorandums of agreements that promote best management practices.

**Criterion 3.** Water quality monitoring including, but not limited to, Tumbling Creek, fails to detect levels of any water pollutant that exceeds USEPA recommended water quality or exceed known toxicity thresholds for the species for a period of 10 consecutive years (including criteria for sediment and suspended organic matter deposition).

The Tumbling Creek cavesnail will be considered for delisting when the downlisting criteria have been met and the following additional criteria have been achieved:

**Criterion 1.** The population is stable or increasing for an additional 10 consecutive years with at least 5,000 individuals. The population shall be considered stable when a linear regression analysis of population numbers estimated within an established survey area reveals no significant decline in numbers.

**Criterion 2.** A minimum of 90% of the surface habitat within the recharge area of Tumbling Creek Cave, including a minimum of 85% of all riparian corridors, sinkholes and losing streams, is appropriately managed, restored, rehabilitated, or stabilized through long term, voluntary, land owner agreements, such as stewardship plans, easements, or memorandums of agreements that promote best management practices.

**Criterion 3.** Water quality monitoring including, but not limited to, Tumbling Creek, fails to detect levels of any water pollutant that exceeds USEPA recommended water quality or exceed known toxicity thresholds for the species for an additional 10 consecutive years (including criteria for sediment and suspended organic matter deposition).

With the purchase of approximately 2,200 acres within the recharge area of Tumbling Creek Cave, multiple land restoration projects by cave owners Tom and Cathy Aley and adjacent property owners, and the implementation of standards and guides under the Mark Twain National Forest's Land Resource Management Plan for portions of the cave's recharge area managed by the U.S. Forest Service, the water quality in Tumbling Creek has improved. Sediment levels have lowered and dissolved oxygen levels have remained stable (Tom Aley, Ozark Underground Laboratory, pers. comm. Aug. 26, 2013). These improvements have contributed to the partial fulfillment of two criteria for downlisting. Although much of the second and third criterion for possible downlisting have been met, the species is a long way from achieving the first and likely most critical criterion related to a stable or increasing population with a minimum of 1,500 individuals. In fact, the minimum of 1,500 individuals has not been met one year let alone 10 consecutive years. Because downlisting criteria have not been met, this species should remain as an endangered species.

## 2.3 Updated Information and Current Species Status

### 2.3.1 Biology and Habitat

**2.3.1.1 New information on the species' biology and life history**: There have been no new study results regarding the life history requirements of this species since the recovery plan was completed in 2003 (U.S. Fish and Wildlife Service 2003, pp. 1-97) but new information has come to light related to the food chain in Tumbling Creek Cave. It is believed that *Antrobia culveri* feeds on biofilm, the organic coating and bacterial layer or detritus associated with the underside of rocks or bare rock stream bottom (Aley and Ashley 2003, p. 19; Krajick 2007, p. 28). This biofilm is directly connected to energy input from the guano of a large colony of roosting bats in Tumbling Creek Cave, particularly the federally listed

gray bat (*Myotis grisescens*) (Aley and Ashley 2003, p.18; U.S. Fish and Wildlife Service 2003, p. 11). The cavesnail is often found on rocks coated with manganese oxide (Aley and Ashley 2003, p. 18); however, the role manganese minerals play in the growth and survival of the cavesnail is unknown. Manganese may or may not be used directly by the cavesnail. The presence of manganese oxide on rocks could possibly be an indication of a bacteria-biofilm coating that the cavesnails feed upon. The manganese oxide may simply be a precipitate of the bacterial populations present as it has been documented that many species of bacteria will oxidize manganese (Ashley, pers. comm. Jan. 20, 2014; Tebo et al. 2005, pp. 421-427; Toner 2005, p. 1300; Yang 2013, pp. 1-12). The detritus food chain in Tumbling Creek is threatened by a rapidly spreading disease (see 2.3.2.3 below) that could eliminate the main source of guano and impact all the cave's invertebrates, especially *Antrobia culveri*.

**2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends**: Since the completion of the recovery plan in 2003 (U.S. Fish and Wildlife Service 2003), population numbers of *Antrobia culveri* have remained precariously low (i.e., ~ 35 individuals: ~ 30 in refugium area and no more than 5 in the transect area since 2007: Ashley, pers. comm. 25 Sep. 2013) and there is insufficient data to attempt any characterization of any demographic parameters, trends, or basic life history requirements. Since emergency listing in 2001, 34 separate surveys have been conducted for the cavesnail along an established transect. Of those surveys, cavesnails were observed only on six counts and more than one individual was only observed on two of those (Nov. 2007 and May 2013, three and four, respectively; Ashley, pers. comm. May and Sep. 2013). For the 34 counts combined, only 11 cavesnails were observed or less than one cavesnail every three surveys. Despite the low numbers observed, however, the documentation of the species within the established transect between 2008 and 2013 is positive news and may suggest a possible increase in numbers. If so, the potential increase could be due to a variety of factors including surface management activities, the control of invasive crayfish, or the cessation of some unidentified environmental perturbation (Ashley, pers. comm. Sep 2013). Although not within the cavesnail survey area, a small number of cavesnails have been observed in the "refugium" upstream of the established transect (see Section 2.3.1.5 below). Surrogate substrate ceramic tiles were placed in this area in 2006 to monitor the refugium population and between 2011 and 2013, 30 or more cavesnails were observed using the tiles (Ashley, pers. comm. Sep. 2013). Nonetheless, *Antrobia culveri* is precariously close to extinction but it is hoped that a combination of conservation measures being implemented within the cave's recharge area, ongoing propagation efforts, and the removal of invasive crayfish will facilitate recovery of the species. It is

hoped that ongoing and future propagation efforts will be successful enough to undergo studies of the species in captivity so that more can be learned about feeding and reproductive habits as well as the complex relationship between gray bat guano and the cavesnail's food chain.

**2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.)**: There have been no studies that compared the genetics of this species to other genera. Given that this is a monotypic species and a site endemic, such studies would be deemed superfluous.

**2.3.1.4 Taxonomic classification or changes in nomenclature**: We are unaware of any studies that support any changes in this species' taxonomic classification or nomenclature.

**2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.)**: There has been no new information that has come to light indicating that this species is found anywhere outside Tumbling Creek and associated underground aquatic karst and/or springs. One thing that has become known since the recovery plan was finalized in 2003 is that there is a short stretch of stream upstream of the area with established transects where there is a small population of cavesnails. We have designated this area as a refugium and it is somewhat fragmented from the main portions of the stream where the species has been regularly monitored. However, because this area often has the endangered gray bats (*Myotis grisescens*) roosting directly above the refugium, it is only monitored when the gray bat roost has moved and disturbance can be avoided. Between 2002 and 2007 wells, and springs in the immediate vicinity of Tumbling Creek Cave as well as 25 caves in Taney County were searched for *Antrobia culveri* but no additional sites were discovered (Elliott et al. 2008b, pp. 107, 111, 116).

**2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem)**: Habitat conditions for *Antrobia culveri* within Tumbling Creek have apparently remained stable or improved. Due to the numerous recovery actions undertaken on surface areas within the recharge area of Tumbling Creek Cave, current sediment levels have lowered and dissolve oxygen levels have remained stable (Tom Aley, Ozark Underground Laboratory, pers. comm. Aug. 26, 2013). In 2013, new equipment was installed in Tumbling Creek to monitor turbidity. This was necessary because older equipment was not providing accurate readings (Tom Aley, Ozark Underground Laboratory, pers. comm. Jan 30, 2014). Nonetheless, cave owners Tom and Cathy Aley

have both noted apparent improvements in turbidity due to numerous above ground conservation actions undertaken and it is hoped that newly installed turbidity equipment will confirm those observations. Mean dissolved oxygen levels have remained relatively stable at ~6.4 ppm (Adam Stallcup, Ozark Underground Laboratory, pers. comm., Jan. 29, 2014). It is not known, however, how the cave's ecosystem will be impacted by climate change (see Section 2.3.2.5 below).

**2.3.1.7 Other**: New information has come to light regarding the threat of predation by the invasive Ringed Crayfish (*Orconectes neglectus neglectus*) on *Antrobia culveri* and the indirect effects of adverse impacts of a rapidly spreading disease called White-nose Syndrome (WNS) that has resulted in the death of millions of bats, including the endangered Indiana bat (*Myotis sodalis*) (http://whitenosesyndrome.org). These invasive crayfish may be entering Tumbling Creek Cave via the movement of individuals from Bull Shoals Reservoir to Big Creek and then habitat occupied by the cavesnail within the cave, especially during periods of excessive rainfall when water in the reservoir backs up and facilitates the emigration of crayfish upstream. The causative agent of WNS is a recently described fungus [*Pseudogymnoascus destructans* (formerly *Geomyces destructans*)]. Potential deaths of gray bats from WNS could adversely impact the energy input and resulting indirect food source for the cavesnail. Both threats are discussed under 2.3.2.3 below.

## 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:** With the exception of the relationship between the spread of the invasive Ringed Crayfish and backwater flooding of Bull Shoals Reservoir and the potential indirect effects of the continued spread of WNS (see Section 2.3.2.3 below regarding predation) there is very little new information regarding any destruction, modification, or curtailment of this species' range other than ongoing efforts to provide additional habitat for *Antrobia culveri* by the placement of ceramic tiles for the cavesnails to attach to. In 2006 a study was initiated to determine if cavesnails would use alternate or surrogate substrates with the placement of tiles in the stream. Initially, the experiment was undertaken in the "refugium" area upstream of the established transect but expanded throughout the cave stream when it was determined that cavesnails did use the additional substrates. Although the number of cavesnails counted during surveys within the established transect and refugium have been generally small (see Section 2.3.1.2 above), the 30 or more cavesnails observed using surrogate tiles between 2011 and 2013 is promising. Nonetheless, it appears that the use of tiles as a surrogate substrate is successful and this technique provides a standardized method for indexing snail populations

(Ashley, pers. comm. Sep. 2013). Additional monitoring is needed to further assess the success of adding surrogate substrates to supplemental natural surfaces.

In 1995 and 2003 semi-permeable membrane devices (SPMD) were installed in Tumbling Creek to detect waterborne contaminants and this study was supplemented with polar organic chemical integrative samplers (POCIS) in 2004 (Elliott et al. 2008b, pp. 107-116). Samples were analyzed between 2004 and 2007 and the results indicated that only minute levels (pg/L of parts per qua-drillion) of some nonpolar organic compounds were detected in the Tumbling Creek stream, far below those allowed by drinking and water and other frequently used standards (Elliott et al. 2008b, p. 120). Neither polar organic compounds nor petroleum hydrocarbons were detected in the samples (Elliott et al. 2008b, p. 120). Based on the results, Elliott et al. 2008b, p. 120) concluded that many potential, persistent organic carbon contaminants were no longer considered as a possible explanation in the decline of *Antrobia culveri*. In 2006, the Ozark Underground Laboratory (OUL) and the Missouri Department of Transportation studied the potential runoff and impact from the application of an emulsified asphalt and rock chip road surfacing technique (characterized as “chip-seal) (Elliott 2008b, p. 116). Total Purgeable Hydrocarbons (TPH) were tested at detection limits of 0.1 mg/L (0.1 ppm) following a rain event and no TPH was detected in the cave stream (Elliott 2008b, p. 120).

Numerous recovery actions have been implemented to benefit the Tumbling Creek Cavesnail since the species was listed. These activities are summarized in (Elliott et al. 2005, pp. 8-13; Elliott et al. 2006, pp. 207-212; Elliott et al. 2008a, pp. 17-21; Elliott et al. 2008b, p. 117). Actions completed or are ongoing include the following:

1) Establishment of the Tumbling Creek Cavesnail Workgroup and Partnership (TCCWP) was established in 2002. This inter-agency and private entity workgroup was established to draft and finalize the Tumbling Creek Cavesnail Recovery Plan (recovery plan) and to facilitate and guide recovery of the species. Members of the workgroup remain active in implementation of the recovery plan, identification of new threats to the species, and coordination of all recovery efforts.

2) Construction of a bat-friendly gate on Tumbling Creek Cave that also reduced crayfish invasions.

3) Repair, diversion of flow, and re-vegetation of 13,000 feet of erosion gullies on the Bray Tract, a portion of property within the cave’s recharge area owned by the Aleys and or the Tumbling

Creek Cave Foundation (see item 15 below). This also included installation of approximately 150 rock check dams in gullies to prevent further erosion.

4) Establishment of a year-round rest-rotation grazing program on former Bray Tract that now provides for about 72 head on 1,358 acres. This replaced a grazing program by the previous owner who ran 300-400 head on same land that resulted in over-grazing and caused extensive erosion and sediment production.

5) Re-vegetation of 3,300 feet of old logging roads within the cave's recharge area.

6) Removal and land rehabilitation of two failing dams on streams draining a minimum of 100 acres. Rehabilitation efforts prevented a possible collapse during a storm event that would have severely damaged the stream below the dams and caused the deposition of sediment within the cave's recharge zone.

7) Stream bank stabilization work using rock structures on about 1,500 feet of eroding stream banks.

8) CRP riparian corridor establishment on all qualifying lands that included cattle exclusion from all stream banks and the planting of about 75,000 native species trees along stream corridors within the cave's recharge area.

9) Restoration of a 50 acre cedar glade within the cave's recharge area that included control of woody vegetation, eradication of invasive species, and the use of prescribed fire.

10) Establishment of 120 acres of native prairie grasses and forbs on land within the cave's recharge area that included treatment of fescue with herbicide and prescribed fire and then subsequent seeding. The sites are now being mowed to control weeds until native grasses becoming established.

11) Removal of woody vegetation (cedars and honey locust trees) using prescribed fire to establish native savannah and enhance native plants on 35 acres within the cave's recharge zone.

12) The main sewage treatment system serving OUL operations was upgraded in 2005. Septic tank effluents from four septic tanks are now transported outside of the recharge area for Tumbling Creek Cave and diverted into a high quality septic field area.

13) Pumping, evaluation, and several upgrades on 13 private on-site septic field systems within the cave's recharge area.

14) Installation of modernized and improved septic systems to replace old systems at two rental properties owned by OUL within the cave's recharge area.

15) Ongoing tours and related educational programs on the Tumbling Creek Cave ecosystem and steps being undertaken to contribute to the conservation of the cave's federally listed species and other inhabitants. These programs reach an average of 1,000 people a year with average group size of 20. Most tours involve college students and professional groups that include training for Missouri Department of Transportation employees.

16) The Tumbling Creek Cave Foundation (TCCF) was incorporated in 2004 and established as a 501 (c)(3) tax exempt, non-profit public operating foundation. The Foundation was established to help maintain the integrity of Tumbling Creek Cave and its recharge area and to further facilitate recovery of the Tumbling Creek cavesnail and federally listed bats.

17) Cleanup and recycling of trash from 31 old dumps within the cave's recharge area that involved the removal, disposal or recycling of approximately 160 tons of trash at recycling facilities or landfills.

18) OUL hired three full-time employees who work primarily on conservation projects to provide benefits to federally listed species within Tumbling Creek Cave including the Tumbling Creek cavesnail.

19) Since 2009, the OUL has undertaken approximately 2.5 man years of work on implementing best management forest practices to re-establish a desirable forest and to reduce the risk of stream bank erosion.

20) Installation of a new sewage system for Mark Twain School in 2006 that is within the cave's recharge area. The total cost was about $89,000 and funding was secured from multiple agencies. The completion of this project has been lauded as an endangered species success story throughout the country.

21) A comprehensive groundwater tracing program was completed to delineate the recharge area for Tumbling Creek Cave and to provide information that assisted in the identification and

characterization of Critical Habitat that was designated for the species in 2001.

22) Owners Tom and Cathy Aley and/or the TCCF now own 2,900 acres that includes ~2,200 acres within the cave's recharge that are managed to benefit the Tumbling Creek cavesnail and federally listed bats. One purchase included 6.2 acres from a land owner that will facilitate the cleanup of a sinkhole trash dump closest to the cave.

23) Predation by the invasive Ringed Crayfish has been recently identified as a new threat to *Antrobia culveri* (see sections 2.3.2.3-2.5 below). Consequently a crayfish removal project began in June 2011. As of January, 2014, 975 crayfish have been captured and removed (Tom Aley, pers. comm., 29 Jan. 2014) and initial results suggest that removal efforts could contribute to recovery efforts for the cavesnail (see Section 2.3.2.3 below).

24) Installation of new monitoring equipment in 2013 to measure turbidity within Tumbling Creek.

**2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:** There is no indication that any commercial, recreational, scientific, or education activities have adversely impacted *Antrobia culveri*. Nonetheless, some precautions have been taken to minimize any potential impact that may inadvertently occur during scientific research. Because cavesnail numbers remain at a precariously low level (i.e., ~ 35 individuals: ~ 30 in refugium area and no more than 5 in the transect area since 2007: Ashley, pers. comm. 25 Sep. 2013), some members of the Tumbling Creek Cave Workgroup and Partnership were somewhat concerned that the need to wade in Tumbling Creek during monitoring efforts possibly crushed snails when stepping on smaller rocks where cavesnails were attached to the under surface. Although there was no evidence that such impacts were realistic, efforts were undertaken to minimize this risk by reducing survey monitoring from once every two months to once every six months, and to take extra precautions to avoid stepping on smaller rocks as much as possible. Additionally, larger rocks that were surveyed for snails were carefully placed back to the same location where they were removed.

**2.3.2.3 Disease or predation:** At the time of listing in 2002 and the completion of the recovery plan in 2003, no diseases or predation threats were identified. Since then, however, two issues have emerged. First, the Ringed Crayfish, although native to Missouri, has become invasive in areas outside of its historical range (Magoulick and DiStefano 2007, pp. 141-150), often due to the dumping of live crayfish into aquatic habitats

by bait fishermen who release them following fishing excursions (Tom Aley, Ozark Underground Laboratory, pers. comm., Jan. 2013; Bob DiStefano, Missouri Department of Conservation, pers. comm. Jan. 2013). This and other species of invasive crayfish have been documented predators on native, aquatic snails and it has been suggested that the Ringed Crayfish is a predator on *Antrobia culveri* and that movement of this species into cavesnail habitat occurred via migration upstream from Bull Shoals Reservoir (Tom Aley, Ozark Underground Laboratory, pers. comm., Jan. 2013; Bob DiStefano, Missouri Department of Conservation, pers. comm. Jan. 2013). Other authors have reported on the impact of predacious crayfish on freshwater snails (Weber and Lodge 1990, p. 38; Lodge et al. 1994, pp. 1271-1279; Lewis 2001, pp. 762-764; Kilburn 2012, pp. 43-58; Dorn 2013, pp.1298-1306). For an extensive list of papers addressing the impacts of crayfish on various aquatic invertebrates, including snails, see Kilburn 2012, pp. 60-68). An aggressive removal of Ringed Crayfish began in 2011 and although it is still too early to determine the overall impact, results of a survey conducted in May 2013 suggests that the cavesnail may be responding, in part, to crayfish removal efforts as multiple individuals were observed along established monitoring transect lines for the first time in several years (Dave Ashley, Missouri Western State University, pers. comm. May, 2013). Additional monitoring is necessary to assess the success of removal efforts and what additional conservation actions may contribute to any potential rebounding of population levels of the cavesnail. As noted by one peer reviewer, improvements in population levels of the species is likely due to a combination of factors such as recharge zone reforestation, dump cleanup, septic system improvements, crayfish removal, and perhaps other actions that have not been monitored.

The second issue that has developed is the documentation of a rapidly spreading disease called White-nose Syndrome (WNS) that has resulted in the death of millions of bats, including the endangered Indiana bat (*Myotis sodalis*) (http://whitenosesyndrome.org). The causative agent is a recently described fungus [*Pseudogymnoascus destructans* (formerly *Geomyces destructans*)] that is believed to be introduced from areas outside the New World, likely Europe (Blehert et al. 2009, pp. 227; Blehert et al. 2011, pp. 267-273; Foley et al. 2011, pp. 223; Thogmartin et al. 2012a, p. 876; Thogmartin et al. 2012b, p. 1086; Thogmartin et al. 2013, p. 162). *Pseudogymnoascus destructans* and WNS have been documented on gray bats but to date no mortality has been attributed to the disease. White nose syndrome (WNS) was first discovered in caves with hibernating bats in New York during the winter of 2006. Since then, the disease has spread to at least 22 other states (Alabama, Arkansas, Connecticut, Delaware, Georgia, Illinois Indiana, Kentucky, Massachusetts, Maryland, Maine, Missouri, New Hampshire, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, Vermont and West

Virginia) and five Canadian Provinces (Quebec, Nova Scotia, Ontario, Prince Edward Island, and New Brunswick). Additionally, *P. destructans* has been documented in Iowa, Minnesota and Oklahoma but with no confirmation of WNS. To date, the disease has been responsible for the death of an estimated 5.7-6.7 million bats, including the federally listed Indiana bat (http://whitenosesyndrome.org). The disease was first reported on gray bats from two caves in Tennessee: Bellamy Cave in Montgomery County and Pearson's Cave in Hawkins County in April of 2012 (http://whitenosesyndrome.org). *Pseudogymnocascus destructans* was documented at Fern Cave, Alabama in April 2013 but with no evidence of WNS. Bellamy Cave, Pearson's Cave and Fern Cave are all three Priority 1 or 2 hibernacula and Fern Cave is the largest known gray bat hibernaculum within the range of the species (U.S. Fish and Wildlife Service 2009, pp. 25-26). In Missouri, WNS has been documented at five caves with records of hibernating or transient gray bats (Shelly Colatskie, Missouri Department of Conservation, pers. comm. Aug. 29, 2013). A total of nine species have been confirmed positive for *P. destructans* and/or the fungal infection. Seven of these species have been documented to both have the fungus and suffer the fungal infection characteristic of WNS disease [i.e., little brown bat (*Myotis lucifugus*), northern long-eared bat (*Myotis septentrionalis*), eastern small-footed bat (*Myotis leibii*), Indiana bat, tricolored bat (*Pipistrellus subflavus*), big brown bat (*Eptesicus fuscus*), and gray bat]. During the winter of 2010, three new species of bats were confirmed positive for the fungus through laboratory testing [i.e., The federally endangered gray bat was confirmed positive in Missouri; the cave myotis (*Myotis velifer*) was documented positive in Oklahoma; and the southeastern bat (*Myotis austroriparius*) was positive in Virginia]; however, at that time, these species did not appear to have suffered the fungal infection that is characteristic of WNS disease in the northeastern U.S. Subsequently, however in April 2010, WNS was confirmed positive on gray bats at the two sites in TN and Fern Cave, AL mentioned above. Additionally, on Jan. 29, 2014, WNS was confirmed in Marion County, AR, at a site that has Northern Long-eared Bat and Ozark Big-eared Bat (*Corynorhinus towsendii ingens*) (http://whitenosesyndrome.org), which is approximately 14 air miles south of Tumbling Creek Cave. Given the proximity of this known infected site, Tumbling Creek Cave may be infected with Pd or may become infected in the near future. Although mortality in gray bats infected with *P. destructans* has not yet been reported, mortality has been reported in several species which are also known to roost in Tumbling Creek Cave (i.e., little brown bat, tricolored bat, northern long-eared bat). Even if grays do not eventually become a common host of the fungus, these other species will maintain the fungal population in Tumbling Creek Cave, and given the impact on Indiana bat and other species of *Myotis* spp. (Thogmartin et al. 2013, pp. 162-172), the highly contagious nature of the causative fungus that can be transported from bat to bat (Hallam and

McCraken 2011, p. 190), the fact that gray bats hibernate in large, dense colonies numbering in the tens and hundreds of thousands, (U.S. Fish and Wildlife Service 2009, p. 11), and the indirect but important relationship between gray bat guano and the cavesnail's food chain (Greelee 1974, pp. 9-11; Aley and Ashley 2003, p. 18; U.S. Fish and Wildlife Service 2003, p. 9 ), confirmed mortality of gray bats from WNS could be catastrophic and further threaten *Antrobia culveri* with extinction if WNS is documented in Tumbling Creek Cave as predicted.

**2.3.2.4 Inadequacy of existing regulatory mechanisms:** There has been no information brought to light since the recovery plan was completed in 2003 (U.S. Fish and Wildlife Service 2003, pp. 20-21) regarding any new regulations or modifications to existing regulations that have substantially changed. One issue, however, that does need to be mentioned is the MDC regulations regarding the release of bait, especially crayfish, into native streams. Under (words boldfaced to emphasize relevance) *3 CSR 10-4.110 General Prohibitions; Applications* it is written: "(1) No bird, fish, **crayfish**, mussel, amphibian, reptile, mammal or other form of wildlife, including their homes, dens, nests, eggs and larvae in Missouri shall be molested, pursued, taken, hunted, trapped, tagged, marked, enticed, poisoned, killed, **transported**, stored, served, bought, sold, given away, accepted, possessed, propagated, imported, exported, or **liberated to the wild** in any manner, number, part, parcel, or quantity, at any time, except as specifically permitted by these rules and any laws consistent with Article IV, sections 40-46 of *Constitution of Missouri*; however, this Code shall not apply to other invertebrates except as specifically provided." Although this statute is applicable to the transport and release of crayfish used for bait into streams where such species are not native, it would be extremely difficult to enforce this regulation. As a result, it should be judged to be inadequate.

**2.3.2.5 Other natural or manmade factors affecting its continued existence:** There has been an increased awareness of the potential impact of climate change on federally listed species. This is certainly the case for aquatic dependent species where climate extremes could impact water levels. Natural communities are dynamic, and species move from one area to another over time as the availability of suitable habitat changes. In particular, we recognize that climate change may cause changes in the arrangement of occupied habitat stream reaches within Tumbling Creek Cave. Tumbling Creek Cave owners Tom and Cathy Aley have noted for years that water flow rates and levels in Tumbling Creek fluctuate depending upon rainfall abundance within the cave's recharge area (Tom Aley, Ozark Underground Laboratory, pers. comm., Aug. 2013). As noted elsewhere, climate change may lead to increased frequency and duration of droughts (Rind *et al.* 1990, p. 9983; Seager *et al.* 2007, pp. 1181-1184; Rahel and Olden 2008, p. 526). Climate warming may increase the

virulence of nonnative parasites and pathogens to native species (Rahel and Olden 2008, p. 525), decrease groundwater levels (Schindler 2001, p. 22), or significantly reduce annual stream flows (Moore *et al.* 1997, p. 925). Increased drought conditions and prolonged low flows associated with climate change may favor the establishment and spread of nonnative species (Rahel and Olden 2008, pp. 526, 529-530). Conversely, in the case of *Antrobia culveri*, above-average rainfall may facilitate the movement of exotic crayfish upstream from Bull Shoals Reservoir into Big Creek and then into Tumbling Creek (Bob DiStefano, Missouri Department of Conservation, pers. comm. Jan. 2013). Multiple authors have suggested that extreme weather events including increases in rainfall and flooding will be an expected result of climate change (e.g. Gordon et al. 1992, pp. 83-101). In the Missouri Ozarks, it is projected that stream basin discharges may be significantly impacted by synergistic effects of changes in land cover and climate change (Hu *et al.* 2005, p. 9). Given the current precariously low population level of cavesnail numbers (i.e., ~ 35 individuals: ~ 30 in refugium area and no more than 5 in the transect area since 2007: Ashley, pers. comm. 25 Sep. 2013), a severe and extended drought could further contribute to a decrease in numbers and speed the species toward extinction.

Due to the precariously low population levels of *Antrobia culveri*, it was determined by the Tumbling Creek Cavesnail Workgroup and Partnership that artificial propagation of cavesnails would be essential to prevent extinction of the species by first using a surrogate species of aquatic snail with similar life history habits. Depending on the success in using an appropriate surrogate species, additional efforts would be undertaken to propagate *Antrobia culveri*. Propagation efforts using the surrogate Stygian cavesnail (*Amnicola stygia*) and Pulmonate snail (*Physa grina*) resulted in limited success between 2005 and 2011. An *in-situ* propagation facility was constructed in 2005 by Dr. Paul Johnson of the Alabama Aquatic Biodiversity Center near Marion, Alabama. Failure of propagation of surrogates was apparently due to the use of well water rather than water from Tumbling Creek. In 2011, new water lines were established that provided cave stream water to the propagation chambers but problems with the successful propagation of surrogates persisted until new components of propagation chambers, a new pump, and new delivery lines were installed in 2011. Between 2011 and 2013, personnel of the OUL and the U.S.G.S. Columbia Environmental Research Center (CERC) in Columbia, Missouri were finally successful in propagating *Physa grina* (Dr. John Besser, CERC, pers. comm. Sep. 2013). These efforts will be critical to the hopeful and eventual propagation of *Antrobia culveri*. Members of the TCCWP are scheduled to meet sometime in 2014 to further outline a propagation plan for *Antrobia culveri* and discuss other recovery issues.

As noted by one peer reviewer, another concern is the possibility of potential pollutant episodes that could be transported within the recharge area of Tumbling Creek Cave via spills on highways and roads, overflowing or leakage of septic tanks or fields, or run off of herbicides or pesticides from adjacent pasture land used to control livestock pests or invasive weeds.

### 2.4 Synthesis

Despite a long list of conservation measures implemented to benefit the Tumbling Creek Cavesnail, population numbers of this species remain precariously low (~ 35 individuals: ~ 30 in refugium area and no more than 5 in the transect area since 2007: Ashley, pers. comm. 25 Sep. 2013) and the species consequently remains on the verge of extinction, especially with the ongoing threat of the impact of WNS on bat populations in Tumbling Creek Cave. Nonetheless, the recent success of propagation of a surrogate aquatic species, ongoing above ground conservation measures, and the removal efforts of the invasive Ringed Crayfish suggest that recovery of the species is still probable. Until such recovery accomplishments have been achieved and until established downlisting criteria have been met, *Antrobia culveri* should remain listed as an endangered species.

## 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 is needed**

### 3.2 New Recovery Priority Number *)*: N/A

**Brief Rationale: N/A**

### 3.3 Listing and Reclassification Priority Number: 1 (no change)

**4.0 RECOMMENDATIONS FOR FUTURE ACTIONS –** There have been significant accomplishments achieved related to habitat for *Antrobia culveri* since the species was listed in 2002. Conservation actions to benefit the species include land acquisition, restoration and maintenance of above ground areas within the cave's recharge area through tree plantings along riparian corridors and

establishment of warm season grasses on overgrazed fields and glades, cleanup of trash dumps in sinkholes, replacement of leaking or subpar sewage/septic systems, road surfacing to reduce the transportation of sediment, replacement of stream drain pipes that impeded stream flow, construction of a bat-friendly gat on the natural exit to Tumbling Creek Cave to eliminate illegal entry and disturbance to gray and Indiana bats, the installation of movement barriers to reduce upstream migration of exotic crayfish, and the installation of new equipment in 2013 to monitor turbidity.

During the next five years, it is recommended that the following actions be undertaken for reasons given below:

a) Despite the accomplishments to habitat within the recharge area of Tumbling Creek Cave, cavesnail numbers remain at a precariously low level (i.e., ~ 35 individuals: ~ 30 in refugium area and no more than 5 in the transect area since 2007: Ashley, pers. comm. 25 Sep. 2013). Significant progress has been made in the successful propagation of surrogate aquatic snails and these efforts should continue. Studies need to be initiated to determine if *Antrobia* can be successfully propagated as was recently demonstrated with a surrogate species. Propagation efforts should be guided by the development of a propagation plan that is developed and approved by the Tumbling Creek Cavesnail Workgroup and Partnership.

b) White-nose syndrome and the causative fungus *Psuedogymnoascus destructans* (Pd) continue their explosive and rapid spread across North America. Both WNS and its causative fungus have been documented in caves inhabited by gray bats and it is likely that the fungus and/or WNS will be documented in Tumbling Creek Cave. Given the recent report of the disease in a cave south of the site in northern, Arkansas, it is may already present. Although there has not yet been a single mortality of a gray bat attributed to WNS, the continued spread of the disease could devastate populations of gray bat and given the link between gray bat guano and the life history requirements of *Antrobia culveri*, impacts to the cavesnail could be catastrophic. Studies need to be initiated to assess the potential loss of gray bat guano which is essential to energy input into Tumbling Creek Cave and what steps should be recommended in the event Pd and/or WNS is documented in Tumbling Creek Cave.

Two peer reviewers suggested the need to assess the utilization of imported nutrient sources by cave invertebrates to determine the feasibility of supplementing energy input into the cave. When the man-made entrance was constructed by the current owner, Tumbling Creek Cave became a model outdoor laboratory for karst ecology workshops and provided numerous educational opportunities and cave tours for schools as well as private, State, and Federal entities. The entrance to the cave was constructed in a manner that facilitated access while maintaining the ecological integrity of the cave, especially air flow and temperature that is crucial to bats that occupy the site throughout the year.

Part of the outdoor karst education included the placement of a small number of woody debris that serve as "decomposition stations." These stations have provided the opportunity to view terrestrial invertebrates that occupy the cave and various researchers have taken the opportunity to maintain some baseline data on species diversity and abundance at these observation points. Woody debris placed as "wildlife viewing" stations have attracted a number of invertebrate species of decomposers (and predators of decomposers) and it has been recommended to consider establishing some additional stations to determine the amount of time it takes for invertebrates to locate these nutrient sources. This information may be applicable to a similar approach for *Antrobia culveri* if it is determined by the Tumbling Creek Cavesnail Workgroup and Partnership and other cave/bat experts that such actions are needed to prevent the extinction of the species in the event WNS wipes out roosting bats whose guano provide energy input into this karst ecosystem. As currently exists at "decomposition stations," any supplemental woody debris would be the same as non-toxic tree species that occur on the surface within the recharge area of Tumbling Creek Cave. One peer reviewer, however, suggested that it may be more appropriate to experiment using different types of guano from species other than bats [e.g. Eastern woodrat (*Neotama floridana*), camel cricket (*Ceuthophilus gracilipes*), raccoon (*Procyon lotor*), etc.] because each has a different nutrient/caloric value. It should be noted that since WNS was documented in New York in 2006, the focus of the overwhelming majority of research has centered on the impact of the disease on bats, actions needed to prevent the potential spread of *Pseudogymnoascus destructans* by humans, or possible control measures to control the fungus. There has been limited research on how the loss of bats will impact ecosystems that are dependent upon guano for energy input or what management actions could be recommended to offset these actions. In absence of such management recommendations, the owners of Tumbling Creek Cave welcome input from the Tumbling Creek Cave Partnership and Workgroup and other cave/bat experts on whether or not alternate energy sources should be added to the cave to help offset the potential reduction in guano due to bat mortality.

c) An ongoing exotic crayfish removal program may enable population numbers of the cavesnail to rebound to historic levels. Although results are preliminary, it appears that exotic crayfish could have contributed to the decline in cavesnail numbers. Additional studies are needed to assess the relationship and potential impact of crayfish predation on cavesnails. Research is needed to determine what situations or circumstances have facilitated the potential movement and increase of exotic crayfish into Tumbling Creek and provide conservation recommendations to reduce and mitigate for impacts to cavesnail habitat.

d) One peer reviewer noted the need to locate a funding source to use molecular markers for different species of hydrobiid snails. This is needed to determine if *Antrobia culveri* exist in the digestive gut of Ringed Crayfish. This would confirm current suspicions that this crayfish is a predator on the Tumbling Creek Cavesnail.

e) Cavesnail numbers and the results of ongoing conservation efforts need to be regularly monitored to assess recovery efforts. Suggested recommendations should be outlined in an adaptive management framework and adjustments made as necessary. Experimental design in monitoring and revisions to approach should consider guidelines found in Gibbs et al. (1999, pp. 1055-1065) regarding fauna on the Galapagos Islands or general recommendations outlined in Stem et al. (2005, pp. 295-309) or other publications cited in the latter document.

f) Further monitoring on the use of surrogate tiles by cavesnails is needed to determine the applicability of using supplemental substrates as a method to index population numbers of *Antrobia culveri*.

g) Consultation between the Army Corps of Engineers and the U.S. Fish and Wildlife Service under Section 7(a)(1) in the development of a conservation program that will contribute to the recovery of the Tumbling Creek cavesnail and under Section 7(a)(2) to assess the potential impact of the operation of Bull Shoals Reservoir on critical habitat established for *Antrobia culveri* in 2011, especially related to backwater flooding and the likely emigration of invasive crayfish into Tumbling Creek via the reservoir and Big Creek.

h) Studies need to be initiated on the potential impacts of climate change on the Tumbling Creek Cavesnail and its habitat. Because the Tumbling Creek cavesnail is an aquatic snail that is totally dependent upon an adequate water supply, adverse effects associated with climate change that may significantly alter the quantity and quality of Tumbling Creek could impact the species in the future. The species could thus be impacted from both droughts and flood events and further research is warranted.

i) Two peer reviewers noted that climate change may also impact the mean annual surface temperature for a given area and this, in turn, could alter critical cave temperatures. Such temperature changes could change the diversity, distribution, and abundance of bats roosting in Tumbling Creek Cave and thus indirectly restrict the nutrient flow into the stream habitats. Conversely, however, it has also been suggested that warmer caves might actually help bats reduce the energy stress during hibernation (Boyles 2009, pp. 92-98) but as one peer reviewer noted, it is more likely that the bats would leave Tumbling Creek Cave to find another cave with the correct temperature profile. Consequently, it is recommended that temperature regimes throughout Tumbling Creek Cave continue to be monitored with the use of HOBO temperature loggers. It is likely that additional units will need to be installed to detect temperature changes throughout the cave. Finally, it has been recommended that weather stations be established in the cave at appropriate locations to evaluate relative changes between surface and subsurface meteorological conditions.

j) One peer reviewer suggested that the use of semi-permeable membrane devices (SPMD) as deployed in 1995 and 2003 and polar organic chemical integrative samplers (POCIS) as installed in 2004 [see 2.3.2.1 above and as outlined in Elliott et al. (2008b, p. 120)] be reinitiated in Tumbling Creek to detect the possible presence of waterborne contaminants, polar organic compounds, nonpolar organic compounds, or petroleum hydrocarbons.

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## Personal Communications

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Besser, John Dr.- Sep. 2013, Columbia Environmental Research Center, Columbia, MO.

DiStefano, Bob- Jan. 2013. Missouri Department of Conservation, Columbia, MO.

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**U.S. FISH AND WILDLIFE SERVICE**
**5-YEAR REVIEW of *Tumbling Creek Cavesnail***

**Current Classification:**

**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:** 1 (no change)

**Review Conducted By:** Dr. Paul McKenzie, Biologist, Columbia, Missouri Field Office

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

Approve _____ Date 2-19-14

**REGIONAL OFFICE APPROVAL:**
**Assistant Regional Director, Fish and Wildlife Service, Midwest Region**

Approve _____ Date 3/21/14