Tumbling Creek Cavesnail Recovery Plan

(*Antrobia culveri*)

September 2003

Department of the Interior
U.S. Fish and Wildlife Service
Great Lakes-Big Rivers Region (Region 3)
Fort Snelling, Minnesota

Tumbling Creek Cavesnail
(*Antrobia culveri*)
Recovery Plan

September 2003

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For

Region 3
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This plan describes actions, objectives and criteria outlining recovery efforts for the Tumbling Creek cavesnail. The plan will be revised as new information on the species, its life history ecology, and management requirements become available.

Literature citation:

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EXECUTIVE SUMMARY

Current Species Status: The Tumbling Creek cavesnail (*Antrobia culveri*) is restricted to a single cave stream in Tumbling Creek Cave in Taney County, southwestern Missouri. The number of cavesnails has significantly decreased over the past few decades, to the point where only one individual was found within survey areas between January 11, 2001 and April 22, 2003. A small population containing approximately 40 individuals exists in a small area upstream of the area that is regularly surveyed. Based on the decline of the Tumbling Creek cavesnail, it was listed as endangered in 2002.

Habitat Requirements and Limiting Factors: Tumbling Creek cavesnail lives on the underside of rocks in areas of Tumbling Creek that have little or no silt. Not much is known about the species and its life history, but it is believed to feed on microscopic animals in the stream. Although the primary limiting factor appears to be decreased water quality due to increased erosion and pollution in the cave's recharge area, scientific research is needed to confirm this hypothesis.

Recovery Strategy: *Antrobia culveri* is on the verge of extinction with only a few individuals being documented during the last 25 surveys conducted between January 11, 2001 and April 22, 2003. Reasons for the sudden and unexpected reduction in cavesnail numbers are unknown but are believed to be related to some yet to be identified factors within the recharge area of Tumbling Creek Cave that have led to a deterioration in the water quality of Tumbling Creek. The primary focuses of the recovery strategy for the Tumbling Creek cavesnail are to: 1) stabilize and augment, if necessary, the existing population and distribution of *Antrobia culveri* in Tumbling Creek, 2) continue to restore, rehabilitate, and stabilize the surface land within the recharge area of Tumbling Creek Cave through various land owner incentive programs, and 3) eliminate or greatly reduce the deposition of sediment and suspended organic matter and other potential sources of contamination that threaten the water quality of Tumbling Creek. For complete strategy, refer to page 28 of this plan.

Recovery Goal: The ultimate recovery goal for the Tumbling Creek cavesnail is to restore viable populations of the species in order to reclassify the species and eventually remove it from the *Federal List of Endangered and Threatened Wildlife and Plants*.

Recovery Objectives: Reclassification and delisting will be achieved by addressing the following parameters: 1) stabilize and augment the existing population, 2) appropriately manage and/or protect surface habitat in the cave's recharge area, and 3) ensure long term, good water quality in Tumbling Creek by meeting all U.S. Environmental Protection Agency (USEPA) recommended water quality criteria for protection of aquatic life.

Recovery Criteria: The Tumbling Creek cavesnail will be considered for reclassification from endangered to threatened when the following criteria have been met: 1) the population is stable or increasing for 10 consecutive years with at least 1,500

individuals, 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, and 3) water quality monitoring fails to detect levels of any water pollutant that exceeds USEPA recommended water quality or exceed known toxicity thresholds for the species for 10 consecutive years.

The Tumbling Creek cavesnail will be considered for delisting when the following additional criteria have been achieved: 1) the population is stable or increasing for an additional 10 consecutive years with at least 5,000 individuals; 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, and 3) water quality monitoring 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. For greater detail, refer to pages 38 to 41 in this plan.

Actions Needed: Recovery actions needed for the Tumbling Creek cavesnail include: 1) stabilize or increase the population, 2) protect surface habitat, 3) monitor contaminants, 4) collect biological and ecological data on *Antrobia culveri* that is relevant to achieve the recovery criteria, 5) initiate educational and public outreach actions to heighten awareness of the Tumbling Creek cavesnail and its important link to good water quality, 6) develop a participation and implementation plan that will facilitate the timely recovery of the Tumbling Creek cavesnail while minimizing social and economic impacts, and 7) conduct regular reviews.

Total Estimated Costs of Recovery: $2.174 million (Table 1).

Date of Recovery: 2023 if fully funded.

Table 1. Estimated recovery time and costs for the Tumbling Creek cavesnail.

	Cost Estimate (000's)			
Year	Priority 1 Actions	Priority 2 Actions	Priority 3 Actions	Total
FY1	225.0	145.0	152.0	522.0
FY2	130.0	85.0	69.5	284.5
FY3	160.0	68.0	39.5	267.5
FY4	150.0	22.0	19.0	191.0
FY5	135.0	23.5	19.0	177.5
FY6	45.0	11.5	19.0	75.5
FY7	45.0	13.5	19.0	77.5
FY8	45.0	11.5	19.0	75.5
FY9	45.0	13.5	19.0	77.5
FY10	25.0	11.5	19.0	55.5
FY11	5.0	13.5	19.0	37.5
FY12	5.0	11.5	19.0	35.5
FY13	5.0	13.5	19.0	37.5
FY14	5.0	11.5	19.0	35.5
FY15	5.0	13.5	19.0	37.5
FY16	5.0	11.5	19.0	35.5
FY17	5.0	13.5	19.0	37.5
FY18	5.0	11.5	19.0	35.5
FY19	5.0	13.5	19.0	37.5
FY20	5.0	11.5	24.0	40.5
Total	1055.0	530.0	589.0	2174.0

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PART I. INTRODUCTION

A. Listing Status

The Tumbling Creek cavesnail (*Antrobia culveri*) is restricted to a single site in southwestern Missouri where it is found only in Tumbling Creek Cave in Taney County (Fig. 1). On December 27, 2001, the species was listed on an emergency basis effective for 240 days (66 FR 66803). On the same date, the Service proposed to list the Tumbling Creek cavesnail as an endangered species after the emergency provisions of the Act expired (66 FR 66868), and on August 14, 2002, it was listed as federally endangered[1] (67 FR 52879). Cavesnail numbers have dropped significantly, from an estimated 15,118 in 1973 (Greenlee 1974) to the point where only one snail has been found within survey areas since January 2001 (Ashley 2003). A population estimate of 17 individuals in October 2002 was based on the single individual observed that month (Ashley 2003). Ashley (2003) failed to observe the species within survey areas during subsequent surveys conducted on December 19, 2002, and April 22, 2003. A small population containing at least 39 snails exists upstream of surveyed areas but it is monitored infrequently so as to minimize any potential disturbance to these individuals. Tumbling Creek cavesnail has a recovery priority number of one meaning that the species is in a monotypic genus with a high degree of threat and despite its recent declines, it is believed to have a high recovery potential (see U.S. Fish and Wildlife Service 1990: 4 and appendix IV).

B. Species' Description and Taxonomy

The Tumbling Creek cavesnail was described as a new species by Hubricht (1971) from specimens taken by David Culver, Thomas Aley, and Leslie Hubricht in 1969 and 1970. *Antrobia culveri* is the type species for the genus *Antrobia*, also described new to science in 1971 by Hubricht. Hershler and Hubricht (1988) examined specimens of *A. culveri* and confirmed the taxonomic placement of this species in the subfamily Littoridininae of the Gastropod family Hydrobiidae. They also noted the similarity of the genus *Antrobia* to, but distinguished it from, the genus *Fontigens*, which contains cave-adapted snails found in other caves and springs of the Ozark Plateau in Missouri and Arkansas. The Tumbling Creek cavesnail is a small, white, blind, aquatic snail. Hubricht (1971) provided the following measurements of the type specimen: height 2.3 millimeters (mm) (0.09 inches (in)); diameter 2.0 mm (0.08 in); aperture height 1.2 mm (0.05 in); aperture diameter 1.1 mm (0.04 in); with a small, conical, well-rounded, pale-yellow shell containing about 3.5 whorls (Hubricht 1971) (Fig. 2).

C. Distribution and Population Trends

Antrobia culveri is known only from Tumbling Creek Cave in Taney County, southwestern Missouri (Fig. 1). In an extensive survey of publicly and privately owned Missouri caves, no additional populations of this cavesnail were discovered (Gardner

[1]An endangered species is defined in section 3 of the Act as any species that is in danger of extinction throughout all or a significant portion of its range. A threatened species is defined as any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

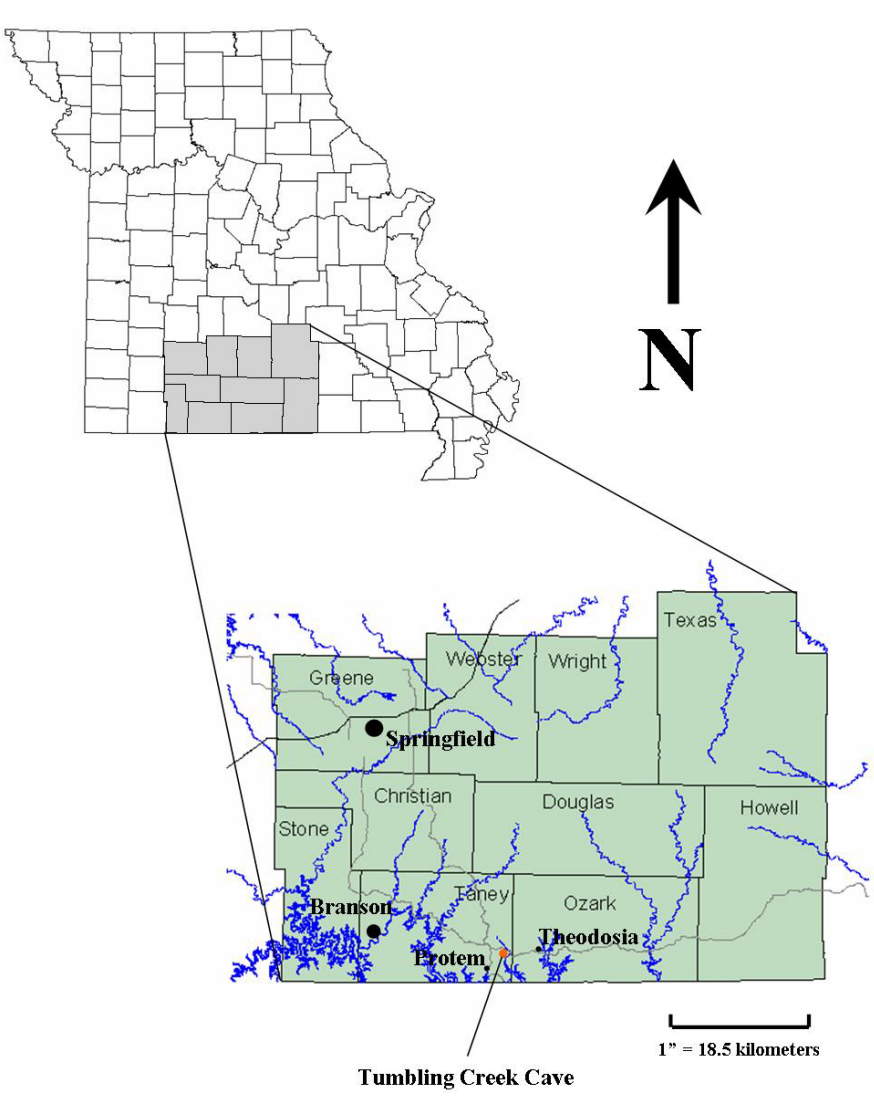

Fig. 1. Location of Tumbling Creek Cave in southwestern Missouri.

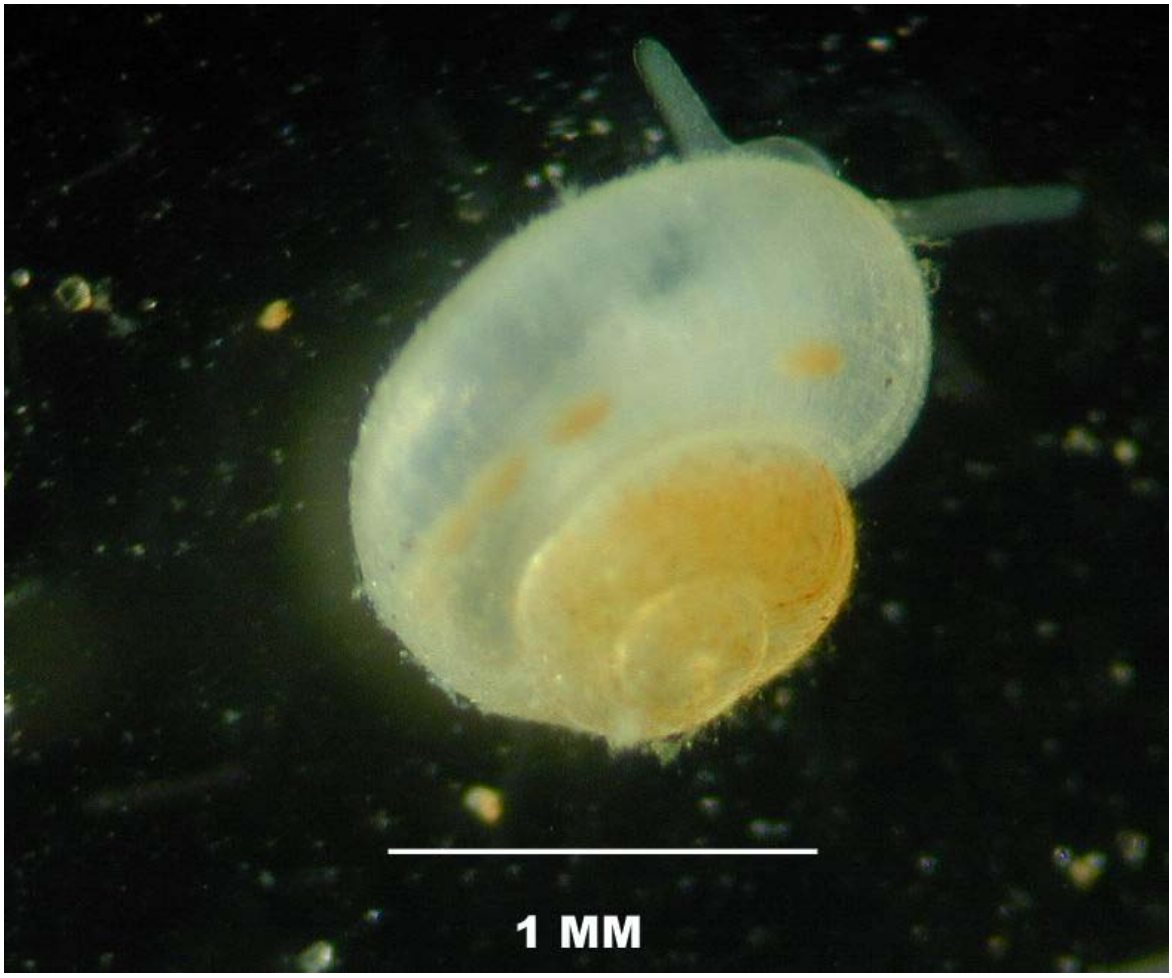

Fig. 2. Tumbling Creek cavesnail (*Antrobia culveri*) (photo by David Ashley, Missouri Western State College, St. Joseph, Missouri, 2001).

1986). Recent surveys conducted in nearby caves and springs by Dr. David Ashley of Missouri Western State College, St. Joseph, MO, have also failed to locate this species at any other sites (David Ashley, in litt. November 2001). The fact that no additional populations were found in springs in close proximity to Tumbling Creek Cave supports the long-held contention that Tumbling Creek cave is the only location where this species occurs.

Antrobia culveri was historically known from an estimated area of 1,016 square meters (m^2) [10,900 square feet (ft^2) or 0.25 acres] of Tumbling Creek along approximately 229 meters (m) [750 feet (ft)] of the stream in the middle one-third of the lower stream passage in Tumbling Creek Cave (Greenlee 1974) (Fig. 3). Based on a survey of approximately 630 m^2 (6,800 ft^2) of suitable habitat within the 457 m (1,500 ft) of human-accessible cave-stream habitat, Greenlee (1974) estimated the population of Tumbling Creek cavesnails at 15,118 individuals.

In 1995, we reviewed the status of the species, including the survey methodology originally established by Greenlee (1974), and determined that an inadequate description of the survey methods made it difficult to determine the number of plots taken. Our lack of knowledge on the number of plots sampled by Greenlee made it difficult to interpret his population estimates and impossible to duplicate his survey methods. Therefore, we concluded that a new and more rigorous statistical survey design would be necessary to establish population trends for the species. In 1996, a sampling protocol (see Ashley 2000 and 2003 for detailed description) was established within an approximate 75 m (247 ft) section of Tumbling Creek that was known to be inhabited by *Antrobia culveri*. This protocol was designed to minimize any potential impacts to the federally endangered gray and Indiana bats.

Following the establishment of seven sampling stations within Tumbling Creek Cave, and an initial September 1996 survey using those stations (McKenzie, in litt. 1996), we began monitoring population trends of the Tumbling Creek cavesnail. Ashley completed 25 separate monitoring trips between September 3, 1997, and April 22, 2003 (Ashley 2000, 2001a, 2001b, 2001c, 2002, 2003; in litt. March 3, 2003). Ashley (2000, 2001a, 2001b, 2001c, 2002, 2003; in litt. March 3, 2003) determined that population estimates of *Antrobia culveri* within the monitoring stations fluctuated both seasonally and annually, and ranged from a high of 1,166 individuals on September 3, 1997, to a low of 0 individuals on January 11, March 17, May 8, July 16, August 31, and November 2, 2001; January 9, March 23, May 30, July 26, and December 19, 2002; and April 22, 2003 (Table 2; Fig. 4). Ashley concluded that a significant decrease in the numbers of cavesnails had occurred between September 9, 1996, and April 22, 2003 (Ashley 2002, Ashley 2003; Fig. 4, 5).

Surveys conducted between January 11, 2001 and July 7, 2002 failed to document the presence of any cavesnails within the established monitoring stations. On October 12, 2002, however, one cavesnail was observed during the survey (Ashley, in litt. March 3, 2003; Ashley 2003). No individuals were located during surveys conducted on December

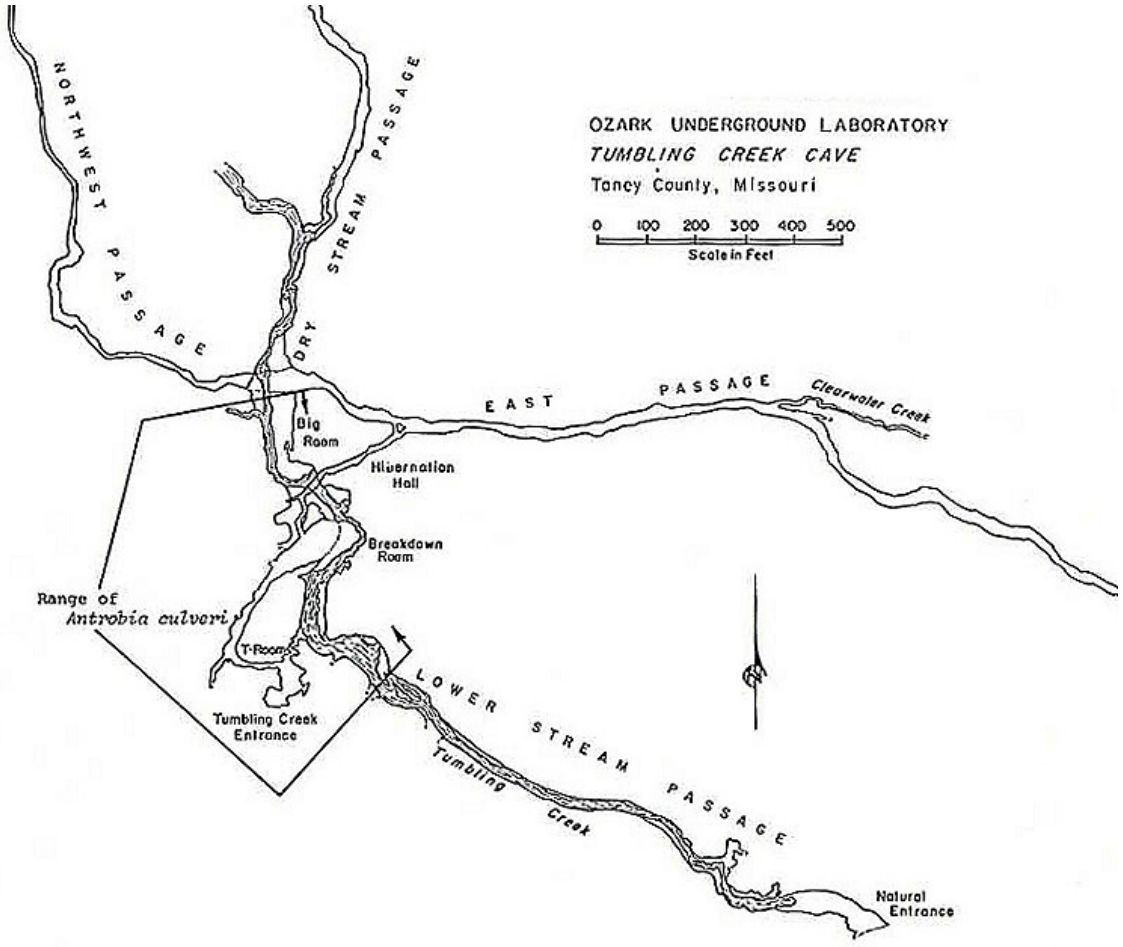

Fig. 3. Historical section of Tumbling Creek occupied by Tumbling Creek cavesnail (after Greenlee 1974).

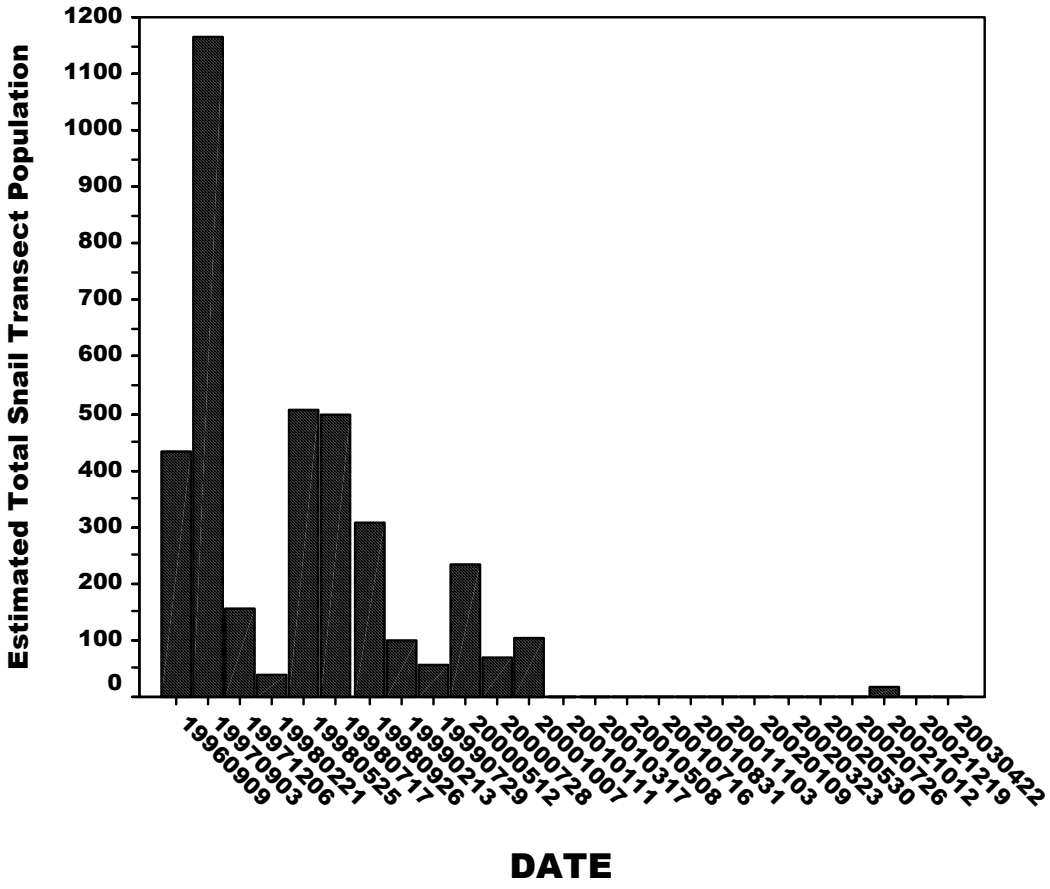

Fig. 4. Bar chart of *Antrobia culveri* population estimates conducted between September 9, 1996 and April 22, 2003 (from Ashley 2003).

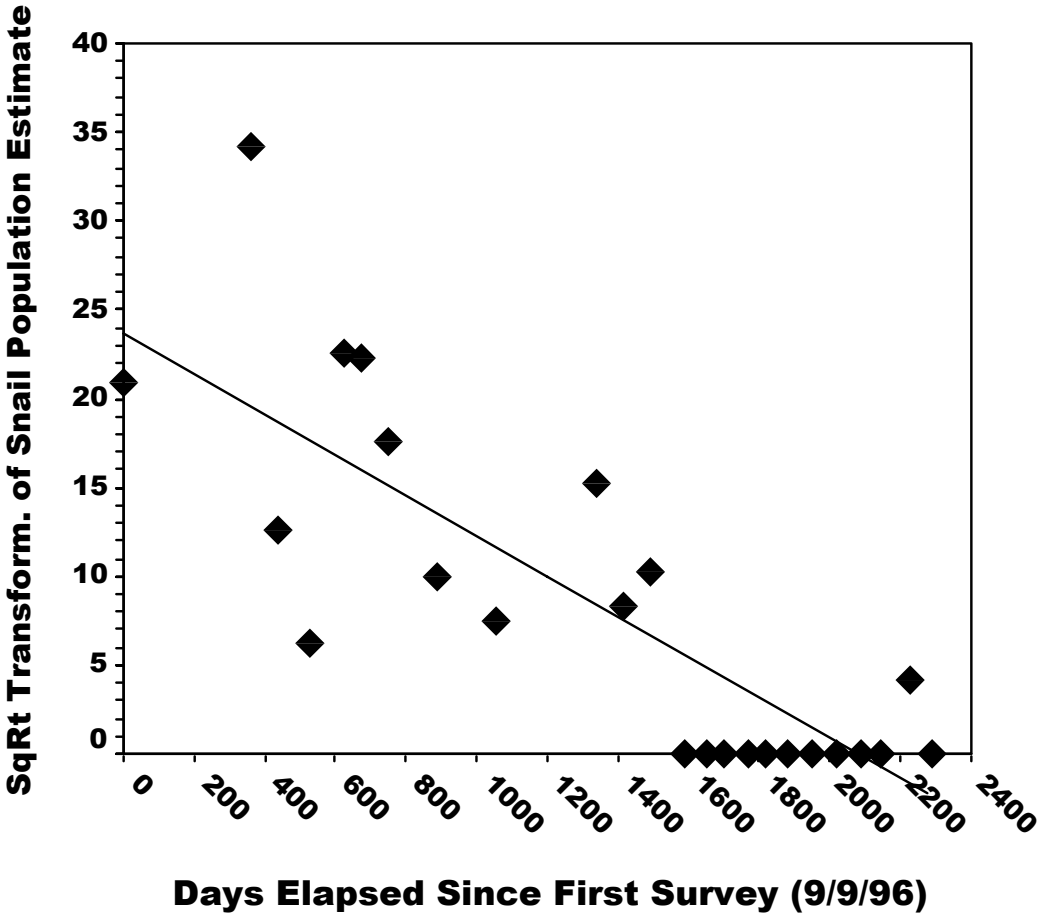

Fig. 5. Scatterplot of square root transformation of *Antrobia culveri* population estimates conducted between September 9, 1996 and April 22, 2003 (from Ashley 2003).

19, 2002 and April 22, 2003 (Ashley 2003; Fig. 4, 5).

Although only one cavesnail was observed during surveys conducted between January 11, 2001 and April 22, 2003 within the established monitoring stations, 40 individuals were discovered upstream of the sampling stations in March 2001 (Table 2). During March 16-18, 2001, Ashley and others surveyed the entire human-accessible 457 m (1,500 ft) of Tumbling Creek, including a small tributary that has approximately nine additional meters (30 ft) of accessible habitat. Thirty nine person-hours were expended in searching 1,054 rocks in the 466 m (1,530 ft) of available habitat. Thirty nine cavesnails were located in a 14-m (45-ft) section of the stream upstream from the monitoring stations, and another cavesnail was found in the tributary (Ashley 2001a; Ashley 2003; Table 2). Subsequent surveys in May, July, September, and November, 2001, and January, 2002, documented the presence of cavesnails only in this 14-m section upstream of the established sampling stations (Ashley 2003). The small tributary stream was not searched during those subsequent surveys. A more thorough search was not conducted in either the tributary or the area upstream from the sampling stations in order to minimize disturbance to cavesnails in those areas. Observations made between September 1997 and April 2003 suggest that the numbers of *Antrobia culveri* have declined significantly from estimates made by Greenlee (1974); however, differing sampling methods make it impossible to directly compare Ashley's estimates with those of Greenlee.

In addition to Greenlee's 1974 survey and the standardized surveys conducted between 1996 and 2003, other attempts have been made to monitor the species' status and derive estimates of its abundance. Forty two individuals were located during a June 1991 survey after a nine person-hour search (McKenzie, pers.obs.). Twenty one cavesnails were observed during a six person-hours search effort in June 1993 (Tom Aley, in litt. 1993), but the number of plots sampled is unknown. On August 29, 1995, two researchers searched for the species and attempted to estimate the number of cavesnails discovered per 0.3 m^2 (1 ft^2) plot. This survey yielded six cavesnails in 22 plots or 0.27 cavesnails per plot (McKenzie, unpubl. data). This compares to an estimated 2.16 cavesnails per plot observed by Greenlee (1974) when equivalent plot sizes were calculated for analysis purposes. Although it is impossible to determine the exact number of plots sampled by Greenlee (1974), he did record the average number of snails per plot, and this can be compared to the same variable measured in 1995. A decrease from 2.16 cavesnails per plot to 0.27 cavesnails per plot would represent an approximate 88 percent decrease in the species' density over the 22-year period between 1974 and 1995.

Ashley (2000) also analyzed the frequency distribution of cavesnail shell lengths from fall data collected between 1997 and 2000 and noted a decrease in the frequency of smaller shells over that period. Ashley (2000) concluded that both fewer snails and fewer smaller snails in the younger age classes were observed in the more recent fall visits conducted from 1997 through 2000 (Fig. 4). This suggests that there was a reduction in recruitment of younger age classes into the population between 1997 and 2000.

D. Life History/Ecology

Although little is known regarding the biology of this cavesnail, Greenlee (1974) postulated that the species feeds on aquatic microfauna (i.e., the microscopic, bacterial film or "biofilm that is potentially ingested by the cavesnail). Because Tumbling Creek cavesnails have been concentrated in sections of Tumbling Creek Cave that are usually adjacent to large deposits of bat guano, it has been postulated that *Antrobia culveri* is indirectly dependent upon these deposits for food (Greenlee 1974). Other life history aspects of this species, including its reproductive behavior, are unknown.

Table 2. Population estimates of *Antrobia culveri* in Tumbling Creek Cave during surveys conducted between September 9, 1996 and April 22, 2003 (from Ashley 2003).

Trip	Date	Elapsed time since first survey (in days)	Population estimate
1	Sep. 9, 1996	0	435
2	Sep. 3,1997	359	1166
3	Dec. 6, 1997	435	157
4	Feb. 21, 1998	530	39
5	May 25, 1998	623	509
6	July 17, 1998	676	497
7	Sep. 26, 1998	747	307
8	Feb. 13, 1999	887	100
9	July 29, 1999	1053	55
10	May 12, 2000	1341	233
11	July 28, 2000	1418	69
12	Oct. 7, 2000	1489	106
13	Jan. 11, 2001	1585	0
14	Mar. 17, 2001	1650	0
15	May 8, 2001	1701	0
16	July 16, 2001	1770	0
17	Aug. 31, 2001	1817	0
18	Nov. 3, 2001	1881	0
19	Jan. 9, 2002	1948	0
20	Mar. 23, 2002	2021	0
21	May 30, 2002	2089	0
22	July 26, 2002	2146	0
23	Oct. 12, 2002	2224	17
24	Dec. 19, 2002	2292	0
25	Apr. 22, 2003	2416	0

E. Habitat Characteristics/Ecosystem

An understanding of both the underground cave topography and the ecosystem characteristics of the surface land within the recharge area of Tumbling Creek Cave is necessary to better assess possible reasons for the decline in the numbers of *Antrobia culveri* and to help outline potential recovery actions for the species. Tumbling Creek Cave is located ca. 24 air kilometers (~15 air miles) southeast of Forsyth, Missouri, in the Ozark Highlands of Taney County (Fig. 1). The cave is situated within the highly dissected, rolling hills of the Western Ozark Mountains just south of the Springfield Plateau (Aley and Thomson 1971; Thomson and Aley 1971). Topographic relief of the surrounding area is ca. 152 m (~ 500 ft.) with elevations ranging from 213 m to 335 m (~ 700 to 1,100 ft.) above sea level (Aley and Thomson 1971; Thomson and Aley 1971). Hillside slopes grade from 50 to 100 percent. Tumbling Creek Cave and adjacent areas are drained by Big Creek and its tributaries. Big Creek, the only perennial stream in the areas, flows south into Bull Shoals Reservoir. Several springs found throughout the area are fed by a complex underground network of ground water (Aley and Thomson 1971; Thomson and Aley 1971).

The predominant rock in Tumbling Creek Cave consists of Cotter Formation made up of a light brown to brown, medium- to finely-crystalline dolomite and argillaceous dolomite (Aley and Thomson 1971; Thomson and Aley 1971). Portions of the cave exhibit weather rock, vertical solutional enlargement of fractures and joints, sections of bedded chert, and chert nodules (Aley and Thomson 1971; Thomson and Aley 1971). An abundance of stromatolites (Aley and Thomson 1971; Thomson and Aley 1971) containing crinoids, brachiopods, and other prehistoric sea animals in cave walls and ledges indicates that the area was sea bound during previous millennia. To date, Tumbling Creek Cave has 9,148 feet of surveyed passage (Aley and Thomson 1971; Thomson and Aley 1971). The physical diversity of Tumbling Creek cave is significant. Passages within the cave range from the largest room (Big Room) which is ~ 18 m high x 55 m long. x 36 m wide (~ 60 ft. x 180 ft x 120 ft.) to long corridor passages which are decorated with cave formations such as stalactites, soda straws, stalagmites, columns, flowstone, rimstone dams, and draperies (Thomas Aley, Ozark Underground Laboratory (OUL), in litt. 1980). The cave's name stems from Tumbling Creek, the underground stream in the cave. Flow rates of Tumbling Creek ranges from 0.014 to 2.8 cubic meters per second (~ 0.5 to 100 cubic ft. per second); the mean annual flow is between 0.08 to 0.14 cubic meters per second (~ 3 to 5 cubic feet per second). The stream contains many chert pebbles which have been highly polished by natural abrasion within the cave; these resemble pebbles which have been in a lapidary tumbler and are the reason the stream was given the name of Tumbling Creek (Thomas Aley, in litt. 1980).

The land surface above the cave includes a variety of woodland and glade natural communities as well as pastures and/or open fields. Surface woodlands would be characterized as dry limestone/dolomite woodlands and glades as dolomite glades under the current draft revision to the Terrestrial Natural Communities of Missouri (Paul W. Nelson, U.S. Forest Service, Rolla, MO, in litt. February 21, 2003). The overstory of the above ground woodlands is dominated by post oak (*Quercus stellata*), white oak (*Q.*

alba), southern red oak (*Q. falcata*), and sugar maple (*Acer saccarhum*); and an understory that includes redbud (*Cercis canadensis*), flowering dogwood (*Cornus florida*), yellowwood (*Cladrastis kentukea*), Carolina buckthorn (*Rhamnus caroliniana*), aromatic sumac (*Rhus aromatica*), sugarberry (*Celtis laevigata* var. *texana*), dwarf hackberry (*Celtis tenuifolia*), and chittim wood (*Bumelia lanuginosa*); and with a ground cover that includes woodland brome (*Bromus pubescens*), rock satin grass (*Muhlenbergia sobolifera*), sang grass (*Brachyletrum erectum*), Indian plantain (*Cacalia plantaginea*), wild quinine (*Parthenium integrifolium*), starry campion (*Silene stellata*), golden alexander (*Zizia aurea*), smooth rock cress (*Arabis laevigata*), black snakeroot (*Sanicula canadensis*), and rough goldenrod (*Solidago radula*). Dolomite glades are characterized by eastern red cedar (*Juniperus virginiana*), chinquapin oak (*Quercus muehlenbergii*), dwarf hackberry, Carolina buckthorn, aromatic sumac, dwarf hackberry, and chittim wood, and smoke tree (*Cotinus obovatus*), with a ground cover that includes little blue stem (*Schizachyrium scoparium*), big blue stem (*Andropogon gerardii*), sideoats gramma (*Bouteloua curtipendula*), Indiana grass (*Sorghastrum nutans*), switch grass (*Panicum virgatum*), a fimbristylis (*Fimbristylis puberula*), prairie dock (*Silphium terebinthinaceum*), Missouri black-eyed Susan (*Rudbeckia missouriensis*), low calamint (*Satureja arkansana*), yellow coneflower (*Echinacea paradoxa*), and Mead's sedge (*Carex meadii*) [Paul W. Nelson, U.S. Forest Service, Rolla, MO, in litt. February 21, 2003; Thomas Aley, in litt. 1980; Paul McKenzie, (U.S. Fish and Wildlife Service, Columbia, Missouri, pers. obs); Yatskievych 1999].

The fauna of Tumbling Creek Cave is highly diverse (Thomas Aley, in litt 1978 ; Cecil Andrus, USDI, in litt. 1980). In addition to one species included in the Missouri Department of Conservation's (MDC) *Checklist of Species of Conservation Concern* (Missouri Natural Heritage Program 2003) [i.e., a cave millipede (*Scoterpes dendropus*)], *Antrobia culveri* is associated with at least three, and possibly as many as six, species that have either been recently described [e.g., Aley's millipede (*Chaetaspis aleyorum*)], or new to science but have not yet been formally classified [i.e., Tumbling Creek Cave isopod (*Brackenridgia* sp.), an amphipod (*Stygobromus* sp.), a dipluran (*Plusiocampa* sp.), a phalangodid harvestman (*Phalangium* sp.), and a cave spider (*Islandiana* sp.). Tumbling Creek Cave also provides habitat for a large maternity colony of federally listed gray bats *(Myotis grisescens*), with a recent estimated breeding population of 12,400 in 1998 (Dr. William Elliott, MDC, in litt. October 9, 2001). Historically, the gray bat breeding population included an estimated 50,000 individuals (MDC 1992, Missouri Natural Heritage Program 2003). The Gray Bat Recovery Plan lists Tumbling Creek Cave as a "Priority 1" cave. Priority 1 gray bat caves have the highest level of biological significance for a gray bat maternity site (i.e., a cave deemed to be "absolutely essential" in preventing the extinction of the endangered gray bat) (U.S. Fish and Wildlife Service 1982). There have also been historical observations of a very small hibernating population of the federally listed Indiana bat (*Myotis sodalis*). However, the Indiana bat has not been documented at the site since 1989 (Missouri Natural Heritage Program 2003). Up to 114 species of animals have been reported from Tumbling Creek Cave including the following: long-tailed salamander (*Eurycea longicauda*), cave salamander (*Eurycea lucifuga*), grotto salamander (*Typhlotriton spelaeus*), ringed crayfish

(*Orconectes neglectus*), Onodaga cave amphipod (*Stygobromus onondagaensis*), Ozark cave amphipod (*Stygobromus ozarkensis*), Antricola cave isopod (*Caecidotea antricola*), Lirceus isopod (*Lirceus hoppinae*), springtail (*Folsomia candida*), webworm (*Macrocera nobilis*), camel cricket (*Ceuthophilus* spp.), pickerel frog (*Rana palustris*), and Eastern pipistrelle bat (*Pipistrellus subflavus*) (Elliott 2003).

Tumbling Creek Cave is privately owned. Because of its rich cave fauna, the large maternity colony for the endangered gray bat, and its diverse physical features, Tumbling Creek Cave was designated as a National Natural Landmark and approved for inclusion on the National Registry of Natural Landmarks under the authority of the Historic Sites Act of 1935 (49 Stat. 666; 16 U.S.C. 461 et seq.) (Cecil Andrus, USDI, in litt., 1980; 48 FR 8693). Tumbling Creek Cave and approximately 395 acres surrounding the cave were embodied in the designation, including about 140 surface acres owned by the Aleys and about 297 surface acres owned by two adjacent property owners.

Greenlee (1974) provided the first information on the habitat of *Antrobia culveri*. He reported that the species was found primarily on "3 inch gravel substrate" [presumably meaning small stones or cobble of 3-inch (7.5 cm) diameter], with a few individuals observed using the recesses of a solid rock stream bottom. Greenlee's use of a Surber Sampler, however, may have biased his survey to search for rocks smaller than 25 cm (10 in) in diameter (Julian J. Lewis, J. Lewis & Associates, Clarksville, IN; in litt., January 27, 2002). Greenlee (1974) did not note whether the snails used the upper or lower surface of the 3-inch gravel he observed them on, or whether the species was ever observed using larger rocks within the cave stream. Subsequent surveyors, however, have failed to document *A. culveri* using a solid rock bottom, and the species is usually observed on the undersurface of rocks and gravel of various sizes (Ashley unpub. data; McKenzie in litt., September 16, 1996; Ashley and McKenzie, pers. obs.). Although Greenlee (1974) stated that the Tumbling Creek cavesnail was absent from areas of the stream that contained bat guano, subsequent observers (Ashley 2001a; Ashley and McKenzie, pers. obs.) have noted *A. culveri* in portions of Tumbling Creek where bat guano occurs. Greenlee (1974) noted that the species appears to prefer areas of the stream that lack silt, but Ashley (2000) found no significant differences in snail populations between habitats having silt and those lacking silt. There is insufficient data to determine if silt is detrimental to the Tumbling Creek cavesnail.

F. Critical Habitat

Critical habitat has not been designated for *Antrobia culveri*. If following completion of this plan, we find that it is prudent and determinable to designate critical habitat for this species, we will prepare a critical habitat proposal in the future at such time as our available resources and other listing priorities under the Act will allow.

G. Reasons for Listing and Current Threats

We followed procedures found in section 4 of the Act (16 U.S.C. 1533) and regulations (50 CFR part 424) promulgated to implement the listing provisions of the Act. The Service may determine a species to be endangered or threatened due to one or more of

the five factors described in section 4(a)(1) of the Act. These factors and their application to the Tumbling Creek cavesnail (*Antrobia culveri*) are as follows:

Destruction, Modification, or Curtailment of Habitat or Range

Antrobia culveri has exhibited a large decline in numbers since the first estimate was made by Greenlee (1974) (see Distribution and Population Trends, above). Systematic sampling within various sections of Tumbling Creek was initiated in 1996 (McKenzie in litt. 1996). Placement of sampling quadrats was done by inspecting the area within each of the sampling sections and arbitrarily placing the sampling squares approximately equidistant along each section. Ashley reported a statistically significant decline in the snail population over the period between 1996 and the first quarter of 2003 (Ashley 2001c, 2002, 2003). Additionally, no cavesnails have been located at established monitoring stations during 11 of the last 12 surveys (Ashley 2001a, 2001b, 2001c, 2002, 2003; Ashley in litt. March 3, 2003).

We also have documented a large reduction in the portion of the cave stream occupied by the cavesnail. *Antrobia culveri* was historically known from an estimated 229 m (750 ft) of Tumbling Creek (Greenlee 1974) (Fig. 3, pg 5). The 229 m of occupied habitat in 1974 constituted 50 percent of the 457 m (1,500 ft) of human-accessible cave-stream habitat that is believed to be suitable for the cavesnail. The entire accessible 457 m (1,500 ft) of Tumbling Creek, including a small tributary that has approximately 9 additional meters (30 ft) of accessible suitable habitat, was surveyed in March 2001. Cavesnails were found solely in one small (14-m) (45-ft) section of the stream and in the small tributary (Ashley 2001a). Observations between March and August 2001 suggest that *A. culveri* is now restricted to 23 m of available stream habitat or approximately 5 percent of the 457 m of accessible suitable habitat. These figures indicate that distribution of this species in Tumbling Creek Cave has decreased by 90 percent.

Species such as the Tumbling Creek cavesnail, which spend all of their life cycle in subterranean waters, are highly vulnerable to changes in the quality and quantity of that water. In turn, the quality and quantity of the subsurface water is highly dependent upon conditions and human activities on the land surface. Water feeds into losing streams and sinkholes that drain into underground karst conduits. Surface water moves into the subsurface system by a number of mechanisms, including sinkholes, percolation through sandy or gravelly soils and stream bottoms, and seepage and flowage into crevices. As water moves from the surface to the subsurface system, it carries the chemicals and particulate matter from the surface (Gines and Gines 1992). The land surface that feeds water into a particular cave stream is referred to as the "recharge area" for that cave stream. Because recharge areas may be large and may consist of all or parts of several surface watersheds, it is critically important to accurately determine the boundaries of the recharge area with reliable hydrogeological methods. Only when the recharge area is accurately delineated can water quality threats be successfully addressed (Aley and Aley 1991).

The recharge area that feeds water into Tumbling Creek Cave has been recently delineated (Aley and Aley 2001). Pending the results of additional recharge delineation studies, the recharge area is estimated to be approximately 2,349 hectares (5,854 acres or 9.02 square miles) (Fig. 6). Land ownership based on current data within the recharge area is: (1) private individuals, who manage their property to protect water quality and benefit the species, own approximately 2,818 acres or 47 percent; (2) an estimated 1,300 acres or 23 percent is within Mark Twain National Forest; (3) the U.S. Army Corps of Engineers (USACE) owns an estimated 100 acres or 2 percent; and (4) other private landowners, whose land use practices and knowledge of the cavesnail are currently unknown to us, own approximately 1,636 acres or 28 percent. Thus, within the delineated recharge area for Tumbling Creek Cave, roughly 4,168 acres or approximately 72 percent is either in public or private ownership by entities who can be expected to manage their land to benefit the species. However, most of this recently purchased land was subject to land use practices (e.g., over-grazing and removal of riparian vegetation) by the previous owner that resulted in heavy soil erosion that probably continues to contribute to deteriorating water quality in Tumbling Creek Cave. Remediation and restoration of these lands are planned and will require considerable funds, effort, and time.

The Tumbling Creek cavesnail is likely threatened by habitat degradation through diminished water quality from upstream locations within the unprotected or improperly managed areas within the cave's delineated recharge zone. The dramatic decrease in the population and area occupied by this species is probably attributable to degraded water quality from these sources. In recent years, there has been a noticeable increase in water turbidity in Tumbling Creek; the increased turbidity has probably had an adverse effect on the water quality in the cave's stream (Tom and Cathy Aley, pers. commun., August 30, 2001). Increased silt loads within Tumbling Creek could adversely affect the cavesnail by hampering reproduction and recruitment by suffocating juvenile cavesnails (Ashley 2000). Several authors (e.g., Poulson 1996, Elliott 2000, Taylor *et al.* 2000) have noted that high sediment loads usually have a negative impact on aquatic species. Clay particles associated with deposited silt in Tumbling Creek have apparently settled between gravel and rocks and cemented them together and to the stream bottom (Tom and Cathy Aley, pers. commun., August 2001). Such cementing decreases habitat available to cavesnails, especially interstitial areas, because the species is generally restricted to the undersurface of gravel and rocks. This hypothesis is supported by observations made by researchers while conducting cavesnail surveys (e.g., Ashley and McKenzie, pers. obs.).

Coineau and Boutin (1992) demonstrated that interstitial habitats are critically important to the dispersal capabilities of animals with limited movements. Comacho (1992) suggested that the size, porosity, and compaction of sediment grains (e.g., clay vs. sand) was a limiting factor in the availability of interstitial habitats to aquatic cave organisms. Despite the potential loss of habitat due to the cementing of some rocks to the stream bottom, Ashley and McKenzie (pers. obs.) have noted an abundance of unoccupied rocks that provided suitable habitat for the species. Whether the loss of additional habitat beyond the abundance of apparently suitable rocks currently available in the cave stream has contributed to the overall decline in the species' numbers is unknown. Interestingly,

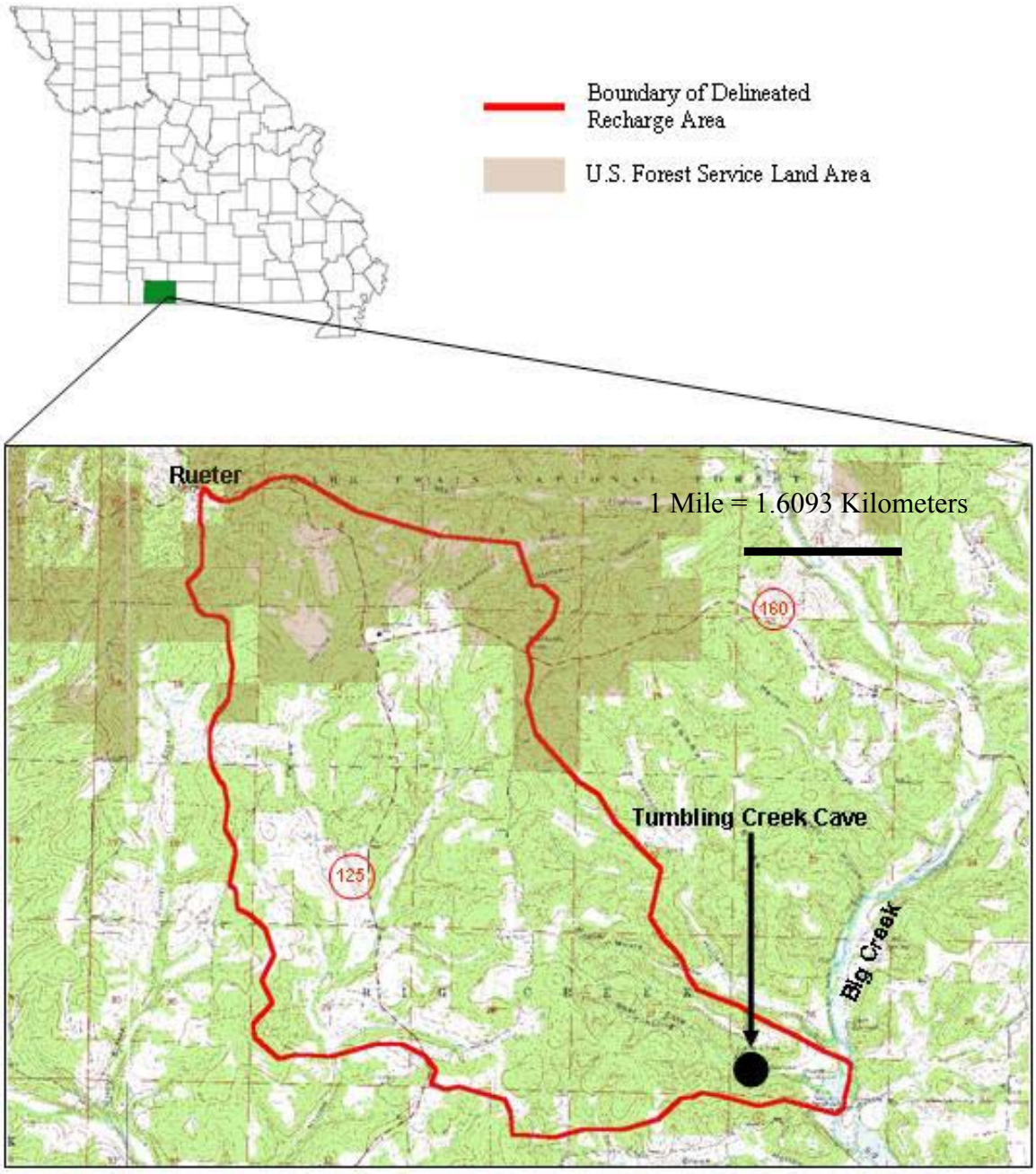

Figure 6. Estimated recharge area for Tumbling Creek Cave based on recharge delineation studies conducted by Aley and Aley (2001).

Ashley (2000) determined that some Tumbling Creek cavesnails use silt-covered substrates. This is different from the observations made by Greenlee (1974) who noted that cavesnails were not observed in areas of the stream where fine silt was deposited. Ashley's observations may be due to a reduction in the amount of silt-free substrates preferred by cavesnails which could force the species to use less favorable habitats. Although silt has been a component of Tumbling Creek since Greenlee's initial survey in 1974, it has apparently increased since that date (Tom and Cathy Aley, pers. commun., August 2001).

Silt could also be harmful to *Antrobia culveri* indirectly due to the interrelationship between various harmful bacteria or viruses and some sediment mediums. Taylor and Webb (2000) reported that the survival of some bacteria and viruses may increase when they become attached to the surface of silt and clay particles and organic matter. Additionally, they noted that such harmful bacteria as coliform and fecal coliform bacteria "may persist and reach much higher concentrations in aquatic sediments (especially in the presence of organic nutrients) than in the water column." Consequently, an increase of silt into Tumbling Creek could exacerbate the potential problems from bacteria and viruses originating from livestock wastes entering Tumbling Creek. Additional research is needed to determine the degree of silt deposition within Tumbling Creek and if the deposition of silt into the cave is adversely impacting the species, especially smaller and younger individuals (Ashley 2000).

Potential sources of silt within the cave's recharge area have been identified on the two tracts recently purchased by Tom and Cathy Aley, including an earthen dam that burst, as well as severely degraded and eroded pastureland due to overgrazing. In the latter case, soil erosion has been exacerbated in the last six years by the removal of nearly all vegetation by bulldozing equipment within the riparian corridors of all semi-permanent and intermittent streams on one of those parcels. Tree removal activities associated with pasture expansion have increased soil erosion and resulted in the subsequent movement of silt into the cave system (Aley, Ashley, and McKenzie, pers. obs.). Harvey (1980) concluded that "accelerated erosion and sediment transport" was a problem within drainage basins that have "excessive slopes," and identified "timber cutting and land clearing for raising livestock, extending urban sprawl, and highway building" as potential sources of "accelerated erosion." Mechanically constructed firebreaks associated with prescribed burning on National Forest lands within the recharge area is another potential source of soil movement if not properly designed and revegetated.

Feral hogs, wild pigs or wild boar (*Sus scrofa*) is a new potential threat to surface habitat within the recharge area of Tumbling Creek Cave that was not identified at the time the species was listed. The range of wild pigs continues to expand throughout the state (Missouri Department of Conservation 2003b) and a herd of these animals was recently observed on private land adjacent to Tumbling Creek Cave (Tom Aley, pers. commun., April 23, 2003). Feral hogs have caused major environmental impact in several areas of the U.S.(impacts summarized by Singer et al. 1984 and Aguirre and Poss 2000) and their rooting and digging can be significant sources of soil disturbance (Missouri

Department of Conservation 2003b). During severe cold weather, wild pigs have been observed using caves for warmth (McKenzie, pers. obs., Fort Leonard Wood Military Installation, Missouri, January, 2003). Wild hogs often disturb soil to a depth of 15-25 cm (6-10 in.) and increase siltation, especially within riparian corridors (Missouri Department of Conservation 2003b). Activities by wild pigs within the recharge area of Tumbling Creek Cave could further exacerbate siltation problems and impact *Antrobia culveri* directly if the animals use Tumbling Creek Cave as refugium.

Other factors within the recharge area of Tumbling Creek Cave that could contribute to the deterioration of the water quality of Tumbling Creek include: (1) nutrient enrichment from livestock feedlots or from fertilizers used for crop production or pasture improvement within the recharge area that could reduce dissolved oxygen levels in Tumbling Creek or become toxic to aquatic organisms at high concentrations; (2) chemicals used for highway maintenance or from accidental spills; and (3) contaminants from different types of trash or hazardous waste materials deposited into sinkholes, ravines, and depressions. Based on research involving similar streams in the United States Koplin et al. (2002), Tumbling Creek could also be contaminated from hormones, antibiotics, disinfectants, or other chemicals found in human and livestock wastes.

Although silt deposition has been identified as a potential problem, especially to younger cohorts of the cavesnail's population, additional research is needed to determine if other contaminants are potentially involved. Non-point source pollution may be a problem in a significant portion of the recharge area that feeds Tumbling Creek Cave. Potential sources of pollution include the drainage of barnyard and feedlot wastes and the discharge of treated sewage into sinkholes and losing streambeds within the cave's recharge area. The water quality of Tumbling Creek may also be threatened due to accidental spills into sinkholes or losing stream valleys feeding Tumbling Creek Cave from State and county highways crossing the recharge area. Such sources of pollution have been identified as potential problems for ground water in the Springfield-Salem Plateaus of southern Missouri (including the watershed that encompasses Tumbling Creek and its identified recharge zone) (Harvey 1980). The decline in numbers of the Tumbling Creek cavesnail may be due to one or several sources of pollution that have resulted in a deterioration of water quality within the recharge area for Tumbling Creek.

In comparing the quality of groundwater sites within the Ozark Plateaus (including southwestern Missouri) with other National Water-Quality Assessment Program (NAWQA) sites, Petersen *et al.* (1998) documented that: (1) nitrate concentrations in parts of the Springfield Plateau aquifer were higher than in most other NAWQA drinking-water aquifers, and (2) volatile organic compounds were detected more frequently in drinking-water aquifers within the Ozark Plateaus than in most other drinking-water aquifers. Tumbling Creek Cave is within the NAWQA study boundaries; consequently, the cavesnail could be threatened from these contaminants. Peck (1998) concluded that all aquatic cave species were especially vulnerable to karst groundwater pollution. Elliott (2000) summarized numerous examples of cave systems being contaminated by a wide range of pollutants that are directly or indirectly dumped into cave streams and further

suggested that reduced biotic diversity correlated with degraded water quality in three caves in Tennessee. Sources identified included agricultural wastes, human sewage, pesticides, leakage from gas tanks and pipelines, and brine pollution from oil distribution facilities. Although no detailed water analyses have yet been performed on Tumbling Creek, an instrumentation package to measure water quality parameters was installed in Tumbling Creek Cave during the summer of 2002.

Contaminants presumably from crop fertilizers were detected at levels high enough in cave streams within the Perryville Karst Region of southeastern Missouri to be detrimental to aquatic life (Vandike 1985; Burr *et al.* 2001). Contamination of groundwater has occurred due to spills associated with traffic accidents in the Mammoth Cave area of Kentucky (U.S. Department of Interior 1983; U.S. Fish and Wildlife Service 1988; Taylor *et al.* 2000). Because portions of Routes 160 and 125 occur within the recharge area for Tumbling Creek Cave, accidental spills resulting from traffic accidents could potentially occur. Taylor and Webb (2000) summarized the deleterious effects of various inorganic ions on the distribution and abundance of different aquatic cave isopods and amphipods. Taylor *et al.* (2000) suggested that several parameters, including depressed oxygen levels, improper pH levels, and the presence of metals, pesticides, and harmful bacteria may all contribute to the persistence or decline of aquatic cave organisms. Burr *et al.* (2001) reported that "no less than one-half of sinkholes in Perry County, MO, contain anthropomorphic refuse, ranging from household cleansers and sewage to used pesticide and herbicide containers." Some unidentified point source pollution that was apparently dumped accidentally into Running Bull Cave in Perry County, MO, resulted in a mass mortality of cave-dwelling grotto sculpin (Burr *et al.* 2001). Elliott (2000) summarized the documented impact of various chemical pollutants into cave systems including sewage, contaminants from old batteries, nitric acid, leaks from petroleum products, brine pollution, herbicides, pesticides, solvents, fertilizers, milk, cream, tobacco waste products, and medical waste. Kolpin *et al.* (2002) sampled 139 streams across 30 States, including Missouri, and documented the presence of human and livestock antibiotics , human prescription and nonprescription drugs, steroid compounds including several biogenic and synthetic reproductive compounds, and 30 different organic wastewater contaminants in 80 percent of the streams sampled. Septic systems that are in need of repair or replacement could leak into groundwater and be potential sources of contamination. Additionally, livestock antibiotics, hormones, and chemical treatments used in controlling insect pests could originate from livestock facilities that occur within the cave's recharge area. The extent to which any of these factors have contributed to the decline of the Tumbling Creek cavesnail remains to be determined.

Overutilization

Because access to Tumbling Creek Cave is controlled by the cave owners, all collection of and research on *Antrobia culveri* is strictly controlled. Consequently, there is no evidence, and very little likelihood, of overutilization of this species for commercial, recreational, scientific, or educational purposes. There is also no evidence that disturbance associated with conducting regular surveys is adversely affecting the species.

Rocks that are examined for cavesnails are carefully replaced in the location from which they were removed, any specimens discovered are disturbed as little as possible and kept moist to reduce stress, and only a small percentage of the available habitat is sampled during each survey.

Disease or Predation

The direct effect of disease on the Tumbling Creek cavesnail is not known and such risks to the species have not been determined. Because the Tumbling Creek cavesnail is known to inhabit only a single location, disease must be considered a potential significant threat to the survival of the species. Other aquatic animals have been adversely affected by disease organisms. For example, certain species of salamanders have been shown to be adversely impacted by the bacterium *Acinetobacter* that flourished due to increasing levels of nitrogen associated with the overstocking of livestock (Worthylake and Hovingh 1989). Similarly, Lefcort *et al.* (1997) and Kiesecker and Blaustein (1997) found that amphibians exposed to high levels of silt are susceptible to infection by different species of water mold of the genus *Saprolegnia*. *Saprolegnia* spp. are widespread in natural waters and commonly grow on dead organic material (Wise *et al.* 1995). Speer (1995) stated that some species of *Saprolegnia* are parasitic on aquatic organisms such as rotifers, nematodes, diatoms, and arthropods. High nitrogen and silt levels from overgrazing or other agricultural or urban runoff may increase the cavesnail's susceptibility to disease and may act synergistically with other risk factors (e.g., competition from limpets, discussed below) to jeopardize the survival of the remaining individuals. Whether the Tumbling Creek cavesnail is being adversely affected by bacteria or water molds associated with increased loads of nitrogen or silt into Tumbling Creek is unknown but warrants further investigation.

During the December 6, 1997, survey, a few individuals of an unknown species of limpet (*Ferrissia* sp.) were discovered for the first time on the same substrates used by *Antrobia culveri* within the established monitoring stations (Ashley, pers. commun., September 10, 2001). Limpets were not observed again until the January 11, 2001, survey, after which their numbers began to increase. By the August 31, 2001, survey, limpet numbers had increased explosively, and the presence of many small limpets, as well as larger limpets with visible, developing embryos, indicated that reproduction was taking place (Ashley, pers. commun., September 10, 2001; McKenzie pers. obs.) The reasons that caused these organisms to appear and increase in numbers within Tumbling Creek are unknown; it is also unknown whether they compete with the cavesnails for food, breeding substrates, or other necessary resources. The disappearance of the rare isopod crustacean *Caecidotea rotunda* coincided with the appearance of limpets in a cave in southern Indiana (Lewis, *in litt*., January 27, 2002). Numerous investigations by Culver and others (e.g., Culver 1970, 1975) have demonstrated that interspecific competition between aquatic cave invertebrates may reduce the availability of important niche habitats. Other cave invertebrates (e.g., a troglobitic isopod, *Caecidota antricola*; a troglobitic amphipod, *Stygobromus* sp.; and a troglophilic amphipod, *Gammarus* sp.) coexist with *Antrobia culveri*, often on the same rocks, but it is unknown if these species compete with

the cavesnail in any way. Additional research is needed to determine if local environmental changes have provided a competitive advantage for one or more of these species over the Tumbling Creek cavesnail.

The near disappearance of the aquatic snail *Physa gyrina* in Tumbling Creek is another barometer that can be used to assess changes in the water quality of the cave stream occupied by *Antrobia culveri*. In the late 1960s and early 1970s, *Physa gyrina* was a common associate of Tumbling Creek cavesnail. In recent years, however, the species has almost completely disappeared from the cave stream for unknown reasons. Whatever the reason, it is likely that the disappearance of *Physa gryina* is linked to the drastic decline in numbers of *Antrobia culveri* (Tom Aley, in litt. May 22, 2003).

Inadequacies of Existing Regulatory Mechanisms

The primary cause of the decline of the Tumbling Creek cavesnail is unknown but is believed to be associated with factors within the 2,349-hectare (5,804-acre) delineated recharge area that have adversely affected the water quality of Tumbling Creek. Federal, State, and local laws have not been sufficient to prevent past and ongoing impacts to areas within the cave's delineated recharge area. *Antrobia culveri* is listed as critically imperiled globally (G1) by The Nature Conservancy, as well as critically imperiled in the State (S1) on the *Missouri Species and Communities of Conservation Concern Checklist* (Missouri Natural Heritage Program 2003). The designation as G1/S1 on this checklist, however, provides no legal protection, but is simply utilized for planning and communication purposes (Missouri Natural Heritage Program 2003). Nonetheless, the species currently receives some protection under the *Wildlife Code of Missouri* (Wildlife Code) (Missouri Department of Conservation 2003a) as a "biological diversity element" (Missouri Natural Heritage Program 2003). "Biological diversity elements" are protected under the following general prohibitions of chapter 4 of the Wildlife Code (3CSR10-4.110): "(1) No bird, fish, amphibian, reptile, mammal or other form of wildlife, including their homes, dens, nests and eggs in Missouri shall be molested, pursued, taken, hunted, trapped, tagged, marked, enticed, poisoned, killed, transported, stored, served, bought, 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 the *Constitution of Missouri*. (2) Except as otherwise provided in this Code, wildlife may be taken only by holders of the prescribed permits and in accordance with prescribed methods. (3) No person, corporation, municipality, county, business or other public or private entity shall cause or allow any deleterious substance to be placed, run or drained into any of the waters of this State in quantities sufficient to injure, stupefy or kill fish or other wildlife which may inhabit such waters."

Under the Section 6 Cooperative Agreement between MDC and the Service, if a species is listed as endangered under the Act, the Conservation Commission of Missouri shall list the species as State endangered. The protection of all species in Missouri is outlined in Chapter 4 of the Wildlife Code, and regulations pertaining to endangered

species are listed in section 3CSR10-4.111. Under the Wildlife Code, citizens can possess (but not sell or purchase) up to five individuals of any species without a permit and when not specifically protected elsewhere in the code (3CSR10-9.110). However, when a species is listed as endangered, citizens cannot possess any individuals and cannot import, transport, purchase, or take the species without a scientific collecting or special use permit. A species' habitat may be protected in only special instances under the Wildlife Code and it is unlikely that such cases would apply to the Tumbling Creek cavesnail.

The *Federal Cave Resources Protection Act* of 1988 (18 U.S.C. 4301-4309; 102 Stat. 4546) was passed to "secure, protect, and preserve significant caves on Federal lands" and to "foster increased cooperation and exchange of information between governmental authorities and those who utilize caves located on Federal lands for scientific, educational, or recreational purposes." Although this statute and a final rule to implement the *Federal Cave Resources Protection Act* on Forest Service land (59 FR 31152; June 17, 1994) provide protection for caves located on property owned by the Forest Service, they do not provide protection for caves whose recharge areas are within Forest Service boundaries if the caves themselves are under private lands, as is the case with Tumbling Creek Cave. Nonetheless, Tumbling Creek Cave is listed as a significant cave by the Forest Service and all National Forest lands within the recharge area for the cave are considered by the Forest Service to be a part of the cave system.

Under Section 578.215 of the *Missouri Cave Resources Act* (Missouri Department of Conservation 2002), the following actions are prohibited: "A person shall not purposely introduce into any cave, cave system, sinkhole, or subsurface waters of the state any substance that will or could violate any provision of the Missouri clean water law as set forth in chapter 204, RSMo (Revised Statutes of Missouri), or any water quality standard or effluent limitation promulgated pursuant thereto." Although this statute is intended to prevent harmful chemicals from being placed into a cave, it is rarely enforced, and an individual prosecuted for a violation of this measure can be convicted of no more than a Class A misdemeanor; therefore, it is largely ineffective at providing protection for aquatic animals within a cave stream (Bill Elliott, Cave Biologist, Missouri Department of Conservation, Jefferson City, MO, pers. commun., March 15, 2002).

The protection afforded *Antrobia culveri* from the statutes mentioned above is limited, does not provide adequate protections to its habitat, and includes no provisions to protect areas within the delineated recharge area for Tumbling Creek Cave. Therefore, we conclude the most likely threats to the species cannot be addressed by existing regulatory mechanisms.

Other Natural or Manmade Factors Affecting its Continued Existence

Several other potential factors, including complexities associated with the relationship between bat guano in the cave and levels of dissolved oxygen in Tumbling Creek, threats from residential and commercial development, fluctuations in climate, potential impacts from the operation of nearby Bull Shoals Reservoir, the species'

critically low population numbers and restricted range may have negative effects on the species. It is possible that the recent decline in cavesnail numbers is attributable to some yet to be identified point or non-point source pollution within the cave's recharge area.

Aley (pers. commun., Jan. 19, 2001) postulated that the decline in cavesnail numbers might result from too much gray bat guano that could deplete oxygen levels in Tumbling Creek, especially during periods of reduced flows as occurred during 1999-2001. Vandike (1982) and Elliott (2000) reported on a massive die-off of the Salem cave crayfish (*Cambarus hubrichti*) and the southern cavefish (*Typhlichthys subterraneus*) when a large quantity of liquid fertilizer containing ammonium nitrate and urea accidentally spilled into a losing stream and significantly lowered dissolved oxygen levels in Meramec Spring, which is 21 km (13 mi) downstream from the spill. What importance gray bat guano plays in the life history requirements of the Tumbling Creek cavesnail is yet to be tested experimentally. The instrumentation package mentioned above will provide data on dissolved oxygen levels once it is installed.

Tumbling Creek Cave is approximately 45 km (28 mi) southeast of Branson, MO, which is one of the most rapidly expanding areas in the State due to tourism, outdoor recreation, and entertainment developments. If recent trends continue, it has been projected that the number of visitors attracted to this area would increase from an estimated level of six million in 1992 to 11 million by the year 2015. The accompanying growth in entertainment- and recreation-related activities will place even greater demands on this area of the State (Mullen and Keith 1992). Tumbling Creek Cave is about 4 km (2.5 mi) northwest of Bull Shoals Reservoir which is also undergoing additional real estate development. Consequently, it is likely that sections of the recharge zone for Tumbling Creek Cave will be adversely affected by real estate development and related construction and land management activities. Elliott (2000) provided multiple examples of how various land development activities have adversely impacted important karst resources in the eastern United States.

Another potential threat to the species results from the close hydrologic association of Tumbling Creek Cave with nearby Bull Shoals Reservoir when water backs up into the cave stream during higher than normal water levels on the reservoir. All of the perennial springs that drain the cave discharge at elevations lower than the flood pool elevation of the reservoir. As a result, any time that lake levels inundate a spring, there is a decrease in the groundwater gradient between the cave and the springs that causes a decrease in flow velocities. A reduction in flow velocities cause a corresponding increase in sediment and organic matter deposition since the water can no longer transport as much material in suspension (Tom Aley, in litt. May 22, 2003). As mentioned above, some believe that the drastic decline in cavesnail numbers is linked to an increase in silt deposition in Tumbling Creek. The USACE is considering raising the conservation pool of the reservoir by five feet (Johnny McLean, USACE, in litt. August 8, 2003), which could possibly increase the frequency and duration of the backup events in Tumbling Creek Cave. Lewis (1994) reported that the habitat of the subterranean hydrobiid snail *Antroselates spiralis* in Mammoth Cave, KY, was reduced significantly due to ponding of the adjacent Green

River by a dam downstream of the cave. The back-flooding created a siltation problem that fragmented previously occupied areas into disjunct islands of habitat (Lewis in litt., January 27, 2002).

Climatic changes, especially recent periods of drought, may also be a contributing factor in the decline of the cavesnail. The National Oceanic and Atmospheric Administration's (NOAA) Palmer Drought Severity Index provides a widely recognized and accepted standard measurement of moisture conditions (NOAA 2001). The Index varies roughly from -6.0 (extreme drought) to +6.0 (extremely wet), with -0.49 to 0.49 indicating near normal conditions. Since the 1974 survey by Greenlee, there have been 4 periods in Southwest Missouri where the Index was below normal for 6 months or longer and was below an Index value of -2.0 (moderate drought) for some part of that period. These events occurred in 2-year cycles: 1980-1981; 1991-1992; 1995-1996; and 1999-2000. The 1980-1981 drought was the most prolonged and severe, with the Index reaching -5.0 (extreme drought). We further analyzed a 6-year period between 1995 and 2000, which is the approximate period that Ashley conducted his cavesnail monitoring. The Index was below normal for 6 months or more for 4 of these 6 years. The years, number of months the Index was below normal, and the averages for the negative indices are: 1995, 6 months, average Index -1.54; 1996, 7 months, average Index -1.2; 1999, 6 months, average Index -1.29; 2000, 10 months, average Index -1.65. Preliminary data on NOAA's website indicate that below-normal moisture (negative Palmer Index) occurred in this region during the early part of 2001, but precipitation levels are now near normal.

According to these climatic data, in 2 recent periods (1995-1996 and 1999-2000) precipitation within the recharge area for Tumbling Creek Cave was below normal for an extended period. Although droughts were undoubtedly apart of the evolutionary history of *Antrobia culveri*, the direct or indirect impacts of such climatic changes on the cavesnail are unknown. Reduced flows in the cave stream, especially when combined with other threats, could hamper essential life history requirements (e.g., reproduction, food availability, water temperature); decrease the flushing of silt, guano, and harmful contaminants from the stream; and create an environment more favorable for competitors (e.g., limpets, isopods, and amphipods).

The small population size and restricted range of *Antrobia culveri* makes it vulnerable to extinction due to genetic drift, inbreeding depression, and random or chance changes to the environment (Smith 1990) that can significantly impact cavesnail habitat. Inbreeding depression can result in death, decreased fertility, smaller body size, loss of vigor, reduced fitness, and various chromosome abnormalities (Smith 1990). Despite any evolutionary adaptations for rarity, habitat loss and degradation increase a species' vulnerability to extinction (Noss and Cooperrider 1994). Numerous authors (e.g., Noss and Cooperrider 1994, Thomas 1994) have indicated that the probability of extinction increases with decreasing habitat availability. Although changes in the environment may cause populations to fluctuate naturally, small and low-density populations are more likely to fluctuate below a minimum viable population (i.e., the minimum or threshold number of individuals needed in a population to persist in a viable state for a given interval; Gilpin

and Soule 1986, Shaffer 1981, Shaffer and Samson 1985). Current threats to the habitat of the Tumbling Creek cavesnail may exacerbate potential problems associated with its low population numbers and increase the chances of this species going extinct.

H. Conservation Measures

Conservation measures provided to the Tumbling Creek cavesnail include recognition, recovery actions, requirements for Federal protection, and prohibitions against certain practices. Recognition through listing results in public awareness and conservation actions by Federal, State, and local agencies, private organizations, groups, and individuals. The Act provides for possible land acquisition and cooperation with the State and requires that recovery actions be carried out for all listed species. The protection required of Federal agencies and the prohibitions against certain activities involving listed species are discussed, in part, below.

Section 6 of the Act allows the Service to provide money to States for the conservation of species. The Service also has the latitude to provide funding to private landowners and researchers interested in the conservation of the Tumbling Creek cavesnail through discretionary monies and other sources as available. The Service's Partners for Fish and Wildlife (PFW) Program can provide funding for habitat restoration or enhancement. Other funding sources are available through other Federal agency programs such as the Farm Service Administration's (FSA) Conservation Reserve Program (Program), and the National Resources Conservation Service's (NRCS) Forestry Incentives Program (FIP),Wetlands Reserve Program (WRP), Environmental Equality Incentives Program (EQIP), and Wildlife Habitat Incentives Program (WHIP) programs. Various completed and ongoing actions/programs have been undertaken within the recharge area of Tumbling Creek Cave and funded through Service discretionary, Section 6, and PFW funds, and FSA CRP funds. These actions involve the following land management actions that have contributed to the conservation of Tumbling Creek cavesnail: 1) delineation of the recharge zone for Tumbling Creek Cave, 2) trash removal, 3) habitat restoration and enhancement through the establishment of planned grazing systems for volunteer landowners to address overgrazing and cattle watering in streams, 4) providing alternative watering sources away from streams and drainages, 5) the reshaping and reseeding of stream slopes, and 6) establishing a protected riparian corridor to reduce erosion and sedimentation of the streams and drainages by planting 30,000 tree seedlings through FSA's Conservation Reserve Program.

Private landowners can also benefit from Safe Harbor Agreements which are voluntary arrangements between the Service and cooperating non-Federal landowners. These agreements benefit endangered or threatened species while giving landowners assurances from additional restrictions. Following development of an agreement, the Service will issue and "enhancement of survival" permit, to authorize any necessary future incidental take to provide participating landowners with assurances that no additional restrictions will be imposed as a result of their conservation actions.

Under sections 2(c)(1) and 7(a)(1) of the Act[2]"Sec. 7. (a) Federal Agency Actions and Consultations.- (1) The Secretary shall review other programs administered by him and utilize such programs in furtherance of the purposes of this Act. All other Federal agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 4 of this Act.", all Federal agencies within the range of the Tumbling Creek cavesnail (this includes the entire 9.1 square mile recharge zone that drains into Tumbling Creek), and in consultation with the Service, have a responsibility to develop and carry out programs for the conservation of this species.

Section 7(a)(2) of the Act, as amended, requires Federal agencies to evaluate their actions with respect to any species that is proposed or listed as endangered or threatened. Regulations implementing the section 7 interagency cooperation provisions of the Act are codified at 50 CFR Part 402. Section 7(a)(2) requires Federal agencies to ensure activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of the Tumbling Creek cavesnail. If a Federal agency's action is likely to adversely affect Tumbling Creek cavesnail, the responsible Federal agency must initiate formal consultation with the Service. Federal agencies that may have jurisdictional responsibilities within the recharge area of Tumbling Creek Cave are the U.S. Forest Service, U.S. Army Corps of Engineers, Natural Resources Conservation Service, Environmental Protection Agency, Farm Services Administration, and Federal Highway Administration.

Sections 9 and 10 of the Act and their implementing regulations found at 50 CFR 17.21 set forth a series of general prohibitions and exceptions that apply to all endangered wildlife. These prohibitions, in part, make it illegal for any person subject to the jurisdiction of the United States to take (including harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect; or attempt any such conduct), import or export, ship in interstate or foreign commerce in the course of commercial activity, or sell or offer for sale in interstate or foreign commerce any listed species. It also is illegal to possess, sell, deliver, carry, transport, or ship any such wildlife that has been taken illegally. Certain exceptions apply to Service agents and those of State conservation agencies.

Section 10 of the Act and its implementing regulations codified at 50 CFR 17.22 and 17.23 provide for the issuance of permits to carry out otherwise prohibited activities involving endangered wildlife under certain circumstances. For endangered species, such permits are available for scientific purposes, to enhance the propagation or survival of the species, and for incidental take in connection with otherwise lawful activities. Requests

2 "(c) Policy- (1)- It is further declared to be the policy of Congress that all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes of this Act." "Sec. 7. (a) Federal Agency Actions and Consultations.- (1) The Secretary shall review other programs administered by him and utilize such programs in furtherance of the purposes of this Act. All other Federal agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 4 of this Act."

for permit applications, copies of the regulations on endangered wildlife and inquiries regarding them may be addressed to Permits Coordinator, Division of Endangered Species, U.S. Fish and Wildlife Service, 1 Federal Drive, Fort Snelling, MN 55111-4056 (phone: 612-713-5350, fax: 612-713-5292, TTY 800-877-8339). Information on permits and other endangered species issues is also available via the internet at http://midwest.fws.gov/Endangered/.

Service monies (i.e., discretionary and Section 6) and MDC funds have also been used to fund the following non-management related actions that have contributed to the conservation of *Antrobia culveri*: 1) ongoing monitoring of the species' population numbers, 2) conducting searches for additional populations, 3) purchase and installation of water quality monitoring equipment in Tumbling Creek, 4) analysis of water samples for possible contaminants, 5) the development of various educational and public outreach material involving caves and cavelife, and 6) the formation of a Tumbling Creek Work Group and Partnership that includes species experts, Federal and State representatives, contaminant specialists, private land specialists, and private land owners, who will assist in outlining recovery actions for the species. Since 1997, approximately $111,360.00 has been expended through the activities outlined above.

I. Biological Constraints and Needs

Tumbling Creek cavesnail is entirely an aquatic snail that inhabits the underside of loose rocks in Tumbling Creek. The survival and eventual recovery of the Tumbling Creek cavesnail is entirely dependent on excellent water quality of the cave stream that the species occupies. Any activities within the cave's recharge area that contribute to a deterioration of the water quality of Tumbling Creek would adversely affect the cavesnail and hinder recovery efforts (see additional discussion in *Destruction, Modification, or Curtailment of Habitat or Range* above). Such activities would include any actions that contribute to an increase in: 1) silt deposition into streams and tributaries that drain into Tumbling Creek (e.g., improperly designed or executed timber harvest operations, over grazing by livestock, land clearing for pasture and residential development, road construction and improper maintenance, improperly designed or executed firebreaks for prescribed fires), 2) chemicals associated with various types of point and non-point source pollution (e.g., application of livestock insecticides, herbicides for weed control, petroleum by products associated with various timber harvest and pasture maintenance activities, faulty septic systems, antibiotics and other additives applied to livestock feed, or different liquids and salts used in the treatment of ice or snow on highways that bisect the recharge area), and 3) eutrophication from an increase in nitrogen-rich sources (e.g., fertilizers, livestock wastes). The actions outlined above may adversely affect the recovery of *Antrobia culveri* and should be evaluated and controlled to the maximum extent possible. The survival and recovery of the Tumbling Creek cavesnail will be enhanced through various voluntary and regulatory programs that either eliminate or reduce potential impacts to the water quality of Tumbling Creek as outlined above.

The water quality of Tumbling Creek Cave should be monitored in comparison to water quality standards establish by the Environmental Protection Agency's (2002)

criteria for stream aquatic life and the criteria established by the Missouri Department of Natural Resource's (2000) Clean Water Commission for coldwater streams. Because it has been scientifically demonstrated (Dwyer et al. 1999) that endangered and threatened species may be more sensitive to various chemicals than test organisms used in establishing water criteria, some contaminant specialists suggest that a safety or impact factor should be included in calculating minimum water quality standards to further eliminate potential negative impacts to federally listed aquatic species (John Besser, U.S. Geological Survey, Biological Resources Division, Columbia Environmental Research Center, Columbia, Missouri, in litt. August 14, 2003).

PART II. RECOVERY

A. Recovery Strategy

Antrobia culveri is on the verge of extinction with only a few individuals being documented during the last 25 surveys conducted between January 11, 2001 and April 22, 2003. Reasons for the sudden and unexpected reduction in cavesnail numbers are unknown but are believed to be related to some yet to be identified factors within the recharge area of Tumbling Creek Cave that have led to a deterioration in the water quality of Tumbling Creek. Silt deposition resulting from poor land management activities or an unknown source of point or non-point pollution within the cave's recharge area are the most likely factors that have contributed to a deterioration in the water quality of Tumbling Creek. Immediate steps need to be undertaken to secure the few remaining individuals of *Antrobia culveri* and to restore the water quality of Tumbling Creek such that the population numbers of the species can rebound to former levels. Due to the precarious status of the Tumbling Creek cavesnail, augmentation of the existing population may be necessary to facilitate recovery. Many of the life history requirements of *Antrobia culveri* are unknown but will need to be identified before the limiting factors affecting the species' population numbers and distribution can be fully understood. The immediate and initial recovery goal or primary focus involving the Tumbling Creek cavesnail will involve implementing actions that will enable the species to be reclassified from endangered to threatened. The following actions will be necessary to achieve reclassification and delisting goals: 1) stabilizing and augmenting, if necessary, the existing population and distribution of *Antrobia culveri* in Tumbling Creek, 2) the continued restoration, rehabilitation, and stabilization of surface land within the cave's recharge area, and 3) absence of a contaminant or other detrimental water quality parameter.

B. Recovery Goal

The ultimate recovery goals outlined in this plan are to reclassify and eventually delist the Tumbling Creek cavesnail.

C. Recovery Objectives

Reclassification and delisting will be achieved by addressing the following parameters: 1) stabilize and augment the existing population, 2) appropriately manage and/or protect surface habitat in the cave's recharge area, and 3) ensuring long term, good water quality in Tumbling Creek by meeting all U.S. Environmental Protection Agency (USEPA) recommended water quality criteria for protection of aquatic life.

To ensure the long-term viability of the Tumbling Creek cavesnail, the initial and primary focus will be to stabilize and augment, if necessary, the species' existing population and to eliminate threats to its survival. To arrest or reverse the species' precipitous decline, it will be necessary to identify and address the limiting factors for the species. These recovery objectives can be achieved, in part, by undertaking the following actions: 1) continue to restore, rehabilitate, and stabilize the surface land within the cave's recharge area, 2) conduct appropriate research on various life history requirements of

Antrobia culveri that will lead directly to the recovery of the species, 3) conduct various contaminant related studies, 4) monitor, protect, and appropriately manage the subsurface and surface habitats within the recharge area of the species, 5) conduct ongoing searches for additional populations of the species, 6) propagate and eventually augment the existing population if necessary, 7) develop and implement various land management plans that encourage the use of best management practices, and 8) develop various educational and public outreach materials.

D. Recovery Criteria

The recovery criteria are based on the available information on the population status, distribution, limited life history ecology, and most likely threats on the Tumbling Creek cavesnail. Criteria will be revised appropriately as additional information becomes available. Priorities for actions and recommended time-frames are contained in the Implementation Schedule of this plan

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 a 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).

The required population numbers and estimated recovery times for reclassification and delisting criteria were chosen for the following reasons: 1) peak numbers of cavesnails historically were as few as 1,200 (based on Dave Ashley's survey estimate of 1,166 individuals on September 3, 1997) or as high as 15,000 (based on Greenlee's 1974 estimate, despite the inability by later researchers to duplicate his methodology), 2) species experts believe that at least 1,500 individuals would be required to facilitate recovery to the point that *Antrobia culveri* no longer meets ESA's definition of an endangered species, 3) species experts believe that 5,000 individuals would be required to achieve recovery, maintain population viability, and no longer fulfill the ESA's definition of an endangered or threatened species, and 4) it has been well established by various cave specialists (Poulson 1969; Lewis 1996) that cave adapted species have a much greater recovery time to low population levels then non-cave species.

There is a possibility that additional, viable populations of Tumbling Creek cavesnail could be discovered during future survey efforts. Any additional viable populations of *Antrobia culveri* discovered will be factored into reclassification and delisting criteria when and if such information becomes available. Following an assessment of the range-wide status of the species that includes cavesnail numbers from newly discovered sites, the population criterion for reclassification and delisting will be adjusted as necessary and appropriate. Additionally, reclassification and delisting criteria may need to be modified based on the results of a population viability analysis (PVA; see recovery action number 4.1.5 below).

E. Step-down Outline

1. Stabilize or increase the population.

- **1.1 Conduct surveys for possible additional populations of *Antrobia culveri.***
  - **1.1.1 Conduct searches within suitable cave stream habitat of nearby caves.**
  - **1.1.2 Survey and sample potential and suitable subterranean habitats as appropriate.**
  - **1.1.3 Survey areas of Tumbling Creek near the stream's natural exit and karst window to determine if the species may be present in areas that may be adversely affected from changes in water levels on Bull Shoals Reservoir.**
- **1.2 Establish artificial propagation protocol.**
  - **1.2.1 Develop propagation methodologies using a surrogate species**

(e.g., an epigean species such as *Antroselates* sp.).

1.2.2 Develop a propagation plan for the species.

1.2.3 Conduct propagation studies on *Antrobia culveri.*

2. Protect or manage surface habitat.

2.1 Continue cleanup and restoration of potential sources of surface contamination within the recharge area of Tumbling Creek Cave.

2.1.1 Identify potential refuse sites and abandoned homesteads within recharge area.

2.1.2 Continue cleanup of refuse sites.

2.1.3 Continue cleanup of abandoned homesteads.

2.1.4 Improve human sewage treatment disposal facilities and the proper abandonment of unused wells that have the potential to adversely affect the water quality of Tumbling Creek.

2.1.5 Improve waste treatment and disposal methods in areas with high density livestock (including CAFOs or confined animal feeding operations).

2.2 Reduce potential sources of siltation and mineral by products on private land through beneficial land management practices and enrollment in landowner incentive programs.

2.2.1 Continue to restore, rehabilitate, and revegetate riparian corridors and stream ravines with various restoration practices.

2.2.2 Recommend improved livestock grazing systems and practices.

2.2.3 Recommend alternative water sources to keep livestock out of losing streams.

2.2.4 Develop management guidelines for the extraction of minerals (i.e., lead, zinc), oil, and gas on private land within the recharge area of Tumbling Creek Cave.

2.2.5 Encourage the voluntary enrollment of private land owners into landowner incentive programs that promote good land use practices.

2.3 Protect land through land acquisition (i.e., land is available and there are willing sellers), and/or long term conservation agreements or easements when possible.

2.4 Develop and implement maintenance and management guidelines to reduce the impact of highway activities within the recharge area for Tumbling Creek Cave.

2.4.1 Partner with the Taney County Commission and the Missouri Department of Transportation, and the Missouri Department of Natural Resources in the development of an emergency contingency plan for potential highway spills.

2.4.2 Partner with the Taney County Commission and the Missouri Department of Transportation in the possible hard surfacing of Wolf Road to decrease sediment load in the area.

2.4.3 Partner with Taney County Commission and the Missouri

Department of Transportation in developing maintenance and management activity guidelines (e.g., shoulder work, revegetation efforts) for all roads within the recharge area of Tumbling Creek Cave.

2.4.4 Partner with Taney County Commission and the Missouri Department of Transportation in developing a plan for the application of herbicides and ice and snow treatment chemicals for all roads within the recharge area of Tumbling Creek Cave.

2.4.5 Partner with Taney County Commission and the Missouri Department of Transportation in developing a construction, maintenance and management plan for all new roads and realignments within the recharge area of Tumbling Creek Cave.

2.4.6 Identify other tertiary (i.e., dirt or gravel) roads within the recharge area of Tumbling Creek Cave that may be a source of soil deposition due to erosion problems.

2.5 Implement applicable standards and guidelines on National Forest lands for timber harvest, range management, glade and savannah restoration, and prescribed fire within the recharge area of Tumbling Creek cave; ensure that any special use permits authorized within the recharge area include provisions for protection of water quality.

2.5.1 Where appropriate and logistically feasible, recommend that the Forest Service establish a demonstration area that will highlight proper grazing techniques and riparian zone management.

2.5.2 In consultation with the U.S. Fish and Wildlife Service (Fish and Wildlife Service), review grazing permits and any associated management plans outlining grazing-system practices.

2.5.3 Provide and distribute FS recommended grazing-system practices to other agencies and individuals as needed.

2.5.4 Implement fire management and wildlife control activities on National Forest lands within the recharge area that reduce or minimize the potential for soil movement, while placing top priority on public and firefighter safety.

2.6 Initiate Geographic Information System (GIS) studies on land use practices within the recharge area of Tumbling Creek Cave.

2.6.1 Create different layers (e.g., soil, land-use practices, land ownership location of streams and sinkholes, etc.) within the recharge area of Tumbling Creek Cave.

2.6.2 Determine relationships of land use practices on water quality in the recharge area of Tumbling Creek Cave using GIS technology.

2.7 In consultation with the Service and the Tumbling Creek Cavesnail Work Group and Partnership, encourage the development and implementation of management plans for all Federal agencies with

jurisdictional responsibilities within the recharge area of Tumbling Creek Cave as part of their responsibility under Sections 2(c)(l) and 7(a)(1) to contribute to the recovery of all federally listed species [i.e., Environmental Protection Agency (EPA), Federal Highways Administration (FHWA), NRCS, USACE, USFS].

2.8 In consultation with the Service and the Tumbling Creek Cavesnail Work Group and Partnership, encourage utility companies with service obligations within the recharge area of Tumbling Creek Cave to develop a management plan for the construction and maintenance of right-of-way corridors involving pipelines, fiber optic cables and utility lines.

2.9 Evaluate potential reasonable and prudent alternatives/measures and accompanying terms and conditions where appropriate, developed during Sec. 7(a)(2) formal consultation between the Service and USACE involving the operation of Bull Shoals Reservoir, that will avoid or minimize the potential impact of any take of *Antrobia culveri* associated with reservoir operations.

2.10 Develop programs for the removal and disposal of feral hogs within the recharge area of Tumbling Creek Cave.

3. Monitor contaminants.

3.1 Conduct water quality monitoring of Tumbling Creek.

3.1.1 Continue to collect and analyze water quality parameters.

3.1.2 Add and evaluate additional water quality parameters such as flow rate, dissolved oxygen, ammonia, coliform bacteria, fecal-coliform bacteria, suspended sediments, antibiotics, hormones, and other yet to be determined parameters.

3.1.3 Monitor water quality of surface and subsurface waters within the recharge area of Tumbling Creek Cave.

3.2 Prioritize and conduct additional subsurface contaminant analyses.

3.2.1 Analyze historical semi-permeable membrane device (SPMD) samples from Tumbling Creek Cave, and collect and analyze new SPMD samples.

3.2.2 Analyze sediments from Tumbling Creek for the presence of persistent contaminants that are not effectively sampled by SPMDs (e.g. toxic metals).

3.2.3 Conduct additional analyses of bat guano.

3.2.4 Collect and analyze tissue samples of associated macroinvertebrates.

3.2.5 Conduct toxicity tests with contaminants of concern (based on water quality monitoring and analyses of SPMDs, sediments, guano, and tissue samples) using subterranean, surrogate hydrobiid species such as *Fontigens* spp. and *Antroselates* spp.

3.2.6 Investigate potential impact of nutrient enrichment (eutrophication) from livestock or fertilizers on the water

quality of Tumbling Creek.

3.2.7 Monitor Tumbling Creek for the potential presence of *Acinetobacter* sp. bacterium and water molds, especially of the genus *Saprolegnia*.

3.3 Conduct surface contaminant analyses.

3.3.1 Identify potential sources of contaminants (e.g., trash dumps, buried containers of toxic chemicals, etc.).

3.3.2 Analyze contaminants in water (with SPMDs) and sediments of surface waters in the recharge area as needed to identify sources of contaminants of concern (based on water quality monitoring and analyses of SPMDs, sediments, guano, and tissue samples).

3.3.3 Evaluate potential spills and impacts of current road maintenance of roads crossing the recharge area of Tumbling Creek Cave including the impact of the application of salt.

3.3.4 Evaluate the potential impact of the toxins present in various species of endophytic fungi associated with non-native pasture grasses.

4. Collect biological and ecological data related to *Antrobia culveri*.

4.1 Conduct research on *A. culveri*

4.1.1 Monitor cave snail numbers at the rate of twice/year.

4.1.2 Conduct life history ecology studies including movements and microhabitat requirements.

4.1.3 Conduct studies on reproductive behavior.

4.1.4 Conduct food habit studies.

4.1.5 Conduct population viability analysis (PVA).

4.1.6 Establish physiological parameters.

4.2 Survey and monitor aquatic macroinvertebrates and obtain population estimates on species associated with Tumbling Creek cavesnail.

4.3 Examine the relationship of bat guano to the energy flow in cave systems.

4.3.1 Investigate a surrogate species in another cave that has a source of bat guano.

4.3.2 Study bat guano in Tumbling Creek Cave and its relationship to the food habits of *Antrobia culveri*.

4.4 Evaluate the effect of removing the barrel gate from the cave stream on numbers of bats using Tumbling Creek Cave.

4.4.1 Install new gate or protection mechanism that will hinder human trespass but allow for free movements of bats.

4.4.2 Conduct before and after estimates of bat numbers by a qualified expert.

4.4.3 Conduct before and after measurement on guano deposition.

4.4.4 Monitor the effectiveness of installation of new gate or

protection mechanism by evaluating effectiveness once every year for the first five years; once every two years thereafter.

5. Initiate educational and public outreach actions to heighten awareness of the Tumbling Creek Cavesnail and its important link to good water quality.

- **5.1 Develop an outreach plan for *Antrobia culveri.* in consultation with the Tumbling Creek Cavesnail Work Group and Partnership, the Service's Region 3 Endangered Species Outreach Specialists, the Service's Region 3 Office of External Affairs, and MDC's Outreach and Education Department.**
- **5.2 Develop outreach materials (e.g., brochures, videos) on the Tumbling Creek cavesnail for general distribution to local schools, post offices, local businesses, governments, real estate offices, Taney (and surrounding) Soil and Water Conservation District offices, and other interested parties.**
- **5.3 Develop a joint letter among multiple agencies to distribute to land owners within the recharge area of Tumbling Creek Cave providing information on the species and management actions underway and proposed that will benefit the cavesnail and local water users.**
- **5.4 Develop and give presentations to local schools, PTA groups, and other interested groups.**
- **5.5 Provide tours of cave and surrounding areas to local residents and schools.**
- **5.6 Provide articles for local and regional newspapers, magazines (e.g., the *Missouri Conservationist*), and newsletters for electric cooperatives, etc.**
- **5.7 Meet with school instructors and administrators to propose the potential development of a program where schools can "adopt" the Tumbling Creek cavesnail as an endangered species.**
- **5.8 Develop and distribute a handout on all available land owner cost share incentive programs.**
- **5.9 Distribute MDC outreach materials on caves and karst.**
- **5.10 Distribute appropriate Service brochures on caves and karst.**
- **5.11 Partner with regional and/or county extension agents in the development and distribution of outreach materials.**

6. In consultation with the Tumbling Creek Cavesnail Work Group & Partnership, the Service, and all affected parties outlined in the Implementation Schedule below, shall develop a participation and implementation plan that will facilitate the timely recovery of the Tumbling Creek cavesnail while minimizing social and economic impacts.

7. Conduct regular reviews.

- **7.1 Evaluate status of species.**
- **7.2 Reassess listing criteria.**
- **7.3 Refine and revise downlisting and delisting criteria, as necessary.**

7.4 Revise recovery plan as needed.

7.5 Evaluate success of management plans and conservation programs and assess their contribution to the recovery of the species.

8. In consultation with the Tumbling Creek Cavesnail Work Group & Partnership, the Service shall develop a post-delisting monitoring plan to monitor continued recovery of *Antrobia culveri* once the species has met the delisting criteria listed above.

F. Recovery Narrative

1. Stabilize or increase the population.

1.1 Conduct surveys for possible additional populations of *Antrobia culveri.*

1.1.1 Conduct searches within suitable cave stream habitat of nearby caves. Despite the failure to discover additional populations of this species in adjacent caves, there is still potentially suitable habitat that has yet to be surveyed. Caves within the White River Basin that have the following characteristics will be searched: 1) the cave has a perennial stream; 2) there is an ample energy source such as bat guano; and 3) the cave's perennial stream has a highly diverse aquatic community. Based on these criteria, the highest priority will be given to the 10 caves that have the greatest potential for documenting the presence of Tumbling Creek cavesnail. Because Ashley (2000, 2003) documented the seasonal variation in cavesnail numbers, multiple surveys should be conducted in suitable habitat. Numbers of cavesnails are currently at such low levels that there are insufficient individuals to conduct various studies (see actions 4.1.2-4.1.6 below) on the species. Consequently, the discovery of additional populations of *Antrobia culveri* would enable various investigations to be initiated until the only currently known population can increase.

1.1.2 Survey and sample potential and suitable subterranean habitats as appropriate. In association with Missouri Western State College, the Missouri Department of Conservation, and the Ozark Underground Laboratory, new techniques are currently being developed that may improve our ability to detect the presence of Tumbling Creek cavesnails. A well- point sampling technique is being developed that may be able to locate cavesnails in groundwater in areas that were previously inaccessible. Additionally, abandoned wells within the recharge area for Tumbling Creek Cave can now be sampled for *Antrobia culveri* and other aquatic invertebrates by using a combination of bait, a

momentum pump, and a pumping system that utilizes airlift technology. These techniques are continually being refined to minimize potential impact to aquatic invertebrates that are targeted for sampling and these procedures may prove useful in locating new populations of the Tumbling Creek cavesnail.

1.1.3 Survey areas of Tumbling Creek near the stream's natural exit and karst window to determine if the species may be present in areas that may be adversely affected from changes in water levels on Bull Shoals Reservoir. A natural, karst window or opening has been recently been discovered near the natural exit of Tumbling Creek from Tumbling Creek Cave. Although access to researchers through this opening is limited, especially during periods when water levels are high, the area may provide suitable habitat for *Antrobia culveri* and should be surveyed when conditions are favorable.

1.2 Establish artificial propagation protocol. Due to its low numbers, artificial propagation of *Antrobia culveri* may be necessary to facilitate recovery. The successful propagation of this species will enable augmentation of the existing population and help prevent extinction in the event of some unforseen catastrophic event. Individuals experimentally propagated will be also be available to conduct various lab-controlled studies on various life history requirements of the species.

1.2.1 Develop propagation methodologies using a surrogate species (e.g., an epigean species such as *Antroselates* sp.). Propagation techniques should be first developed with a surrogate species before experimenting with Tumbling Creek cavesnail. A suitable surrogate will be a closely related species that occurs in similar habitats, has similar feeding requirements, is relatively common, and is readily accessible for research. The selection on an appropriate surrogate will be established in consultation with the Tumbling Creek Cavesnail Work Group and Partnership.

1.2.2 Develop a propagation plan for the species. Results of techniques obtained from surrogate species will be used in developing a propagation plan for *Antrobia culveri*. A propagation plan will be developed by the Tumbling Creek Cavesnail Work Group and Partnership and follow Service guidance published in the September 20, 2000 issue of the *Federal Register* (65 FR 56916).

1.2.3 Conduct propagation studies on *Antrobia culveri.* If *Antrobia culveri* can be successfully propagated, augmentation of existing populations will occur only after individuals targeted for release

have been verified to be free of any disease that could be detrimental to the species. Augmentations will be monitored to evaluate the success of releases. Life history studies will also be initiated if the species can be successfully propagated.

2. Protect or manage surface habitat.

2.1 Continue cleanup and restoration of potential sources of surface contamination within the recharge area of Tumbling Creek Cave. Various cleanup operations and land restoration efforts on surface lands within the recharge area of Tumbling Creek Cave have already been initiated but additional rehabilitation actions are needed.

2.1.1 Identify potential refuse sites and abandoned homesteads within recharge area. Potential refuse sites and abandoned homesteads within the recharge area should be identified using aerial photography and GIS equipment. Once identified, sites should be visited and prioritized based on the amount and magnitude of possible contaminants present.

2.1.2 Continue cleanup of refuse sites. Cleanup of some sites within the recharge area has already been accomplished but potentially harmful chemicals and refuse need to be removed from others. Private land owners should be contacted by personnel of the Private Lands Division of the Missouri Department of Conservation to solicit voluntary support of cleanup activities. Cleanup activities should be done in coordination with local representatives of the Taney Co. Soil and Water Conservation District.

2.1.3 Continue cleanup of abandoned homesteads. Abandoned homesteads are a potential source for different contaminants. Although some areas have been cleaned, potentially harmful chemicals and debris should be removed from other areas within the recharge area of Tumbling Creek Cave. As in action 2.1.2 above private land owners should be contacted by personnel of the Private Lands Division of the Missouri Department of Conservation to solicit voluntary support of cleanup activities. As in action 2.1.2 above, cleanup activities should be done in coordination with local representatives of the Taney Co. Soil and Water Conservation District.

2.1.4 Improve human sewage treatment disposal facilities and the proper abandonment of unused wells that have the potential to adversely affect the water quality of Tumbling Creek. Some human sewage treatment disposal facilities (e.g., sewage lagoons)

within the recharge area of Tumbling Creek Cave are leaking (Tom Aley, pers. commun., April 23, 2003) and either need to be upgraded or replaced. A few abandoned wells have been discovered within the recharge area of Tumbling Creek cave. Such wells are potential sources of contamination and should be properly secured.

2.1.5 Improve waste treatment and disposal methods in areas with high density livestock [including CAFOs (i.e., confined animal feeding operations)]. A few high density livestock areas exist within the recharge area of Tumbling Creek Cave. Such areas may be a source of concentrated levels of different chemicals used to treat livestock (including insecticides, antibiotics, hormones, etc.) and areas where high levels of livestock feces and urine provide unusually high amounts of nitrogen. Such areas should be appropriately managed to reduce or eliminate waste products and other contaminants from entering into the watershed of Tumbling Creek Cave.

2.2 Reduce potential sources of siltation and mineral by products on private land through beneficial land management practices and enrollment in landowner incentive programs. Erosion control through various land restoration efforts and beneficial management practices may be realized by encouraging private land owners to voluntarily enroll in various land management agreements. Such agreements should be done in consultation with the Tumbling Creek Cavesnail Work Group and Partnership, the Service's Ecological Services and Partners for Fish and Wildlife programs, NRCS, and MDC's Private Lands Division. Potential sources of contamination, especially related to soil deposition related to erosion control problems, can be reduced through the voluntary enrollment of private landowners into different landowner incentive programs available through different Federal agencies.

2.2.1 Continue to restore, rehabilitate, and revegetate riparian corridors and stream ravines with various restoration practices. Continued restoration efforts will be necessary to halt soil deposition that originates from erosion problems within the cave's recharge area. Such actions will be best achieved by revegetating exposed soil with the planting of native species, especially along riparian corridors and stream ravines. Cedar tree revetments have been useful in reducing erosion problems on one property within the recharge area of Tumbling Creek Cave. This and other techniques help stabilize or restore riparian zones and eliminate potential sources of soil deposition. Such programs should be encouraged through the Service's Ecological Services and Partners

for Fish and Wildlife programs, NRCS, and MDC's Private Lands Division.

2.2.2 Recommend improved livestock grazing systems and practices. Overgrazing has been identified as a major contributing factor to erosion problems within the recharge area of Tumbling Creek Cave (Tom and Cathy Aley, in litt., March 29, 2002). Improved stocking rates through efficient grazing systems and practices on private and U.S. Forest Service land will be helpful in reducing soil erosion problems. Grazing systems and practices should be done in consultation with personnel of the U.S. Forest Service, NRCS, and MDC's Private Lands Division.

2.2.3 Recommend alternative water sources to keep livestock out of losing streams. Various government land owner incentive programs are available that allow for the construction of alternative water sources and fencing opportunities to restrain livestock from occupying losing stream channels or sinkholes.

2.2.4 Develop management guidelines for the extraction of minerals (i.e., lead, zinc), oil, and gas on private land within the recharge area of Tumbling Creek Cave. *Antrobia culveri* could be adversely impacted when waste by-products associated with mining of different minerals or the extraction of oil and gas reserves are deposited in areas that drain into Tumbling Creek. In some cases, private property mineral rights are owned by an individual/s different than the primary owner. Potential impact to the Tumbling Creek cavesnail can be minimized by following good mining guidelines or extraction procedures outlined for the removal of gas and oil reserves.

2.2.5 Encourage the voluntary enrollment of private land owners into landowner incentive programs that promote good land use practices. Numerous landowner incentive programs are available to private land owners through such programs as the Service's Partners for Fish and Wildlife and Safe Harbor Programs; as well as various private land owner incentive programs, including FSA's, CRP Program and NRCS's Forestry Incentives Program (FIP),Wetlands Reserve Program (WRP), Environmental Equality Incentives Program (EQIP), and Wildlife Habitat Incentives Program (WHIP). These programs not only provide government cost share opportunities but also provide recommendations for best management practices that will benefit the Tumbling Creek cavesnail.

2.3 Protect land through land acquisition (i.e., land is available and there are willing sellers), and/or long term conservation agreements or easements when possible. Land protection may be possible through various land acquisition funds (e.g., the Service's Recovery Land Acquisition Funds) or through the voluntary enrollment of private landowners in long term conservation agreements or easements. Land acquisition will only be possible when there is a willing seller and funds are available. Conservation agreements or easements should be developed in consultation with the Tumbling Creek Cavesnail Work Group and Partnership, the Service's Ecological Services and Partners for Fish and Wildlife programs, NRCS, and MDC's Private Lands Division.

2.4 Develop and implement maintenance and management guidelines to reduce the impact of highway activities within the recharge area for Tumbling Creek Cave. Portions of the recharge area of Tumbling Creek Cave are crossed by Rt. 125, Rt. 160, and multiple county roads. Silt deposition or chemicals associated with highway construction, improvements, or maintenance could runoff into Tumbling Creek. Accidents and potential accompanying spills may be influenced by maintenance and management actions taken within the highway right-of-ways. Guidelines that improve road and driving conditions may reduce the potential for accidents and accompanying spills. Road construction or improvement and maintenance plans may offset any potential impact to *Antrobia culveri*.

2.4.1 Partner with the Taney County Commission and the Missouri Department of Transportation, and the Missouri Department of Natural Resources in the development of an emergency contingency plan for potential highway spills. To be prepared for a potential spill along the above-mentioned roads, an emergency contingency plan should be developed and made available for implementation. A spill response team should be established and operational protocols developed.

2.4.2 Partner with the Taney County Commission and the Missouri Department of Transportation in the possible hard surfacing of Wolf Road to decrease sediment load in the area. Wolf Road is the only county road within the recharge area of Tumbling Creek Cave that has a soil and gravel base and therefore could be a source of sediment deposition within the recharge area for Tumbling Creek Cave. The paving of Wolf Road would help decrease the sediment load in the area.

2.4.3 Partner with Taney County Commission and the Missouri Department of Transportation in developing maintenance and

management activity guidelines (e.g., shoulder work, revegetation efforts) for all roads within the recharge area of Tumbling Creek Cave.

2.4.4 Partner with Taney County Commission and the Missouri Department of Transportation in developing a plan for the application of herbicides and ice and snow treatment chemicals for all roads within the recharge area of Tumbling Creek Cave. Chemicals used for weed control and the treatment of ice and snow could adversely affect the water quality of Tumbling Creek. Such potential impacts could be reduced by developing a plan that outlines highway maintenance activities that minimizes possible runoff into Tumbling Creek.

2.4.5 Partner with Taney County Commission and the Missouri Department of Transportation in developing a construction, maintenance and management plan for all new roads and realignments within the recharge area of Tumbling Creek Cave. Given the relative close proximity of Tumbling Creek Cave to Branson, Missouri, it is likely that areas within the cave's recharge area will witness an increase in development in the near future. To meet the demand, it is likely that existing State highways (i.e., Rts. 125 and 160) will be upgraded or new roads constructed. Such constructions activities would increase the likelihood of sediment deposition or potential contamination from chemicals used in maintenance activities (see recovery action number 2.4.4 above). To minimize any potential impact to the Tumbling Creek cavesnail, this species should be incorporated into all highway construction and improvement project plans.

2.4.6 Identify other tertiary (i.e., dirt or gravel) roads within the recharge area of Tumbling Creek Cave that may be a source of soil deposition due to erosion problems. Some private roads within the recharge area of Tumbling Creek Cave that are not properly managed or maintained may be erodible and thus a potential source of soil deposition. Private roads subject to erosion should be identified and best management practices established to reduce soil deposition. Management guidelines should be recommended through consultation between private landowners and NRCS, or MDC's Private Lands Division. Erosion control and reduction could be accomplished through numerous landowner incentive programs are available to private land owners through such programs as the Service's Partners for Fish and Wildlife and Private Land Owner Incentive programs, FSA's, CRP Program and NRCS's Forestry Incentives Program (FIP),Wetlands Reserve

Program (WRP), Environmental Equality Incentives Program (EQIP), and Wildlife Habitat Incentives Program (WHIP) programs**.**

2.5 Implement applicable standards and guidelines on National Forest lands for timber harvest, range management, glade and savannah restoration, and prescribed fire within the recharge area of Tumbling Creek cave; ensure that any special use permits authorized within the recharge area include provisions for protection of water quality. Approximately 23% of the recharge area of Tumbling Creek Cave is within the Ava/Cassville District of the U.S. Forest Service's Mark Twain National Forest. Standards and guidelines applicable to timber harvest, glade, savanna, and range management (USDA Forest Service 1986) that may benefit the Tumbling Creek cavesnail by improving water quality and reducing the potential for soil erosion are being incorporated into the revised Land and Resource Management Plan (Forest Plan) (Ronnie Raum, in litt., Aug. 7, 2003). Such beneficial standards and guidelines will contribute to the Forest Service's responsibility to develop a conservation program for the species under Sections 2(c)(l) and 7(a)(1) of the Act (see action 2.7 below).

2.5.1 Where appropriate and logistically feasible, recommend that the Forest Service establish a demonstration area that will highlight proper grazing techniques and riparian zone management. The Tumbling Creek cavesnail will benefit from best management practices involving livestock grazing and the maintenance of riparian corridors. Demonstration areas established on Forest Service land that follow best management principles can be used as models to inform private land owners on what techniques and practices can be performed to meet stated objectives while providing positive benefits to *Antrobia culveri*.

2.5.2 In consultation with the U.S. Fish and Wildlife Service (Fish and Wildlife Service), review grazing permits and any associated management plans outlining grazing-system practices. A few grazing permits are issued annually to individuals by the FS for livestock on Forest Service land. Such permits should be reviewed by the Service's Columbia, Missouri Ecological Services Field Office to ensure that grazing densities do not become high enough to cause overgrazing problems that could result in sediment deposition within the recharge area of Tumbling Creek Cave. Additionally, stocking rates should be regularly monitored through field investigations to determine if grazing levels are adequate to prevent soil movement or resource damage.

2.5.3 Provide and distribute FS recommended grazing-system practices to other agencies and individuals as needed. Different agency personnel and individuals may benefit from a demonstration of good grazing-system practices being employed on Forest Service units. Such examples of efficient grazing practices should be provided and made available to interested parties through field instruction or appropriate literature.

2.5.4 Implement fire management and wildlife control activities on National Forest lands within the recharge area that reduce or minimize the potential for soil movement, while placing top priority on public and firefighter safety. Steps need to be taken to ensure that standards and guidelines developed for prescribed burning and glade/savanna restoration in the revised Mark Twain National Forest Land and Resource Management Plan (Forest Plan) include provisions for protection of water quality within the recharge area of Tumbling Creek Cave. Such standards and guidelines should be developed through 2(c)(1) and 7(a)(1) consultation with the Fish and Wildlife Service.

2.6 Initiate Geographic Information System (GIS) studies on land use practices within the recharge area of Tumbling Creek Cave. GIS can be used to identify landownership and to investigate various landscape related projects by analyzing 7.5' topographic quadrangles and aerial photographs. The location of various cover types, intermittent and losing streams, potential contaminant sites, areas of severe erosion, and areas requiring special management can be mapped using GIS equipment.

2.6.1 Create different layers (e.g., soil, land-use practices, land ownership location of streams and sinkholes, etc.) within the recharge area of Tumbling Creek Cave. Analysis of different ownerships, land-use practices, location of streams, sinkholes, and possible sources of contamination (e.g., trash dumps, abandoned buildings, vehicles, and equipment, etc.) will be helpful in identifying priority areas for improvement management or cleanup where necessary. Such areas can be identified as different data layers using GIS software.

2.6.2 Determine relationships of land use practices on water quality in the recharge area of Tumbling Creek Cave using GIS technology. GIS technology would be a useful tool when attempting to determine what activities within the recharge area of Tumbling Creek Cave may adversely impact the water quality of the cave stream. This tool could be used to identify potential sources of contamination, riparian corridors with erosion problems,

overgrazed fields, or areas that could benefit from various restoration and rehabilitation programs.

2.7 In consultation with the Service and the Tumbling Creek Cavesnail Work Group and Partnership, encourage the development and implementation of management plans for all Federal agencies with jurisdictional responsibilities within the recharge area of Tumbling Creek Cave as part of their responsibility under Sections 2(c)(l) and 7(a)(1) to contribute to the recovery of all federally listed species [i.e., Environmental Protection Agency (EPA), Federal Highways Administration (FHWA), NRCS, USACE, USFS]. Under Sections 2(c)(l) and 7(a)(1) of the Act, it was the intent of the U.S. Congress that all Federal agencies who have federally listed species under their jurisdictional and management authorities, carry out programs for the conservation of such species. A written management plan outlining actions that will benefit the Tumbling Creek cavesnail will enable each Federal agency listed above to contribute to their responsibilities under these sections of the Act. Such management plans should be done in consultation with the Service and the Tumbling Creek Cavesnail Work Group and Partnership.

2.8 In consultation with the Service and the Tumbling Creek Cavesnail Work Group and Partnership, encourage utility companies with service obligations within the recharge area of Tumbling Creek Cave to develop a management plan for the construction and maintenance of right-of-way corridors involving pipelines, fiber optic cables and utility lines. The construction and maintenance of right-of-way corridors for different utility services within the recharge area of Tumbling Creek Cave could be pose a threat to *Antrobia culveri* if such activities include soil disturbance and the application of herbicides. Any potential impacts from construction and maintenance activities can be addressed through a management plan that outlines best management practices for such actions.

2.9 Evaluate potential reasonable and prudent alternatives/measures and accompanying terms and conditions where appropriate, developed during Sec. 7(a)(2) formal consultation between the Service and USACE involving the operation of Bull Shoals Reservoir, that will avoid or minimize the potential impact of any take of *Antrobia culveri* associated with reservoir operations. Any potential adverse effects that could not be removed through actions outlined in a management plan for the Tumbling Creek cavesnail would require formal consultation between the Service and the USACE. A resulting jeopardy biological opinion would likely provide reasonable and prudent alternatives that would preclude jeopardy. The impact of any incidental take associated with a jeopardy or no jeopardy biological opinion would be minimized through reasonable and prudent measures and associated terms and conditions

provided.

2.10 Develop programs for the removal and disposal of feral hogs within the recharge area of Tumbling Creek Cave. Feral hogs are increasingly becoming a problem in the southern Missouri Ozarks. Despite ongoing control efforts in some areas such as the Mark Twain National Forest, these animals are continuing to expand their range into new areas where they cause significant disturbance to the soil and plant communities. Continued soil disturbance can become a source of significant silt deposition into sinkholes, losing streams and riparian corridors that drain into Tumbling Creek. Feral hogs have recently been discovered on Forest Service and private land within the recharge area of Tumbling Creek (Tom Aley, pers. commun., April 23, 2003) and steps should be initiated to eliminate these animals.

3. Monitor contaminants.

3.1 Conduct water quality monitoring of Tumbling Creek. Although the exact causes for the drastic decline in the numbers and distribution of *Antrobia culveri* in Tumbling Creek Cave is unknown, most researchers are convinced that the downslide is probably due to some unknown deterioration in the water quality of Tumbling Creek. Continual monitoring of the water quality of Tumbling Creek will be necessary before any potential causative agents can be identified.

3.1.1 Continue to collect and analyze water quality parameters. Water monitoring equipment was recently installed in Tumbling Creek. The equipment measures several water quality parameters (e.g., turbidity, pH, conductivity) that can be automatically down loaded into a computer. Data collection should continue and the data already collected should be analyzed.

3.1.2 Add and evaluate additional water quality parameters such as flow rate, dissolved oxygen, ammonia, coliform bacteria, fecal-coliform bacteria, suspended sediments, antibiotics, hormones, and other yet to be determined parameters. Currently, flow rate, water temperature, specific conductivity, turbidity, and dissolved oxygen are being monitored in Tumbling Creek. Additional water quality parameters are needed to expand the scope of identifying potential biological and chemical contamination in Tumbling Creek. An extensive study conducted by Kolpin et al. (2002) of 139 streams across 30 states, including Missouri, indicated that over 80 % of the streams revealed the presence of human and livestock antibiotics, human prescription and nonprescription drugs, steroid

compounds, and 30 different organic wastewater contaminants. Water quality sampling techniques may need to be further refined to possibly detect the presence of such contaminants in Tumbling Creek.

3.1.3 Monitor water quality of surface and subsurface waters within the recharge area of Tumbling Creek Cave. The monitoring of water sources within the recharge area of Tumbling Creek cave that is deposited into Tumbling Creek may pinpoint potential contamination and more accurately identify the source of such pollutants. This includes water sources separate from Tumbling Creek such as active and abandoned wells that could be contaminated with various pollutants.

3.2 Prioritize and conduct additional subsurface contaminant analyses. Additional studies other than monitoring the water quality in Tumbling Creek will be necessary to identify any biological or chemical contaminants that may adversely impact *Antrobia culveri*.

3.2.1 Analyze historical semi-permeable membrane device (SPMD) samples from Tumbling Creek Cave, and collect and analyze new SPMD samples. SPMD samples were taken from Tumbling Creek in 1994 and new collection bags were recently placed in the cave stream to further investigate the potential presence of various contaminants. Both collections need to be analyzed and compared to assess if there have been any changes in the levels of various contaminants and to determine if certain chemicals have been persistent.

3.2.2 Analyze sediments from Tumbling Creek for the presence of persistent contaminants that are not effectively sampled by SPMDs (e.g. toxic metals). Various contaminants present in sediments in Tumbling Creek could be leached into the water and negatively affect the Tumbling Creek cavesnail. Different analyses should be undertaken to identify any potential harmful biological or chemical agent in the soil.

3.2.3 Conduct additional analyses of bat guano. Clawson and Clark (1989), Clawson (1991) and Clark *et al.* (1982) have analyzed gray bat guano and documented the presence of various contaminants, including chemicals that can be persistent in the environment for several years. Additional analyses of gray bat guano from Tumbling Creek Cave may result in the detection of chemicals that could leach into Tumbling Creek and adversely affect *Antrobia culveri*.

3.2.4 Collect and analyze tissue samples of associated macroinvertebrates. Analysis of tissue samples of amphipods and isopods that occupy the same habitat as Tumbling Creek cavesnail may reveal the presence of various biological or chemical contaminants. Studies using such surrogates may be helpful in determining if *Antrobia culveri* is exposed to the same contaminants.

3.2.5 Conduct toxicity tests with contaminants of concern (based on water quality monitoring and analyses of SPMDs, sediments, guano, and tissue samples) using subterranean, surrogate hydrobiid species such as *Fontigens* spp. and *Antroselates* spp. Studies need to be initiated that evaluate the susceptibility of *Antrobia culveri* and other aquatic macroinvertebrates to pollutants that are identified by water quality monitoring and analyses of SPMDs and sediments. Toxicity tests should be conducting using a common surrogate hydrobiid species of aquatic snail such as *Fontigens* sp. or *Antroselates* sp. Results of such tests may help identify possible reasons for the sudden decline in cavesnail numbers.

3.2.6 Investigate potential impact of nutrient enrichment (eutrophication) from livestock wastes or fertilizers on the water quality of Tumbling Creek. Although *Antrobia culveri* is apparently dependent upon energy input from bat guano in Tumbling Creek, too much nitrogen and other trace elements found in livestock wastes at concentration points (e.g., livestock feedlots) and fertilizers used for crop production and pasture improvement could adversely affect Tumbling Creek. Nutrient enrichment should be monitored and done in conjunction with the collection of other water quality monitoring data. What impacts this additional nutrient source has on the ecosystem of Tumbling Creek should be further investigated.

3.2.7 Monitor Tumbling Creek for the potential presence of *Acinetobacter* sp. bacterium and water molds, especially of the genus *Saprolegnia*. Tumbling Creek should be monitored for the presence of the *Acinetobacter* sp. bacterium and species of the water mold genus *Saprolegnia* that have been found to be harmful other aquatic organisms. If such organisms are found to exist within Tumbling Creek, tests should be initiated to determine if such organisms are harmful to *Antrobia culveri*. Initial studies could examine the potential impact of the *Acinetobacteri sp.* bacterium and *Spaprolegnia* spp. on such surrogate hydrobiid

species of snails as *Fontigens* spp. or *Antroselates* spp.

3.3 Conduct surface contaminant analyses. The population decline of *Antrobia culveri* may be related to contaminants from surface areas within the recharge zone of Tumbling Creek Cave. Recent clean up operations on properties newly acquired by Tom and Cathy Aley revealed various sources of contamination (e.g., junk metal, wood refuse from abandoned farm houses, buried dead cattle, partially decayed creosote treated railroad ties) that were previously unknown (Tom and Cathy Aley, in litt., March 29, 2002). Such sites should be analyzed for potential chemicals that could leach into losing streams that eventually drain into Tumbling Creek.

3.3.1 Identify potential sources of contaminants (e.g., trash dumps, buried containers of toxic chemicals, etc.). Other unidentified sources of contaminants may be discovered during land cleanup and restoration efforts. Such sites should be located on maps, scheduled for cleanup, and disposed of following various waste disposal guidelines, especially if they contain hazardous materials.

3.3.2 Analyze contaminants in water (with SPMDs) and sediments of surface waters in the recharge area as needed to identify sources of contaminants of concern (based on water quality monitoring and analyses of SPMDs, sediments, guano, and tissue samples). Sediments of losing streams that drain into Tumbling Creek should be analyzed for various chemicals, especially persistent organochlorines, polynuclear aromatic hydrocarbons (PAHs), and toxic metals.

3.3.3 Evaluate potential spills and impacts of current road maintenance of roads crossing the recharge area of Tumbling Creek Cave including the impact of the application of salt. Various chemicals applied to roads during ice and snow events may leach into losing streams or sinkholes that drain into Tumbling Creek. Studies need to be initiated to determine if such chemicals may adversely affect the Tumbling Creek cavesnail.

3.3.4 Evaluate the potential impact of the toxins present in various species of endophytic fungi associated with non-native pasture grasses. Different species of endophytic fungi are associated with non-native pasture grasses that are commonly planted in Missouri for forage [e.g., the endophytic fungus *Neotyphodium coenophialum* is commonly associated with the KY31 variety of tall fescue (*Festuca arundinacea*) (Cook and Lewis 2001)]. Although toxins associated with these fungi are known to adversely affect different species of terrestrial invertebrates, there is apparently no

information available on the potential impact of such chemicals to aquatic invertebrates. Given that large number of acres of non-native pasture grasses within the recharge area of Tumbling Creek Cave, the potential impact of these toxins to *Antrobia culveri* could potentially be significant and requires substantial study.

4. Collect biological and ecological data related to *Antrobia culveri*.

4.1 Conduct research on *A. culveri*. Much of the life history requirements for Tumbling Creek cavesnail are unknown. The lack of information on various life stages of this species prevents the refinement of recovery criteria and precludes our ability to fully understand the limiting factors for *Antrobia culveri* and the reasons population numbers declined so drastically.

4.1.1 Monitor cave snail numbers at the rate of twice/year. Biannual surveys on cavesnail numbers are necessary to assess changes in population numbers and to evaluate the effectiveness of land restoration efforts to surface habitats within the recharge area of Tumbling Creek Cave. More frequently conducted surveys are currently not recommended in order to minimize any potential impact from researchers performing cavesnail counts.

4.1.2 Conduct life history ecology studies including movements and microhabitat requirements. Although Greenlee (1974) and Ashley (2000, 2001a, 2001b, 2001c, 2002, 2003) have provided some preliminary information on the life history ecology of this species, further studies are needed that help identify habitat preferences and movements. It is suspected that cavesnails become detached from the underside of rocks during high water events where they are swept downstream in the water current. If so, it is not known how long it takes for reattachment to suitable habitat or if the species is completely washed from the cave system. The influence of silt on cavesnail movements also needs to be investigated. The use of drift or plankton nets may be helpful in studying the drift of cavesnails over time and should be included in research studies aimed at assessing cavesnail movements.

4.1.3 Conduct studies on reproductive behavior. Nothing is known regarding the mating habits, fecundity, timing or recruitment of this species. Additionally, it is not known whether *Antrobia culveri* is a live bearer or an egg layer. Information on the breeding ecology of this species will be essential to the success of propagation efforts. The use of drift or plankton nets may be useful in capturing young cavesnails that are dislodged from rock surfaces and adrift in the

water column of the cave stream.

4.1.4 Conduct food habit studies. Analyses of the intestinal tract of Tumbling Creek cavesnail will contribute to our understanding regarding what this animal eats. Greenlee (1974) postulated that *Antrobia culveri* feeds on various aquatic microfauna/biofilm but to date no microscopic analyses have been conducted.

4.1.5 Conduct population viability analysis (PVA). A computer generated PVA is needed to assess the likelihood of persistence of this species. Additional information on basic life history parameters (e.g., birth rate, life span, mortality rate, etc.), however, will be necessary before such an analysis can be performed (see taks 4.1.1 above).

4.1.6 Establish physiological parameters. Different aspects of the physiology of the Tumbling Creek cavesnail are unknown. Knowledge of the physiology (e.g., respiration rate, oxygen consumption) of *Antrobia culveri* will help facilitate controlled propagation experiments and contribute to an understanding of the species' limiting factors.

4.2 Survey and monitor aquatic macroinverebrates and obtain population estimates on species associated with Tumbling Creek cavesnail. Monitoring the number of associated macroinvertebrates may be useful is assessing the overall health of Tumbling Creek. Ashley (e.g., 2000) established a methodology to regularly monitor numbers of isopods and amphipods within the survey area of Tumbling Creek while conducting surveys for Tumbling Creek cavesnail. These monitoring efforts should continue. Ashley (pers. commun., September 10, 2001) also reported an exponential increase in numbers of limpets (*Ferrissia* sp.) during a survey of August 31, 2001 (McKenzie, in litt. September 10, 2001). Following a subsequent, significant rain event during mid-March 2002, few limpets were observed during the March 23, 2002 survey (McKenzie, in litt. March 25, 2002), and the species has apparently not rebounded to levels that were observed August 31, 2001 (Ashley 2003). Nonetheless, numbers of limpets should continue to be monitored. Changes in abundance of limpets may signal underlying water quality problems that would favor this species over *Antrobia culveri.*

4.3 Examine the relationship of bat guano to the energy flow in cave systems. Multiple authors (Greenlee 1974; Thomas Aley, in litt. 1978; Cecil Andrus, USDI, in litt. 1980) have commented on the importance of bat guano as an energy source in cave systems. Others (reviewed in Taylor and Webb 2000), however have demonstrated that organic pollution in

some cave systems may actually result in the extirpation of various cave-adapted aquatic invertebrates. The relationship of gray bat guano to the energy cycle in Tumbling Creek Cave needs scientific scrutiny.

4.3.1 Investigate a surrogate species in another cave that has a source of bat guano. To minimize potential impact to *Antrobia culveri*, especially when numbers of the species are critically low, the relationship of bat guano to a cave's energy flow should be first investigated at a surrogate cave that has an abundance of bats and aquatic invertebrates. Information gleaned from this study will enable researchers to better design a similar study in Tumbling Creek Cave.

4.3.2 Study bat guano in Tumbling Creek Cave and its relationship to the food habits of *Antrobia culveri*. The relationship of gray bat guano to the food habits of Tumbling Creek cavesnail needs to be examined. It is believed that bat guano is a main component of the food chain in Tumbling Creek but how it is transformed into food items available to the cavesnail is unknown.

4.4 Evaluate the effect of removing the barrel gate from the cave stream on numbers of bats using Tumbling Creek Cave. Although a study needs to be conducted to assess the relationship of bat guano to the energy flow in Tumbling Creek Cave (see 4.3.1-4.3.2 above), bats are important features of the cave's ecosystem. Access by bats to various portions of Tumbling Creek Cave must be accomplished by traversing a small, barrel gate constructed in 1968 approximately 0.36 km (~1,200 ft.) upstream of the natural cave exit. This gate was constructed to prevent trespass by humans into Tumbling Creek. Although the structure has been successful in preventing human trespass into portions of the cave, some have postulated that the gate may also partially hinder movement by bats, especially gray bats that use Tumbling Creek Cave as a major maternity site. One suggestion is to remove the barrel gate while installing other protection mechanisms. The effectiveness of replacing the current structure should be closely monitored to evaluate potential impacts to the gray bat.

4.4.1 Install new gate or protection mechanism that will hinder human trespass but allow for free movements of bats. Some type of protection mechanism will need to be installed once the existing barrel gate has been removed. This may involve another gate or the placement of light sensors or an alarm system at the cave's natural exit.

4.4.2 Conduct before and after estimates of bat numbers by a

qualified expert. Population estimates of gray bats should be taken before and after the current structure has been removed to assess the species response to gate removal. Estimates should be conducted by an expert experienced with the identification of gray bats.

4.4.3 Conduct before and after measurement on guano deposition. Differences in use of Tumbling Creek Cave before and after gate removal can also be evaluated by measuring guano deposition.

4.4.4 Monitor the effectiveness of installation of new gate or protection mechanism by evaluating effectiveness once every year for the first five years; once every two years thereafter. The effectiveness of any newly installed protection mechanism should be monitored to assess the response by gray bats. Monitoring of cave use by gray bats after installation should be conducted no less than once every year for the first five years and then once every two years thereafter. Modifications should be recommended if monitoring indicates that new protection mechanisms are ineffective in preventing human trespass or if it is documented that new structures hinder entrance or exit into the cave by gray bats.

5. Initiate educational and public outreach actions to heighten awareness of the Tumbling Creek Cavesnail and its important link to good water quality. Outreach to Federal and State congressionals, local schools and businesses, PTA groups, landowners within the recharge area of Tumbling Creek Cave, and other interested groups in the area will be an effective avenue to educate individuals on the Tumbling Creek cavesnail and the importance of appropriately managing surface land within the recharge area of this species.

5.1 Develop an outreach plan for *Antrobia culveri.* in consultation with the Tumbling Creek Cavesnail Work Group and Partnership, the Service's Region 3 Endangered Species Outreach Specialists, the Service's Region 3 Office of External Affairs, and MDC's Outreach and Education Department. An outreach plan will be helpful in identifying available outreach materials, outlining target audiences, and recognizing various sources of multimedia products useful in outreach.

5.2 Develop outreach materials (e.g., brochures, videos) on the Tumbling Creek cavesnail for general distribution to local schools, post offices, local businesses, governments, real estate offices, Taney (and surrounding) Soil and Water Conservation District offices, and other interested parties. Brochures should be developed that can be used for a diverse audience including Federal, State, and local governments, and private landowners. Materials should contain general information on the

cavesnail, reasons it was listed, good land-use practices, and the importance of good water quality in Tumbling Creek and other underground aquifers within the recharge area of Tumbling Creek Cave. Local organizations and businesses regularly Partner with area landowners and probably have the best pulse on interests and issues of communities within the recharge area of Tumbling Creek Cave.

5.3 Develop a joint letter among multiple agencies to distribute to land owners within the recharge area of Tumbling Creek Cave providing information on the species and management actions underway and proposed that will benefit the cavesnail and local water users. Despite the widespread readership of the *Missouri Conservationist* (see action 5.6 below), it may be difficult to contact some private land owners, local businesses, and other interested groups within the recharge area of Tumbling Creek Cave. One method in reaching these individuals would be through a letter that provides information on *Antrobia culveri*, management actions underway that will benefit the species, and a list of government landowner incentive programs available (see action 5.8 below). Such a letter would likely be most effective if it was written as a joint communique between multiple Federal and State agencies, and the OUL.

5.4 Develop and give presentations to local schools, PTA groups, and other interested groups. A power point presentation should be developed that includes information on *Antrobia culveri*, reasons for Federal listing, potential threats to the species, best management practices that may benefit the Tumbling Creek cavesnail, and the relationship of good water quality in Tumbling Creek to water from underground aquifers used by local residents. Copies of such a presentation could be made available to individuals asked to give talks to various interested parties.

5.5 Provide tours of cave and surrounding areas to local residents and schools. A better understanding on the importance of protecting *Antrobia culveri* and the recharge area of Tumbling Creek Cave may be obtained by providing local residents and schools with a tour of the cave and the surrounding landscape. A visual observation of proper land management techniques within the recharge area of Tumbling Creek Cave will hopefully encourage other land owners to implement best management practices that will benefit the cavesnail and themselves by improving the quality of underground aquifers.

5.6 Provide articles for local and regional newspapers, magazines (e.g., the *Missouri Conservationist*), and newsletters for electric cooperatives, etc. The *Missouri Conservationist* has one of the largest state wide readerships of any publication and can reach rural residents who do not have access to other sources of printed media. Due to a lack of understanding and

education on *Antrobia culveri*, numerous myths regarding land acquisition and restoration efforts by the owners of Tumbling Creek Cave, Tom and Cathy Aley, have been generated. A popular article published in the *Missouri Conservationist* may be helpful in dispelling such myths. Reprints from such an article should be made available for general distribution. To date, several newspaper articles have been written outlining the location, status, and threats to the species as well as highlighting the excellent partnerships that have developed between Federal and State agencies, universities, and private land owners. Additional newspaper articles and agency newsletters should be developed when opportunities are presented.

5.7 Meet with school instructors and administrators to propose the potential development of a program where schools can "adopt" the Tumbling Creek cavesnail as an endangered species. Interest in *Antrobia culveri* in local schools could be enhanced through the development of an "Adopt the Tumbling Creek Cavesnail" Program where various school projects focused on the importance of the species and the link between a healthy population of the Tumbling Creek cavesnail and good water quality.

5.8 Develop and distribute a handout on all available land owner cost share incentive programs. Numerous landowner incentive programs are available to private land owners through such programs as the Service's Partners for Fish and Wildlife and Private Land Owner Incentive programs; FSA's CRP program; and NRCS's WRP, FIP, EQIP, and WHIP programs, and the Recovery Land Acquisition Program. A short handout should be developed that outlines responsibilities of each program, funding availability, application procedures, and possible examples of successful agreements in place.

5.9 Distribute MDC outreach materials on caves and karst. The Missouri Department of Conservation has developed multiple outreach materials involving caves and karst ecosystems including: 1) a *"Just Kidding Around"* video on caves, 2) a *Missouri Conservationist* 's article "*Conserving Missouri's Caves and Karst*," 3) *"A Guide to Missouri Cave Life*," and other miscellaneous brochures and posters.

5.10 Distribute appropriate Service brochures on caves and karst. The Service has recently developed a brochure on the Ozark cavefish. This brochure highlights the importance of protecting fragile karst ecosystems and outlines the relationship between the proper management of caves and good water quality for cave organisms as well as humans. Similar Service brochures should be developed and made available to all interested parties.

5.11 Partner with regional and/or county extension agents in the development and distribution of outreach materials.

6. In consultation with the Tumbling Creek Cavesnail Work Group & Partnership, the Service, and all affected parties outlined in the Implementation Schedule below, shall develop a participation and implementation plan that will facilitate the timely recovery of the Tumbling Creek cavesnail while minimizing social and economic impacts. In the July 1, 1994 *Federal Register* (59 FR 34270), the Service and the National Marine Fisheries Service issued a joint interagency cooperative policy on recovery plan participation and implementation under the Act. This policy highlights the importance of cooperation and participation among all affected parties in the development and implementation of recovery plans and how such cooperation can reduce any potential social or economic impacts. The excellent partnership that has evolved during the preparation of this plan should be expanded during the implementation of the recovery actions outlined herein.

7. Conduct regular reviews. Under Sections 4 (c)(2)(A) & (B) of the Act, the Service is required to conduct regular reviews of all federally-listed species to determine if such species should 1) be removed from the list, 2) be changed in status form an endangered species to a threatened species, or 3) be changed in status from a threatened species to an endangered species.

7.1 Evaluate status of species. The Service shall, in consultation with the Tumbling Creek Cavesnail Work Group and Partnership, regularly evaluate the status of *Antrobia culveri*. This examination will include an assessment on the overall distribution and population trends of the Tumbling Creek cavesnail, an appraisal of the surface land areas within the recharge areas of Tumbling Creek Cave, and an evaluation of the health of Tumbling Creek.

7.2 Reassess listing criteria. Listing criteria identified in the Service's final rule of August 14, 2002 (67 FR 52879) will be reevaluated on a regular basis to determine if the issues and threats outlined in that determination are still applicable to *Antrobia culveri*.

7.3 Refine and revise downlisting and delisting criteria, as necessary. The downlisting and delisting criteria outlined in this recovery plan will be assessed to determine if the species warrants reclassification. A summary will be provided that outlines what percentage of recovery objectives outlined in the recovery plan have been accomplished.

7.4 Revise recovery plan as needed. As new information becomes available on the species, recovery objectives will be revised accordingly. Minor changes to the recovery plan would necessitate an update to the document while any major changes would require a revision (U.S. Fish and Wildlife

Service 1990). A revision to the recovery plan would address: 1) any new data collected on *Antrobia culveri*, 2) any necessary refinement to the reclassification and delisting criteria, and 3) the status of the Tumbling Creek Cavesnail Recovery Participation and Implementation Plan.

7.5 Evaluate success of management plans and conservation programs and assess their contribution to the recovery of the species. The status of all management plans and conservation programs developed by Federal agencies in consultation with the Service under Sections 2(c)(1) and 7(a)(1) of the Act should be evaluated to assess their overall contribution to the recovery of *Antrobia culveri*.

8. In consultation with the Tumbling Creek Cavesnail Work Group & Partnership, the Service shall develop a post-delisting monitoring plan to monitor continued recovery of *Antrobia culveri* once the species has met the delisting criteria listed above. Steps need to be taken to continue to monitor the recovery of *Antrobia culveri* once the delisting criteria listed above have been met. A post-delisting monitoring plan will be written to gauge the ongoing recovery of the species. The monitoring plan will include recommended survey protocol, the number and timing of surveys, potential contractors, and estimated cost.

PART III. IMPLEMENTATION SCHEDULE

The implementation schedule that follows lists the actions and estimated costs for the recovery program for the Tumbling Creek cavesnail. It is a guide for meeting the recovery goals outlined in this plan. Potential partners with authority or expressed interest to implement a specific recovery action are identified in the Implementation Schedule. The listing of a potential partner in the Implementation Schedule does not require, nor imply a requirement, that the identified entity has agreed to implement the action(s) or to secure funding for implementing the action(s). However, potential partners willing to participate on a volunteer basis may benefit by being able to identify in their own budgets, that their funding request is for a recovery action outlined in an approved recovery plan, and therefore contributes to the recovery of the Tumbling Creek cavesnail. Additionally, proposals submitted by willing private land owners through various land owner incentive programs are generally ranked higher and have a greater opportunity of being funded if proposed actions benefit a federally listed species.

The implementation schedule outlines action priorities, action numbers, action descriptions, duration of actions, potential partners, and estimated costs to fulfill the recovery objective outlined in part II of this plan. These actions, when accomplished, should bring about the recovery of the Tumbling Creek cavesnail and protect its essential habitat. The estimated funding needs for all parties anticipated to be involved in recovery are identified. The estimate recovery cost for the 20 year program is $2,174,000.00.

The costs presented are the estimates of the potential partners of the plan and the Service, based on experience with costs of similar work. They are not based on budgets prepared for individual sub-actions. Actual costs may be higher or lower than costs indicated in the implementation schedule.

Recovery actions for the Tumbling Creek cavesnail are outlined in multiple priority levels defined as follows:

Priority 1. An action *must* be taken to prevent extinction or to prevent the species from declining irreversibly in the *foreseeable* future.

Priority 2. An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3. All other actions necessary to meet the recovery objectives.

Action numbers are taken from the recovery step-down outline and narrative. The acronyms of the potential partners for implementation are listed below.

ECCOM	Eastern County Commission (Taney County)
FSA	Farm Services Administration
JLABC	J. Lewis & Assoc. Biological Consulting

MDNR	Missouri Department of Natural Resources
MDC	Missouri Department of Conservation
MODOT	Missouri Department of Transportation
MORAP	Missouri Resource Assessment Partnership
MWSC	Missouri Western State College
NFH	Neosho National Fish Hatchery
NRCS	National Resources Conservation Service
PFW	U.S. Fish and Wildlife's Partners for Fish & Wildlife Program
OUL	Ozark Underground Laboratory
SMS	Southwest Missouri State University
REA	Rural Electrification Administration
TBD	To Be Determined
TCSWCD	Taney County Soil and Water Conservation District
TCCWG&P	Tumbling Creek Cavesnail Work Group and Partnership
UMN	University of Minnesota
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USFS	U.S. Forest Service
USGS	U.S. Geological Survey

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
1	1.2.1	Develop propagation methodologies using surrogate species	1	FWS, MDC, OUL, NFH, USGS, TBD	20	10	10	-	-	-	
1	1.2.2	Develop a propagation plan for the species	1	FWS, MDC, OUL, TCCWG&P, USGS	5	-	5	-	-	-	
1	1.2.3	Conduct propagation studies using *Antrobia*	2	FWS, MDC, OUL, USGS	20	-	-	10	10	-	
1	2.1.1	Identify potential refuse sites and abandoned homesteads within recharge area	1	FWS, MDC, MORAP, OUL, TCSWCD, TCCWG&P, USGS	10	-	-	-	-	-	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
1	2.1.2	Continue cleanup of refuse sites within the recharge area of Tumbling Creek Cave	5	MDNR, OUL, TBD, TCSWCD, USEPA	75	15	15	15	15	15	
1	2.1.3	Continue cleanup of abandoned homesteads within the recharge area of Tumbling Creek Cave	5	MDNR, OUL, TBD, TCSWCD, USEPA	75	15	15	15	15	15	
1	2.1.4	Improve human sewage treatment disposal facilities and proper abandonment of unused wells	5	MDNR, TBD, TCSWCD, USEPA	100	20	20	20	20	20	
1	2.1.5	Improve waste treatment in areas with high density livestock	2	MDNR, NRCS, TCSWCD, USEPA	20	10	10	-	-	-	
1	2.2.1	Continue to restore & rehabilitate riparian corridors	2	MDC, NRCS, OUL, TCSWCD	30	15	15	-	-	-	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
1	3.1.1	Collect & analyze existing water quality parameters	20	OUL, SMS, USGS	220	30	10	10	10	160	
1	3.1.2	Collect & analyze additional water quality parameters	20	OUL, SMS, USGS	220	30	10	10	10	160	
1	3.1.3	Monitor water quality at other sites in recharge area	20	MDNR OUL, SMS, USGS	110	15	5	5	5	80	Done in coordination with USEPA
1	3.2.1	Analyze SMPD samples	1	OUL, USGS	10	10	-	-	-	-	
1	3.2.2	Evaluate sediments in Tumbling Creek	1	OUL, USGS	10	10	-	-	-	-	
1	3.2.3	Conduct additional analyses of bat guano	1	OUL, USGS	10	10	-	-	-	-	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
1	3.2.4	Collect and analyze tissue samples of macroinvertebrates	1	OUL, USGS	20	20	-	-	-	-	
1	3.3.1	Identify potential sources of contaminants	1	OUL, TCSWCD, USGS	10	10	-	-	-	-	
1	3.3.2	Evaluate sediments within stream valleys for potential contaminants	1	OUL, USGS	10	-	10	-	-	-	
1	4.1.1	Monitor cave snail numbers	ongoing	FWS, MDC, MWSC, OUL	100	5	5	5	5	80	
1	4.1.2	Conduct life history ecology studies	7	JLABC, MDC, MWSC, OUL	140	-	-	20	20	100	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
1	4.1.3	Conduct reproductive studies	3	JLABC, MDC, MWSC, OUL	60	-	-	20	20	20	
1	4.1.4	Conduct food habit studies	2	JLABC, MDC, MWSC, OUL	20	-	-	10	10	-	
1	4.1.6	Establish physiological parameters	3	JLABC, MDC, MWSC, OUL	60	-	-	20	20	20	
2	1.1.1	Conduct searches in adjacent caves	3	JLABC, MDC, MWSC, OUL	3	1	1	1	-	-	
2	1.1.2	Sample streams & wells with new techniques	3	JLABC, MDC, MWSC, OUL	6	2	2	2	-	-	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
2	1.1.3	Survey karst window	1	JLABC, MDC, MWSC, OUL	2	2	-	-	-	-	
2	2.2.2	Recommend improved livestock grazing systems & practices	2	MDC, NRCS, USFS	30	10	10	10	-	-	
2	2.2.3	Recommend alternative water sources for livestock	3	MDC, NRCS, PFW	30	10	10	10	-	-	
2	2.3	Protect land when possible through acquisition and/or conservation agreements/easements	ongoing	MDC, PFW, USFWS	TBD*	TBD	TBD	TBD	TBD	TBD	* First priority will be given to voluntary enrollment in long term conservation agreements or easements- see pages 41, 92

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
2	2.4.1	Partner with agencies to develop an emergency contingency plan for potential highway spills	2	ECCOM, MDNR, MODOT, TCCWG&P	5	2.5	2.5	-	-	-	To be done in conjunction with actions 2.4.3, 2.4.4, and 2.4.5
2	2.4.3	Partner with agencies to develop road maintenance and management activity guidelines	2	ECCOM, MODOT, TCCWG&P	5	2.5	2.5	-	-	-	To be done in conjunction with actions 2.4.1, 2.4.4, and 2.4.5
2	2.4.4	Partner with agencies to develop a plan for application of herbicides and other chemicals	2	ECCOM, MODOT, TCCWG&P	5	2.5	2.5	-	-	-	To be done in conjunction with action 2.4.1, 2.4.3, and 2.4.5
2	2.7	Encourage Federal agencies that have jurisdictional responsibilities within the recharge area to develop management plans for *Antrobia culveri*	1	REA, TCCWG&P, TBD	2.5	2.5	-	-	-	-	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
2	2.9	Initiate formal consultation between the USFWS and the USACE on the operation of Bull Shoals Reservoir	2	USACE, USFWS	4	2	2	-	-	-	
2	3.2.5	Conduct toxicity tests using surrogate species	2	OUL, USGS	30	10	20	-	-	-	
2	3.2.6	Investigate the potential impact of nutrient enrichment on Tumbling Creek	1	MDNR, OUL, USGS	20	20	-	-	-	-	
2	3.2.7	Monitor Tumbling Creek for *Acinetobacter* sp. bacterium & water molds	ongoing	MDNR, OUL, USGS	100	5	5	5	5	80	
2	3.3.3	Evaluate potential spills and impacts of current road maintenance of roads crossing recharge area	1	ECCOM, MODOT	5	5	-	-	-	-	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
2	4.1.5	Conduct PVA	1	UMN, TBD	10	-	-	10	-	-	
2	4.2	Survey associated macroinvertebrates	Ongoing	JLABC, MDC, MWSC, OUL,	-	-	-	-	-	-	To be done during survey for *Antrobia culveri* (action 1.4 above)
2	4.3.1	Investigate relationship of bat guano and energy flow using a surrogate species	5	JLABC, MDC, MWSC, OUL, USGS	25	5	5	5	5	5	
2	4.3.2	Study bat guano relationship to food habits of *Antrobia culveri*	5	JLABC, MDC, MWSC, OUL, USGS	25	5	5	5	5	5	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
2	4.4.1	Install new gate or protection mechanism	1	MDC, OUL, TBD	25	25	-	-	-	-	
2	4.4.2	Conduct before & after estimates of gray bats	2	MDC	4	2	-	2	-	-	
2	4.4.3	Conduct before and after measurements of bat guano	2	MDC, OUL	2	1	-	1	-	-	
2	4.4.4	Monitor new protection mechanism once every year for first 5 years; once every two years thereafter	ongoing	MDC, OUL	24	2	2	2	2	16	
2	5.1	Develop an outreach plan	1	MDC, USFWS	5	5	-	-	-	-	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
2	5.2	Develop and distribute outreach materials on the Tumbling Creek cavesnail	3	MDC, OUL, TCCWG&P, TCSWCD, USFWS	30	10	10	10	-	-	Development of materials will take 1-3 years but distribution will be ongoing
2	5.3	Develop joint letter among agencies outlining management actions for the Tumbling Creek cavesnail	1	MDC, OUL, TCCWG&P, USFWS	1	1	-	-	-	-	
2	5.4	Develop and give presentation to local schools and interested groups	1/ongoing	MDC, OUL, TCCWG&P, USFWS	2	2	-	-	-	-	Development of presentation will take one year- providing program will be ongoing
2	5.5	Provide tours of cave and surrounding areas to local residents and schools	ongoing	OUL	40	2	2	2	2	32	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
2	5.6	Provide articles for local and regional newspapers and magazines on the Tumbling Creek cavesnail	ongoing	MDC, OUL, TCCWG&P, USFWS, others yet to be identified	40	2	2	2	2	32	
2	5.7	Develop an "adopt" a cavesnail program for local schools	1/ongoing	MDC, OUL, TCCWG&P, USFWS	2	2	-	-	-	-	Development of program, will take one year- providing program will be ongoing
2	5.8	Develop and distribute a handout on available land owner incentive programs	1/ongoing	FSA, MDC, OUL, NRCS, TCSWCD,* USFWS	1	1	-	-	-	-	Development of program, will take one year- providing program will be ongoing; TCSWCD would likely assist in distributing handout

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
2	5.9	Distribute MDC brochures on caves and karst	ongoing	FSA, MDC, OUL, NRCS, TCSWCD, USFWS	1	1	-	-	-	-	Development of program, will take one year- providing program will be ongoing
2	5.10	Distribute Service brochures on caves and karst	ongoing	FSA, MDC, OUL, NRCS, TCSWCD, USFWS	1	1	-	-	-	-	Development of program, will take one year- providing program will be ongoing
2	5.11	Partner with regional and/or county extension agents in the development and distribution of outreach materials	ongoing	MDC, NRCS, TBD, TCSWCD	20	1	1	1	1	16	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
3	2.2.4	Develop management guidelines for extraction of minerals, gas, & oil	2	MDC MDNR, NRCS, OUL, TCCWG&P, USFWS	10	5	5	-	-	-	
3	2.2.5	Encourage the voluntary enrollment of private land owners into landowner incentive programs	ongoing	FSA, MDC, NRCS, TCSWCD, PWF	100	5	5	5	5	80	
3	2.4.2	Partner with agencies to hard surface Wolf Road	1	ECCOM, MODOT	50	50	-	-	-	-	
3	2.4.5	Partner with agencies to develop a plan for new roads and road realignments	2	ECCOM, MODOT, TCCWG&P	5	2.5	2.5	-	-	-	To be done in conjunction with actions 2,4.1, 2.4.3, and 2.4.4

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
3	2.4.6	Identify tertiary roads that may be a source of soil deposition	2	MDC, OUL, TCCWG&P	5	2.5	2.5	-	-	-	
3	2.5.1	Encourage the FS to develop a proper grazing demonstration area	1	NRCS, TCCWG&P, USFS, USFWS	10	10	-	-	-	-	
3	2.5.2	Review FS grazing plans	ongoing	USFWS	50	2.5	2.5	2.5	2.5	40	
3	2.5.3	Provide FS grazing guidelines to other agencies	ongoing	FSA, MDC, NRCS, USFS	100	5	5	5	5	80	
3	2.5.4	Review fire management and wildlife control activities on USFS land	ongoing	USFWS	50	2.5	2.5	2.5	2.5	40	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
3	2.6.1	Create GIS layers for land ownership and various activities within the cave's recharge area	3	MORAP, OUL, USGS	60	20	20	20	-	-	
3	2.6.2	Determine relationships of land use practices on water quality using GIS technology	2	MORAP, OUL, USGS	25	20	5	-	-	-	
3	2.8	Encourage utility companies to develop management plans for *Antrobia culveri*	2	REA, TCCWG&P, TBD	2.5	2.5	-	-	-	-	
3	2.10	Develop programs for the removal & disposal of feral hogs within the recharge area of Tumbling Creek Cave	3	MDC, OUL, TBD, TCSWCD, USFWS	1.5	0.5	0.5	0.5	-	-	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
3	3.3.4	Evaluate the potential impact of toxins from endophytic fungi on *Antrobia culveri*	2	SMS, USGS	30	15	15	-	-	-	
3	6	Develop a participation and implementation plan to facilitate recovery of the Tumbling Creek cavesnail	1	MDC, OUL, TCCWG&P, USFWS	5	5	-	-	-	-	
3	7.1	Regularly evaluate status of species	ongoing	MDC, OUL, TCCWG&P, USFWS	20	1	1	1	1	16	
3	7.2	Reassess listing criteria	ongoing	MDC, OUL, TCCWG&P, USFWS	20	1	1	1	1	16	

Table 3. Implementation Schedule for the Tumbling Creek Cavesnail Recovery Plan (cont.)

Priority Number	Action Number	Action Description	Action Duration (Years)	Potential Partners	Total Cost ($1,000's)	Cost Estimates ($1000's)					Comments
						Year 1	Year 2	Year 3	Year 4	Year 5-20	
3	7.3	Refine downlisting & delisting criteria as needed	ongoing	MDC, OUL, TCCWG&P, USFWS	20	1	1	1	1	16	
3	7.4	Revise recovery plan as needed	ongoing	MDC, OUL, TCCWG&P, USFWS	TBD	TBD	TBD	TBD	TBD	TBD	
3	7.5	Evaluate success of management plans and conservation programs	ongoing	MDC, OUL, TCCWG&P, USFWS	20	1	1	1	1	16	
3	8	Develop a post-delisting monitoring plan	1	MDC, OUL, TCCWG&P, USFWS	5	-	-	-	-	5	Development will take only 1 year but implementation will take a minimum of 5 years

PART IV. LITERATURE CITED

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Appendix 1. Relationship of Listing Factors and Threats to Recovery Criteria, and Related Action Numbers Outlined in the Tumbling Creek Cavesnail Recovery Plan.

Listing Factor	Threat (Known & Postulated)	Recovery Criteria	Action Numbers Identified to Address Threat
A	Siltation due to erosion problems within the cave's recharge area; habitat degradation adversely affecting the water quality of Tumbling Creek	1, 2, 3	Protect or manage surface habitat; develop and implement maintenance and management guidelines; (Actions 2.1.1-2.10; 5.1-5.11)
A	Contaminants	2, 3	Monitor contaminants (Actions 3.1.1-3.3.4)
A	Nutrient enrichment	2, 3	Monitor nutrient enrichment of Tumbling Creek from livestock operations within the cave's recharge area (Action 3.2.6)
C	Impact of bacteria, water mold, or endophytic fungi	1	Monitor Tumbling Creek for potential presence of *Acinetobacter* bacteria and different species of water molds; monitor cavesnail numbers (Action 3.2.7, 4.1.1)
C	Interspecific competition from limpets and other macroinvertebrates	1	Survey and monitor aquatic invertebrates and obtain population estimates on species associated with Tumbling Creek cavesnail; monitor cavesnail numbers (Actions 4.1.1, 4.2)
D	State and Federal laws (other than ESA) do no provide adequate protection of habitat and much of the recharge area for Tumbling Creek Cave is under private ownership	2	Protect land through land acquisition, long-term conservation agreements, or long-term management plans (Actions 2.3, 2.6-2.8, 7.5)

Appendix 1. Relationship of Listing Factors and Threats to Recovery Criteria, and Related Action Numbers Outlined in the Tumbling Creek Cavesnail Recovery Plan (cont.).

Listing Factor	Threat (Known & Postulated)	Recovery Criteria	Action Numbers Identified to Address Threat
E	Improper balance of food chain and Energy input of gray bats	1, 3	Examine the relationship of bat guano to the energy flow in cave systems and evaluate the effect of removing the barrel gate from the cave stream on numbers of bats using Tumbling Creek Cave (Actions 4.3.1-4.4.4)
E	Small population size and restricted range	1	Stabilize or increase the population; conduct research on *Antrobia culveri* (Actions 1.1.1-1.1.3,1.2.1-1.2.3,4.1.1, 4.1.6. 5.1-5.11, 7.1)

Listing Factors:
A. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range
B. Overutilization for Commercial, Recreational, Scientific, Educational Purposes (Not applicable in this species- see Part 1, Introduction)
C. Disease or Predation
D. The Inadequacy of Existing Regulatory Mechanisms
E. Other Natural or Manmade Factors Affecting Its Continued Existence

Recovery Criteria:
The Tumbling Creek cavesnail will be considered for reclassification from endangered to threatened when the following criteria have been met: 1) the population is stable or increasing for 10 consecutive years with at least 1,500 individuals, 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, and 3) water quality monitoring fails to detect levels of any water pollutant that exceeds USEPA recommended water quality or exceed known toxicity thresholds for the species for 10 consecutive years.

The Tumbling Creek cavesnail will be considered for delisting when the following additional criteria have been achieved: 1) the population is stable or increasing for an additional 10 consecutive years with at least 5,000 individuals; 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, and 3) water quality monitoring fails to detect levels of any water pollutant that exceeds USEPA recommended water quality or exceed known toxicity thresholds for the species for 10 consecutive years.

Appendix 2. Summary of Comments on Draft Recovery Plan and U.S. Fish and Wildlife Service responses.

On July 11, 2003, the U.S. Fish and Wildlife Service (Service) released the Draft Recovery Plan for the Tumbling Creek cavesnail (*Antrobia culveri*), for a 30-day review and comment period ending on August 11, 2003. Availability of the plan was announced in the *Federal Register* (FR 68 41395) and via a news release to media contacts throughout Missouri.

In accordance with Service policy, requests for peer review of the draft plan were sent to two experts outside the Service. Additionally, the Service solicited peer review from two recognized cave experts within the agency. In particular these experts were asked the following questions: 1) does the recovery plan adequately present an ecologically and biologically defensible recovery strategy for the Tumbling Creek cavesnail?; 2) given the data currently available, as presented in the recovery plan, are the recovery criteria as outlined in plan sufficient to achieve reclassification and eventual delisting?; 3) are the proposed research, management, and public outreach actions appropriate and sufficient?; and 4) are the recovery actions presented in the plan's Implementation Schedule appropriately prioritized to facilitate Tumbling Creek cavesnail recovery? Requests for peer review were sent to the following individuals:

Dr. Christopher Barnhart, Southwest Missouri State University, Springfield, Missouri
Dr. Cary Chevalier, Missouri Western State College, St. Joseph, Missouri
Mr. Steve Hensley, Ozark Plateau National Wildlife Refuge, Tulsa, Oklahoma
Mr. David Kampwerth, U.S. Fish and Wildlife Service, Conway, Arkansas

The Service also solicited input and review from the following members of the Tumbling Creek Cavesnail Work Group and Partnership (a consortium of representatives from Federal and State governments and private individuals, including species experts, dedicated to the conservation and recovery of the Tumbling Creek cavesnail) who had provided input on early versions of the Draft Recovery Plan:

Tom and Cathy Aley, Ozark Underground Laboratory, Protem, Missouri
Dr. David Ashley, Missouri Western State College, St. Joseph, Missouri
Dr. John Besser, U.S. Geological Survey- Columbia Environmental Research Center, Columbia, Missouri
Bruce Caldwell, U.S. Army Corps of Engineers, Mountain Home, Arkansas
Theresa Davidson, U.S. Fish and Wildlife Service, Ava, Missouri
Dr. Bill Elliott, Missouri Department of Conservation, Jefferson City, Missouri
Peggy Horner, Missouri Department of Conservation, Columbia, Missouri
Dr. J. Julian Lewis, J. Lewis & Assoc. Biological Consulting, Clarksville, Indiana
Ron Oesch, Glendale, Missouri
Tricia Radford, Missouri Department of Conservation, Ozark, Missouri
Dwayne Rambo, U.S. Forest Service, Rolla, Missouri
Mike Slay, University of Arkansas, Gentry, Arkansas
Dr. Steve Taylor, Illinois Natural History Survey, Champaign, Illinois

Leslie Tewinkel, U.S. Fish and Wildlife Service, Fort Snelling, Minnesota

We also solicited input from Martha BalisLarsen, of the U.S. Fish and Wildlife Service in Arlington, Virginia, and Jody Eberly, U.S. Forest Service in Rolla, Missouri.

During the comment period, 94 copies of the Draft Recovery Plan were distributed to affected government agencies, organizations, and interested individuals. Included were two copies to individuals who requested copies after reading the notice of availability in the *Federal Register*.

The following letters were received: four from peer reviewers, two from representatives of Federal agencies, two from representatives of State agencies, and one from a private landowner.

Each letter contained one or more comments, with some respondents raising similar issues. Most letters requested explanation or clarification of points made in the plan and included suggestions for changes. Forty-eight comments were received that were either editorial or minor. The majority of these comments were incorporated into the approved recovery plan. Other comments were more substantive and included recommendations to delete or change recovery criteria, add or reword recovery actions, or change the priority number for recovery actions in the implementation schedule. Significant comments that were incorporated, not incorporated, or those that require further clarification are addressed below.

All letters and associated correspondence are on file at the U.S. Fish and Wildlife Service, 608 E. Cherry St.; Room 200, Columbia, Missouri 65201-7712.

Comments and Service Responses

- **Comment:** A few reviewers wanted the Service to provide justification for the target population numbers and estimated recovery period established for the reclassification and delisting criteria.

  Response: The Service agrees that our rationale for choosing these numbers should be clarified and we have provided the justification on page 30 of the final plan.

- **Comment:** Two reviewers were concerned with language in the draft recovery plan that identified timber harvest as being potentially harmful to the Tumbling Creek cavesnail due to associated soil disturbance that could contribute to soil erosion and the deposition of soil into Tumbling Creek. One private land owner interpreted the statement as meaning that the Service would prohibit or severely restrict timber harvest within the recharge area of Tumbling Creek Cave.

Response: The Service intended the language to mean that timber harvest could adversely impact *Antrobia culveri* only if associated operations were not properly managed (i.e., failure to put erosion control measures in place, revegetate exposed soil, etc.). The Service does not intend to prohibit or restrict timber management within the recharge area of Tumbling Creek cave. The Service will work closely with the U.S. Forest Service through Sections 7(a)(1) and 7(a)(2) consultations involving Forest Service projects that are within the recharge area of Tumbling Creek Cave, and further recommends that representatives with the Missouri Department of Conservation or the National Resources Conservation Service, provide technical assistance to private landowners on ways to reduce soil erosion and movement during and following timber harvest operations.

- **Comment:** One reviewer suggested that the number of years (5) required to monitor water quality data (criterion 3) should equal the first criterion's requirement of having the population stable for 10 years for reclassification and an additional 10 years for delisting.

  Response: After discussing the suggestion with water quality monitoring specialists, the Service agrees and the appropriate changes have been on pages 29-30 of the final plan.

- **Comment:** One reviewer requested that the second criterion (surface habitat protection) for both reclassification and delisting be deleted because: 1) the percentages were too high to ever achieve recovery, 2) it was redundant due to water quality monitoring criterion, and 3) private land owners would be concerned that the suggested protection would negatively impact activities on their land.

  Response: The Service believes that the protection of surface habitat within the recharge area of Tumbling Creek Cave is crucial to the recovery of *Antrobia culveri* for the following reasons: 1) good water quality will be totally dependent on the proper protection and management of surface habitat, 2) water quality criteria are lacking for certain contaminants that require monitoring and that could be partially responsible for the decline in cavesnail numbers (e.g., various suspended solids); in the absence of protective criteria for these contaminants, the recommended protection of surface habitat will ensure any further deterioration of the water quality of Tumbling Creek, and 3) one of the main focuses of the recovery plan for Tumbling Creek cavesnail is the voluntary cooperation of private land owners in the recovery of this species; given the special emphasis placed on facilitating the support and cooperation of private landowners within the recharge area, we do not believe these conservation actions will negatively impact private landowners. Although the Service agrees that the protection percentages are ambitious, we believe that such high percentages are necessary to restore the water quality of Tumbling Creek and facilitate recovery. Additionally, as indicated on page 14 of the final recovery plan, 4,168 acres or approximately 72 percent of the recharge area is either in public ownership or by entities who can be expected to

manage their land to benefit the species. Consequently, the Service believes that the target percentages in the second criterion for reclassification and delisting are achievable and necessary to assist in the recovery of the species.

- **Comment:** One reviewer believed that the text on page 30 of the draft recovery plan was confusing and should be clarified related to what role any potentially new populations of Tumbling Creek cavesnail that are discovered would have on reclassification and delisting criteria.

  Response: The Service agrees that language on page 30 of the draft recovery plan could be misinterpreted and agrees that reclassification and delisting criteria should be less stringent if new, viable populations of *Antrobia culveri* are discovered. Consequently, we have revised the language in the final plan accordingly.

- **Comment:** One reviewer suggested adding a recovery action regarding using a technique that measures either pebble counts or "embeddedness" for assessing changes in silt deposition and availability of rock or pebble substrate to cavesnails.

  Response: The Service contacted multiple species experts to assess the utility of using such techniques. Based on their input, the Service believes that adding such techniques as new recovery actions would be inappropriate because: 1) these techniques would require significant disturbance to rock and pebble habitat used by *Antrobia culveri* and could therefore adversely impact the cavesnail while being conducted, and 2) such techniques would only be meaningful if historical measurements using the same methodology was available for comparison and such information is lacking.

- **Comment:** One reviewer believed that a recovery action and discussion should be added that examines the potential predation of fish in the cave on *Antrobia culveri*.

  Response: The Service acknowledges that different species of fish are occasionally observed in sections of Tumbling Creek occupied by the Tumbling Creek cavesnail but believes that adding a related recovery action would be inappropriate because: 1) cavesnails inhabit the underside of rocks and would probably be mostly inaccessible to stream-dwelling fish, 2) land owners of Tumbling Creek Cave are reluctant to allow the collection of enough fish to conduct stomach analyses, 3) if fish predation was a problem, we would expect a decrease in numbers of isopods and amphipods that would be larger prey and a more readily available food source; analyses of isopod and amphipod numbers by Ashley (2003) between 1996 and 2003, however, failed to show any such declines, and 4) even if fish were predators on cavesnails, negative results from stomach analyses could simply be a reflection of the current rarity of the cavenail rather than be a true representation of the diet of stream-dwelling fish.

- **Comment:** One reviewer asked that the Service consider using the term "biofilm" as an alternative to the phrase "aquatic microfauna" because it was more biologically correct and currently an accepted term in cave literature.

  Response: Although the term "biofilm' may be more accurate biologically, some cave specialists believe that the term may be more confusing to some readers of the final recovery plan than the phrase "aquatic microfauna. Nonetheless, the Service will parenthetically add this term at the first use of the phrase "aquatic microfauna."

- **Comment:** One peer reviewer who has previously visited Tumbling Creek Cave questioned whether the construction of the man-made entrance into the cave by the cave owners adversely affected the cave environment and eventually impacted *Antrobia culveri*. This peer reviewer also suggested that the door at the man-made entrance into the cave be further sealed to prevent influence of the outside climate on the delicate cave ecosystem and recommended that Hobo temperature/humidity dataloggers be installed throughout the cave to monitor changes in the cave environment.

  Response: The Service does not believe that the man-made entrance into Tumbling Creek Cave has adversely affected the Tumbling Creek cavesnail for multiple reasons. The man-made structure was constructed between 1966 and 1968 by the cave owner who is a recognized cave specialist and expert karst hydrogeologist. Extensive measures were implemented to ensure that impact to the delicate cave ecosystem was avoided. The man-made entrance was constructed at a location where cave features suggested that another natural cave entrance was nearby. Such an analysis was done by observing "moon milk" on the land surface. This is a karst phrase denoting the presence of an aqueous suspension of calcite crystals and bacteria on the land surface. An observation of "moon milk" provides strong and routine evidence that a natural cave entrance is near the land surface (Tom Aley, pers. commun., August 22, 2003). On August 21, 2003, the cave owner evaluated the potential influence of weather conditions outside the man-made entrance to the cave ecosystem when the ambient air temperature was approximately 35°C (95°F). Air temperatures were recorded throughout the cave and it was noted that: a) there was no difference in air temperature beyond approximately 100 meters from the man-made entrance, and b) air temperature was constant in areas adjacent to Tumbling Creek and where a maternity roost of gray bats are frequently observed; this area is located about 300 meters from the man-made entrance. We find it highly improbable that minor alterations in air temperature near the man-made entrance would adversely impact an aquatic cavesnail 300 meters distant. Notwithstanding these observations, the cave owners are willing to implement measures that would improve the seal around the entrance door and to further evaluate any potential adverse impacts to the cave environment. They are also willing to add the Hobo temperature/humidity dataloggers as recommended.

- **Comment:** One reviewer commented that the public outreach action involving cave tours would result in a significant increase in the number of visitors that could alter the cave environment.

  Response: The Service agrees that cave tours should be controlled to reduce potential impact to the cave but believes that this is unlikely to be a problem because the cave owners restrict field trips to an average of about 20 trips per year with an average of about 15 participants per field trip (Tom Aley, pers. commun., August 27, 2003).

- **Comment:** One reviewer suggested using drift/plankton nets to study the potential drift of cavesnails over time and to possibly capture young.

  Response: The Service agrees that such a technique could provide important information on *Antrobia culveri* and has added text to recovery actions 4.1.2 and 4.1.3 to incorporate this suggestion.

- **Comment:** One reviewer suggested adding a action that identified potential refuse sites and abandoned homesteads within the recharge area of Tumbling Creek Cave and that actions related to the cleanup of refuse sites and abandoned homesteads should be expanded to include areas within the recharge area of the cave.

  Response: The Service agrees with the suggestions and has added new language accordingly.

- **Comment:** One reviewer recommended that the following recovery actions be changed from priority 1 to priority 2: A) 2.4.1- development of an emergency contingency plan for potential highway spills, B) 3.2.4- tissue analysis of associated macroinvertebrates, C) 3.2.5- toxicity tests using surrogate species, D) 4.1.2- conduct life history ecology studies, E) 4.1.3- conduct reproductive studies, and F) 4.1.4- conduct food habit studies.

  Response: The Service agrees that the likelihood of a potential highway spill within the recharge area of Tumbling Creek Cave is probably small and that it is more appropriate to classify the corresponding action as priority 2. The Service does not agree, however, that actions 3.2.4, 3.2.5, 4.1.2, 4.1.3, and 4.1.4 should be changed to priority 2 for the following reasons: 1) various toxicity tests, including those using surrogate species are critical to identifying what factors have contributed to the deterioration of water quality of Tumbling Creek; identifying what factors have contributed to the decline in cavesnail numbers is essential to the recovery of the species, and 2) studying the life history ecology of this species is necessary to help identify the limiting factors for *Antrobia culveri* and in understanding important aspects of its reproductive behavior to facilitate artificial propagation efforts.

- **Comment:** One reviewer recommended that recovery action 2.2.1 ("Continue to restore and rehabilitate riparian corridors") should be changed from a priority 2 to a priority 1 action.

  Response: Because the restoration and rehabilitation of riparian corridors within the recharge area is necessary to significantly reduce the deposition of silt into Tumbling Creek, the Service agrees with this recommendation and has, accordingly, changed the priority number for this action.

- **Comment:** One reviewer commented that the Service's estimate cost for land acquisition under action number 2.3 was grossly underestimated and requested that a goal be established on how many acres should be protected. The same reviewer questioned whether land managed through conservation agreements or easements would accomplish the same purpose.

  Response: The Service agrees that land acquisition is not necessary if long term agreements or easements can be secured. However, we do not believe that it is appropriate to provide a target for land acquisition as it would only be a secondary option to the voluntary enrollment of landowners into long term conservation agreements and easements. Additionally, land acquisition would be opportunistic at best and will only be possible if: 1) there are willing sellers, 2) funding is available (e.g., Recovery Land Acquisition funds through the Missouri Department of Conservation), and 3) as stated above, land is not first protected through long-term conservation agreements or easements.

- **Comment:** One reviewer suggested that language be included in the final plan that discusses what criteria will be used to assess the water quality of Tumbling Creek.

  Response: The Service agrees with this suggestion and has included additional text and references on water quality criteria under the "Biological Constraints and Needs" section of the introduction.

- **Comment:** One reviewer noted that feral hogs were not previously discussed as a potential threat to the Tumbling Creek cavesnail, but control of these animals was listed as recovery action (2.10). Clarification on the issue was requested.

  Response: Feral hogs is a new threat to the Tumbling Creek cavesnail that did not exist at the time of listing. The Service agrees that information should be provided on this new threat and has included text and references under factor A: "destruction, modification, or curtailment of habitat or range" on pages 16-17 of the introduction.

- **Comment:** Two reviewers requested clarification or rewording of the recovery

objective and recovery criteria for water quality and one suggested rewording item number three of the recovery objectives on page vii that read "ensuring long term, good water quality in Tumbling Creek by adopting the Environmental Protection Agency's water quality standards for this stream." It was suggested to be rewritten to read, "ensure long term, good water quality in Tumbling Creek by meeting all U.S. Environmental Protection Agency (USEPA) recommended water quality criteria for protection of aquatic life." The same reviewer also recommended rewording item number three of the recovery criteria on the same page that read "water quality monitoring fails to detect any contaminant or water quality parameter likely to be detrimental to the species for five consecutive years." It was suggested to read, "water quality monitoring fails to detect levels of any water pollutant that exceed USEPA recommended water quality or exceed known toxicity thresholds for the species."

Response: The Service believes that the recommended language changes from the one reviewer clarifies our intent and we have incorporated the suggested changes in text into the final plan.

- **Comment:** One reviewer suggested rewording recovery action 3.2.2 on pages 33 and 47 that read, "Evaluate sediments in Tumbling Creek for the presence of persistent contaminants." It was suggested to be rewritten to read, "Analyze sediments from Tumbling Creek for the presence of persistent contaminants that are not effectively sampled by SPMDs (e.g. toxic metals)." The same reviewer also recommended that the order of actions 3.2.2 and 3.2.1 be reversed such that the analysis of historical SMPD samples be analyzed before new samples are collected and analyzed.

  Response: The Service has incorporated these suggested changes into the final plan.

- **Comment:** One reviewer suggested rewording recovery action 3.3.2 on pages 33 and 47 that read, "Evaluate sediments within stream valleys for potential contaminants." It was suggested to be rewritten to read, "Analyze contaminants in water (with SPMDs) and sediments of surface waters in the recharge area as needed to identify sources of contaminants of concern (based on water quality monitoring and analyses of SPMDs, sediments, guano, and tissue samples)."

  Response: The Service has incorporated this suggested change into the final plan.

- **Comment:** One reviewer requested that a table be inserted into the final plan that outlines the correlation between the listing factors and threats identified on pages 12-24, and the recovery criteria and actions listed on pages 29-30 of the draft recovery plan.

  Response: The Service has incorporated this recommendation into the final plan

by adding the suggested table under Appendix 1 (pages 84-85 of the final plan).

- **Comment:** One reviewer suggested adding a recovery action that addresses the need for a post-delisting monitoring plan.

  Response: The Service has incorporated this recommendation into the final plan as recovery action number 8.

- **Comment:** One reviewer suggested removing the term "partner" that is used throughout the draft recovery plan because such language is redundant given that the recovery plan in its entirety is a partnership.

  Response: The Service has retained use of the term "partner" to repeatedly acknowledge that recovery of the Tumbling Creek cavesnail will only be possible through a cooperative partnership involving Federal, State, and private entities within the recharge area of Tumbling Creek Cave. It is our position that the importance of voluntary cooperation among all interested parities can not be over emphasized.

- **Comment:** One reviewer questioned the taxonomic validity of *Antrobia culveri* and suggested that genetic studies using modern molecular techniques be undertaken to confirm the specific status of the cavesnail.

  Response: Although such studies could be useful in further clarifying the relationship of *Antrobia culveri* to other hydrobiid snails, all cavesnail experts unanimously concur the current taxonomy of the species is not in question.

- **Comment:** One reviewer suggested that monitoring of gray bat numbers following the replacement of the barrel gate in the cave should be conducted once every year for the first five years and once every two years thereafter.

  Response: The Service has incorporated this suggestion into the final plan.

- **Comment:** The Forest Service recommended changing the following on the last sentence of the third paragraph of page 16: "In addition to these sources, the construction of fire lanes associated with controlled burning on Forest Service property within the recharge area may increase the threat of soil erosion with a resulting decrease in water quality in Tumbling Creek." It was suggested to be rewritten to read, "Mechanically constructed firebreaks associated with prescribed burning on National Forest lands within the recharge area is another potential source of soil movement if not properly designed and revegetated."

  Response: The Service has incorporated this suggested change into the final plan.

- **Comment:** The Forest Service recommended changing item number 1 on page 26

of the third paragraph that read: "silt deposition into streams and tributaries that drain into Tumbling Creek (e.g., timber harvest operations, over grazing by livestock, land clearing for pasture and residential development, road construction and maintenance, prescribed fires)." It was suggested to be rewritten to read, "silt deposition into streams and tributaries that drain into Tumbling Creek (e.g., improperly designed or executed timber harvest operations, over grazing by livestock, land clearing for pasture and residential development, road construction and improper maintenance, improperly designed or executed firebreaks for prescribed fires)."

Response: The Service has incorporated this suggested change into the final plan.

- **Comment:** The Forest Service recommended changing action number 2.5 on pages 32 and 43 that read: "Encourage the Forest Service to follow Forest Service standards and guides for timber, glade, savannah, and range management as well as any special use permits authorized within the recharge area of Tumbling Creek Cave." It was suggested to be rewritten to read, "Implement applicable standards and guidelines on National Forest lands for timber harvest, range management, glade and savannah restoration, and prescribed fire within the recharge area of Tumbling Creek cave. Ensure that any special use permits authorized within the recharge area include provisions for protection of water quality."

  Response: The Service has incorporated this suggested change into the final plan but combined the two sentences into a single sentence.

- **Comment:** The Forest Service recommended changing text associated with action number 2.5.2 on page 43 because it noted that environmental review of Forest Service grazing permits was the purview of the Fish and Wildlife Service and not other agencies and groups under Section 7(a)(2) of the ESA. They also recommended rewriting the last sentence under the same action that read: "Additionally, stocking rates should be regularly monitored through field investigations to determine if overgrazing has been kept in check." It was suggested to be rewritten to read, "Additionally, stocking rates should be regularly monitored through field investigations to determine if grazing levels are adequate to prevent soil movement or resource damage."

  Response: The Service agrees that consultation between the Forest Service and Fish and Wildlife Service under Section 7(a)(2) of the ESA is the appropriate venue for the review of grazing permits, and has reworded the text under action 2.5.2 to read: "Such permits should be reviewed by the Service's Columbia, Missouri Ecological Services Field Office to ensure that grazing densities do not become high enough to cause overgrazing problems that could result in sediment deposition within the recharge area of Tumbling Creek Cave." The Service also incorporated the suggested language change in the last sentence.

- **Comment:** The Forest Service recommended rewording action number 2.5.4 on pages 32 and 44 and the associated text that read: "Review fire management and wildlife control activities on FS land. Runoff following rain events on recently burned FS land could be a source of sediment deposition. The appropriate use of prescribed fire as an effective and useful management tool can be outlined in related FS standards and guides and in management plans developed through 2(c)(1) and 7(a)(1) consultation with the Service." It was suggested to be rewritten to read, "Implement fire management and wildlife control activities on National Forest lands within the recharge area that reduce or minimize the potential for soil movement, while placing top priority on public and firefighter safety. Ensure that standards and guidelines developed for prescribed burning and glade/savanna restoration in the revised Mark Twain National Forest Land and Resource Management Plan (Forest Plan) include provisions for protection of water quality within the recharge area of Tumbling Creek Cave. Develop standards and guidelines through 2(c)(1) and 7(a)(1) consultation with Service."

  Response: The Service has revised action 2.5.4 as suggested but has modified the associated text to read, "Steps need to be taken to ensure that standards and guidelines developed for prescribed burning and glade/savanna restoration in the revised Mark Twain National Forest Land and Resource Management Plan (Forest Plan) include provisions for protection of water quality within the recharge area of Tumbling Creek Cave. Such standards and guidelines should be developed through 2(c)(1) and 7(a)(1) consultation with the Fish and Wildlife Service."

- **Comment:** One reviewer recommended that the Service identify how many caves should be searched for new populations of *Antrobia culveri* and further questioned the suggested 322 km (~ 200 mi.) radius, as discussed on page 30 of the draft recovery plan, regarding the distance from Tumbling Creek Cave surveys are to be conducted.

  Response: The Service agrees that the 322 km radius is unrealistic and solicited input from cave and cavesnail specialists on how many caves should be searched and at what radius from Tumbling Creek Cave. Based on their recommendations, the Service has revised the text and adopted a survey protocol. Text under recovery action number 1.1.1 has been modified to incorporate the revised survey protocol. Caves within the White River Basin that have the following characteristics will be searched: 1) the cave has a perennial stream; 2) there is an ample energy source such as bat guano; and 3) the cave's perennial stream has a highly diverse aquatic community. Based on these criteria, the highest priority will be given to the 10 caves that have the greatest potential for documenting the presence of *Antrobia culveri*.

- **Comment:** One reviewer suggested that a PVA needed to be conducted before a meaningful recovery criterion involving cavesnail numbers could be developed.

Response: Although results of a PVA analysis could help refine the criterion involving cavesnail numbers, all PVA models require detailed demographic information that is currently unavailable for *Antrobia culveri*, and given the current low population level of the species, may not be obtainable in the foreseeable future. Consequently, the Service used the best scientific and commercial data available in establishing this criterion. The Service, has, however, noted under recovery criteria on page 30 that the results of a future PVA analysis may be helpful in modifying the reclassification and delisting criteria when necessary and appropriate.

- **Comment:** Due to the currently low population of *Antrobia culveri*, one reviewer suggested that artificial propagation should involve the species rather than using a surrogate.

  Response: The Service agrees with a consensus of species experts that propagation techniques should be first developed and refined before attempting propagation experiments with *Antrobia culveri*. Despite the critically low numbers of Tumbling Creek cavesnail, the Service believes that it would be prudent not to remove the few remaining individuals until propagation techniques can be developed using a surrogate species. Additionally, many troglobitic, cave-adapted species have a low survival rate when removed from a cave environment. Consequently, *Antrobia culveri* should not be removed from Tumbling Creek Cave until we can be confident that the species has a high probability of surviving in an artificial environment.

- **Comment:** One reviewer commented on the results of Ashley's (Ashley 2000, 2003) statistical analysis that compared silted versus unsilted habitats. This reviewer suggested, as others have postulated, that it was unlikely that silt was benign to the Tumbling Creek cavesnail, and questioned whether the lack of statistical significance was because sample sizes were too small to detect a difference.

  Response: The reviewer was correct in hypothesizing that the sample size was too small to detect a significant difference in comparing silted versus unsilted habitats with silt versus those without. This was particularly true when cavesnail numbers decreased to such low levels that there were too few individuals to conduct a meaningful comparison. Ashley (pers. commun., August 27, 2003), agrees that a significant difference is likely to be detected between silted versus unsilted habitats once cavesnail numbers rebound to more stable levels.