Appendix C: Animals

Arachnids

SPECIES ACCOUNT: *Adelocosa anops* (Kauai cave wolf or pe'e pe'e maka 'ole spider)

Species Taxonomic and Listing Information

Listing Status: Endangered; January 14, 2000

Physical Description

Troglobite; obligate cave dweller ; restricted to two caves, but regularly encountered in only one; low population number (3); comparitively low rate of reproduction producing 30 or fewer offspring ; eyeless (blind); adults are about 12.7 to 19.0 millimeters (mm) (0.5 to 0.75 in) in total body length with a reddish-brown carapace, pale to silvery abdomen, and beige to pale orange legs; sexually mature in 1 year ; primary prey listed as endangered; both spider and prey vulnerable to catastrophic events (USFWS unpublished data 1996 through 2005; USFWS 2003; USFWS 2010).

Taxonomy

Family Lycosidae (wolf spiders; hunting spiders) of the order Araneae

Historical Range

Originally, the spider probably ranged throughout the available subterranean spaces in the Koloa Lava Flow, which covers the lowlands on the southeastern portion of Kauai, Hawaiian Islands. Subsequent ash deposits and erosion have filled the voids in the upslope portion above about 200 feet elevation, so that the historic range was probably about 15 square kilometers (six square miles). Recent land surface modifications for agriculture, urbanization, and recreation have destroyed more than one half of the historic habitat (Howarth, 1983a; 1983b).

Current Range

Discovered in 1971; described from Koloa Cave #2, in a lava flow with an area of 10.5 square kilometres (4.1 sq mi) in the Koloa–Po?ipu region of Kaua?i (Koloa Basin), Hawaiian Islands. (USFWS 2010); known to occupy five caves in the area, but only one currently and regularly (USFWS 2003; USFWS 2006).

Distinct Population Segments Defined

No; not applicable to invertebrates.

Critical Habitat Designated

Yes; 4/9/2003.

Legal Description

On April 9, 2003, the U.S. Fish and Wildlife Service (Service) designated critical habitat for the Kauai cave wolf spider (Adelocosa anops) pursuant to the Endangered Species Act of 1973, as amended (Act) (68 FR 17430 - 17470). The critical habitat designation consists of 14 units whose boundaries encompass an area of approximately 110 hectares (ha)(272 acres (ac)) on the island of Kauai, Hawaii.

Critical Habitat Designation

Areas designated as critical habitat for the Kauai cave wolf spider occur in 14 separate units. Designated critical habitat includes land under private, county, and State ownership. Designated lands include areas known to be occupied by the Kauai cave wolf spider and includes habitat with similar distribution of geologic and soil characteristics of known occupied habitat and that contain the most probable distribution of appropriate caves and mesocaverns.

Unit 1: Unit 1 incorporates a newly found cave and associated mesocaverns with the verified occurrence of the Kauai cave wolf spider. It is one of only six caves with a verified occurrence of the spider. This unit contains a minimum of two of the primary constituent elements essential to these species and which may require protection.

Unit 2: Unit 2 incorporates four caves and surrounding mesocaverns with two of the caves having verified occurrences of both the Kauai cave wolf spider and the Kauai cave amphipod. This unit contains three of the primary constituent elements essential to these species and which may require protection.

Unit 3: Unit 3 consists of a cave and surrounding mesocaverns with suitable habitat for both cave animals. It was identified by Dr. Frank Howarth, an expert in this field, as important to maintaining the presence of these animals in this area. This unit contains at minimum two of the primary constituent elements and is one of only three sites west of Waikomo Stream. This unit adds to a wide distribution across the Koloa Basin which will protect the species from extinction from a single catastrophic event and therefore is essential to the conservation of the species.

Unit 4: Unit 4 consists of a cave with verified occurrences of both the amphipod and the spider and the surrounding mesocaverns. It is one of only six caves with a verified occurrence of the spider, and one of only seven verified occurrence of the amphipod. It contains at minimum two of the primary constituent elements, essential to the these species and which may require protection.

Unit 5: Unit 5 consists of a cave with verified occurrences of both the amphipod and the spider mapped by the Service and the surrounding mesocaverns. It is one of only seven verified occurrences of the amphipod, and one of only six verified occurrences for the spider. This unit contains three of the primary constituent elements essential to these species and which may require protection.

Unit 6: Unit 6 consists of a cave and surrounding mesocaverns identified in an archaeological survey and is likely to be occupied by one or both of the species. At this time, its occupancy status is unknown. This unit adds to the wide distribution across the Koloa Basin that will protect the species from extinction from a single catastrophic event and therefore is essential to the conservation of the species.

Unit 7: Unit 7 consists of a cave with a verified occurrence of the amphipod and surrounding available mesocaverns. It is one of only seven verified occurrences of the amphipod. This unit contains at minimum two of the primary constituent elements essential to the conservation of the species.

Unit 8: Unit 8 contains a lava tube identified through an archaelogical survey and the surrounding mesocaverns associated with the tube. It is an area that is most likely to harbor the animals and contains at least two of the primary constituent elements. This unit adds to the wide distribution across the Koloa Basin that will protect the species from extinction from a single catastrophic event and therefore is essential to the conservation of the species.

Unit 9: Unit 9 consists of a cave with the verified occurrence of the cave amphipod and surrounding available mesocaverns. It is only one of seven verified occurrences of the amphipod. It contains three of the primary constituent elements considered essential to the conservation of both species.

Unit 10: Unit 10 is located in the Koloa district, an area with cave-bearing rock containing an abundance of mesocaverns (small voids, cracks and passages). As previously discussed in the Background section of the rule, the Hawaiian basalt, found in this area, shrinks and cracks upon cooling creating the mesocaverns. In addition, this unit contains a cave that was used as a Civil Defense shelter. The entrance to the cave was sealed and has not been subsequently relocated. Therefore, the current occupancy status for these species is unknown. Although human use can detrimentally impact cave systems (see discussion under threats), they do not necessarily make the cave permanently unsuitable. For example, one of the cave systems included in critical habitat on Alexander and Baldwin (A&B) property (Unit 2) was also previously used as a civil defense shelter and is currently occupied by these species. Since the cave in Unit 10 was so large and long, it is unlikely that it has been completely filled in and the sealing of the entrance likely increased the humidity levels available in the cave. As discussed in the Cave Habitat section of the rule, cave systems for these species include one or more caves comprised of five zones (entrance, twilight, transition, dark and stagnant) and mesocaverns. While these mesocaverns can possess characteristics of each of the five zones, they frequently represent conditions of the stagnant zone. These mesocaverns are believed to provide refugia for these species when impacts make the caves uninhabitable for them. Unit 10 is believed to contain at least three PCEs (cave, mesocaverns, and appropriate microclimate [i.e., high levels of humidity]). Information provided during the comment period (drilling records) show that the other areas surrounding Unit 10 have large deposits of clay or housing and other structures have been built in the area. The presence of clay and housing developments make it unlikely that additional areas adjacent to Unit 10 contain any remaining PCEs. Unit 10 is necessary to maintain continuity of the distribution of areas throughout the Koloa Basin making it essential to the conservation of the species.

Unit 11: Unit 11 consists of habitat that has been identified as an area most likely to be occupied by one or both of the species. The area within Unit 11 contains barren exposed rock, minimal prior surface disturbance, and minimal soil deposits, all of which provide higher quality caves and mesocaverns. This unit adds to the wide distribution across the Koloa Basin that will protect the species from extinction from a single catastrophic event and therefore is essential to the conservation of the species.

Unit 12: Unit 12 consists of habitat that has been identified as an area most likely to be occupied by one or both of the species. The area within Unit 12 contains barren exposed rock, minimal prior surface disturbance, and minimal soil deposits, all of which provide higher quality caves and mesocaverns. This unit adds to the wide distribution across the Koloa Basin that will protect the species from extinction from a single catastrophic event and therefore is essential to the conservation of the species

Unit 13: Unit 13 consists of the only known occupied limestone cave and surrounding mesocaverns. The cave is occupied by both arthropods and is one of only seven verified locations of the amphipod, and one of six verified locations of the spider. This unit contains three of the primary constituent elements considered essential to the conservation of both species.

Unit 14: Unit 14 is composed of uplifted coral and algal reefs and consolidated calcareous deposits (MacDonald et al. 1960). Exposed basaltic flows are not believed to be present within this unit. This unit lies only a short distance (approximately 350 m (1,100 ft)) from Unit 13, which is occupied, and was likely once connected to that unit in the geologic past (Pleistocene Era) by deposits that have since eroded away or have been covered by unconsolidated sediments. It is not known if this unit is currently occupied by the Kauai cave wolf spider, Kauai cave amphipod, or other endemic troglobites. Recent visits to this unit have found that the area is composed of exposed calcareous deposits containing cracks and solution pockets, which are indicative of the presence of underlying cave and mesocavern habitats. While accessible caves have not been located, air-passages, holes, and fissures visible above ground strongly suggest the presence of underlying caves or mesocaverns. Critical habitat is designated in this unit because of the cave-bearing nature of the geology, and because of the occurrence of occupied habitat in adjacent areas with similar geologic features. Because the types of voids that occur in these calcareous formations continuously reform, thereby providing suitable habitat for very long time spans, this area is essential to provide for population expansion and refuge from human and catastrophic environmental threats. This unit currently has minimal human presence in the area, and there are no known current plans for development. Inclusion of this area with Units 1 through 13 provides a diverse geographic distribution that will increase the likelihood the species will survive stochastic or catastrophic impacts and is therefore considered essential to the conservation of both species.

Primary Constituent Elements/Physical or Biological Features

Primary constituent elements (PCEs) are the physical and biological features of critical habitat essential to a species' conservation. The primary constituent elements for the Kauai cave wolf spider are (68 FR 17430 - 17470):

(i) The presence of subterranean spaces from 5 mm to 25 cm (0.2 in to 10 in) at their narrowest point (collectively termed ‘‘mesocaverns’’) and/or cave passages greater than 25 cm (>10 in);

(ii) Dark and/or stagnant air zones that maintain relative humidity at saturation levels (=100 percent); and

(iii) The presence in these types of mesocaverns or caves of roots from living, nontoxic plants such as, but not limited to, ohia (Metrosideros polymorpha), maiapilo (Capparis sandwichiana), and aalii (Dodonea viscosa).

Special Management Considerations or Protections

Existing human-constructed features and structures within the boundaries of mapped units that involved trenching, filling, or excavation resulting in below-surface modification or alteration would not contain either of the primary constituent elements and are excluded from critical habitat designation. Such features and structures include but are not limited to: Homes and buildings for which the underlying bedrock has been altered for their construction or through incorporation of or connection to buried structural foundations, septic tanks, city sewage and drainage systems, or water or underground electrical supply corridors; paved roads; and areas previously or currently used as a quarry.

Areas that have been modified on the surface but without trenching, filling, or excavation resulting in belowsurface modification or alteration are included in the critical habitat designation, even if they are adjacent to areas that have undergone below-surface modification.

Life History

Feeding Narrative

Adult: The primary prey for A. anops is the endangered amphipod, Spelaeorchestia koloana. The amphipod feeds on the decaying roots of surface vegetation that reach into the cave system, as well as rotting sticks, branches, and other plant materials. After hatching, the spiderlings ride on the back of their mother for a time before leaving her to hunt independently. (USFWS 2010). This amphipod, which is believed to be one of the primary prey items of the Kauaʻi cave wolf spider, is known from only five populations.Nutrients in most cave ecosystems are derived from the surface either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the cave invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller troglophiles and troglobites that grow on the leaves or feces rather than the original material itself. Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through cave fissures and solution features. For predatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave. Troglobytes typically have very slow metabolisms, an adaptation to the sparse amounts of food found in their environment. Because they are adapted to an environment with little food, pollution by the addition of large amounts of nutrients to the cave can actually be harmful to the species, because it allows invertebrates that are not cave adapted, such as cockroaches and a variety of flies to survive in the care and even-out-compete the cave species (USFWS 2000b).

Reproduction Narrative

Adult: Cave invertebrates (troglobites) are described as having reproductive strategies similar to large mammals in that they are K-strategists, producing few offspring and living relatively long lives (for invertebrates). This also means their populations are more sensitive to losing even fairly small numbers of individuals, and that it takes a long time for their population sizes to recovery from any catastrophe. A. anops, produces from 15-30 spiderlings per year, which is low for a Lycosidae, which usually produce 100-300 spiderlings per brood. Also, unlike most Lycosidae, A. anops carries her egg sac in her mouth parts, instead of on her abdomen, until the spiderlings hatch. After hatching, the spiderlings ride on the back of their mother for a time before leaving her to live and hunt independently. (USFWS 2010).

Geographic or Habitat Restraints or Barriers

Juvenile: Same as adult

Adult: caves/lava tubes

Spatial Arrangements of the Population

Juvenile: Same as adult

Adult: Unknown

Environmental Specificity

Juvenile: Same as adult

Adult: Inhabits the deep zone and stagnant air zone of lava tubes and intermediate-size voids (mesocaverns) in pahoehoe lava (Howarth, 1973; 1991a), which are damp to wet areas with calm, stagnant, water-saturated air (Howarth 1991a). Its lowland (about 100 feet above sea level) habitat is warm between 25 and 30 C, and sometimes contains >3% by volume CO_2.

Tolerance Ranges/Thresholds

Juvenile: Same as adult

Adult: Unknown, but likely low due to site restriction.

Site Fidelity

Juvenile: Same as adult

Adult: High; restricted to one four cave systems.

Dependency on Other Individuals or Species for Habitat

Juvenile: Same as adult

Adult: Unknown

Habitat Narrative

Adult: Inhabits a very restricted environment, the "deep zone" and "stagnant air zone" of one to a maximum of five lava tubes in pahoehoe lava (Howarth, 1973; 1991a), always in damp to wet areas with calm, stagnant, water-saturated air (Howarth 1991a). Its lowland (about 100 feet above sea level) habitat is warm between 25 and 30 C, and sometimes contains more than three percent by volume carbon dioxide (Howarth 1991a). This restricted environment is highly susceptible to outside influences, disturbance and degradation by humans. (USFWS 2003, 2006a, 2010).

Dispersal/Migration

Motility/Mobility

Juvenile: Very low

Migratory vs Non-migratory vs Seasonal Movements

Juvenile: None

Dispersal

Juvenile: Unknown; but likely low as known from only one to four cave systems and evident low tolerance to other environments.

Immigration/Emigration

Juvenile: Unknown

Dependency on Other Individuals or Species for Dispersal

Juvenile: Unknown, but is prey-dependent on a single species of amphipod, the endangered Spelaeorchestia koloana known from only five caves in Koloa Basin area as A. anops.

Dispersal/Migration Narrative

Juvenile: Dispersal/migration information on this species is not known, but occurence is likely low as they are known from only one to four cave systems and have low tolerance to other environments. Also, it is prey-dependent on a single species of amphipod, the endangered Spelaeorchestia koloana known from only five caves in Koloa Basin area as A. anops.

Population Information and Trends

Resiliency:

Very low due to low population numbers and numbers of individuals.

Representation:

Low

Redundancy:

Low; only 4 populations recorded

Population Growth Rate:

Low (K-strategy)

Number of Populations:

Four known subpopulations totally 16-28 individuals (adults and spiderlings) have been recorded in a single cave, but the species has been recorded in very low numbers of individuals in as many as four caves (USFWS 2010)

Population Size:

Since annual to biannual monitoring first began in 1996, this cave system has routinely contained 16 to 28 spiders per monitoring visit (USFWS 2006).

Minimum Viable Population Size:

Unknown

Resistance to Disease:

Likely low due to isolation

Adaptability:

Unknown, but likely very low due to restricted environment and conditions

Population Narrative:

The low/unknown population numbers (4 known subpopulations) of this k-strategist (i.e., low reproductive rate; high investment in off-spring; long period to maturity for off-spring) inhabiting a restricted environment, with one primary prey species (amphipod, Spelaeorchestia koloana), which is also critically endangered, suggest that this species is susceptible to catastrophic events (USFWS 2006; 2010). Currently, the Kauai cave wolf spider is only known to regularly occupy a single cave system, referred to here as Koloa Cave 2 located in the southwest corner of the range of the cave arthropods. Since annual to biannual monitoring first began in 1996, this cave has routinely contained 16 to 28 spiders per monitoring visit (U.S. Fish and Wildlife Service, unpublished data 1996 through 2005). Both sub-adult and adult spiders are regularly observed and females with egg sacs are occasionally seen. In 2005, new-born spiders were observed in Koloa Cave 2 and, for the first time, photo-documented. These observations suggest this cave and the surrounding cave-bearing rock contains a healthy breeding population of cave wolf spiders. In an adjacent cave (Koloa Cave 1), about 200 to 300 meters (260 to 390 feet) away, there is only a single record from 1998 of an adult cave wolf spider being present (U.S. Fish and Wildlife Service, unpublished data 1996 through 2000, 2002, 2005). This is likely due to the drier conditions of the latter cave. Koloa Caves 1 and 2 are lavatubes that parallel one another and which are likely connected by small mesocaverns inaccessible to humans. The sporadic presence/evidence (i.e., cast skin) of A. anops has been recorded in Kiahuna Makai, Kiahuna Mauka, and a Quarry caves, but not since 2002. In addition to those populations cited in the previous 5-year review, new observations include the following: • Individual spiders were observed for the first time in Cave 3075C (USFWS, unpublished data 2006 through 2016). Juvenile spiders were found in the cave in 2006, 2007, 2013, and 2015. Adult spiders were observed in the cave in 2007 and 2013. A population of the Kauai cave wolf spider was not detected in this cave until air blocks were installed to increase humidity in the cave as part of a cave preservation management plan in cooperation with Kukuiula Development Company (Hawaii), LLC. In 2006, when critical habitat was designated for this species, two of the four caves had verified occurrences of the Kauai cave wolf spider. These recent observations increase the number of caves with verified occurrences from two to three in critical habitat unit number 2 (USFWS, 2015).

Threats and Stressors

Stressor: human visitation
Exposure: dumping, disturbance of cave interior
Response: crushing, poisoning, destruction of habitat
Consequence: reduction in population numbers, decreased reproductive success
Narrative: Human visitation to and uses of caves are a serious threat (Culver 1986). Cave ecosystems are affected by the following activities: used as sites for dumping and filling, contaminated by surface sources of toxic chemicals from spills, pesticides, and waste disposal which enter caves via streams and/or ground-water seepage, and mining and quarrying. In addition, Polynesians utilized caves as burial sites and many of the caves in the Koloa District show signs of this use (Hammatt and Tomonari Tuggle 1978; Hammatt et al. 1988), which often attract curiosity seekers (Howarth 1982, 1983; Culver 1986). The narrow passages in many caves increase the chances that human visitors may inadvertently and unknowingly crush or injure ground-dwelling cave-inhabiting species or destroy food resources such as root systems, which are critical to most Hawaiian cave systems. Cave visitors may leave trash or toxic materials in caves, both of which can have devastating effects. Discarded food and trash can attract arthropods (e.g., cockroaches) that can compete with the resident cave-dwelling animals, and

elevated numbers of such scavengers may attract non-native predators (e.g., centipedes, spiders) that may prey on the natural cave inhabitants. Discarded trash can attract social insects such as ants which have had a devastating impact in cave systems in Texas (U. S. Fish and Wildlife Service 1994) and have likely had similar impacts in Hawaii (Howarth 1985; Cole et al. 1992). Nicotine, contained in cigarette smoke, is a powerful insecticide that can have devastating effects in the cave environment (Howarth 1982). Use of open fires in caves and cave openings may have massive, unseen impacts on cave-dwelling species both from the release of toxic fumes as well as from drying the cave interior reducing relative humidity (Howarth 1982). (USWFS 2006b).

Stressor: bio-control agents
Exposure: introduction of predators o
Response: competion from and consumption by predators
Consequence: reduction in population numbers, decreased repro success
Narrative: Bio-control agents (living organisms used to control pests) may attack species other than their intended targets and have caused or contributed to the decline and extinction of several Hawaiian insects (Howarth 1983, 1991). Several entomopathogens (including nematodes, fungi, and bacteria) are available or are under development for use as biological pesticides. They are isolated from moist soil and would likely survive and do well in subterranean environments. The native Hawaiian cave fauna would be highly susceptible to this threat (Howarth 1991; Howarth et al. 2003). Should they become established, entomopathogens may also spread to new areas with suitable host arthropods, and become impossible to eliminate.

Stressor: contaminants/pesticides
Exposure: introduction of poison
Response: poisoning of cave spider and prey items
Consequence: reduction in population numbers, decreased repro success
Narrative: Runoff and recharge that contain urban and household pesticides may inadvertently deliver high concentrations of insecticides or other pesticides (e.g., herbicides, fungicides) into cave and mesocavern habitats, with potentially devastating effects on the Kauai cave wolf spider. The presence of septic tanks and leaching fields associated with urban development in cave-bearing rock is likely of mixed benefit to the Kauai cave wolf spider. Leaching fields would increase soil moisture levels and elevate the relative humidity within local caves, and could result in increased food import (i.e., detritus). However, they are equally likely to be a source of toxic and caustic wastes in the form of household cleaners such as drain-cleaners, bleach, and other discarded chemicals.

Stressor: development of area above cave
Exposure: loss of tree roots; loss of rain water; introduction of poison
Response: loss of food source; dessication of cave habitat; poisoning
Consequence: reduction in population numbers, decreased repro success
Narrative: Development in the Koloa District of Kauai (construction of roads, houses, golf courses, and a quarrying operation (Howarth 1981; Mueller-Dombois and Howarth 1981; Howarth and Stone 1993; KPMG Peat Marwick 1993; Burney et al. 2001) poses a threat to rocky cave-containing areas located in substandard agriculture land. Intervening caves, subterranean cracks, and mesocaverns being destroyed or filled with soil may confine populations of cave-dwelling species to caves without climatic refugia (e.g., cracks and mesocaverns with high relative humidity), increasing chances of local extinction during periods of prolonged drought. Caves, subterranean cracks, and mesocaverns are periodically exposed to the surface

environment during construction activities and this can result in the desiccation of cave habitat and provide access to alien species. Urbanization typically results in large areas being covered by asphalt or other artificial surfaces that lack or have only limited permeability. Reduced local ground water recharge may greatly reduce humidity levels within caves, subterranean cracks, and mesocaverns, degrading or eliminating habitat for this species.

Stressor: drought; rainwater diversion;
Exposure: loss of tree roots; loss of rain water; introduction of poison
Response: loss of food source; dessication of cave habitat
Consequence: reduction in population numbers, decreased repro success
Narrative: All of the caves may be threatened by prolonged drought, brought about either by global climatic changes or by local alteration of the vegetation that may reduce rainfall or otherwise result in reduced soil moisture content. Prolonged drought may desiccate the cave interior, making it less accommodating to cave-dwelling animals (Howarth 1983). As a result of reduced humidity, Dark and Stagnant Air Zones may become more prone to invasion by damaging, non-native species such as the brown violin spider.

Stressor: Demographics; small population size
Exposure: Not analyzed
Response: Not analyzed
Consequence: Not analyzed
Narrative: Small populations are demographically vulnerable to extinction caused by random fluctuations in population size and sex ratio and to catastrophies such as hurricanes. In addition, the low reproductive potential of both cave species (less than 10 percent of their surface relatives) means that they require more time and space to recover from a disturbance than would similar animals living on the surface (F. Howarth, In litt. 2001. (USFWS 2006b).

Recovery

Reclassification Criteria:
Downlisting to threatened status may be considered when nine populations, spread across the known range (single cave), are shown to be:(a) Self-sustaining populations (contain representatives of all generations, sexes, and age classes); (b) Stable or increasing (intrinsic growth rate (?) is greater than or equal to 1) over a monitoring period of at least 10 consecutive years; (c) Protected from non-native, predatory species; human visitation of cave (dumping area, party site); bio-control agents; pesticides; development; or other damaging land uses such as quarrying, filling areas, rain water diversion due to surface areas being covered by asphalt or other artificial surfaces that lack or have only limited permeability (Listing Factors 1, 3, and 5); and (d) With the habitat being used in a fashion consistent with conservation (protecting cave habitat from future development, preventing disturbance to cave interiors via gating, and protecting and/or restoring the vegetation that lies over the cave) (Listing Factors 1 and 5).

Delisting Criteria:
Delisting may be considered when 12 populations, spread across the known range, are shown to meet the same four downlisting criteria described above.

Recovery Actions:

- 1. Continue population and demographic monitoring of currently occupied caves on a quarterly basis; 2. Survey caves that have been identified but never surveyed; 3. Resurvey previously occupied caves to determine if the species is present and record numbers; 4. Modify characteristics (e.g., increase surface vegetation, reduce airflow through the cave) of one unoccupied caves to improve suitability for the species; 5. Revegetate the surface of one the cave footprint with appropriate native plants; 6. Increase the number of surveys within caves that have been identified but never surveyed; 7. Restrict access into occupied caves (2006c); 8. Revegetate, protect and maintain the plant communities over the caves, subterranean cracks and mesocaverns that provide habitat for this species. Protection to the surface above the caves will improve the long term conservation value of the below-ground habitat, which is also home to an endangered, endemic amphipod that feeds on the roots of surface vegetation (2006c). Some of the recovery actions identified in the 2006 Recovery Plan are being implemented. Several willing landowners have worked cooperatively with us to install gates for three caves to prevent unauthorized access and one more gate over an additional cave is planned to be installed this year. These same landowners have allowed projects to restore, protect, and enhance overlying plant communities of five different caves. Monitoring for the presence/absence and numbers of animals encountered is also being conducted biannually (USFWS 2006b). In addition, to ensure their survival into the future, a number of important caves have been provided with protected status by the landowners, including the caves below Kiahuna Golf Club.The U.S. Fish and Wildlife Service has been working with the Kukuiʻula Development Corporation since 1995 to help restore and protect two caves on the company's property that provide habitat for these two endangered cave animals. The company has agreed to set aside the land area above these two caves as either a limited use park or reserve to further protect these species. The Service hopes to undertake similar partnerships with other private landowners (USFWS 2010).

Conservation Measures and Best Management Practices:

- " Several willing landowners have worked cooperatively with us to install gates for three caves to prevent unauthorized access and one more gate over an additional cave is planned to be installed this year. These same landowners have allowed projects to restore, protect, and enhance overlying plant communities of five different caves. Monitoring for the presence/absence and numbers of animals encountered is also being conducted biannually (USFWS 2006b). In addition, to ensure their survival into the future, a number of important caves have been provided with protected status by the landowners, including the caves below Kiahuna Golf Club. The U.S. Fish and Wildlife Service has been working with the Kukuiʻula Development Corporation since 1995 to help restore and protect two caves on the company's property that provide habitat for these two endangered cave animals. The company has agreed to set aside the land area above these two caves as either a limited use park or reserve to further protect these species. The Service hopes to undertake similar partnerships with other private landowners (USFWS 2010). "
- Cave climate manipulation - Air blocks to increase humidity were installed in four caves (Cave 3179, Cave 1927C, Cave 3075B, and Cave 3075C within critical habitat unit #2) as part of a cave preservation management plan in cooperation with Kukuiula Development Company (Hawaii), LLC. The air-blocks are constructed of metal, plastic sheeting, and foam (as an edge insulator) each with a plastic sheet entrance that can be lifted for human passage (W. Kishida, pers.comm.). The air blocks are temporary, requiring regular maintenance for the structures to last over longer periods. Installation of the air blocks was an important step in testing equipment to determine if manipulation of the cave climate can be used to improve habitat for endangered cave arthropods,

including the Kauai cave wolf spider and the Kauai Cave Amphipod (Spelaeorchestia koloana) (under recovery priority 3, action 3.6; USFWS 2006b) (USFWS, 2015).

- Habitat and natural process management and restoration – Out-planting of native plants and irrigation to enhance habitat at the above four caves under the above cave preservation management plan as well as at Kiahuna Mauka Cave (in cooperation with Kiahuna Golf Course) was carried out to enhance habitat (W. Kishida, unpublished data). This work was an effort toward planting and maintaining surface vegetation that provides root systems for endangered cave arthropods which is a food resource (under recovery priority 2, action number 2.1; USFWS 2006b) and helps maintain a consistent high humidity environment (under recovery priority 1, action 2.2; USFWS 2006b) (USFWS, 2015).
- Surveys / monitoring – Surveys, ranging from monthly to annually, have been conducted at Koloa Cave 1 and 2, Cave 1927C, Cave 3179, Cave 3075B and Cave 3017C (within critical habitat unit #2), Kiahuna Mauka Cave, and the Quarry Cave from 2006 to 2009 and 2013 to 2016 (USFWS, unpublished data 2006 through 2016). This monitoring was primarily carried out to assess population trends in caves and assess recovery actions (under recovery priority 1, action 3.1; USFWS 2006b). It also provided valuable information to determine if manipulation of cave climate can be used to improve habitat (under recovery priority 3, action 3.6; USFWS 2006b). Surveys have not been conducted in the Kiahuna Makai Cave since 2004, when the new landowner denied permission to the Service to monitor the cave due to liability concerns (USFWS, 2015).
- Protect caves from unauthorized human entry – Maintenance (e.g., painting, replacing locks) of the locking gates at Koloa Cave 1 and 2, Kiahuna Mauka Cave, and Quarry Cave (under recovery priority 1, action 1.1; USFWS 2006b).
- Recommendations for Future Actions: • Above ground plant restoration – Out-planting of native plants to provide roots and irrigate surface. Control established ecosystem-altering non-native invasive plant species around all caves. • Control non-native predator species around entrance and outside of caves. 4 • Enhance habitat by sealing currently non-occupied caves with temporary air blocks – Increase relative humidity by restricting air flow through cave entrances. • Design permanent air blocks (e.g., walls) and develop plans to replace temporary air blocks (USFWS, 2015).

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USFWS. 2015. 5-YEAR REVIEW. Short Form Summary Species Reviewed: Pe`e pe`e maka`ole or Kauai Cave Wolf Spider (Adelocosa anops).

SPECIES ACCOUNT: *Cicurina baronia* (Robber Baron Cave Meshweaver)

Species Taxonomic and Listing Information

Listing Status: Endangered; 12-26-2000

Physical Description

Troglobite (spends entire life in subterranean environment); builds irregular webs close to or directly on the ground; typically a tangle of wooly fibers to trap prey; small; essentially eyeless.

Taxonomy

Family Dictynidae of cribellate spiders (hackled band-producing); aka Robber Baron Cave Spider.

Historical Range

Unknown, but likely similar to current distribution

Current Range

Robber Baron Cave and OB2 Cave, Bexar County, TX

Distinct Population Segments Defined

No; not applicable to invertebrates

Critical Habitat Designated

Yes; 4/8/2003.

Legal Description

On February 14, 2012, the U.S. Fish and Wildlife Service (Service) designated critical habitat for Robber Baron Cave meshweaver (Cicurina baronia) (and eight other species) under the Endangered Species Act of 1973, as amended (77 FR 8450 - 8523). These species are collectively known as the nine Bexar County invertebrates.This critical habitat replaces critical habitat previously designated April 8, 2003 (68 FR 17156 - 17231). For Robber Baron Cave meshweaver , approximately 347 ac (141 ha) fall within the boundaries of the critical habitat designation.

Critical Habitat Designation

Critical habitat for the Robber Baron Cave meshweaver in Bexar County, Texas, occurs in Units 20 and 25.

Unit 20: Unit 20 consists of 247 ac (100 ha) of private land located in north-central San Antonio, south of Loop 410 West, and primarily along Nacogdoches Road northeast of Broadway in the Alamo Heights KFR. This unit contains one known occupied cave, Robber Baron Cave, which is the only known cave for the Cokendolpher Cave harvestman. It is also one of only two caves known to be occupied by the Robber Baron Cave meshweaver (OB3 in Unit 25 is the other cave). Robber Baron Cave was occupied at the time of listing and is the longest cave in Bexar County, consisting of approximately 0.9 mi (1.5 km) of passages (Veni 2003, p. 19). The estimated footprint of the cave now underlies numerous residential and commercial developments. Veni (1997, p. 29) reported a slow decline in moisture in the cave over time. The Texas Cave Management

Association (TCMA) now owns and manages the cave and about 0.5 ac (0.2 ha) surrounding the opening. The TCMA is a nonprofit organization dedicated to the study and management of Texas cave resources. Cave gates and modifications to the cave entrance have reduced airflow into the cave and the opportunity for cave crickets to move into and out of the cave. Installation of a new cave gate, removal of trash, and revegetation of a small area surrounding the entrance was completed in 2008 by TCMA (TCMA 2011, pp 2–3) and improved these issues for a portion of the cave. This unit was occupied at the time of listing and contains both PCEs. Surface vegetation within Unit 20 has been significantly reduced and degraded by urban development, although portions of primarily landscaped areas remain. The unit requires special management because of the high levels of residential and commercial development within the unit. Threats include the potential for destruction of habitat from vandalism, soil compaction from cave visitation, lack of a nutrient sources, contamination of the subsurface drainage area of the unit, drying of karst, and infestation of fire ants. Because of the extensive development, high levels of impervious cover, and diversion of storm water over the cave, intensive management may be needed to provide nutrients and water to the karst environment. The unit was delineated to encompass the estimated extent of the surface and subsurface drainage and all of the contiguous Karst Zone 1. We did not use the standard procedure that we used to delineate other units because the cave footprint and contiguous Karst Zone 1 are long and narrow, and because the overall size exceeds 100 ac (40 ha).

Unit 25: Unit 25 consists of 100 ac (41 ha) of private land located in north central San Antonio near the intersection of Shook Avenue and East Kings Highway in the Alamo Heights KFR. This unit contains cave OB3, occupied by the Robber Baron Cave meshweaver. The cave feature was discovered during excavation in 2009, after the Robber Baron Cave meshweaver had already been listed. However, the cave was likely occupied at the time of listing because surveys to detect the species had not been conducted prior to listing. Therefore, we are considering it to be occupied at the time of listing, and we believe it is essential for the conservation of the species, because a total of only two locations are known for the species and both have impacts to the surface habitat. The surface habitat around this feature has been highly modified and is covered with residential and commercial development, including numerous streets. Unit 25 also contains landscaped lawns and residential and commercial development. The vegetation within the unit provides nutrient input into the area occupied by the species and to features and mesocaverns. The unit is primarily threatened by high levels of residential and commercial development within the unit. Threats include the potential for destruction of habitat from vandalism and potential new development, contamination of the subsurface drainage area of the unit, drying of the karst feature, reduction of nutrient input, and infestation of fire ants. The unit was delineated by drawing a circle with an area of 100 ac (40 ha) around the feature. A small area of the south-central portion of the unit around a large church and parking lot and part of the west-central portion of the circle around an athletic field and parking lots were removed because they contain a large amount of impervious cover and do not contain sources of nutrients. Because no listed species were known from this area of the Alamo Heights KFR when Karst Zones were delineated by Veni (2003, p. 12), the entire unit is located in Karst Zone 2.

Primary Constituent Elements/Physical or Biological Features

The primary constituent elements of critical habitat for the Robber Baron Cave meshweaver are:

(i) Karst-forming rock containing subterranean spaces (caves and connected mesocaverns) with stable temperatures, high humidities (near saturation), and suitable substrates (for example, spaces between and underneath rocks for foraging and sheltering) that are free of contaminants; and

(ii) Surface and subsurface sources (such as plants and their roots, fruits, and leaves, and animal (e.g., cave cricket) eggs, feces, and carcasses) that provide nutrient input into the karst ecosystem.

Special Management Considerations or Protections

Developed lands that do not contain the subsurface primary constituent elements and that existed on the effective date of this rule are not considered to be critical habitat.

Threats to the nine Bexar County invertebrates include clearing of vegetation for commercial or residential development, road building, quarrying, or other purposes. Infestation by nonnative vegetation causes adverse changes in the plant and animal community and possibly in moisture availability. An increase in fire ants can occur with development and cause competition with and predation on other invertebrates in the karst ecosystem. In addition, filling cave features for construction, ranching, or other purposes can adversely affect the listed invertebrate species by reducing nutrient input, reducing small mammal access, and changing moisture regimes. Excavation for construction or operation of quarries can directly destroy karst features occupied by any of the nine Bexar County invertebrates, including the mesocaverns they use.

Examples of management that would alleviate these threats include: (1) Protecting vegetation around occupied karst features and overlying connected mesocaverns; (2) protecting subsurface karst habitat to allow movement of karst invertebrates through caves and mesocaverns; (3) controlling nonnative fire ants around cave features and within the karst cricket foraging area; (4) preventing unauthorized access to karst features by installing fencing and cave gates; and (5) keeping the surface and subsurface areas surrounding cave features and associated mesocaverns free from sources of contamination.

Life History

Feeding Narrative

Adult: Nutrients in most karst ecosystems are derived from the surface either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the karst invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller troglophiles and troglobites that grow on the leaves or feces rather than the original material itself. Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through karst fissures and solution features. Forpredatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave. The cave cricket (Ceuthophilus spp.) is a particularly important nutrient component and is found in most caves in Texas (USFWS 2011). Troglobytes typically have very slow metabolisms, an adaptation to the sparse amounts of food found in their environment. Because they are adapted to an environment with little food, pollution by the addition of large amounts of nutrients to the cave can actually be harmful to the species, because it allows invertebrates that are not cave adapted, such as cockroaches and a variety of flies to survive in the care and even-out-compete the cave species (USFWS 2000).

Reproduction Narrative

Adult: Cave invertebrates are described as more similar to large mammals than to their invertebrate cousins that live on the land surface. Like large mammals, they have few offspring and live relatively long lives (for invertebrates). This also means their populations are more sensitive to losing even fairly small numbers of individuals, and that it takes a long time for their population sizes to recovery from any catastrophe. (USFWS 2000).

Geographic or Habitat Restraints or Barriers

Adult: Karst/cave

Spatial Arrangements of the Population

Adult: Unknown

Environmental Specificity

Adult: High; Surface vegetation to provide nutrients from: (1) direct flow of plant material into the karst with water; (2) habitat and food sources provided for the animal communities that contribute nutrients to the karst ecosystem (such as cave crickets, small mammals); and (3) roots that extend into subsurface areas and may provide a major energy sources in shallow caves. (USFWS 2011)

Tolerance Ranges/Thresholds

Adult: Low

Site Fidelity

Adult: High; limited to single cave

Dependency on Other Individuals or Species for Habitat

Adult: Unknown

Habitat Narrative

Adult: The six listed Bexar County arachnids are restricted to cave/karst habitat, and can be found in as few as one cave or as many as 20 (USFWS 2011). How they may disperse, or be dispersed, to other caves is unknown. What is known is that the karst/cave system (shelter) is highly susceptible to degradation from outside influences (USFWS 2011).

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: No

Dispersal

Adult: No

Immigration/Emigration

Adult: Unknown/likely very low

Dependency on Other Individuals or Species for Dispersal

Adult: Unknown

Dispersal/Migration Narrative

Adult: The six listed arachnids are restricted to the cave/karst environment of the Edwards Aquifer in Bexar County, Texas. Very little is known about their dispersal/migration within/among the caves (USFWS 2011).

Population Information and Trends

Population Trends:

Unknown

Species Trends:

Unknown

Resiliency:

Uknown; but likely low

Representation:

Low

Redundancy:

Low

Population Growth Rate:

Low

Number of Populations:

Unknown

Population Size:

Unknown

Minimum Viable Population Size:

Unknown

Resistance to Disease:

Unknown; but likely low due to isolation

Adaptability:

Unknown, but likely low

Population Narrative:

Very little is known about this species, populations, status.

Threats and Stressors

Stressor: Edge effects
Exposure: impact native communities; disrupt natural systems; introduce non-native predators (such as fire ants)
Response: loses nutrients; competes for limited resources; death by predation
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Edge effects - "Edge effects" are changes to the floral and faunal communities where different habitats meet. The length and width of the edge, as well as the contrast between the vegetational communities, all contribute to the amount of impacts (Smith 1990, Harris 1984). Some types of edge effects include increases in solar radiation, changes in soil moisture due to elevated levels of evapotranspiration, wind buffeting (Ranny et al. 1981), changes in nutrient cycling and the hydrological cycle (Saunders et al. 1990), and changes in the rate of leaf litter decomposition (Didham 1998). These edge effects alter plant communities, which in turn impact the associated animal species. Edge effects can also affect animal species directly. The changes caused by edge effects can occur rapidly. Vegetation located 2 m (6.6 ft) from an edge can be visibly affected within days (Lovejoy et al. 1986). Edge effects associated with soil disturbance and disruption to native communities that accompany urbanization (for example, waste associated with housing) may attract redimported fire ants (RIFA)(discussed in factor C) or other surface species that prey on or compete with cave species (Reddell 1993). The invasion of RIFA is aided by "any disturbance that clears a site of heavy vegetation and disrupts the native ant community" (Porter et al. 1988) such as road building and urbanization. Development and edges often allow enough disruption for invasive or exotic species to displace native communities that had previously prevented their spread (Saunders et al. 1990, Kotanen et al. 1998, Suarez et al. 1998, Meiners and Steward 1999). (USFWS 2011a).

Stressor: Human visitation and vandalism, including commercialization
Exposure: degrades/destroys habitat; introduces predators and competitors
Response: Loses habitat; competes for limited resources; death by predation; crushed
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Human visitation and vandalism - Visitation can impact caves by increasing soil compaction, trash deposition, and vandalism; altering airflow as entrances are expanded and excavated; scaring away trogloxenes (Culver 1986, Elliott 2000); and may also lead to direct mortality of cave organisms crushed by human disturbance (Crawford and Senger 1988). Commercialization of caves affects cave communities due to (1) competition with introduced surface species; (2) harmful effects of commercial lighting, for example increased temperature and decreased humidity near lights; (3) substrate changes around trails; (4) changes in microclimate due to cave ventilation; (5) and increases in the nutrient regime that favor surface species (Culver 1986, Northup 1988, Northup et al. 1988; Reddell 1993, Krejca and Myers 2005, Mulec and Kosi 2009). Conversely, some researchers have found high diversity and/or abundance of some species in show caves that have higher nutrient and water availability (Culver and Sket 2000, Paquin 2007). However, for the reasons stated above we believe that commercialization of caves is generally a threat because (1) these activities alter the natural habitat and nutrient regime of these species and (2) because most caves in Texas have limited nutrient and water availability. (USFWS 2011a)

Stressor: Contamination
Exposure: introduced pollutions, poisons to groundwater

Response: Loses habitat; direct poisoning
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Contamination - Karst landscapes are particularly susceptible to groundwater contamination because water penetrates rapidly through bedrock conduits and little or no filtration occurs (White 1988). In some areas the water that moves through the habitat of these species percolates to the Edwards Aquifer below. The Edwards Aquifer is an important source of drinking water for 1.7 million people (Edwards Aquifer Authority 2008). So, information on sources of water contamination of the Edwards Aquifer may also be indicative of sources of contamination of karst invertebrate habitat. The ranges of these species are becoming increasingly urbanized and thereby are becoming more susceptible to contaminants including sewage, oil, fertilizers, pesticides, herbicides, seepage from landfills, pipeline leaks, or leaks in storage structures and retaining ponds. Activities on the surface, such as disposing of toxic chemicals or motor oil, can also contaminate caves (White 1988). Continued urbanization will increase the likelihood that karst ecosystems are polluted by contamination from the leaks and spills, which have often occurred in Bexar County (see TWC 1989, TCEQ 2010a, TCEQ 2010b for information on contamination events). Texas Commission on Environmental Quality (TCEQ) (2010a) summarizes information on groundwater contamination reported by a number of agencies, and in 2010 they reported that 1,712 leaking petroleum storage tanks were located in Bexar County.

Stressor: Alterations of Drainage Patterns
Exposure: degrades/destroys habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of temperature, humidity, and nutrients that are washed into caves. To sustain these conditions, both natural surface and subsurface flow of water and nutrients should be maintained. Decreases in water flow or infiltration can result in excessive drying and may slow decomposition, while increases can cause flooding that drowns air-breathing species and carries away available nutrients. Alterations to surface topography, including decreasing or increasing soil depth or adding non-native fill, can change the nutrient flow into the cave and affect the cave community (Howarth 1983). Impermeable cover, collection of water in devices like storm sewers, increased erosion and sedimentation, and irrigation and sprinkler systems can affect water flow to caves and karst ecosystems. Altering the quantity or timing of water input to the karst ecosystem, or its organic content, may negatively impact the listed species. (USFWS 2011a).

Stressor: Quarrying and mining operations
Exposure: destroys/degrades habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Quarrying and mining operations - Quarries and mines exist in Bexar County, including the northern half, where the majority of the listed species occur. While quarrying activities have revealed some caves (which can lead to protecting these sites), they have also completely destroyed others (Elliott 2000). As caves and mesocavernous spaces are destroyed at mines and quarries, karst invertebrates, possibly including some listed species, will also be lost. (USFWS 2011a).

Stressor: Alterations of surface plant and animal communities -
Exposure: destroy/degrades habitat; introduces competition; introduces predators
Response: Loses habitat; competes for limited resources; is predated upon
Consequence:
Narrative: Alterations of surface plant and animal communities - Karst ecosystems are heavily reliant on surface plant and animal communities to maintain nutrient flows, reduce sedimentation, and resist exotic and invasive species. As the surface around a cave entrance becomes developed, native plant communities are often replaced with impermeable cover or exotic plants from nurseries. The abundance and diversity of native animals may decline due to decreased food and habitat combined with increased competition and predation from urban, exotic, and pet species. The leaf litter and wood that make up most of the detritus may also be reduced or altered, resulting in a reduction of nutrient and energy flow into the cave. (USFWS 2011a).

Recovery

Reclassification Criteria:
(1) at least one high quality protected Karst Fauna Area (KFA) per Karst Fauna Region (KFR); (2) at least three total medium or high quality protected KFAs per KFR; (3) a minimum of six protected KFAs rangewide; (4) a minimum of three high quality KFAs; (5) all KFAs must at be of at least mediium or high quality.

Delisting Criteria:
In addition to the five downlisting criteria, monitoring an dresearch will have to have been completed to conclude with a high degree of certainlty that KFA size, quality, configuration, and management are adquate to provide a high probably of the species survival (greater than 90 percdnt over 100 years). To assess adequacy, results should be measured over a long enough time that cause and effect can be inferred with a high degree of certainty.

Recovery Actions:

- Reduce threats to the species by securing an adequate quantity and quality of caves, including selecting caves or cave clusters that represent the range of the species and potential genetic diversity, then preserving these caves, including their drainage basins and surface communities upon which they rely.
- Maintain cave preserves to keep them free from contamination, excessive human visitation, and non-native fire ants by regularly tracking progress and implementing adaptive management to control these and any new threats when necessary.
- Monitor the population status and threats because many aspects of the population dynamics and habitat requirements of the species are poorly understood.
- Recovery is dependent on incorporating research findings into adaptive management actions.

References

USFWS. 2000. Final Rule to List Nine Bexar County, Texas Invertebrate Species as Endangered, 65 FR 81419-81433

(2) USFWS 2012, Designation of Critical Habitat for Nine Bexar County, TX Invertebrates Final Rule, FR 8450-8523.

U.S. Fish and Wildlife Service. 2012. Endangered and Threatened Wildlife and Plants

Designation of Critical Habitat for Nine Bexar County, TX, Invertebrates. Final rule. 77 FR 8450 - 8523 (February 14, 2012)

U.S. Fish and Wildlife Service. 2003. Endangered and Threatened Wildlife and Plants

Designation of Critical Habitat for Seven Bexar County, TX, Invertebrate Species. 68 FR 17156 - 17231 (April 8, 2003).

USFWS, 2000. Final Rule to List Nine Bexar County, Texas Invertebrate Species as Endangered, 65 FR 81419-81433

USFWS 2012, Designation of Critical Habitat for Nine Bexar County, TX Invertebrates Final Rule, FR 8450-8523.

U.S. Fish and Wildlife Service (USFWS). 2011a. Bexar County Karst Invertebrate Recovery Plan.

USFWS. 2011. Bexar County Karst Invertebrate Final Recovery Plan.

SPECIES ACCOUNT: *Cicurina madla* (Madla's Cave Meshweaver)

Species Taxonomic and Listing Information

Listing Status: Endangered; 12-26-2000

Physical Description

Troglobite (spends entire life in subterranean environment); builds irregular webs close to or directly on the ground; typically a tangle of wooly fibers to trap prey; small; essentially eyeless; reduced pigment.

Taxonomy

Family Dictynidae of cribellate spiders (hackled band-producing); aka Madla's Cave Spider

Historical Range

Unknown, but likely similar to current distribution

Current Range

Limited to 20 Caves in Bexar County, TX: Christmas Cave, Madla's Cave, Madla's Drop Cave, Helotes Blowhole, Helotes Hilltop Cave, Headquarters Cave, Breathless Cave, Feature No. 50, Hills and Dales Pit, John Wagner Ranch Cave No. 3, La Cantera Cave No. 1, Robber's Cave, Unnamed Cave Holotes Area, Fat man's Nightmare Cave, Lithic Ridge Cave, Lost Pothole, Pig Cave, San Antonio Ranch Pit, Scenic Overlook Cave, Surprise Sink.

Distinct Population Segments Defined

No; not applicable to invertebrates

Critical Habitat Designated

Yes; 4/8/2003.

Legal Description

On February 14, 2012, the U.S. Fish and Wildlife Service (Service) designated critical habitat for Madla Cave meshweaver (Cicurina madla) (and eight other species) under the Endangered Species Act of 1973, as amended (77 FR 8450 - 8523). These species are collectively known as the nine Bexar County invertebrates. This critical habitat replaces critical habitat previously designated April 8, 2003 (68 FR 17156 - 17231). For Madla Cave meshweaver , approximately 196 ac (79 ha) fall within the boundaries of the critical habitat designation.

Critical Habitat Designation

Critical habitat for the Madla's Cave meshweaver in Bexar County, Texas, occurs in Units 1a, 1c, 1d, 1e, 2, 3, 5, 6, 8, 9, 17, and 22. Eight caves and their associated karst management areas established under the La Cantera Habitat Conservation Plan section 10(a)(1)(B) permit are adjacent to or within the boundaries of Units 1e, 3, 6, 8, and 17, but are not designated as critical habitat. These caves are Canyon Ranch Pit, Fat Man’s Nightmare Cave, Scenic Overlook Cave and the surrounding approximately 75 ac (30 ha) adjacent to Unit 1e; Helotes Blowhole and Helotes Hilltop Caves and the surrounding approximately 25 ac (10 ha) adjacent to Unit 3; John Wagner Cave No. 3 and the surrounding approximately 4 ac (1.6 ha) adjacent to Unit 6; Hills and Dales Pit and the surrounding approximately 70 ac (28 ha) adjacent to Unit 8; and Madla's Cave and the surrounding approximately 5 ac (2 ha) within Unit 17.

Unit 1a: Unit 1a consists of 144 ac (58 ha) of State-owned land located in northwestern Bexar County in the northwestern part of Government Canyon State Natural Area (GCSNA) in the Government Canyon KFR. The GCSNA is an area of approximately 8,622 ac (2,688 ha) owned and managed by the Texas Parks and Wildlife Department (TPWD). The GCSNA is accessible to the public under certain restrictions. This unit is all undeveloped woodland and is crossed by a wet weather stream and a trail. Unit 1a contains Surprise Sink, which is occupied by Madla Cave meshweaver and R. infernalis, and Bone Pile Cave, which is occupied by R. infernalis. Surprise Sink was believed to be occupied by Government Canyon Bat Cave spider, but further investigation showed that this identification could not be confirmed (Ledford 2011, pp. 160–161). The caves in this unit were occupied at the time of listing by each of the species listed above, and the unit contains the features essential to the conservation of each species (PCEs 1 and 2). The features essential to the conservation of the species in this unit may require special management considerations or protection to address the main threat in this unit, which is infestation of fire ants. The GCSNA currently has a management plan in place that includes treating for fire ants and managing for the benefit of the Madla Cave meshweaver and R. infernalis. The treatment of fire ants only temporarily alleviates the threat, so special management is required in perpetuity to remove the threat. The unit was delineated by drawing a circle with an area of 100 ac (40 ha) around each of the two caves and connecting the edges of the overlapping circles. Unit 1a is all Karst Zone 1.

Unit 1c: Unit 1c consists of 100 ac (40 ha) of State-owned land located in northwestern Bexar County in the central part of GCSNA in the Government Canyon KFR. This unit is primarily undeveloped native woodland that is crossed by a hiking trail. There is only one cave in this unit, Lost Pothole Cave. The cave was occupied at the time of listing, and the unit contains all the PCEs for the species. A small amount of the woody vegetation in this unit has been cleared in the past for ranching prior to TPWD ownership. The main threat to species in the unit is infestation of fire ants. GCSNA currently has a management plan in place that includes treating for fire ants and managing for the benefit of the species. Because the treatment for fire ants only temporarily alleviates the threat, special management is required in perpetuity. This unit was delineated by drawing a circle with an area of 100 ac (40 ha) around the cave. Unit 1c is all Karst Zone 1.

Unit 1d: Unit 1d consists of 225 ac (91 ha) of State-owned land located in northwestern Bexar County in the central part of the GCSNA in the Government Canyon KFR. This unit is wooded and undeveloped. The unit is primarily native vegetation, but small portions of the unit appear to have been thinned in the past for ranching prior to TPWD ownership. Unit 1d contains three caves: Dancing Rattler Cave, Lithic Ridge Cave, and Hackberry Sink. The Lithic Ridge Cave is occupied by Madla Cave meshweaver, R. exilis, and R. infernalis. The Dancing Rattler Cave and Hackberry Sink are occupied by R. infernalis. The caves in this unit were occupied at the time of listing, and the unit contains all the PCEs for the species. The main threat to the unit is infestation of fire ants. The GCSNA currently has a management plan in place that includes treating for fire ants. Because the treatment for fire ants only temporarily alleviates the threat, special management is required in perpetuity. This unit was delineated by drawing a circle with an area of 100 ac (40 ha) around each of the caves and connecting the edges of the overlapping circles. Unit 1d is all Karst Zone 1.

Unit 1e: Unit 1e consists of 410 ac (166 ha) in northwestern Bexar County that includes the northeastern part of Stateowned GCSNA, adjacent City of San Antonio-owned land, and private land in the Government Canyon KFR for the Madla Cave meshweaver, R. infernalis, R. exilis, and Helotes mold beetle. About 64 ac (26 ha) of land managed under the La Cantera HCP are not included in this designation of critical habitat (see explanation below). The majority of Unit 1e consists of undeveloped land, with the exception of several small private and county roads. Woody vegetation has been thinned for ranching on a small area of the northeastern part of the unit. Unit 1e contains eight caves. Four caves are occupied by Madla Cave meshweaver (Fat Man's Nightmare Cave, Pig Cave, San Antonio Ranch Pit, and Scenic Overlook Cave). Fat Man's Nightmare Cave is also occupied by R. infernalis; Pig Cave is also occupied by R. infernalis and R. exilis; San Antonio Ranch Pit is occupied by R. infernalis, R. exilis, and Helotes mold beetle; and Scenic Overlook Cave is occupied by R. infernalis and Helotes mold beetle. The unit also contains Canyon Ranch Pit and Continental Park Cave, which are occupied by R. infernalis; Creek Bank Cave, which is occupied by R. exilis; and Tight Cave, which is occupied by R. exilis and Helotes mold beetle. The caves were likely occupied at the time of listing, but surveys sufficient to detect the species were not conducted before the time of listing. Since listing, the species has been found in the caves. Due to the long lifespan of these critters, or lack of dispersal that occurs, we assume they must have been there all along. Therefore, we are considering these caves to be occupied at the time of listing. The unit contains all the PCEs for the species. In addition, populations and known occurrences are so low that all need to be conserved. Special management is needed in this unit because of infestation of fire ants and vandalism from unauthorized access. Five of the caves in this unit are owned by GCSNA, and they currently have a management plan in place that includes treating for fire ants and managing for the benefit of the species. These five caves are San Antonio Ranch Pit, Pig Cave, Creek Bank Cave, Tight Cave, and Continental Park Cave. Three of the eight known occupied caves within this unit and their associated preserve lands are part of the 75-ac (30-ha) Canyon Ranch Preserve. The Canyon Ranch Preserve, which was acquired and is managed by La Cantera under their HCP, contains Canyon Ranch Pit, Fat Man's Nightmare Cave, and Scenic Overlook Cave. In accordance with the La Cantera HCP, these three caves and the surrounding preserve lands will be managed in perpetuity for the conservation of the species. In accordance with section 4(b)(2) of the Act, we excluded from critical habitat designation approximately 64 ac (26 ha) of the preserve from this unit (see Exclusions section). When this unit was delineated, there was an 11-ac (4-ha) portion of the 75-ac (30-ha) preserve that fell outside the boundaries. Therefore, we excluded the approximately 64-ac (26-ha) portion of the preserve land that fell within the unit boundary. This unit was delineated by drawing a circle with an area of 100 ac (40 ha) around each of the caves and generally connecting the edges of the overlapping circles. Unit 1e is all Karst Zone 1.

Unit 2: Unit 2 consists of 180 ac (73 ha) of private land located in northwestern Bexar County north of Bandera Road and southeast of High Bluff Road in the Helotes KFR. This unit contains a mix of large, wooded tracts with several residential buildings, cleared areas, a quarry on the southeastern edge, and private or county roads. Unit 2 contains two caves. Madla's Drop Cave is occupied by Madla Cave meshweaver and R. infernalis. Logan's Cave is occupied by R. infernalis and R. exilis. These caves were occupied at the time of listing, and the unit contains all the PCEs for the species. Two paved roads cross the cave cricket foraging area of this unit and act as barriers to cricket movement. The features essential to the conservation of the species may require special management considerations or protection, because of residential development. Threats include the potential for destruction of habitat from vandalism, contamination of the subsurface drainage area of the unit, drying of karst, reduction of nutrient input, and infestation of fire ants. This unit was delineated by drawing a circle with an area of 100 ac (40 ha) around each of the caves and generally connecting the edges of the overlapping circles. Areas of Karst Zone 3 karst along the southern portion of the unit were left out, and the unit was expanded outside the circles in a small area to the east and to the southwest to include the estimated subsurface drainage basin. Unit 2 is all Karst Zone 1.

Unit 3: Unit 3 consists of 110 ac (45 ha) of private land in northwestern Bexar County, east of Bandera Road and northwest of Scenic Loop in the Helotes KFR. About 25 ac (10 ha) of lands managed under the La Cantera HCP are not included in this designation of critical habitat (see explanation below). The unit contains relatively large, wooded tracts. This unit contains two caves, Helotes Blowhole and Helotes Hilltop Cave. Helotes Blowhole is occupied by Madla Cave meshweaver, R. infernalis, and R. exilis. The Helotes Hilltop Cave is occupied by Madla Cave meshweaver, R. exilis, and Helotes mold beetle. Both caves were occupied at the time of listing, and the unit contains all the PCEs for the species. Special management is needed in this unit because of the potential for destruction of habitat from vandalism, contamination of the subsurface drainage area of the unit, and infestation of fire ants. In addition, a small portion of the northern side of the unit has been developed with residential homes. Unit 3 contains several small residential roads and is bordered on its southwestern edge by Bandera Road, a four-lane divided highway. This unit does not include the entire 344-ft (105- m) cave cricket foraging area around Helotes Hilltop Cave in Karst Zone 3, because a paved road creates a barrier to cave cricket movement. The road is located in Karst Zone 3, and the area east of the road is not included in critical habitat. This unit was delineated by drawing a circle with an area of 100 ac (40 ha) around each of the caves and generally connecting the edges of the overlapping circles. Because of the large amount of Karst Zone 3 to the east was left out, we expanded the western circle to the north and northwest in Karst Zone 1 to the boundary proposed for the unit. Some areas of Zone 3 are included along the eastern boundary of the unit to include more of the cave cricket foraging area for Helotes Hilltop Cave. Areas of Zone 3 along all but a part of the northern portion of the unit were left out of this designation. The rest of Unit 3 is Karst Zone 1. In accordance with section 4(b)(2) of the Act, we excluded from critical habitat designation approximately 25 ac (10 ha) of land surrounding the caves under the La Cantera HCP (see Exclusions section). These caves and the surrounding preserve lands will be managed in perpetuity for the conservation of the species. The remainder of the unit needs special management because of the presence of roads and residential development.

Unit 5: Unit 5 consists of 100 ac (40 ha) of private land in northwestern Bexar County, northwest of Cedar Crest Drive and north of Madla Ranch Road in the Helotes KFR. The unit contains a large tract of undeveloped woodland and several smaller, wooded tracts developed with homes and associated residential roads. This unit contains one cave, Christmas Cave, which is occupied by R. exilis, R. infernalis, Helotes mold beetle, and Madla Cave meshweaver. The cave was occupied at the time of listing, and the unit contains all the PCEs for the species. The unit requires special management because of the presence of residential development and impending future development. Threats include the potential for destruction of habitat from development and vandalism, contamination of the subsurface drainage area of the unit, reduction of moisture and nutrients, and infestation of fire ants. The unit was delineated by drawing a circle with an area of 100 ac (40 ha) around the cave. Large areas of Zone 3 were then removed from the southeast portion, but a small amount of Karst Zone 3 is included along the southeastern boundary of the unit to include the cave cricket foraging area for Christmas Cave. The rest of Unit 5 is Karst Zone 1. The boundary circle was expanded to include more Karst Zone 1 along its northeast edge, around the northwest side, and to the southwest edge to include 100 ac (40 ha) of undisturbed vegetation. However, there are homes and associated roads within the cave cricket foraging area of the cave.

Unit 6: Unit 6 consists of 96 ac (39 ha) of private and City of San Antonio-owned land located in northwestern Bexar County, bordered to the south by Menchaca Road and to the west by Morningside Drive in the UTSA KFR. About 4 ac (1.6 ha) of land managed under the La Cantera HCP are not included in this designation of critical habitat (see explanation below). Unit 6 consists primarily of large, undeveloped, woodland tracts with several smaller areas developed with homes. John Wagner Ranch Cave No. 3 is the only cave in this unit, and it is occupied by Madla Cave meshweaver, R. exilis, and R. infernalis. The cave was occupied at the time of listing, and the unit contains all the PCEs for the species. Special management is needed in this unit because of the destruction of habitat from development and vandalism, contamination of the subsurface drainage area of the unit, and infestation of fire ants. The unit was delineated by drawing a circle with an area of 100 ac (40 ha) around the cave and then cutting most of Karst Zone 3 out of the circle, which is primarily the southern portion of the circle. A small portion of Karst Zone 3 is included in the unit to include the cave cricket foraging area on the south side. The unit was expanded outside the remaining circle on the northeastern side to include a minimum of 100 ac (40 ha) of native vegetation. The majority of land included in Unit 6 is in Karst Zone 1. In accordance with section 4(b)(2) of the Act, we excluded from critical habitat designation in this unit the John Wagner Ranch Cave No. 3 and approximately 4 ac (1.6 ha) surrounding the cave under the La Cantera HCP (see Exclusions section). The cave and surrounding preserve lands will be managed in perpetuity for the conservation of the species.

Unit 8: Unit 8 consists of 243 ac (98 ha) of private and City of San Antonio’s Thrift Tract land located in northwestern Bexar County in the UTSA KFR. About 52 ac (21 ha) of land managed under the La Cantera HCP are not included in this designation of critical habitat (see explanation below). The unit is bordered by Kyle Seale Parkway on the northwest, by Moss Brook Drive on the northeast, and by Cotton Trail Lane on the south. Some of the land is undeveloped woodland, but some areas on the edges of the unit have been developed or have been cleared for future development. This unit contains three caves: Three Fingers Cave, Hills and Dales Pit, and Robber’s Cave. Hills and Dales Pit and Robber’s Cave are occupied by Madla Cave meshweaver, R. exilis, and R. infernalis. Three Fingers Cave is occupied by R. exilis and R. infernalis. This unit was occupied at the time of listing, and the unit contains all the PCEs for the species. The extreme southern portions of this unit have been subdivided and developed with homes. Several roads cross the unit. Threats in this unit include the potential for destruction of habitat from vandalism and development, contamination of the subsurface drainage area of the unit, drying of karst, reduction of nutrient input, and infestation of fire ants. The unit was delineated by drawing a circle with an area of 100 ac (40 ha) around each of the three caves and generally connecting the edges of the resulting circles. Areas with dense development were cut out of the circle along the northeastern and extreme southern edges. A quarry was cut out from the northwestern portion. The unit is entirely in Karst Zone 1. In accordance with section 4(b)(2) of the Act, we excluded from critical habitat designation in this unit the Hills and Dales Pit and approximately 52 ac (21 ha) surrounding the cave under the La Cantera HCP (see Exclusions section). The cave and surrounding preserve lands will be managed in perpetuity for the conservation of the species. There is a total of approximately 70 ac (28 ha) of preserve area surrounding the cave and being managed under the La Canter HCP. However, approximately 18 ac (7 ha) of the 70 ac (28 ha) preserve fell outside the boundaries of this unit when the unit was delineated. Therefore, we excluded the approximately 52-ac (21- ha) portion of the preserve land that fell within the unit boundary.

Unit 9: Unit 9 consists of 105 ac (42 ha) of State and private land in north-central Bexar County on the South side of Loop 1604 and east of the Loop 1604 intersection with IH 10 in the UTSA KFR. This unit is primarily a large tract of undeveloped woodland. The unit is bordered to the west by the University of Texas at San Antonio campus and to the east by Valero Way. Unit 9 has two caves: Mastodon Pit and Feature No. 50. Feature No. 50 is occupied by Madla Cave meshweaver, and Mastodon Pit is occupied by R. exilis. Both caves were occupied at the time of listing, and the unit has all of the PCEs for the species. Threats include the potential for destruction of habitat from vandalism and development, contamination of the subsurface drainage area of the unit, drying of karst, reduction of nutrient input, and infestation of fire ants. The unit was delineated by drawing a circle with an area of 100 ac (40 ha) around the two caves and generally connecting the edges of the resulting circles. The majority of the land included in Unit 9 is Karst Zone 1 or Karst Zone 2 (because Feature No. 50 was found to be occupied after Veni (2003) delineated the zones). We stopped the boundary of the unit on the north side at the southern edge of Loop 1604, because this major roadway and the major shopping mall north of it do not have one or more of the PCEs, including sources of nutrient input. The western edge generally follows the edge of development. The area to the north of Loop 1604 is not included in this final critical habitat designation, because it was authorized for adverse impacts under La Cantera's HCP (see Exclusions section). We expanded the edge of the circles to the south to include 100 ac (40 ha) of undisturbed vegetation and contiguous karst.

Unit 17: Unit 17 consists of 96 ac (39 ha) of private land in northwest Bexar County east of Scenic Loop Road and south of Madla Ranch Road in the Helotes KFR. About 5 ac (2 ha) within this unit's boundary are not included in this designation of critical habitat (see explanation below). The unit contains some houses and paved roads in the eastern portion and one house in the southeastern portion. The unit contains one cave, Madla's Cave, which is occupied by Madla Cave meshweaver and R. infernalis. The cave was occupied at the time of listing, and the unit has all the PCEs of the species. In accordance with section 4(b)(2) of the Act, we excluded from critical habitat designation in this unit Madla's Cave and the surrounding approximately 5 ac (2 ha), which has been acquired as a preserve in accordance with the La Cantera HCP (see Exclusions section). The cave and surrounding preserve land will be managed in perpetuity for the conservation of the species. The unit requires special management, because of the presence of residential development and potential future development within the unit. Threats include the potential for destruction of habitat from new development and vandalism, contamination of the subsurface drainage area of the unit from future development, reduction of moisture and nutrient input, and infestation of fire ants. The unit was delineated by drawing a circle with an area of 100 ac (40 ha) around the cave and removing areas that are not Karst Zone 1 from the northern and southwestern parts of the resulting circle. The southern, eastern, and western portions of the circle were expanded to include 101 ac (40 ha) of undisturbed surface vegetation. However, we subtracted the 5-ac (2-ha) portion that we excluded under the La Cantera HCP in the middle of this unit to arrive at approximately 96 ac (39 ha) of designated critical habitat. A small area of Karst Zone 3 is included in the southwestern portion of the unit to reduce edge effects of drawing the boundary along Karst Zone 1.

Unit 22: Unit 22 consists of 100 ac (40 ha) of private and City of San Antonio's Woodland Hills land located in northwestern Bexar County, northeast of Babcock Road and northwest of

Heuermann Road in the UTSA KFR. There are several unpaved roads and trails, including one within the cave cricket foraging area. The unit is mostly undeveloped woodland, but some areas appear to have been cleared in the past for ranching. Unit 22 is a combination of private land and the City of San Antonio's Woodland Hills Preserve for protection of the Edwards Aquifer recharge. Breathless Cave is the only cave in this unit. Breathless Cave is occupied by Madla Cave meshweaver. The cave was not known to be occupied at the time of listing, but it is currently occupied. The cave likely was at the time of listing, but surveys sufficient to detect the species were not conducted before the listing. Therefore, we are considering it to be occupied at the time of listing. In addition, populations and known occurrences are so low that all need to be conserved. The unit contains all the PCEs for the species. The major threat in this unit is potential future development within the unit. Threats include the potential for destruction of habitat from new development and vandalism, contamination of the subsurface drainage area of the unit from future development, reduction of moisture and nutrient input, and infestation of fire ants. The unit was delineated by drawing a circle with an area of 100 ac (40 ha) around Breathless Cave. The resulting unit is mostly Karst Zone 1, except for a small sliver of Karst Zone 3 in its western portion, which we include because of its narrow width and the increased edge effects associated with removing this area.

Primary Constituent Elements/Physical or Biological Features

The primary constituent elements of critical habitat for the Madla's Cave Meshweaver are:

(i) Karst-forming rock containing subterranean spaces (caves and connected mesocaverns) with stable temperatures, high humidities (near saturation), and suitable substrates (for example, spaces between and underneath rocks for foraging and sheltering) that are free of contaminants; and

(ii) Surface and subsurface sources (such as plants and their roots, fruits, and leaves, and animal (e.g., cave cricket) eggs, feces, and carcasses) that provide nutrient input into the karst ecosystem.

Special Management Considerations or Protections

Developed lands that do not contain the subsurface primary constituent elements and that existed on the effective date of this rule are not considered to be critical habitat.

Threats to the nine Bexar County invertebrates include clearing of vegetation for commercial or residential development, road building, quarrying, or other purposes. Infestation by nonnative vegetation causes adverse changes in the plant and animal community and possibly in moisture availability. An increase in fire ants can occur with development and cause competition with and predation on other invertebrates in the karst ecosystem. In addition, filling cave features for construction, ranching, or other purposes can adversely affect the listed invertebrate species by reducing nutrient input, reducing small mammal access, and changing moisture regimes. Excavation for construction or operation of quarries can directly destroy karst features occupied by any of the nine Bexar County invertebrates, including the mesocaverns they use.

Examples of management that would alleviate these threats include: (1) Protecting vegetation around occupied karst features and overlying connected mesocaverns; (2) protecting subsurface karst habitat to allow movement of karst invertebrates through caves and mesocaverns; (3) controlling nonnative fire ants around cave features and within the karst cricket foraging area; (4)

preventing unauthorized access to karst features by installing fencing and cave gates; and (5) keeping the surface and subsurface areas surrounding cave features and associated mesocaverns free from sources of contamination.

Life History

Feeding Narrative

Adult: Nutrients in most karst ecosystems are derived from the surface either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the karst invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller troglophiles and troglobites that grow on the leaves or feces rather than the original material itself. Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through karst fissures and solution features. Forpredatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave. The cave cricket (Ceuthophilus spp.) is a particularly important nutrient component and is found in most caves in Texas (USFWS 2011). Troglobytes typically have very slow metabolisms, an adaptation to the sparse amounts of food found in their environment. Because they are adapted to an environment with little food, pollution by the addition of large amounts of nutrients to the cave can actually be harmful to the species, because it allows invertebrates that are not cave adapted, such as cockroaches and a variety of flies to survive in the care and even-out-compete the cave species (USFWS 2000).

Reproduction Narrative

Adult: Cave invertebrates are described as more similar to large mammals than to their invertebrate cousins that live on the land surface. Like large mammals, they have few offspring and live relatively long lives (for invertebrates). This also means their populations are more sensitive to losing even fairly small numbers of individuals, and that it takes a long time for their population sizes to recovery from any catastrophe. (USFWS 2000).

Geographic or Habitat Restraints or Barriers

Adult: Restricted to cave/karst environments

Spatial Arrangements of the Population

Adult: unknown

Environmental Specificity

Adult: High

Tolerance Ranges/Thresholds

Adult: Low

Site Fidelity

Adult: High;

Dependency on Other Individuals or Species for Habitat

Adult: Unknown

Habitat Narrative

Adult: The six listed Bexar County arachnids are restricted to cave/karst habitat, and can be found in as few as one cave or as many as 20 (USFWS 2011). How they may disperse, or be dispersed, to other caves is unknown. What is known is that the karst/cave system (shelter) is highly susceptible to degradation from outside influences (USFWS 2011).

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: None

Dispersal

Adult: Unknown

Immigration/Emigration

Adult: Unknown

Dependency on Other Individuals or Species for Dispersal

Adult: Unknown

Dispersal/Migration Narrative

Adult: The six listed arachnids are restricted to the cave/karst environment of the Edwards Aquifer in Bexar County, Texas. Very little is known about their dispersal/migration within/among the caves. How they may disperse or be dispersed to other caves is unknown. (USFWS 2011).

Population Information and Trends

Population Trends:

Uknown

Species Trends:

Unknown

Resiliency:

Unknown

Representation:

Low; known from 20 caves

Redundancy:

Low

Population Growth Rate:

Unknown

Number of Populations:
Known from 20 caves

Population Size:
Unknown

Minimum Viable Population Size:
Unknown

Resistance to Disease:
Unknown, but likely low due to isolation

Adaptability:
Unknown, but likely low due to limited habitat parameters

Population Narrative:
Population estimates are unavailable for any of the six troglobites listed as endangered in Bexar County due to a lack of adequate techniques, their cryptic behavior, and inaccessibility of habitat. While some troglobites are known from a few specimens, detailed studies suggest that "as a rule" most troglobites are not numerically rare and thus are not susceptible to the problems of small populations." However, considering the lack of population estimates and limited study of these species, data are insufficient to indicate whether Bexar County karst invertebrates are numerous enough to rule out small population concerns (USFWS, 2011).

Threats and Stressors

Stressor: Edge effects
Exposure: impact native communities; disrupt natural systems; introduce non-native predators (such as fire ants)
Response: loses nutrients; competes for limited resources; death by predation
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Edge effects - “Edge effects” are changes to the floral and faunal communities where different habitats meet. The length and width of the edge, as well as the contrast between the vegetational communities, all contribute to the amount of impacts (Smith 1990, Harris 1984). Some types of edge effects include increases in solar radiation, changes in soil moisture due to elevated levels of evapotranspiration, wind buffeting (Ranny et al. 1981), changes in nutrient cycling and the hydrological cycle (Saunders et al. 1990), and changes in the rate of leaf litter decomposition (Didham 1998). These edge effects alter plant communities, which in turn impact the associated animal species. Edge effects can also affect animal species directly. The changes caused by edge effects can occur rapidly. Vegetation located 2 m (6.6 ft) from an edge can be visibly affected within days (Lovejoy et al. 1986). Edge effects associated with soil disturbance and disruption to native communities that accompany urbanization (for example, waste associated with housing) may attract redimported fire ants (RIFA)(discussed in factor C) or other surface species that prey on or compete with cave species (Reddell 1993). The invasion of RIFA is aided by “any disturbance that clears a site of heavy vegetation and disrupts the native ant community” (Porter et al. 1988) such as road building and urbanization. Development and edges

often allow enough disruption for invasive or exotic species to displace native communities that had previously prevented their spread (Saunders et al. 1990, Kotanen et al. 1998, Suarez et al. 1998, Meiners and Steward 1999). (USFWS 2011a).

Stressor: Human visitation and vandalism, including commercialization
Exposure: degrades/destroys habitat; introduces predators and competitors
Response: Loses habitat; competes for limited resources; death by predation; crushed
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Human visitation and vandalism - Visitation can impact caves by increasing soil compaction, trash deposition, and vandalism; altering airflow as entrances are expanded and excavated; scaring away trogloxenes (Culver 1986, Elliott 2000); and may also lead to direct mortality of cave organisms crushed by human disturbance (Crawford and Senger 1988). Commercialization of caves affects cave communities due to (1) competition with introduced surface species; (2) harmful effects of commercial lighting, for example increased temperature and decreased humidity near lights; (3) substrate changes around trails; (4) changes in microclimate due to cave ventilation; (5) and increases in the nutrient regime that favor surface species (Culver 1986, Northup 1988, Northup et al. 1988; Reddell 1993, Krejca and Myers 2005, Mulec and Kosi 2009). Conversely, some researchers have found high diversity and/or abundance of some species in show caves that have higher nutrient and water availability (Culver and Sket 2000, Paquin 2007). However, for the reasons stated above we believe that commercialization of caves is generally a threat because (1) these activities alter the natural habitat and nutrient regime of these species and (2) because most caves in Texas have limited nutrient and water availability. (USFWS 2011a)

Stressor: Contamination
Exposure: introduced pollutions, poisons to groundwater
Response: Loses habitat; direct poisoning
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Contamination - Karst landscapes are particularly susceptible to groundwater contamination because water penetrates rapidly through bedrock conduits and little or no filtration occurs (White 1988). In some areas the water that moves through the habitat of these species percolates to the Edwards Aquifer below. The Edwards Aquifer is an important source of drinking water for 1.7 million people (Edwards Aquifer Authority 2008). So, information on sources of water contamination of the Edwards Aquifer may also be indicative of sources of contamination of karst invertebrate habitat. The ranges of these species are becoming increasingly urbanized and thereby are becoming more susceptible to contaminants including sewage, oil, fertilizers, pesticides, herbicides, seepage from landfills, pipeline leaks, or leaks in storage structures and retaining ponds. Activities on the surface, such as disposing of toxic chemicals or motor oil, can also contaminate caves (White 1988). Continued urbanization will increase the likelihood that karst ecosystems are polluted by contamination from the leaks and spills, which have often occurred in Bexar County (see TWC 1989, TCEQ 2010a, TCEQ 2010b for information on contamination events). Texas Commission on Environmental Quality (TCEQ) (2010a) summarizes information on groundwater contamination reported by a number of agencies, and in 2010 they reported that 1,712 leaking petroleum storage tanks were located in Bexar County.

Stressor: Alterations of Drainage Patterns
Exposure: degrades/destroys habitat

Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of temperature, humidity, and nutrients that are washed into caves. To sustain these conditions, both natural surface and subsurface flow of water and nutrients should be maintained. Decreases in water flow or infiltration can result in excessive drying and may slow decomposition, while increases can cause flooding that drowns air-breathing species and carries away available nutrients. Alterations to surface topography, including decreasing or increasing soil depth or adding non-native fill, can change the nutrient flow into the cave and affect the cave community (Howarth 1983). Impermeable cover, collection of water in devices like storm sewers, increased erosion and sedimentation, and irrigation and sprinkler systems can affect water flow to caves and karst ecosystems. Altering the quantity or timing of water input to the karst ecosystem, or its organic content, may negatively impact the listed species. (USFWS 2011a).

Stressor: Quarrying and mining operations
Exposure: destroys/degrades habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Quarrying and mining operations - Quarries and mines exist in Bexar County, including the northern half, where the majority of the listed species occur. While quarrying activities have revealed some caves (which can lead to protecting these sites), they have also completely destroyed others (Elliott 2000). As caves and mesocavernous spaces are destroyed at mines and quarries, karst invertebrates, possibly including some listed species, will also be lost. (USFWS 2011a).

Stressor: Alterations of surface plant and animal communities -
Exposure: destroy/degrades habitat; introduces competition; introduces predators
Response: Loses habitat; competes for limited resources; is predated upon
Consequence:
Narrative: Alterations of surface plant and animal communities - Karst ecosystems are heavily reliant on surface plant and animal communities to maintain nutrient flows, reduce sedimentation, and resist exotic and invasive species. As the surface around a cave entrance becomes developed, native plant communities are often replaced with impermeable cover or exotic plants from nurseries. The abundance and diversity of native animals may decline due to decreased food and habitat combined with increased competition and predation from urban, exotic, and pet species. The leaf litter and wood that make up most of the detritus may also be reduced or altered, resulting in a reduction of nutrient and energy flow into the cave. (USFWS 2011a).

Recovery

Reclassification Criteria:
(1) at least one high quality protected Karst Fauna Area (KFA) per Karst Fauna Region (KFR); (2) at least three total medium or high quality protected KFAs per KFR; (3) a minimum of six protected KFAs rangewide; (4) a minimum of three high quality KFAs; (5) all KFAs must at be of at least mediium or high quality. (USFWS 2011)

Delisting Criteria:
In addition to the five downlisting criteria, monitoring an dresearch will have to have been completed to conclude with a high degree of certainlty that KFA size, quality, configuration, and management are adquate to provide a high probably of the species survival (greater than 90 percdnt over 100 years). To assess adequacy, results should be measured over a long enough time that cause and effect can be inferred with a high degree of certainty. (USFWS 2011)

Recovery Actions:

- Reduce threats to the species by securing an adequate quantity and quality of caves, including selecting caves or cave clusters that represent the range of the species and potential genetic diversity.
- Preserve these caves, including their drainage basins and surface communities upon which they rely.
- Maintain these cave preserves, keeping them free from contamination, excessive human visitation, and non-native fire ants by regularly tracking progress and implementing adaptive management to control these and any new threats when necessary.
- Monitor the population status and threats.
- Incorporate research findings into adaptive management actions, because many aspects of the population dynamics and habitat requirements of the species are poorly understood.

Conservation Measures and Best Management Practices:

- Not addressed.

References

USFWS. 2000. Final Rule to List Nine Bexar County, Texas Invertebrate Species as Endangered, 65 FR 81419-81433

USFWS. 2012. Designation of Critical Habitat for Nine Bexar County, TX Invertebrates Final Rule, FR 8450-8523.

U.S. Fish and Wildlife Service. 2012. Endangered and Threatened Wildlife and Plants

Designation of Critical Habitat for Nine Bexar County, TX, Invertebrates. Final rule. 77 FR 8450 - 8523 (February 14, 2012)

U.S. Fish and Wildlife Service. 2003. Endangered and Threatened Wildlife and Plants

Designation of Critical Habitat for Seven Bexar County, TX, Invertebrate Species. 68 FR 17156 - 17231 (April 8, 2003).

USFWS. 2000. Final Rule to List Nine Bexar County, Texas Invertebrate Species as Endangered, 65 FR 81419-81433

USFWS. 2011. Bexar County Karst Invertebrates Recovery Plan. Veni, G. and Associates. 2006. Hydrogeological, biological, archeological, and paleontological karst investigations, Camp Bullis, Texas, 1993-2006. Report for Natural and Cultural Resources, Environmental Division, Fort Sam Houston, Texas.

U.S. Fish and Wildlife Service (USFWS). 2011a. Bexar County Karst Invertebrate Recovery Plan.

USFWS. 2011. Bexar County Karst Invertebrate Final Recovery Plan.

SPECIES ACCOUNT: *Cicurina venii* (Braken Bat Cave Meshweaver)

Species Taxonomic and Listing Information

Listing Status: Endangered; 12-26-2000

Physical Description

Troglobite (spends entire life in subterranean environment); builds irregular webs close to or directly on the ground; typically a tangle of wooly fibers to trap prey; small; essentially eyeless.

Taxonomy

Family Dictynidae of cribellate spiders (hackled band-producing); aka Veni's Cave Spider

Historical Range

Unknown, but likely similar to current distribution

Current Range

Single cave: Braken Bat Cave, Bexar County, TX; <100 sq km (~40 sq mi)

Distinct Population Segments Defined

No; not applicable to invertebrates

Critical Habitat Designated

Yes; 4/8/2003.

Legal Description

On February 14, 2012, the U.S. Fish and Wildlife Service (Service) designated critical habitat for Braken Bat Cave meshweaver (Cicurina venii) (and eight other species) under the Endangered Species Act of 1973, as amended (77 FR 8450 - 8523). These species are collectively known as the nine Bexar County invertebrates. This critical habitat replaces critical habitat previously designated April 8, 2003 (68 FR 17156 - 17231). For Braken Bat Cave meshweaver , approximately 217 ac (88 ha) fall within the boundaries of the critical habitat designation.

Critical Habitat Designation

Critical habitat for the Braken Bat Cave meshweaver in Bexar County, Texas, occurs in Unit 15.

Unit 15 consists of 217 ac (88 ha) of private land located in western Bexar County, west of Talley Road and north of Farm to Market Road 1957 in the Culebra Anticline KFR. The majority of the lands within Unit 15 are within a subdivision, and all are privately owned. Tracts in the subdivision are relatively large and still contain wooded vegetation, but roads and houses have fragmented the cave cricket foraging areas around all of the occupied caves. There is a substantial amount of the vegetation in the unit. This unit contains four caves: Braken Bat Cave, Isopit, Obvious Little Cave, and Wurzbach Bat Cave. Bracken Bat Cave is the only one that contains the Bracken Bat Cave meshweaver. All four caves are known to contain R. infernalis, and all were occupied at the time of listing. This unit contains all the PCEs for the species. The unit requires special management because of the proximity of development, the potential for destruction of habitat from vandalism, and the fragmentation of the surface community of plants and animals. Threats include potential future development, contamination of the subsurface drainage area of the unit, drying of karst, reduction of nutrient input, and infestation of fire ants. This unit was delineated by drawing a 100-ac (40-ha) circle around each of the four caves and connecting the edges of the overlapping circles. A small portion of the circle on the eastern edge in a high-density development was removed from the unit. All of Unit 15 is Karst Zone 1.

Primary Constituent Elements/Physical or Biological Features

The primary constituent elements of critical habitat for the Braken Bat Cave meshweaver are:

(i) Karst-forming rock containing subterranean spaces (caves and connected mesocaverns) with stable temperatures, high humidities (near saturation), and suitable substrates (for example, spaces between and underneath rocks for foraging and sheltering) that are free of contaminants; and

(ii) Surface and subsurface sources (such as plants and their roots, fruits, and leaves, and animal (e.g., cave cricket) eggs, feces, and carcasses) that provide nutrient input into the karst ecosystem.

Special Management Considerations or Protections

Developed lands that do not contain the subsurface primary constituent elements and that existed on the effective date of this rule are not considered to be critical habitat.

Threats to the nine Bexar County invertebrates include clearing of vegetation for commercial or residential development, road building, quarrying, or other purposes. Infestation by nonnative vegetation causes adverse changes in the plant and animal community and possibly in moisture availability. An increase in fire ants can occur with development and cause competition with and predation on other invertebrates in the karst ecosystem. In addition, filling cave features for construction, ranching, or other purposes can adversely affect the listed invertebrate species by reducing nutrient input, reducing small mammal access, and changing moisture regimes. Excavation for construction or operation of quarries can directly destroy karst features occupied by any of the nine Bexar County invertebrates, including the mesocaverns they use.

Examples of management that would alleviate these threats include: (1) Protecting vegetation around occupied karst features and overlying connected mesocaverns; (2) protecting subsurface karst habitat to allow movement of karst invertebrates through caves and mesocaverns; (3) controlling nonnative fire ants around cave features and within the karst cricket foraging area; (4) preventing unauthorized access to karst features by installing fencing and cave gates; and (5) keeping the surface and subsurface areas surrounding cave features and associated mesocaverns free from sources of contamination.

Life History

Feeding Narrative

Adult: Nutrients in most karst ecosystems are derived from the surface either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the karst invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller troglophiles and troglobites that grow on the leaves or feces rather than the original material itself. Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through karst fissures and solution features. Forpredatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave. The cave cricket (Ceuthophilus spp.) is a particularly important nutrient component and is found in most caves in Texas (USFWS 2011). Troglobytes typically have very slow metabolisms, an adaptation to the sparse amounts of food found in their environment. Because they are adapted to an environment with little food, pollution by the addition of large amounts of nutrients to the cave can actually be harmful to the species, because it allows invertebrates that are not cave adapted, such as cockroaches and a variety of flies to survive in the care and even-out-compete the cave species (USFWS 2000).

Reproduction Narrative

Adult: Cave invertebrates are described as more similar to large mammals than to their invertebrate cousins that live on the land surface. Like large mammals, they have few offspring and live relatively long lives (for invertebrates). This also means their populations are more sensitive to losing even fairly small numbers of individuals, and that it takes a long time for their population sizes to recovery from any catastrophe. (USFWS 2000).

Geographic or Habitat Restraints or Barriers

Adult: Restricted to cave/karst environments

Spatial Arrangements of the Population

Adult: Unknown

Environmental Specificity

Adult: High

Tolerance Ranges/Thresholds

Adult: Likely low

Site Fidelity

Adult: High

Dependency on Other Individuals or Species for Habitat

Adult: Unknown

Habitat Narrative

Adult: The six listed Bexar County arachnids are restricted to cave/karst habitat, and can be found in as few as one cave or as many as 20. They require a stable temperature and constant, high humidity and surface vegetation to provide nutrients from: (1) direct flow of plant material into the karst with water; (2) habitat and food sources provided for the animal communities that contribute nutrients to the karst ecosystem (such as cave crickets, small mammals); and (3) roots that extend into subsurface areas and may provide a major energy sources in shallow caves. (USFWS 2011). Habitat is susceptible to degradation harmful to the species.

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements
Adult: None

Dispersal
Adult: Unknown

Immigration/Emigration
Adult: Unknown

Dependency on Other Individuals or Species for Dispersal
Adult: Unknown

Dispersal/Migration Narrative
Adult: The six listed arachnids are restricted to the cave/karst environment of the Edwards Aquifer in Bexar County, Texas. Very little is known about their dispersal/migration within/among the caves. How they may disperse, or be dispersed, to other caves is unknown. (USFWS 2011).

Population Information and Trends

Population Trends:
Unknown

Species Trends:
Unknown

Resiliency:
Unknown

Representation:
Unknown, but known from a single cave

Redundancy:
Unknown, but known from only a single cave.

Population Growth Rate:
Unknown, but likely low

Number of Populations:
Unknown, but only from a single cave.

Population Size:
Unknown

Minimum Viable Population Size:
Unknown

Resistance to Disease:

Unknown, but likely low due to isolation

Adaptability:

Unknown, but likely low

Population Narrative:

Population estimates are unavailable for any of the six troglobites listed as endangered in Bexar County due to a lack of adequate techniques, their cryptic behavior, and inaccessibility of habitat. While some troglobites are known from a few specimens, detailed studies suggest that "as a rule" most troglobites are not numerically rare and thus are not susceptible to the problems of small populations." However, considering the lack of population estimates and limited study of these species, data are insufficient to indicate whether Bexar County karst invertebrates are numerous enough to rule out small population concerns (USFWS, 2011).

Threats and Stressors

Stressor: Edge effects
Exposure: impact native communities; disrupt natural systems; introduce non-native predators (such as fire ants)
Response: loses nutrients; competes for limited resources; death by predation
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Edge effects - "Edge effects" are changes to the floral and faunal communities where different habitats meet. The length and width of the edge, as well as the contrast between the vegetational communities, all contribute to the amount of impacts (Smith 1990, Harris 1984). Some types of edge effects include increases in solar radiation, changes in soil moisture due to elevated levels of evapotranspiration, wind buffeting (Ranny et al. 1981), changes in nutrient cycling and the hydrological cycle (Saunders et al. 1990), and changes in the rate of leaf litter decomposition (Didham 1998). These edge effects alter plant communities, which in turn impact the associated animal species. Edge effects can also affect animal species directly. The changes caused by edge effects can occur rapidly. Vegetation located 2 m (6.6 ft) from an edge can be visibly affected within days (Lovejoy et al. 1986). Edge effects associated with soil disturbance and disruption to native communities that accompany urbanization (for example, waste associated with housing) may attract redimported fire ants (RIFA)(discussed in factor C) or other surface species that prey on or compete with cave species (Reddell 1993). The invasion of RIFA is aided by "any disturbance that clears a site of heavy vegetation and disrupts the native ant community" (Porter et al. 1988) such as road building and urbanization. Development and edges often allow enough disruption for invasive or exotic species to displace native communities that had previously prevented their spread (Saunders et al. 1990, Kotanen et al. 1998, Suarez et al. 1998, Meiners and Steward 1999). (USFWS 2011a).

Stressor: Human visitation and vandalism, including commercialization
Exposure: degrades/destroys habitat; introduces predators and competitors
Response: Loses habitat; competes for limited resources; death by predation; crushed
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Human visitation and vandalism - Visitation can impact caves by increasing soil compaction, trash deposition, and vandalism; altering airflow as entrances are expanded and

excavated; scaring away trogloxenes (Culver 1986, Elliott 2000); and may also lead to direct mortality of cave organisms crushed by human disturbance (Crawford and Senger 1988). Commercialization of caves affects cave communities due to (1) competition with introduced surface species; (2) harmful effects of commercial lighting, for example increased temperature and decreased humidity near lights; (3) substrate changes around trails; (4) changes in microclimate due to cave ventilation; (5) and increases in the nutrient regime that favor surface species (Culver 1986, Northup 1988, Northup et al. 1988; Reddell 1993, Krejca and Myers 2005, Mulec and Kosi 2009). Conversely, some researchers have found high diversity and/or abundance of some species in show caves that have higher nutrient and water availability (Culver and Sket 2000, Paquin 2007). However, for the reasons stated above we believe that commercialization of caves is generally a threat because (1) these activities alter the natural habitat and nutrient regime of these species and (2) because most caves in Texas have limited nutrient and water availability. (USFWS 2011a)

Stressor: Contamination
Exposure: introduced pollutions, poisons to groundwater
Response: Loses habitat; direct poisoning
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Contamination - Karst landscapes are particularly susceptible to groundwater contamination because water penetrates rapidly through bedrock conduits and little or no filtration occurs (White 1988). In some areas the water that moves through the habitat of these species percolates to the Edwards Aquifer below. The Edwards Aquifer is an important source of drinking water for 1.7 million people (Edwards Aquifer Authority 2008). So, information on sources of water contamination of the Edwards Aquifer may also be indicative of sources of contamination of karst invertebrate habitat. The ranges of these species are becoming increasingly urbanized and thereby are becoming more susceptible to contaminants including sewage, oil, fertilizers, pesticides, herbicides, seepage from landfills, pipeline leaks, or leaks in storage structures and retaining ponds. Activities on the surface, such as disposing of toxic chemicals or motor oil, can also contaminate caves (White 1988). Continued urbanization will increase the likelihood that karst ecosystems are polluted by contamination from the leaks and spills, which have often occurred in Bexar County (see TWC 1989, TCEQ 2010a, TCEQ 2010b for information on contamination events). Texas Commission on Environmental Quality (TCEQ) (2010a) summarizes information on groundwater contamination reported by a number of agencies, and in 2010 they reported that 1,712 leaking petroleum storage tanks were located in Bexar County.

Stressor: Alterations of Drainage Patterns
Exposure: degrades/destroys habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of temperature, humidity, and nutrients that are washed into caves. To sustain these conditions, both natural surface and subsurface flow of water and nutrients should be maintained. Decreases in water flow or infiltration can result in excessive drying and may slow decomposition, while increases can cause flooding that drowns air-breathing species and carries away available nutrients. Alterations to surface topography, including decreasing or increasing soil depth or adding non-native fill, can change the nutrient flow into the cave and affect the cave

community (Howarth 1983). Impermeable cover, collection of water in devices like storm sewers, increased erosion and sedimentation, and irrigation and sprinkler systems can affect water flow to caves and karst ecosystems. Altering the quantity or timing of water input to the karst ecosystem, or its organic content, may negatively impact the listed species. (USFWS 2011a).

Stressor: Quarrying and mining operations
Exposure: destroys/degrades habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Quarrying and mining operations - Quarries and mines exist in Bexar County, including the northern half, where the majority of the listed species occur. While quarrying activities have revealed some caves (which can lead to protecting these sites), they have also completely destroyed others (Elliott 2000). As caves and mesocavernous spaces are destroyed at mines and quarries, karst invertebrates, possibly including some listed species, will also be lost. (USFWS 2011a).

Stressor: Alterations of surface plant and animal communities -
Exposure: destroy/degrades habitat; introduces competition; introduces predators
Response: Loses habitat; competes for limited resources; is predated upon
Consequence:
Narrative: Alterations of surface plant and animal communities - Karst ecosystems are heavily reliant on surface plant and animal communities to maintain nutrient flows, reduce sedimentation, and resist exotic and invasive species. As the surface around a cave entrance becomes developed, native plant communities are often replaced with impermeable cover or exotic plants from nurseries. The abundance and diversity of native animals may decline due to decreased food and habitat combined with increased competition and predation from urban, exotic, and pet species. The leaf litter and wood that make up most of the detritus may also be reduced or altered, resulting in a reduction of nutrient and energy flow into the cave. (USFWS 2011a).

Recovery

Reclassification Criteria:
(1) at least one high quality protected Karst Fauna Area (KFA) per Karst Fauna Region (KFR); (2) at least three total medium or high quality protected KFAs per KFR; (3) a minimum of six protected KFAs rangewide; (4) a minimum of three high quality KFAs; (5) all KFAs must at be of at least mediium or high quality. (USFWS 2011)

Delisting Criteria:
In addition to the five downlisting criteria, monitoring an dresearch will have to have been completed to conclude with a high degree of certainlty that KFA size, quality, configuration, and management are adquate to provide a high probably of the species survival (greater than 90 percdnt over 100 years). To assess adequacy, results should be measured over a long enough time that cause and effect can be inferred with a high degree of certainty. (USFWS 2011)

Recovery Actions:

- Reduce threats to the species by securing an adequate quantity and quality of caves, including selecting caves or cave clusters that represent the range of the species and potential genetic diversity.
- Preserve these caves, including their drainage basins and surface communities upon which they rely.
- Maintain these cave preserves, keeping them free from contamination, excessive human visitation, and non-native fire ants by regularly tracking progress and implementing adaptive management to control these and any new threats when necessary.
- Monitor the population status and threats.
- Incorporate research findings into adaptive management actions, because many aspects of the population dynamics and habitat requirements of the species are poorly understood.

Conservation Measures and Best Management Practices:

- Not addressed.

References

USFWS. 2000. Final Rule to List Nine Bexar County, Texas Invertebrate Species as Endangered, 65 FR 81419-81433

USFWS. 2011. Bexar County Karst Invertebrate Recovery Plan

USFWS 2012, Designation of Critical Habitat for Nine Bexar County, TX Invertebrates Final Rule, FR 8450-8523.

U.S. Fish and Wildlife Service. 2012. Endangered and Threatened Wildlife and Plants

Designation of Critical Habitat for Nine Bexar County, TX, Invertebrates. Final rule. 77 FR 8450 - 8523 (February 14, 2012)

U.S. Fish and Wildlife Service. 2003. Endangered and Threatened Wildlife and Plants

Designation of Critical Habitat for Seven Bexar County, TX, Invertebrate Species. 68 FR 17156 - 17231 (April 8, 2003).

USFWS. 2000. Final Rule to List Nine Bexar County, Texas Invertebrate Species as Endangered, 65 FR 81419-81433

USFWS. 2011. Bexar County Karst Invertebrates Recovery Plan.

U.S. Fish and Wildlife Service (USFWS). 2011a. Bexar County Karst Invertebrate Recovery Plan.

USFWS. 2011. Bexar County Karst Invertegrate Final Recovery Plan.

SPECIES ACCOUNT: *Cicurina vespera* (Government Canyon Bat Cave Meshweaver)

Species Taxonomic and Listing Information

Listing Status: Endangered; 12-26-2000

Physical Description

Troglobite (spends entire life in subterranean environment); builds irregular webs close to or directly on the ground; typically a tangle of wooly fibers to trap prey; small; essentially eyeless; reduced pigment.

Taxonomy

Family Dictynidae of cribellate spiders (hackled band-producing); aka Vesper Cave Spider.

Historical Range

Unknown, but likely similar to current distribution

Current Range

Known from one cave: Government Canyon Bat Cave, Bexar County, TX; < 100 sq km (~40 sq mi)

Distinct Population Segments Defined

No; not applicable to invertebrates

Critical Habitat Designated

Yes; 2/14/2012.

Legal Description

On February 14, 2012, the U.S. Fish and Wildlife Service (Service) designated critical habitat for Government Canyon Bat Cave meshweaver (Cicurina vespera) (and eight other species) under the Endangered Species Act of 1973, as amended (77 FR 8450 - 8523). These species are collectively known as the nine Bexar County invertebrates. For GovernmentCanyon Bat Cave meshweaver , approximately 100 ac (40 ha) fall within the boundaries of the critical habitat designation.

Critical Habitat Designation

Critical habitat for the Government Canyon Bat Cave meshweaver in Bexar County, Texas, occurs in Unit 1b.

Unit 1b - Unit 1b consists of 100 ac (40 ha) of State-owned land located in northwest Bexar County in the western portion of the GCSNA in the Government Canyon KFR. Land within the unit consists of undeveloped woodland. However, there are several one-lane gravel roads that serve primarily as pedestrian trails within the State natural area. A small portion of the vegetation appears to have been cleared for ranching prior to TPWD ownership. The unit contains one cave, Government Canyon Bat Cave, which is the only cave known to be occupied by the Government Canyon Bat Cave meshweaver. The cave is also occupied by Government Canyon Bat Cave spider, R. exilis, and R. infernalis. The Government Canyon Bat Cave was occupied at the time of listing, and the unit contains all the PCEs. The main threat to species in this unit is infestation of fire ants. The GCSNA currently has a management plan in place that includes treating for fire ants and managing for the benefit of the species. Because the treatment for fire ants only temporarily alleviates the threat, special management is required in perpetuity. The unit was delineated by drawing a circle with an area of 100 ac (40 ha) around the cave. A small piece of Karst Zone 2 on the northern part of the circle is included because removing it would increase the edge effects. The remainder of Unit 1b is Karst Zone 1.

Primary Constituent Elements/Physical or Biological Features

The primary constituent elements of critical habitat for the Government Canyon Bat Cave meshweaver are:

(i) Karst-forming rock containing subterranean spaces (caves and connected mesocaverns) with stable temperatures, high humidities (near saturation), and suitable substrates (for example, spaces between and underneath rocks for foraging and sheltering) that are free of contaminants; and

(ii) Surface and subsurface sources (such as plants and their roots, fruits, and leaves, and animal (e.g., cave cricket) eggs, feces, and carcasses) that provide nutrient input into the karst ecosystem.

Special Management Considerations or Protections

Developed lands that do not contain the subsurface primary constituent elements and that existed on the effective date of this rule are not considered to be critical habitat.

Threats to the nine Bexar County invertebrates include clearing of vegetation for commercial or residential development, road building, quarrying, or other purposes. Infestation by nonnative vegetation causes adverse changes in the plant and animal community and possibly in moisture availability. An increase in fire ants can occur with development and cause competition with and predation on other invertebrates in the karst ecosystem. In addition, filling cave features for construction, ranching, or other purposes can adversely affect the listed invertebrate species by reducing nutrient input, reducing small mammal access, and changing moisture regimes. Excavation for construction or operation of quarries can directly destroy karst features occupied by any of the nine Bexar County invertebrates, including the mesocaverns they use.

Examples of management that would alleviate these threats include: (1) Protecting vegetation around occupied karst features and overlying connected mesocaverns; (2) protecting subsurface karst habitat to allow movement of karst invertebrates through caves and mesocaverns; (3) controlling nonnative fire ants around cave features and within the karst cricket foraging area; (4) preventing unauthorized access to karst features by installing fencing and cave gates; and (5) keeping the surface and subsurface areas surrounding cave features and associated mesocaverns free from sources of contamination.

Life History

Feeding Narrative

Adult: Nutrients in most karst ecosystems are derived from the surface either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the karst invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller troglophiles and troglobites that grow on the leaves or feces rather than the original material itself. Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through karst fissures and solution features. For predatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave. The cave cricket (Ceuthophilus spp.) is a particularly important nutrient component and is found in most caves in Texas (USFWS 2011). Troglobytes typically have very slow metabolisms, an adaptation to the sparse amounts of food found in their environment. Because they are adapted to an environment with little food, pollution by the addition of large amounts of nutrients to the cave can actually be harmful to the species, because it allows invertebrates that are not cave adapted, such as cockroaches and a variety of flies to survive in the care and even-out-compete the cave species (USFWS 2000).

Reproduction Narrative

Adult: Cave invertebrates are described as more similar to large mammals than to their invertebrate cousins that live on the land surface. Like large mammals, they have few offspring and live relatively long lives (for invertebrates). This also means their populations are more sensitive to losing even fairly small numbers of individuals, and that it takes a long time for their population sizes to recovery from any catastrophe. (USFWS 2000).

Geographic or Habitat Restraints or Barriers

Adult: Limited to one cave site

Spatial Arrangements of the Population

Adult: Unknown

Environmental Specificity

Adult: High

Tolerance Ranges/Thresholds

Adult: Very low

Site Fidelity

Adult: High; restricted to one site

Dependency on Other Individuals or Species for Habitat

Adult: Unknown

Habitat Narrative

Adult: The six listed Bexar County arachnids are restricted to cave/karst habitat, and can be found in as few as one cave or as many as 20 (USFWS 2011). They require a stable temperature and constant, high humidity, and surface vegetation to provide nutrients from: (1) direct flow of plant material into the karst with water; (2) habitat and food sources provided for the animal communities that contribute nutrients to the karst ecosystem (such as cave crickets, small mammals); and (3) roots that extend into subsurface areas and may provide a major energy sources in shallow caves. What is known is that the karst/cave system (shelter) is highly susceptible to degradation from outside influences (USFWS 2011).

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: None

Dispersal

Adult: Unknown

Immigration/Emigration

Adult: Limited to a single cave

Dependency on Other Individuals or Species for Dispersal

Adult: Unknown

Dispersal/Migration Narrative

Adult: The six listed arachnids are restricted to the cave/karst environment of the Edwards Aquifer in Bexar County, Texas. Very little is known about their dispersal/migration within/among the caves (USFWS 2011).

Population Information and Trends

Population Trends:

Unknown

Species Trends:

Unknown

Resiliency:

Unknown, but likely low; vulnerable to habitat alteration and destruction

Representation:

Unknown, but limited to a single cave

Redundancy:

Unknown, but limited to a single cave

Population Growth Rate:

Unknown

Number of Populations:

Unknown; limited to one cave

Population Size:

Unknown

Minimum Viable Population Size:

Unknown

Resistance to Disease:

Unknown, but likely low due to isolation

Adaptability:

Unknown, but likely low due to environmental specificity

Population Narrative:

Population estimates are unavailable for any of the six troglobites listed as endangered in Bexar County due to a lack of adequate techniques, their cryptic behavior, and inaccessibility of habitat. While some troglobites are known from a few specimens, detailed studies suggest that "as a rule" most troglobites are not numerically rare and thus are not susceptible to the problems of small populations." However, considering the lack of population estimates and limited study of these species, data are insufficient to indicate whether Bexar County karst invertebrates are numerous enough to rule out small population concerns (USFWS, 2011).

Threats and Stressors

Stressor: Edge effects
Exposure: impact native communities; disrupt natural systems; introduce non-native predators (such as fire ants)
Response: loses nutrients; competes for limited resources; death by predation
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Edge effects - "Edge effects" are changes to the floral and faunal communities where different habitats meet. The length and width of the edge, as well as the contrast between the vegetational communities, all contribute to the amount of impacts (Smith 1990, Harris 1984). Some types of edge effects include increases in solar radiation, changes in soil moisture due to elevated levels of evapotranspiration, wind buffeting (Ranny et al. 1981), changes in nutrient cycling and the hydrological cycle (Saunders et al. 1990), and changes in the rate of leaf litter decomposition (Didham 1998). These edge effects alter plant communities, which in turn impact the associated animal species. Edge effects can also affect animal species directly. The changes caused by edge effects can occur rapidly. Vegetation located 2 m (6.6 ft) from an edge can be visibly affected within days (Lovejoy et al. 1986). Edge effects associated with soil disturbance and disruption to native communities that accompany urbanization (for example, waste associated with housing) may attract redimported fire ants (RIFA)(discussed in factor C) or other surface species that prey on or compete with cave species (Reddell 1993). The invasion of RIFA is aided by "any disturbance that clears a site of heavy vegetation and disrupts the native ant community" (Porter et al. 1988) such as road building and urbanization. Development and edges often allow enough disruption for invasive or exotic species to displace native communities that had previously prevented their spread (Saunders et al. 1990, Kotanen et al. 1998, Suarez et al. 1998, Meiners and Steward 1999). (USFWS 2011a).

Stressor: Human visitation and vandalism, including commercialization

Exposure: degrades/destroys habitat; introduces predators and competitors
Response: Loses habitat; competes for limited resources; death by predation; crushed
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Human visitation and vandalism - Visitation can impact caves by increasing soil compaction, trash deposition, and vandalism; altering airflow as entrances are expanded and excavated; scaring away trogloxenes (Culver 1986, Elliott 2000); and may also lead to direct mortality of cave organisms crushed by human disturbance (Crawford and Senger 1988). Commercialization of caves affects cave communities due to (1) competition with introduced surface species; (2) harmful effects of commercial lighting, for example increased temperature and decreased humidity near lights; (3) substrate changes around trails; (4) changes in microclimate due to cave ventilation; (5) and increases in the nutrient regime that favor surface species (Culver 1986, Northup 1988, Northup et al. 1988; Reddell 1993, Krejca and Myers 2005, Mulec and Kosi 2009). Conversely, some researchers have found high diversity and/or abundance of some species in show caves that have higher nutrient and water availability (Culver and Sket 2000, Paquin 2007). However, for the reasons stated above we believe that commercialization of caves is generally a threat because (1) these activities alter the natural habitat and nutrient regime of these species and (2) because most caves in Texas have limited nutrient and water availability. (USFWS 2011a)

Stressor: Contamination
Exposure: introduced pollutions, poisons to groundwater
Response: Loses habitat; direct poisoning
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Contamination - Karst landscapes are particularly susceptible to groundwater contamination because water penetrates rapidly through bedrock conduits and little or no filtration occurs (White 1988). In some areas the water that moves through the habitat of these species percolates to the Edwards Aquifer below. The Edwards Aquifer is an important source of drinking water for 1.7 million people (Edwards Aquifer Authority 2008). So, information on sources of water contamination of the Edwards Aquifer may also be indicative of sources of contamination of karst invertebrate habitat. The ranges of these species are becoming increasingly urbanized and thereby are becoming more susceptible to contaminants including sewage, oil, fertilizers, pesticides, herbicides, seepage from landfills, pipeline leaks, or leaks in storage structures and retaining ponds. Activities on the surface, such as disposing of toxic chemicals or motor oil, can also contaminate caves (White 1988). Continued urbanization will increase the likelihood that karst ecosystems are polluted by contamination from the leaks and spills, which have often occurred in Bexar County (see TWC 1989, TCEQ 2010a, TCEQ 2010b for information on contamination events). Texas Commission on Environmental Quality (TCEQ) (2010a) summarizes information on groundwater contamination reported by a number of agencies, and in 2010 they reported that 1,712 leaking petroleum storage tanks were located in Bexar County.

Stressor: Alterations of Drainage Patterns
Exposure: degrades/destroys habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of temperature, humidity, and nutrients that are washed into caves. To sustain these conditions,

both natural surface and subsurface flow of water and nutrients should be maintained. Decreases in water flow or infiltration can result in excessive drying and may slow decomposition, while increases can cause flooding that drowns air-breathing species and carries away available nutrients. Alterations to surface topography, including decreasing or increasing soil depth or adding non-native fill, can change the nutrient flow into the cave and affect the cave community (Howarth 1983). Impermeable cover, collection of water in devices like storm sewers, increased erosion and sedimentation, and irrigation and sprinkler systems can affect water flow to caves and karst ecosystems. Altering the quantity or timing of water input to the karst ecosystem, or its organic content, may negatively impact the listed species. (USFWS 2011a).

Stressor: Quarrying and mining operations
Exposure: destroys/degrades habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Quarrying and mining operations - Quarries and mines exist in Bexar County, including the northern half, where the majority of the listed species occur. While quarrying activities have revealed some caves (which can lead to protecting these sites), they have also completely destroyed others (Elliott 2000). As caves and mesocavernous spaces are destroyed at mines and quarries, karst invertebrates, possibly including some listed species, will also be lost. (USFWS 2011a).

Stressor: Alterations of surface plant and animal communities
Exposure: destroy/degrades habitat; introduces competition; introduces predators
Response: Loses habitat; competes for limited resources; is predated upon
Consequence:
Narrative: Alterations of surface plant and animal communities - Karst ecosystems are heavily reliant on surface plant and animal communities to maintain nutrient flows, reduce sedimentation, and resist exotic and invasive species. As the surface around a cave entrance becomes developed, native plant communities are often replaced with impermeable cover or exotic plants from nurseries. The abundance and diversity of native animals may decline due to decreased food and habitat combined with increased competition and predation from urban, exotic, and pet species. The leaf litter and wood that make up most of the detritus may also be reduced or altered, resulting in a reduction of nutrient and energy flow into the cave. (USFWS 2011a).

Recovery

Reclassification Criteria:
(1) at least one high quality protected Karst Fauna Area (KFA) per Karst Fauna Region (KFR); (2) at least three total medium or high quality protected KFAs per KFR; (3) a minimum of six protected KFAs rangewide; (4) a minimum of three high quality KFAs; (5) all KFAs must at be of at least mediium or high quality.

Delisting Criteria:
In addition to the five downlisting criteria, monitoring an dresearch will have to have been completed to conclude with a high degree of certainlty that KFA size, quality, configuration, and management are adquate to provide a high probably of the species survival (greater than 90

percdnt over 100 years). To assess adequacy, results should be measured over a long enough time that cause and effect can be inferred with a high degree of certainty.

Recovery Actions:

- This cave occurs in Government Canyon State Natural Area (GCSNA) and contains 4 of Bexar County endangered species, R. infernalis, R. exilis, C. vespera, and N. microps. The distance from the cave entrance and footprint to the nearest edge is about 1,440 m (4,724 ft) and 1,425 m (4,674 ft), respectively (Veni 1988). These edges are just outside the preserve boundary. The cave cricket foraging area for this cave is undeveloped. The surface and subsurface drainage basins are included in the preserve and are unaltered. Management for this cave includes biannual RIFA monitoring and treatment, occasional faunal monitoring (based on availability of a Service-permitted volunteer biologist), annual cave cricket exit counts, and monthly surface inspections per the GCSNA Karst Management and Maintenance Plan (TPWD 2002, TPWD 2010). This area appears to have adequate undeveloped acreage to be considered a high quality KFA. However, a protective mechanism (such as a conservation easement) needs to be in place to ensure that this cave will be managed, monitored, and protected in perpetuity.

Conservation Measures and Best Management Practices:

- Not yet addressed.

References

USFWS. 2000. Final Rule to List Nine Bexar County, Texas Invertebrate Species as Endangered, 65 FR 81419-81433

USFWS. 2012. Designation of Critical Habitat for Nine Bexar County, TX Invertebrates Final Rule, FR 8450-8523.

U.S. Fish and Wildlife Service. 2012. Endangered and Threatened Wildlife and Plants

Designation of Critical Habitat for Nine Bexar County, TX, Invertebrates. Final Rule. 77 FR 8450 - 8523 (February 14, 2012).

USFWS. 2000. Final Rule to List Nine Bexar County, Texas Invertebrate Species as Endangered, 65 FR 81419-81433

USFWS. 2011. Bexar County Karst Invertebrates Recovery Plan.

(USFWS. 2011. Bexar County Karst Invertebrates Recovery Plan.

U.S. Fish and Wildlife Service (USFWS). 2011a. Bexar County Karst Invertebrate Recovery Plan.

USFWS. 2011b. Bexar County Karst Invetebrates 5-Year Review, 08/29/2011.

SPECIES ACCOUNT: *Microhexura montivaga* (Spruce-fir moss spider)

Species Taxonomic and Listing Information

Listing Status: Endangered; February 6, 1995, Southeast Region (R4)

Physical Description

A small light brown to reddish-brown spider.A small mygalomorph spider (2.5 - 3.8 mm adult size) ranging in color from light brown to a darker reddish brown. There are no markings on the abdomen and the carapace is generally yellowish brown (Harp 1992). (NatureServe, 2015)

Taxonomy

This spider belongs to the family Dipluridae and is one of the world's smallest mygalomorph spiders. Mygalomorph spiders are members of the primitive spider suborder Mygalomorphae.

Historical Range

Microhexura montivaga is historically known from four mountain peaks in western North Carolina and one in eastern Tennessee (Coyle 1981). In North Carolina the species has been recorded from Mount Mitchell, Yancey County; Grandfather Mountain, Avery and Caldwell Counties; and Mount Collins and Clingman's Dome, Swain County. In Tennessee the species has been recorded only from Mount LeConte in Sevier County.

Current Range

This species occurs in North Carolina, Tennessee, and Virginia. Reproducing populations of M. montivaga still survive on Grandfather Mountain in North Carolina (Harp 1992; authors' personal observations, 1995) and on Mount LeConte in Tennessee (Coyle 1997). The Mount Mitchell population is believed to be extirpated (Harp 1992), and both the Mount Collins and Clingman's Dome populations (if still present) are extremely small, with only one spruce-fir moss spider having been found at each of these two sites in recent years (Harp 1991).

Distinct Population Segments Defined

No

Critical Habitat Designated

Yes; 7/6/2001.

Legal Description

On July 6, 2001, the Fish and Wildlife Service (Service) designated critical habitat for the spruce-fir moss spider (Microhexura montivaga), under the Endangered Species Act of 1973, as amended (Act). The areas designated as critical habitat include portions of Avery, Caldwell, Mitchell, Swain, and Watauga Counties, in North Carolina and Sevier and Carter County in Tennessee. The areas designated as critical habitat for the spider are within the boundaries of the Great Smoky Mountains National Park (GSMNP); the Pisgah National Forest, and the Cherokee National Forest; and an area privately owned but is being managed by The Nature Conservancy through an agreement with the landowner.

Critical Habitat Designation

Designated critical habitat includes spruce-fir moss spider habitat throughout the species' existing range in the United States. Lands designated as critical habitat have been divided into four critical habitat units.

Unit 1: Swain County, North Carolina, and Sevier County, Tennessee Unit 1 encompasses all portions of the GSMNP bounded to the north and to the south of the North Carolina/Tennessee State line (State line) by the 1,646-m (5,400-ft) contour, from the intersection of the 1,646-m (5,400-ft) contour with the State line, south of Mingus Lead, Tennessee, southwest and then west to the intersection of the 1,646-m (5,400-ft) contour with the State line, east of The Narrows and west of Jenkins Knob, North Carolina, and Tennessee.

Unit 2: Sevier County, Tennessee Unit 2 encompasses all portions of the GSMNP at and above the 1,646-m (5,400-ft) contour, bounded on the southwest side by the North Carolina/ Tennessee State line from the intersection of the State line with the 1,646-m (5,400-ft) contour near Dry Sluice Gap, southeast to the intersection of the State line with the 1,646-m (5,400-ft) contour at the head of Minnie Ball Branch, North Carolina, northwest of Newfound Gap, North Carolina, and Tennessee.

Unit 3: Avery and Mitchell Counties, North Carolina, and Carter County, Tennessee Unit 3 encompasses all portions of the Pisgah National Forest in North Carolina and the Cherokee National Forest in Tennessee, bounded to the north and to the south of the North Carolina/ Tennessee State line by the 1,646-m (5,400-ft) contour, from the intersection of the 1,646-m (5,400-ft) contour with the State line north of Elk Hollow Branch, Avery County, North Carolina, and southwest of Yellow Mountain, Carter County, Tennessee, west to the 1,646-m (5,400-ft) contour at Eagle Cliff, Mitchell County, North Carolina.

Unit 4: Avery, Caldwell, and Watauga Counties, North Carolina Unit 4 encompasses all areas of privately owned Grandfather Mountain at and above the 1,646-m (5,400-ft) contour.

Primary Constituent Elements/Physical or Biological Features

Within these critical habitat units, the primary constituent elements include:

(i) Fraser fir or fir-dominated sprucefir forests at and above 1,646 m (5,400 ft) in elevation; and

(ii) Moderately thick and humid, but not wet, moss (species in the genus Dicranodontium, and possibly Polytrichum) and/or liverwort mats on rock surfaces that are adequately sheltered from the sun and rain (by overhang and aspect) and include a thin layer of humid soil and/or humus between the moss and rock surface.

Special Management Considerations or Protections

Existing human structures and other features not containing all of the primary constituent elements are not considered critical habitat.

Life History

Feeding Narrative

Adult: The spider has not been observed taking prey in the wild nor is there any record of prey having been found in A. montivaga webs, but the abundant springtails (Collembola sp.) found in moss mats with the spiders provide the most likely source offood. They have been observed to take springtails in captivity (David Hodge, Lousville Zoological Park, personal communication, 1998). Possible predators and competitors of M. montivaga include pseudoscorpions, centipedes, carabid beetles, and other spiders. A number ofaraneomorph spiders are commonly found in the same moss as the spruce-fir moss spiders. These include the common hahniid, Neoantistea magna (Keyserling), and agelenids such as Coras sp.

Reproduction Narrative

Adult: Females ofthe species A. montivaga lay their eggsin June (Coyle 1981), with spiderlings emerging during September. The egg sac ofthe species is thin-walled, nearly transparent, and may contain seven to nine eggs (Coyle 1981). The female remains with the egg sac and, when disturbed, will carry the sac with her fangs. Males mature during September and October, evidently at either 2 or 3 years of age (Coyle 1997).

Geographic or Habitat Restraints or Barriers

Adult: Does not occur below 5,300 feet in elevation

Dependency on Other Individuals or Species for Habitat

Adult: Bryophyte mats (especially Dicranodontium spp.), liverworts (especially Bazzania spp.)

Habitat Narrative

Adult: This species is endemic to the spruce-fir forests of the Southern Applachians. The spider is confined to a handful of isolated, high elevation (5,300 to over 6,000 feet) peaks. The optimal habitat of M. montivaga appears to be bryophyte mats growing on rocks and boulders in humid, well-shaded situations in association with mature fir trees (Coyle 1981,1997; Harp 1991, 1992). These moss mats are generally from ito 4 centimeters thick and are well drained. They cannot be too dry, because the spider is quite sensitive to desiccation. Neither can they be too wet, because large drops ofstanding water can also be a threat. Bryophyte mats that harbored the spider were distinguished by those that did not by two distinct features: 1) the mat included a thin layer of moist soil and/or humus between it and the rock surface and 2) the mat was moderately (often 10 - 40 mm), but not extremely thick (Coyle 1999, 2004). The importance of mosses in the genus (Dicranodontium) has been well documented (Coyle 1997, 1999, 2004, 2009). Additionally, the liverwort of the genus Bazzania is a common component of many bryophyte mats where the spider has been found (Coyle 2004, 2009).The spider has also been found under moss and litter mats at the base of rock outcrops (Coyle 1981), under moss on loose rock at the base of rock outcrops (Coyle 1997), and in litter/humus under flat rocks (about 15 millimeters thick and 200 to 1,350 cm2 large) lying on the ground in well-shaded situations in the vicinity ofrock outcrops (Coyle 1997). The species has also rarely been found in moss mats on tree trunks (Coyle 1981), in moss mats on logs (Harp 1992), and on well-drained, well-shaded ground in or under needle and/or heath litter and moss(Coyle 1997).

Dispersal/Migration

Dispersal

Adult: Unknown

Dispersal/Migration Narrative

Adult: Modes of dispersal of spiderlings from the parental moss mats are unknown.

Population Information and Trends

Population Trends:
Unknown

Species Trends:
Stable

Resiliency:
Low

Representation:
Low

Redundancy:
Low

Number of Populations:
4 (See Reclassification criteria)

Population Narrative:
Reported as stable given the species' continued presence at sites; however, there continues to be no means of confidently determining population levels or trends. There are only two known reproducing populations.

Threats and Stressors

Stressor: Loss of habitat due to deline of Frasier fir
Exposure:
Response:
Consequence:
Narrative: The primary threat to, and reason for the recent decline of, Microhexura montivaga at the majority ofthe sites from which it has been recorded appears to be associated with the loss of suitable moss habitat due to the decline ofthe Fraser fir. As previously stated, the species appears to be very sensitive to desiccation and requires situations of high and constant humidity. Loss ofthe forest canopy (primarily the Fraser fir, the dominate canopy species in the forest stands where the spider has been found), leading to increased light and decreased moisture on the forest floor (resulting in desiccation ofthe moss mats) appears to be the major cause of the loss ofthe spruce-fir moss spider on Mount Mitchell and the recent decline and possible loss (additional surveys are needed to verify this) of the Mount Collins and Clingman's Dome populations. Fraser fir at all four of these sites--Mount Mitchell, Mount Collins, Clingman's Dome, and Mount LeConte--have suffered extensive mortality, believed to be primarily due to infestation by the balsam wooly adelgid, Adelges picea (Homoptera, Adelgidac). Another potential source of tree mortality and decreased vigor is air pollution.

Stressor: Restricted range
Exposure:

Response:
Consequence:
Narrative: The restricted range of each of the surviving populations ofspruce-fir moss spider causes them to be extremely vulnerable to extirpation from a single event or activity, such as a drought, severe storm, wildfire, land-clearing or timber-harvesting operation, pesticide/herbicide application, etc.

Stressor: Trampling
Exposure:
Response:
Consequence:
Narrative: The spider and the moss mats it inhabits are very fragile and easily destroyed by human trampling. The Grandfather Mountain population appears to be restricted to the moss mats on a single rock outcrop and a few surrounding boulders. Trampling or other significant disturbance ofthe moss mats or damage to the surrounding vegetation shading the mats could result in the extirpation of this population.

Stressor: Climate change
Exposure:
Response:
Consequence:
Narrative: If temperatures in the Southern Appalachians increase and precipitation decreases, it is anticipated that the areal extent of boreal forests will decrease (NC NHP 2010).

Recovery

Reclassification Criteria:
1. A total of four distinct viable populations distributed throughout a significant portion of the species' historical range.

2. Biological and ecological studies have been completed and any required recovery measures developed and implemented from these studies are showing signs of success, as evidenced by an increase in population density and/or an increase in the amount of habitat occupied by each of the four populations. There is evidence that these four populations are stable or increasing, under natural conditions over at least a 15-year period.

3. Where habitat has been degraded, noticeable imporvements in the quality of the spider's habitat have occurred.

4. Each of these four populations and their habitats are protected from any present and foreseeable threats that would jeopardize their continued existence.

Delisting Criteria:
1. Through protection of existing populations, successful establishment of reintroduced populations, or the discovery of additional populations, a total of six distinct viable populations exist. These six populations shall be distributed throughout a significant portion of the species' historic range

2. Biological and ecological studies have been completed and any required recovery measures developed and implemented from these studies are showing signs of success, as evidenced by an increase in population density and/or an increase in the amount of habitat occupied by each of the six populations. Evidence that these six populations are stable or increasing over at least a 15-year period (see Date of Recoverv, page iv.) is considered necessary for delisting.

3. Where habitat has been degraded, noticeable improvements in the quality of the spider's habitat have occurred.

4. Each of these six populations and their habitats are protected from any present and foreseeable threats that would jeopardize their continued existence.

References

USFWS 2014. Spruce-fir Moss Spider (Microhexura montivaga) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service Southeast Region. Asheville Ecological Services Field Office. Asheville, North Carolina

U.S. Fish and Wildlife Service. 1998. Recovery Plan for the Spruce-fir Moss Spider. Atlanta, GA. 22 pp.

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Designation of Critical Habitat for the Spruce-fir Moss Spider. Final rule. 66 FR 35547 - 35566 (July 6, 2001).

USFWS. 2014. Spruce-fir Moss Spider (Microhexura montivaga) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service Southeast Region. Asheville Ecological Services Field Office. Asheville, North Carolina

SPECIES ACCOUNT: *Neoleptoneta (=Leptoneta) myopica* (Tooth Cave Spider (Neoleptoneta))

Species Taxonomic and Listing Information

Listing Status: Endangered, 1988.

Physical Description

A very small, pale cream-colored cave spider; reduced eyes; occurs in small isolated dry caves within Edwards Limestone Formation; sedentary, spinning webs from the ceiling and walls of the cave; invertivore feeding on microarthropods; 1.6 cm in length

Taxonomy

Class Arachnida (arachnids), Order Araneae (spiders), Infraorder Araneomorphae (true spiders), Family Leptonetidae. Spiders and other arachnids are not insects. Unlike insects, arachnids possess four pairs of legs, pedipalps, and chelicerae, and lack antennae. Insects have three pairs of legs, mandibles, and antennae. Leptonetids are minute spiders with six eyes, commonly found in caves and similar habitats. Some leptonetid spiders in Europe and the United States are completely eyeless, but members of this family typically have small eyes. Small genus with 6-20 species.

Historical Range

Unknown; likely same as current.

Current Range

Currently known from six caves (Tooth Cave, Gallifer Cave, Geode Cave, Stovepipe Cave, New Comanche Trail Cave, and Moonmilk Cave) in Travis and Williamson counties, Texas, in the Edwards Plateau area (USFWS 2009).

Distinct Population Segments Defined

No; not applicable to invertebrates

Critical Habitat Designated

Yes;

Life History

Feeding Narrative

Adult: Nutrients in most karst ecosystems are derived from the surface either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the karst invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller troglophiles and troglobites that grow on the leaves or feces rather than the original material itself. Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through karst fissures and solution features. For predatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave. The cave cricket (Ceuthophilus spp.) is a particularly important nutrient component and is found in most caves in Texas (USFWS 2011). Troglobites typically have very slow metabolisms, an adaptation to the sparse amounts of food found in their environment. Because they are adapted to an environment with little food, pollution by the addition of large amounts of nutrients to the cave can actually be harmful to the species, because it allows invertebrates that are not cave adapted, such as cockroaches and a variety of flies to survive in the care and even-out-compete the cave species (USFWS 2000).

Reproduction Narrative

Adult: Cave invertebrates are described K-strategists -- more similar to large mammals than to their invertebrate cousins that live on the land surface. Like large mammals, they have few offspring and live relatively long lives (for invertebrates). This also means their populations are more sensitive to losing even fairly small numbers of individuals, and that it takes a long time for their population sizes to recovery from any catastrophe. Nothing is known about the reproductive parameters of this species (USFWS 2000).

Geographic or Habitat Restraints or Barriers

Adult: Restricted to cave/karst environment

Spatial Arrangements of the Population

Adult: Unknown

Environmental Specificity

Adult: High

Tolerance Ranges/Thresholds

Adult: Unknown, but likely low due to habitat specialization and isolation

Site Fidelity

Adult: Unknown, but likely high due to isolation

Dependency on Other Individuals or Species for Habitat

Adult: Unknown

Habitat Narrative

Adult: N. myopica is restricted to cave/karst habitat, and has been recorded from a six caves (Tooth Cave, Gallifer Cave, Geode Cave, Stovepipe Cave, New Comanche Trail Cave, and Moonmilk Cave) in Travis and Williamson counties, Texas (USFWS, 2009). Habitat is susceptible to degradation harmful to the species. Most individuals are found under large rocks. This species feeds on microarthropods. The species requires surface vegetation to provide nutrients from: (1) direct flow of plant material into the karst with water; (2) habitat and food sources provided for the animal communities that contribute nutrients to the karst ecosystem (such as cave crickets, small mammals); and (3) roots that extend into subsurface areas and may provide a major energy sources in shallow caves. Troglobitic habitat includes caves and mesocavernous voids in karst limestone (a terrain characterized by landforms and subsurface features, such as sinkholes and caves, which are produced by solution of bedrock) in Travis and Williamson counties. Karst areas commonly have few surface streams; most water moves through cavities underground. Within this habitat this species depends on high humidity, stable temperatures, and nutrients derived from the surface. Examples of nutrient sources include leaf litter fallen or washed in, animal droppings, and animal carcasses.

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: None

Dispersal

Adult: Likely low. Known from six caves (<100-250 sq km (< 40-100 sq mi); distributed along a 40 km distance in Travis and Williamson counties, Texas .

Immigration/Emigration

Adult: Unknown

Dependency on Other Individuals or Species for Dispersal

Adult: Unknown

Dispersal/Migration Narrative

Adult: Known from six caves in Travis and Williamson counties, Texas. Nothing is known about its dispersal/migration. Species' specialization requires dispersal/migration corridor habitat or an alternative method for dispersal/migration.

Population Information and Trends

Population Trends:

Unknown

Species Trends:

Unknown

Resiliency:

Unknown, but likely low due to isolation

Representation:

Unknown, but likely low due to restricted habitat

Redundancy:

Unknown, but known from only 6 caves

Population Growth Rate:

Unknown, but likely low

Number of Populations:

Unknown; known from 6 caves

Population Size:
Unknown

Minimum Viable Population Size:
Unknown

Resistance to Disease:
Unknown, but likely low due to isolation

Adaptability:
Unknown, but likely low due to isolation and highly specialized habitat

Population Narrative:
Population estimates are unavailable due to a lack of adequate techniques, its cryptic behavior, and inaccessibility of habitat. The species is currently known from six caves in Travis and Williamson counties, Texas. While some troglobites are known from a few specimens, detailed studies suggest that "as a rule" most troglobites are not numerically rare and thus are not susceptible to the problems of small populations." However, considering the lack of population estimates and limited study of these species, data are insufficient to indicate whether the Travis and Williamson counties karst invertebrates are numerous enough to rule out small population concerns (USFWS, 2011). Species' resiliency, redundancy, and representation are unknown, but likely low due to limited known habitat; disease resistance and adaptability are unknown, but are also likely low due to specialized habitat and isolation.

Threats and Stressors

Stressor: Edge effects
Exposure: impact native communities; disrupt natural systems; introduce non-native predators (such as fire ants)
Response: loses nutrients; competes for limited resources; death by predation
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Edge effects - “Edge effects” are changes to the floral and faunal communities where different habitats meet. The length and width of the edge, as well as the contrast between the vegetational communities, all contribute to the amount of impacts (Smith 1990, Harris 1984). Some types of edge effects include increases in solar radiation, changes in soil moisture due to elevated levels of evapotranspiration, wind buffeting (Ranny et al. 1981), changes in nutrient cycling and the hydrological cycle (Saunders et al. 1990), and changes in the rate of leaf litter decomposition (Didham 1998). These edge effects alter plant communities, which in turn impact the associated animal species. Edge effects can also affect animal species directly. The changes caused by edge effects can occur rapidly. Vegetation located 2 m (6.6 ft) from an edge can be visibly affected within days (Lovejoy et al. 1986). Edge effects associated with soil disturbance and disruption to native communities that accompany urbanization (for example, waste associated with housing) may attract redimported fire ants (RIFA)(discussed in factor C) or other surface species that prey on or compete with cave species (Reddell 1993). The invasion of RIFA is aided by “any disturbance that clears a site of heavy vegetation and disrupts the native ant community” (Porter et al. 1988) such as road building and urbanization. Development and edges

often allow enough disruption for invasive or exotic species to displace native communities that had previously prevented their spread (Saunders et al. 1990, Kotanen et al. 1998, Suarez et al. 1998, Meiners and Steward 1999). (USFWS 2011a).

Stressor: Human visitation and vandalism, including commercialization
Exposure: degrades/destroys habitat; introduces predators and competitors
Response: Loses habitat; competes for limited resources; death by predation; crushed
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Human visitation and vandalism - Visitation can impact caves by increasing soil compaction, trash deposition, and vandalism; altering airflow as entrances are expanded and excavated; scaring away trogloxenes (Culver 1986, Elliott 2000); and may also lead to direct mortality of cave organisms crushed by human disturbance (Crawford and Senger 1988). Commercialization of caves affects cave communities due to (1) competition with introduced surface species; (2) harmful effects of commercial lighting, for example increased temperature and decreased humidity near lights; (3) substrate changes around trails; (4) changes in microclimate due to cave ventilation; (5) and increases in the nutrient regime that favor surface species (Culver 1986, Northup 1988, Northup et al. 1988; Reddell 1993, Krejca and Myers 2005, Mulec and Kosi 2009). Conversely, some researchers have found high diversity and/or abundance of some species in show caves that have higher nutrient and water availability (Culver and Sket 2000, Paquin 2007). However, for the reasons stated above we believe that commercialization of caves is generally a threat because (1) these activities alter the natural habitat and nutrient regime of these species and (2) because most caves in Texas have limited nutrient and water availability. (USFWS 2011a)

Stressor: Contamination
Exposure: introduced pollutions, poisons to groundwater
Response: Loses habitat; direct poisoning
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Contamination - Karst landscapes are particularly susceptible to groundwater contamination because water penetrates rapidly through bedrock conduits and little or no filtration occurs (White 1988). In some areas the water that moves through the habitat of these species percolates to the Edwards Aquifer below. The Edwards Aquifer is an important source of drinking water for 1.7 million people (Edwards Aquifer Authority 2008). So, information on sources of water contamination of the Edwards Aquifer may also be indicative of sources of contamination of karst invertebrate habitat. The ranges of these species are becoming increasingly urbanized and thereby are becoming more susceptible to contaminants including sewage, oil, fertilizers, pesticides, herbicides, seepage from landfills, pipeline leaks, or leaks in storage structures and retaining ponds. Activities on the surface, such as disposing of toxic chemicals or motor oil, can also contaminate caves (White 1988). Continued urbanization will increase the likelihood that karst ecosystems are polluted by contamination from the leaks and spills, which have often occurred in Bexar County (see TWC 1989, TCEQ 2010a, TCEQ 2010b for information on contamination events). Texas Commission on Environmental Quality (TCEQ) (2010a) summarizes information on groundwater contamination reported by a number of agencies, and in 2010 they reported that 1,712 leaking petroleum storage tanks were located in Bexar County.

Stressor: Alterations of Drainage Patterns
Exposure: degrades/destroys habitat

Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of temperature, humidity, and nutrients that are washed into caves. To sustain these conditions, both natural surface and subsurface flow of water and nutrients should be maintained. Decreases in water flow or infiltration can result in excessive drying and may slow decomposition, while increases can cause flooding that drowns air-breathing species and carries away available nutrients. Alterations to surface topography, including decreasing or increasing soil depth or adding non-native fill, can change the nutrient flow into the cave and affect the cave community (Howarth 1983). Impermeable cover, collection of water in devices like storm sewers, increased erosion and sedimentation, and irrigation and sprinkler systems can affect water flow to caves and karst ecosystems. Altering the quantity or timing of water input to the karst ecosystem, or its organic content, may negatively impact the listed species. (USFWS 2011a).

Stressor: Quarrying and mining operations
Exposure: destroys/degrades habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Quarrying and mining operations - Quarries and mines exist in Bexar County, including the northern half, where the majority of the listed species occur. While quarrying activities have revealed some caves (which can lead to protecting these sites), they have also completely destroyed others (Elliott 2000). As caves and mesocavernous spaces are destroyed at mines and quarries, karst invertebrates, possibly including some listed species, will also be lost. (USFWS 2011a).

Stressor: Alterations of surface plant and animal communities -
Exposure: destroy/degrades habitat; introduces competition; introduces predators
Response: Loses habitat; competes for limited resources; is predated upon
Consequence:
Narrative: Alterations of surface plant and animal communities - Karst ecosystems are heavily reliant on surface plant and animal communities to maintain nutrient flows, reduce sedimentation, and resist exotic and invasive species. As the surface around a cave entrance becomes developed, native plant communities are often replaced with impermeable cover or exotic plants from nurseries. The abundance and diversity of native animals may decline due to decreased food and habitat combined with increased competition and predation from urban, exotic, and pet species. The leaf litter and wood that make up most of the detritus may also be reduced or altered, resulting in a reduction of nutrient and energy flow into the cave. (USFWS 2011a).

Stressor: Non-Native invasive ant species
Exposure:
Response:
Consequence:
Narrative: Since the 2009 5-year review, a new non-native invasive ant species has established colonies at sites in Travis County. The tawny crazy ant (Nylanderia fulva), native to South America, was documented in Texas in 2002 and has established populations along the state's Gulf Coast and some central Texas counties (Wang et al. 2016, p. 4). This ant has exhibited a

potential to affect native animal and plant communities (LeBrun et al. 2013, p. 2439; Wang et al. 2016, p. 5). Tawny crazy ant colonies are often polygynous and can form dense infestations that dominate the local ant community (LeBrun et al. 2013, p. 2433). Arthropod species richness and abundance may decline in areas infested by tawny crazy ants (LeBrun et al. 2013, pp. 2434-2435; Wang et al. 2016, pp. 5, 7). Tawny crazy ants also appear capable of eliminating red-imported fire ants from areas where the species co-occur (LeBrun et al. 2013, pp. 2436-2437). Unlike redimported fire ants that generally prefer open-habitat types, the tawny crazy ant can reach high densities in forested habitats along with grasslands and other open-habitat types (LeBrun et al. 2013, pp. 2439-2440). Sites with dense canopies, therefore, would be afforded some decreased susceptibility to redimported fire ants but not the tawny crazy ant. Tawny crazy ants have established populations at Whirlpool and No Rent Caves in Travis County (LeBrun 2017, p. 3). LeBrun (2017, entire) assessed the effects of tawny crazy ants at these caves. Based on observations at these two sites, use of caves by ants was tied to surface temperatures and moisture with tawny crazy ants most prevalent in caves during hot, dry summer conditions (LeBrun 2017, p. 35). Tawny crazy ants preyed on cave crickets and other karst invertebrates with one species, the spider Cicurina varians, experiencing decreased abundance associated with that ant's presence (LeBrun 2017, pp. 2122, 35-36). No declines were noted for other karst invertebrates examined, though sample size was small (LeBrun 2017, pp. 22, 35). Additional research is needed to determine the potential for the tawny crazy ant to affect listed karst invertebrates.

Recovery

Reclassification Criteria:
Not addressed.

Delisting Criteria:
According to recovery criterion (1) in USFWS 1994, 3 KFAs within each KFR should be protected. Protection is defined as an area sufficiently large to maintain the integrity of the karst ecosystem on which the species depends. These areas must also provide protection from threats such as RIFA, habitat destruction, and contaminants. Recovery criterion (2) requires at least 5 consecutive years of a cave meeting KFA status and that perpetual protection of these areas is in place.

Recovery Actions:
- Confirm the subsurface drainage basins for Gallifer Cave and Stovepipe Cave.
- Confirm and/or implement RIFA control at Tooth Cave and Gallifer Cave.
- Confirm that there are no pipelines going through potential KFAs including: water, wastewater, natural gas, and petroleum.
- Find more locations for this species that could meet KFA status and protect them to meet downlisting criteria.
- Recovery Priority Number: 2C

Conservation Measures and Best Management Practices:
- RECOMMENDATIONS FOR FUTURE ACTIONS I. Obtain information for sites within the Balcones Canyonlands Preserve to include surface and subsurface drainage basins, potential development impacts, tract acreage, management, and perpetual protection mechanisms among others. Review

information to determine the potential for sites to be recognized as karst fauna areas (USFWS, 2018). II. Search for additional locations of the Tooth Cave Spider in the McNeil/Round Rock Karst Fauna Region (USFWS, 2018). III. Acknowledge the genus-level taxonomic transfer of the Tooth Cave spider from Neoleptoneta to Tayshaneta (USFWS, 2018). IV. Draft quantitative delisting criteria for the Tooth Cave spider and other listed karst invertebrates in Travis and Williamson counties, Texas USFWS, 2018). V. Reassess the current karst fauna regions of Travis and Williamson counties, Texas using current data and revise regions as necessary to better inform recovery efforts (USFWS, 2018).

References

USFWS. 1988. Final Rule to Determine 5 Texas Cave Invertebrates to be Endangered Species, 53FR 36029-36033

USFWS 2009. Tooth Cave Spider (Neoleptoneta myopica), Kretschmarr Cave Mold Beetle (Texamaurops reddelli), and Tooth Cave Pseudoscorpion (Tartarocreagris texana) 5-Year Review: Summary and Evaluation.

USFWS 1994. Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson counties, Texas. USFWS 2007. 5-Year Reviews of 24 Southwestern Species. USFWS 2009. Tooth Cave Spider (Neoleptoneta myopica), Kretschmarr Cave Mold Beetle (Texamaurops reddelli), and Tooth Cave Pseudoscorpion (Tartarocreagris texana) 5-Year Review: Summary and Evaluation. (4) U.S. Fish and Wildlife Service (USFWS). 2011. Bexar County Karst Invertebrate Recovery Plan.

USFWS 1994. Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson counties, Texas. USFWS 2007. 5-Year Reviews of 24 Southwestern Species. USFWS 2009. Tooth Cave Spider (Neoleptoneta myopica), Kretschmarr Cave Mold Beetle (Texamaurops reddelli), and Tooth Cave Pseudoscorpion (Tartarocreagris texana) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service (USFWS). 2011. Bexar County Karst Invertebrate Recovery Plan.

U.S. Fish and Wildlife Service (USFWS). 2011. Bexar County Karst Invertebrate Recovery Plan. Note: This Bexar County reference/material was used because it is more up to date than the general information contained in the 1994 Recovery Plan for Travis and Williamson Counties. and the threats are identical.

U.S. Fish and Wildlife Service. 2018. Tooth Cave Spider (Tayshaneta myopica=Neoleptoneta myopica) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service Austin Ecological Services Field Office Austin, Texas. 34 pp.

USFWS 1994. Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas. USFWS 2009. Tooth Cave Spider (Neoleptoneta myopica), Kretschmarr Cave Mold Beetle (Texamaurops reddelli), and Tooth Cave Pseudoscorpion (Tartarocreagris texana) 5-Year Review: Summary and Evaluation.

U.S. Fish and Wildlife Service. 2018. Tooth Cave Spider (Tayshaneta myopica=Neoleptoneta myopica) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service Austin Ecological Services Field Office Austin, Texas. 34 pp.

SPECIES ACCOUNT: *Neoleptoneta microps* (Government Canyon Bat Cave Spider)

Species Taxonomic and Listing Information

Listing Status: Endangered, 4/21/2000

Physical Description

Troglobite (spends entire life in subterranean environment); very small; reduced pigment, yellowish color; essentially eyeless; cavernicole. Family Leptonetidae; aka Government Canyon Cave Spider Endangered, 4/21/2000 Unknown, but likely similar to current distribution 2 Caves in Bexar County, TX: Government Canyon Bat Cave and Surprise Sink;

Taxonomy

Family Leptonetidae; aka Government Canyon Cave Spider

Historical Range

Unknown, but likely similar to current distribution

Current Range

2 Caves in Bexar County, TX: Government Canyon Bat Cave and Surprise Sink;

Distinct Population Segments Defined

No; not applicable to invertebrates

Critical Habitat Designated

Yes; 2/14/2012.

Legal Description

On February 14, 2012, the U.S. Fish and Wildlife Service (Service) designated critical habitat for Government Canyon Bat Cave Spider (Cicurina baronia) (and eight other species) under the Endangered Species Act of 1973, as amended (77 FR 8450 - 8523). These species are collectively known as the nine Bexar County invertebrates. For Government Canyon Bat Cave Spider, approximately xx ac (xx ha) fall within the boundaries of the critical habitat designation.

Critical Habitat Designation

Critical habitat for the Government Canyon Bat Cave spider in Bexar County, Texas, occurs in Unit 1b.

Unit 1b consists of 100 ac (40 ha) of State-owned land located in northwest Bexar County in the western portion of the GCSNA in the Government Canyon KFR. Land within the unit consists of undeveloped woodland. However, there are several one-lane gravel roads that serve primarily as pedestrian trails within the State natural area. A small portion of the vegetation appears to have been cleared for ranching prior to TPWD ownership. The unit contains one cave, Government Canyon Bat Cave, which is the only cave known to be occupied by the Government Canyon Bat Cave meshweaver. The cave is also occupied by Government Canyon Bat Cave spider, R. exilis, and R. infernalis. The Government Canyon Bat Cave was occupied at the time of listing, and the unit contains all the PCEs. The main threat to species in this unit is infestation of fire ants. The GCSNA currently has a management plan in place that includes treating for fire ants and managing for the benefit of the species. Because the treatment for fire ants only temporarily alleviates the threat, special management is required in perpetuity. The unit was delineated by drawing a circle with an area of 100 ac (40 ha) around the cave. A small piece of Karst Zone 2 on the northern part of the circle is included because removing it would increase the edge effects. The remainder of Unit 1b is Karst Zone 1.

Primary Constituent Elements/Physical or Biological Features

The primary constituent elements of critical habitat for the Robber Baron Cave meshweaver are:

(i) Karst-forming rock containing subterranean spaces (caves and connected mesocaverns) with stable temperatures, high humidities (near saturation), and suitable substrates (for example, spaces between and underneath rocks for foraging and sheltering) that are free of contaminants; and

(ii) Surface and subsurface sources (such as plants and their roots, fruits, and leaves, and animal (e.g., cave cricket) eggs, feces, and carcasses) that provide nutrient input into the karst ecosystem.

Special Management Considerations or Protections

Developed lands that do not contain the subsurface primary constituent elements and that existed on the effective date of this rule are not considered to be critical habitat.

Threats to the nine Bexar County invertebrates include clearing of vegetation for commercial or residential development, road building, quarrying, or other purposes. Infestation by nonnative vegetation causes adverse changes in the plant and animal community and possibly in moisture availability. An increase in fire ants can occur with development and cause competition with and predation on other invertebrates in the karst ecosystem. In addition, filling cave features for construction, ranching, or other purposes can adversely affect the listed invertebrate species by reducing nutrient input, reducing small mammal access, and changing moisture regimes. Excavation for construction or operation of quarries can directly destroy karst features occupied by any of the nine Bexar County invertebrates, including the mesocaverns they use.

Examples of management that would alleviate these threats include: (1) Protecting vegetation around occupied karst features and overlying connected mesocaverns; (2) protecting subsurface karst habitat to allow movement of karst invertebrates through caves and mesocaverns; (3) controlling nonnative fire ants around cave features and within the karst cricket foraging area; (4) preventing unauthorized access to karst features by installing fencing and cave gates; and (5) keeping the surface and subsurface areas surrounding cave features and associated mesocaverns free from sources of contamination.

Life History

Feeding Narrative

Adult: Nutrients in most karst ecosystems are derived from the surface either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the karst invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller troglophiles and troglobites that grow on the leaves or feces rather than the original material itself. Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through karst fissures and solution features. For predatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave. The cave cricket (Ceuthophilus spp.) is a particularly important nutrient component and is found in most caves in Texas (USFWS 2011). Troglobytes typically have very slow metabolisms, an adaptation to the sparse amounts of food found in their environment. Because they are adapted to an environment with little food, pollution by the addition of large amounts of nutrients to the cave can actually be harmful to the species, because it allows invertebrates that are not cave adapted, such as cockroaches and a variety of flies to survive in the care and even-out-compete the cave species (USFWS 2000).

Reproduction Narrative

Adult: Cave invertebrates are described as more similar to large mammals than to their invertebrate cousins that live on the land surface. Like large mammals, they have few offspring and live relatively long lives (for invertebrates). This also means their populations are more sensitive to losing even fairly small numbers of individuals, and that it takes a long time for their population sizes to recovery from any catastrophe. (USFWS 2000).

Geographic or Habitat Restraints or Barriers

Adult: Cave/karst

Spatial Arrangements of the Population

Adult: Unknown

Environmental Specificity

Adult: High

Tolerance Ranges/Thresholds

Adult: Low

Site Fidelity

Adult: Restricted

Dependency on Other Individuals or Species for Habitat

Adult: Unknown

Habitat Narrative

Adult: Very little is known about this species. More is known about karst habitat and its vulnerability to outside influences effecting damaging results. Species requires stable temperature and constant, high humidity, and surface vegetation to provide nutrients from: (1) direct flow of plant material into the karst with water; (2) habitat and food sources provided for the animal communities that contribute nutrients to the karst ecosystem (such as cave crickets, small mammals); and (3) roots that extend into subsurface areas and may provide a major energy sources in shallow caves.

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: None

Dispersal

Adult: Unknown

Immigration/Emigration

Adult: Unknown

Dependency on Other Individuals or Species for Dispersal

Adult: Unknown

Dispersal/Migration Narrative

Adult: The six listed arachnids are restricted to the cave/karst environment of the Edwards Aquifer in Bexar County, Texas. Very little is known about their dispersal/migration within/among the caves (USFWS 2011).

Population Information and Trends

Population Trends:

Unknown

Species Trends:

Unknown

Resiliency:

Unknown, but likely low due to specialized habitat requirements

Representation:

Unknown

Redundancy:

Low

Population Growth Rate:

Unknown

Number of Populations:

Unknown

Population Size:

Unknown

Minimum Viable Population Size:

Unknown

Resistance to Disease:

Unknown, but may be low due to isolation

Adaptability:

Unknown, but likely low due to habitat specialization

Population Narrative:

Population estimates are unavailable for any of the nine troglobites listed as endangered in Bexar County due to a lack of adequate techniques, their cryptic behavior, and inaccessibility of habitat. While some troglobites are known from a few specimens, detailed studies suggest that "as a rule" most troglobites are not numerically rare and thus are not susceptible to the problems of small populations." However, considering the lack of population estimates and limited study of these species, data are insufficient to indicate whether Bexar County karst invertebrates are numerous enough to rule out small population concerns (USFWS, 2011).

Threats and Stressors

Stressor: Edge effects
Exposure: impact native communities; disrupt natural systems; introduce non-native predators (such as fire ants)
Response: loses nutrients; competes for limited resources; death by predation
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Edge effects - "Edge effects" are changes to the floral and faunal communities where different habitats meet. The length and width of the edge, as well as the contrast between the vegetational communities, all contribute to the amount of impacts (Smith 1990, Harris 1984). Some types of edge effects include increases in solar radiation, changes in soil moisture due to elevated levels of evapotranspiration, wind buffeting (Ranny et al. 1981), changes in nutrient cycling and the hydrological cycle (Saunders et al. 1990), and changes in the rate of leaf litter decomposition (Didham 1998). These edge effects alter plant communities, which in turn impact the associated animal species. Edge effects can also affect animal species directly. The changes caused by edge effects can occur rapidly. Vegetation located 2 m (6.6 ft) from an edge can be visibly affected within days (Lovejoy et al. 1986). Edge effects associated with soil disturbance and disruption to native communities that accompany urbanization (for example, waste associated with housing) may attract redimported fire ants (RIFA)(discussed in factor C) or other surface species that prey on or compete with cave species (Reddell 1993). The invasion of RIFA is aided by "any disturbance that clears a site of heavy vegetation and disrupts the native ant community" (Porter et al. 1988) such as road building and urbanization. Development and edges often allow enough disruption for invasive or exotic species to displace native communities that had previously prevented their spread (Saunders et al. 1990, Kotanen et al. 1998, Suarez et al. 1998, Meiners and Steward 1999). (USFWS 2011a).

Stressor: Human visitation and vandalism, including commercialization
Exposure: degrades/destroys habitat; introduces predators and competitors
Response: Loses habitat; competes for limited resources; death by predation; crushed

Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Human visitation and vandalism - Visitation can impact caves by increasing soil compaction, trash deposition, and vandalism; altering airflow as entrances are expanded and excavated; scaring away trogloxenes (Culver 1986, Elliott 2000); and may also lead to direct mortality of cave organisms crushed by human disturbance (Crawford and Senger 1988). Commercialization of caves affects cave communities due to (1) competition with introduced surface species; (2) harmful effects of commercial lighting, for example increased temperature and decreased humidity near lights; (3) substrate changes around trails; (4) changes in microclimate due to cave ventilation; (5) and increases in the nutrient regime that favor surface species (Culver 1986, Northup 1988, Northup et al. 1988; Reddell 1993, Krejca and Myers 2005, Mulec and Kosi 2009). Conversely, some researchers have found high diversity and/or abundance of some species in show caves that have higher nutrient and water availability (Culver and Sket 2000, Paquin 2007). However, for the reasons stated above we believe that commercialization of caves is generally a threat because (1) these activities alter the natural habitat and nutrient regime of these species and (2) because most caves in Texas have limited nutrient and water availability. (USFWS 2011a)

Stressor: Contamination
Exposure: introduced pollutions, poisons to groundwater
Response: Loses habitat; direct poisoning
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Contamination - Karst landscapes are particularly susceptible to groundwater contamination because water penetrates rapidly through bedrock conduits and little or no filtration occurs (White 1988). In some areas the water that moves through the habitat of these species percolates to the Edwards Aquifer below. The Edwards Aquifer is an important source of drinking water for 1.7 million people (Edwards Aquifer Authority 2008). So, information on sources of water contamination of the Edwards Aquifer may also be indicative of sources of contamination of karst invertebrate habitat. The ranges of these species are becoming increasingly urbanized and thereby are becoming more susceptible to contaminants including sewage, oil, fertilizers, pesticides, herbicides, seepage from landfills, pipeline leaks, or leaks in storage structures and retaining ponds. Activities on the surface, such as disposing of toxic chemicals or motor oil, can also contaminate caves (White 1988). Continued urbanization will increase the likelihood that karst ecosystems are polluted by contamination from the leaks and spills, which have often occurred in Bexar County (see TWC 1989, TCEQ 2010a, TCEQ 2010b for information on contamination events). Texas Commission on Environmental Quality (TCEQ) (2010a) summarizes information on groundwater contamination reported by a number of agencies, and in 2010 they reported that 1,712 leaking petroleum storage tanks were located in Bexar County.

Stressor: Alterations of Drainage Patterns
Exposure: degrades/destroys habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of temperature, humidity, and nutrients that are washed into caves. To sustain these conditions, both natural surface and subsurface flow of water and nutrients should be maintained. Decreases in water flow or infiltration can result in excessive drying and may slow

decomposition, while increases can cause flooding that drowns air-breathing species and carries away available nutrients. Alterations to surface topography, including decreasing or increasing soil depth or adding non-native fill, can change the nutrient flow into the cave and affect the cave community (Howarth 1983). Impermeable cover, collection of water in devices like storm sewers, increased erosion and sedimentation, and irrigation and sprinkler systems can affect water flow to caves and karst ecosystems. Altering the quantity or timing of water input to the karst ecosystem, or its organic content, may negatively impact the listed species. (USFWS 2011a).

Stressor: Quarrying and mining operations
Exposure: destroys/degrades habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Quarrying and mining operations - Quarries and mines exist in Bexar County, including the northern half, where the majority of the listed species occur. While quarrying activities have revealed some caves (which can lead to protecting these sites), they have also completely destroyed others (Elliott 2000). As caves and mesocavernous spaces are destroyed at mines and quarries, karst invertebrates, possibly including some listed species, will also be lost. (USFWS 2011a).

Stressor: Alterations of surface plant and animal communities -
Exposure: destroy/degrades habitat; introduces competition; introduces predators
Response: Loses habitat; competes for limited resources; is predated upon
Consequence:
Narrative: Alterations of surface plant and animal communities - Karst ecosystems are heavily reliant on surface plant and animal communities to maintain nutrient flows, reduce sedimentation, and resist exotic and invasive species. As the surface around a cave entrance becomes developed, native plant communities are often replaced with impermeable cover or exotic plants from nurseries. The abundance and diversity of native animals may decline due to decreased food and habitat combined with increased competition and predation from urban, exotic, and pet species. The leaf litter and wood that make up most of the detritus may also be reduced or altered, resulting in a reduction of nutrient and energy flow into the cave. (USFWS 2011a).

Recovery

Reclassification Criteria:
(1) at least one high quality protected Karst Fauna Area (KFA) per Karst Fauna Region (KFR); (2) at least three total medium or high quality protected KFAs per KFR; (3) a minimum of six protected KFAs rangewide; (4) a minimum of three high qual

Delisting Criteria:
In addition to the five downlisting criteria, monitoring an dresearch will have to have been completed to conclude with a high degree of certainlty that KFA size, quality, configuration, and management are adquate to provide a high probably of the species survival (greater than 90 percdnt over 100 years). To assess adequacy, results should be measured over a long enough time that cause and effect can be inferred with a high degree of certainty.

Recovery Actions:

- Reduce threats to the species by securing an adequate quantity and quality of caves, including selecting caves or cave clusters that represent the range of the species and potential genetic diversity, then preserving these caves, including their drainage basins and surface communities upon which they rely.
- Maintenance of these cave preserves involves keeping them free from contamination, excessive human visitation, and non-native fire ants by regularly tracking progress and implementing adaptive management to control these and any new threats when necessary
- Monitoring the population status and threats are also components of recovery.
- Incorporating research findings into adaptive management actions because many aspects of the population dynamics and habitat requirements of the species are poorly understood.

Conservation Measures and Best Management Practices:

- Not addressed.

References

USFWS. 2000. Final Rule to List Nine Bexas County, Texas Invertebrate Species as Endangered, 65 FR 81419-81433

USFWS. 2012. Designation of Critical Habitat for Nine Bexar County, TX Invertebrates Final Rule, FR 8450-8523.

U.S. Fish and Wildlife Service. 2012. Endangered and Threatened Wildlife and Plants

Designation of Critical Habitat for Nine Bexar County, TX, Invertebrates. Final rule. 77 FR 8450 - 8523 (February 14, 2012).

USFWS. 2000. Final Rule to List Nine Bexar County, Texas Invertebrate Species as Endangered, 65 FR 81419-81433

USFWS. 2011. Bexar County Karst Invertebrates Recovery Plan.

U.S. Fish and Wildlife Service (USFWS). 2011a. Bexar County Karst Invertebrate Recovery Plan.

U.S. Fish and Wildlife Service (USFWS). 2011. Bexar County Karst Invertebrate Recovery Plan.

SPECIES ACCOUNT: *Tartarocreagris texana* (Tooth Cave pseudoscorpion)

Species Taxonomic and Listing Information

Listing Status: Endangered, 1988.

Physical Description

T. texana is a cave pseudoscorpion that resembles a small, tailless scorpion; relatively large (at ~4 mm in length) for a pseudoscorpion; carapace, chelicerae, and palps are golden brown, the body and legs light tan; no eyes or eyespots present; chelicera is about 2/3 as long as the carapace, 1.95 times as long as broad. Palps relatively long and slender. Male is very similar to female in most respects. It is a non-migrant; subterrestrial, subterranean obligate (troglobite); invertivore; occurs in very small, isolated dry caves within the Edwards Limestone Formation; usually found under rocks. Pseudoscorpions lack a stinger and are harmless to humans. They use their pincers to prey on small insects and other arthropods.

Taxonomy

Class Arachnida; order Pseudoscorpiones, family Neobisidae, genus Tartarocreagris (very small genus with only 2-5 species); synonymous with Australinocreagris texana and Microcreagris texana; aka Tooth Cave Pseudoscropion.

Historical Range

Unknown, but likely similar to current distribution, unless cave systems have been destroyed historically.

Current Range

Known from 4 caves in Travis County, Texas (Tooth Cave, Amber Cave, Kretschmarr Double Pit Cave, Jester Estates Cave); <100-250 sq km (<40-100 sq mi) (USFWS 2009).

Distinct Population Segments Defined

N/A for invertebrates

Critical Habitat Designated

Yes;

Life History

Feeding Narrative

Adult: Nutrients in most karst ecosystems are derived from the surface either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the karst invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller troglophiles and troglobites that grow on the leaves or feces rather than the original material itself. Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through karst fissures and solution features. For predatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave. The cave cricket (Ceuthophilus spp.) is a particularly important nutrient component and is found in most caves in Texas (USFWS 2011). Troglobites typically have very slow metabolisms, an adaptation to the sparse amounts of food found in their environment. Because they are adapted to an environment with little food, pollution by the addition of large amounts of nutrients to the cave can actually be harmful to the species, because it allows invertebrates that are not cave adapted, such as cockroaches and a variety of flies to survive in the care and even-out-compete the cave species (USFWS 2000).

Reproduction Narrative

Adult: Cave invertebrates are described as K-strategists, more similar to large mammals than to their invertebrate cousins that live on the land surface. Like large mammals, they have few offspring and live relatively long lives (for invertebrates). This also means their populations are more sensitive to losing even fairly small numbers of individuals, and that it takes a long time for their population sizes to recovery from any catastrophe. Reproductive information is unknown for this species.

Geographic or Habitat Restraints or Barriers

Adult: Restricted to cave/karst environment

Spatial Arrangements of the Population

Adult: Unknown

Environmental Specificity

Adult: High

Tolerance Ranges/Thresholds

Adult: Unknown, but likely low

Site Fidelity

Adult: Unknown, but likely high

Dependency on Other Individuals or Species for Habitat

Adult: Unknown

Habitat Narrative

Adult: T. texana is restricted to cave/karst habitat, and has been recorded in four caves (USFWS, 2009). The species is especially sensitive to drying and requires very moist, humid conditions (Elliott 1991a-f and unpublished data) susceptible to degradation harmful to the species. Most individuals are found under large rocks, but are rarely seen. Like most moist cave troglobites, they seldom occur farther in the cave where there is less water and food. This species feeds on microarthropods (USFWS 1994). Surface vegetation to provide nutrients from: (1) direct flow of plant material into the karst with water; (2) habitat and food sources provided for the animal communities that contribute nutrients to the karst ecosystem (such as cave crickets, small mammals); and (3) roots that extend into subsurface areas and may provide a major energy sources in shallow caves. Troglobitic habitat includes caves and mesocavernous voids in karst limestone (a terrain characterized by landforms and subsurface features, such as sinkholes and caves, which are produced by solution of bedrock) in Travis, Williamson, and Bexar counties. Karst areas commonly have few surface streams; most water moves through cavities underground. Within this habitat this species depends on high humidity, stable temperatures, and nutrients derived from the surface. Examples of nutrient sources include leaf litter fallen or washed in, animal droppings, and animal carcasses.

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: None; unknown

Dispersal

Adult: Unknown; some species are known to "hitchhike" on other larger, more mobile species of invertebrate.

Immigration/Emigration

Adult: Unknown; low

Dependency on Other Individuals or Species for Dispersal

Adult: Unknown

Dispersal/Migration Narrative

Adult: Very little is known about pseudoscorpions in general and about this species in particular. They are rarely seen. Population estimates are unavailable due to a lack of adequate techniques, its cryptic behavior, and inaccessibility of habitat. The species is currently known from four caves in Travis and Williamson counties, Texas. Information about dispersal and migration are not available, but some species are known to "hitchhike" on other larger, more mobile species of invertebrate.

Population Information and Trends

Population Trends:

Unknown

Species Trends:

Unknown

Resiliency:

Unknown, but likely low if populations are few and of low numbers

Representation:

Unknown, but likely low if populations are few and of low numbers

Redundancy:

Unknown, but likely low if populations are few and of low numbers

Population Growth Rate:
Unknown

Number of Populations:
Unknown, but known from 4 caves in Travis County, Texas

Population Size:
Unknown

Minimum Viable Population Size:
Unknown

Resistance to Disease:
Unknown, but likely low due to isolation

Adaptability:
Unknown, but likely low due to specialized resource requirements

Population Narrative:
The species is known from 4 caves in Travis County, Texas. Finding individuals of this species is so rare that little is known of its status (USFWS 1994).

Threats and Stressors

Stressor: Edge effects
Exposure: impact native communities; disrupt natural systems; introduce non-native predators (such as fire ants)
Response: loses nutrients; competes for limited resources; death by predation
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Edge effects - "Edge effects" are changes to the floral and faunal communities where different habitats meet. The length and width of the edge, as well as the contrast between the vegetational communities, all contribute to the amount of impacts (Smith 1990, Harris 1984). Some types of edge effects include increases in solar radiation, changes in soil moisture due to elevated levels of evapotranspiration, wind buffeting (Ranny et al. 1981), changes in nutrient cycling and the hydrological cycle (Saunders et al. 1990), and changes in the rate of leaf litter decomposition (Didham 1998). These edge effects alter plant communities, which in turn impact the associated animal species. Edge effects can also affect animal species directly. The changes caused by edge effects can occur rapidly. Vegetation located 2 m (6.6 ft) from an edge can be visibly affected within days (Lovejoy et al. 1986). Edge effects associated with soil disturbance and disruption to native communities that accompany urbanization (for example, waste associated with housing) may attract redimported fire ants (RIFA)(discussed in factor C) or other surface species that prey on or compete with cave species (Reddell 1993). The invasion of RIFA is aided by "any disturbance that clears a site of heavy vegetation and disrupts the native ant community" (Porter et al. 1988) such as road building and urbanization. Development and edges often allow enough disruption for invasive or exotic species to displace native communities that had previously prevented their spread (Saunders et al. 1990, Kotanen et al. 1998, Suarez et al. 1998, Meiners and Steward 1999). (USFWS 2011a).

Stressor: Human visitation and vandalism, including commercialization
Exposure: degrades/destroys habitat; introduces predators and competitors
Response: Loses habitat; competes for limited resources; death by predation; crushed
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Human visitation and vandalism - Visitation can impact caves by increasing soil compaction, trash deposition, and vandalism; altering airflow as entrances are expanded and excavated; scaring away trogloxenes (Culver 1986, Elliott 2000); and may also lead to direct mortality of cave organisms crushed by human disturbance (Crawford and Senger 1988). Commercialization of caves affects cave communities due to (1) competition with introduced surface species; (2) harmful effects of commercial lighting, for example increased temperature and decreased humidity near lights; (3) substrate changes around trails; (4) changes in microclimate due to cave ventilation; (5) and increases in the nutrient regime that favor surface species (Culver 1986, Northup 1988, Northup et al. 1988; Reddell 1993, Krejca and Myers 2005, Mulec and Kosi 2009). Conversely, some researchers have found high diversity and/or abundance of some species in show caves that have higher nutrient and water availability (Culver and Sket 2000, Paquin 2007). However, for the reasons stated above we believe that commercialization of caves is generally a threat because (1) these activities alter the natural habitat and nutrient regime of these species and (2) because most caves in Texas have limited nutrient and water availability. (USFWS 2011a)

Stressor: Contamination
Exposure: introduced pollutions, poisons to groundwater
Response: Loses habitat; direct poisoning
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Contamination - Karst landscapes are particularly susceptible to groundwater contamination because water penetrates rapidly through bedrock conduits and little or no filtration occurs (White 1988). In some areas the water that moves through the habitat of these species percolates to the Edwards Aquifer below. The Edwards Aquifer is an important source of drinking water for 1.7 million people (Edwards Aquifer Authority 2008). So, information on sources of water contamination of the Edwards Aquifer may also be indicative of sources of contamination of karst invertebrate habitat. The ranges of these species are becoming increasingly urbanized and thereby are becoming more susceptible to contaminants including sewage, oil, fertilizers, pesticides, herbicides, seepage from landfills, pipeline leaks, or leaks in storage structures and retaining ponds. Activities on the surface, such as disposing of toxic chemicals or motor oil, can also contaminate caves (White 1988). Continued urbanization will increase the likelihood that karst ecosystems are polluted by contamination from the leaks and spills, which have often occurred in Bexar County (see TWC 1989, TCEQ 2010a, TCEQ 2010b for information on contamination events). Texas Commission on Environmental Quality (TCEQ) (2010a) summarizes information on groundwater contamination reported by a number of agencies, and in 2010 they reported that 1,712 leaking petroleum storage tanks were located in Bexar County.

Stressor: Alterations of Drainage Patterns
Exposure: degrades/destroys habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success

Narrative: Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of temperature, humidity, and nutrients that are washed into caves. To sustain these conditions, both natural surface and subsurface flow of water and nutrients should be maintained. Decreases in water flow or infiltration can result in excessive drying and may slow decomposition, while increases can cause flooding that drowns air-breathing species and carries away available nutrients. Alterations to surface topography, including decreasing or increasing soil depth or adding non-native fill, can change the nutrient flow into the cave and affect the cave community (Howarth 1983). Impermeable cover, collection of water in devices like storm sewers, increased erosion and sedimentation, and irrigation and sprinkler systems can affect water flow to caves and karst ecosystems. Altering the quantity or timing of water input to the karst ecosystem, or its organic content, may negatively impact the listed species. (USFWS 2011a).

Stressor: Quarrying and mining operations
Exposure: destroys/degrades habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Quarrying and mining operations - Quarries and mines exist in Bexar County, including the northern half, where the majority of the listed species occur. While quarrying activities have revealed some caves (which can lead to protecting these sites), they have also completely destroyed others (Elliott 2000). As caves and mesocavernous spaces are destroyed at mines and quarries, karst invertebrates, possibly including some listed species, will also be lost. (USFWS 2011a).

Stressor: Alterations of surface plant and animal communities -
Exposure: destroy/degrades habitat; introduces competition; introduces predators
Response: Loses habitat; competes for limited resources; is predated upon
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Alterations of surface plant and animal communities - Karst ecosystems are heavily reliant on surface plant and animal communities to maintain nutrient flows, reduce sedimentation, and resist exotic and invasive species. As the surface around a cave entrance becomes developed, native plant communities are often replaced with impermeable cover or exotic plants from nurseries. The abundance and diversity of native animals may decline due to decreased food and habitat combined with increased competition and predation from urban, exotic, and pet species. The leaf litter and wood that make up most of the detritus may also be reduced or altered, resulting in a reduction of nutrient and energy flow into the cave. (USFWS 2011a).

Stressor: Invasive Ant Species
Exposure:
Response:
Consequence:
Narrative: Since the 2009 5-year review, a new non-native invasive ant species has established colonies at sites in Travis County. The tawny crazy ant (Nylanderia fulva), native to South America, was documented in Texas in 2002 and has established populations along the state's Gulf Coast and some central Texas counties (Wang et al. 2016, p. 4). This ant has exhibited a potential to affect native animal and plant communities (LeBrun et al. 2013, p. 2439; Wang et al. 2016, p. 5). Tawny crazy ant colonies are often polygynous and can form dense infestations

that dominate the local ant community (LeBrun et al. 2013, p. 2433). Arthropod species richness and abundance may decline in areas infested by tawny crazy ants (LeBrun et al. 2013, pp. 2434-2435; Wang et al. 2016, pp. 5, 7). Tawny crazy ants also appear capable of eliminating red-imported fire ants from areas where the species co-occur (LeBrun et al. 2013, pp. 2436-2437). Unlike redimported fire ants that generally prefer open-habitat types, the tawny crazy ant can reach high densities in forested habitats along with grasslands and other open-habitat types (LeBrun et al. 2013, pp. 2439-2440). Sites with dense canopies, therefore, would be afforded some decreased susceptibility to redimported fire ants but not the tawny crazy ant. Tawny crazy ants have established populations at Whirlpool and No Rent Caves in Travis County (LeBrun 2017, p. 3). LeBrun (2017, entire) assessed the effects of tawny crazy ants at these caves. Based on observations at these two sites, use of caves by ants was tied to surface temperatures and moisture with tawny crazy ants most prevalent in caves during hot, dry summer conditions (LeBrun 2017, p. 35). Tawny crazy ants preyed on cave crickets and other karst invertebrates with one species, the spider Cicurina varians, experiencing decreased abundance associated with that ant's presence (LeBrun 2017, pp. 2122, 35-36). No declines were noted for other karst invertebrates examined, though sample size was small (LeBrun 2017, pp. 22, 35). Additional research is needed to determine the potential for the tawny crazy ant to affect listed karst invertebrates (USFWS, 2018).

Recovery

Reclassification Criteria:
Not addressed.

Delisting Criteria:
According to recovery criterion (1) in USFWS 1994, 3 KFAs within each KFR should be protected. Protection is defined as an area sufficiently large to maintain the integrity of the karst ecosystem on which the species depends. These areas must also provide protection from threats such as RIFA, habitat destruction, and contaminants. Recovery criterion (2) requires at least 5 consecutive years of a cave meeting KFA status and that perpetual protection of these areas is in place.

Recovery Actions:

- Confirm and/or implement RIFA control at Tooth Cave (USFWS, 2009).
- Confirm and/or implement monitoring of Kretschmarr Cave.
- Confirm that there are no pipelines going through potential KFAs including: water, wastewater, natural gas, and petroleum.
- Find more locations for these species that could meet KFA status and protect them to meet downlisting criteria.
- Recovery Priority Number: 2C

Conservation Measures and Best Management Practices:

- RECOMMENDATIONS FOR FUTURE ACTIONS (USFWS, 2018) I. Obtain information for sites within the Balcones Canyonlands Preserve to include surface and subsurface drainage basins, potential development impacts, tract acreage, management, and perpetual protection mechanisms among others. Review information to determine the potential for sites to be recognized as karst fauna areas (USFWS, 2018). II. Draft quantitative delisting criteria for the Tooth Cave pseudoscorpion and other listed karst invertebrates in Travis and Williamson counties, Texas (USFWS, 2018). III. Reassess the current karst fauna regions of Travis and Williamson counties, Texas using current data and revise regions as necessary to better inform recovery efforts (USFWS, 2018).

References

USFWS. 1988. Final Rule to Determine 5 Texas Cave Invertebrates to be Endangered Species

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USFWS. 2009. Tooth Cave Spider (Neoleptoneta myopica), Kretschmarr Cave Mold Beetle (Texamaurops reddelli), and Tooth Cave Pseudoscorpion (Tartarocreagris texana) 5-Year Review: Summary and Evaluation.

USFWS 1994. Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson counties, Texas. USFWS 2007. 5-Year Reviews of 24 Southwestern Species.USFWS 2009. Tooth Cave Spider (Neoleptoneta myopica), Kretschmarr Cave Mold Beetle (Texamaurops reddelli), and Tooth Cave Pseudoscorpion (Tartarocreagris texana) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service (USFWS). 2011. Bexar County Karst Invertebrate Recovery Plan.

USFWS 2009. Tooth Cave Spider (Neoleptoneta myopica), Kretschmarr Cave Mold Beetle (Texamaurops reddelli), and Tooth Cave Pseudoscorpion (Tartarocreagris texana) 5-Year Review: Summary and Evaluation.

U.S. Fish and Wildlife Service (USFWS). 2011. Bexar County Karst Invertebrate Recovery Plan. Note: This Bexar County reference/material was used because it is more up to date and concise than the general information contained in the 1994 Recovery Plan for Travis and Williamson Counties. The threats are identical in all three Texas counties (Bexar, Travis, Williamson).

U.S. Fish and Wildlife Service. 2018. Tooth Cave Pseudoscorpion (Tartarocreagris texana) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service Austin Ecological Services Field Office Austin, Texas. 32. pp.

USFWS. 2009. Tooth Cave Spider (Neoleptoneta myopica), Kretschmarr Cave Mold Beetle (Texamaurops reddelli), and Tooth Cave Pseudoscorpion (Tartarocreagris texana)

5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Austin Ecological Services Field Office, Austin, Texas.

U.S. Fish and Wildlife Service. 2018. Tooth Cave Pseudoscorpion (Tartarocreagris texana) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service Austin Ecological Services Field Office Austin, Texas. 32. pp.

SPECIES ACCOUNT: *Texella cokendolpheri (=reyesi)* (Cokendolpher Cave Harvestman)

Species Taxonomic and Listing Information

Listing Status: Endangered; 12-26-2000

Physical Description

Troglobite (spends entire life in subterranean environment); small, essentially eyeless daddy long-legs; very long, thin legs and a small body; pale orange in color; do not have silk glands, so do not build webs; can swallow chunks of solid food, not just liquid; males have a penis (unlike other arachnids); all species lay eggs.

Taxonomy

Order Opiliones, not closely related to other arachnids, although often confused with spiders (order Araneae); aka Robber Baron cave harvestman.

Historical Range

Unknown, but likely similar to current distribution

Current Range

Robber Baron Cave, Alamo Heights (KFA), Bexar County, TX; <100 sq km (~40 sq mi)

Distinct Population Segments Defined

No; not applicable to invertebrates

Critical Habitat Designated

Yes; 4/8/2003.

Legal Description

On February 14, 2012, the U.S. Fish and Wildlife Service (Service) designated critical habitat for Cokendolpher Cave harvestman (Texella cokendolpheri) (and eight other species), under the Endangered Species Act of 1973, as amended (77 FR 8450 - 8523). These species are collectively known as the nine Bexar County invertebrates. This critical habitat replaces critical habitat previously designated April 8, 2003 (68 FR 17156 - 17231). For Cokendolpher Cave harvestman, approximately 247 ac (100 ha) fall within the boundaries of the critical habitat designation.

Critical Habitat Designation

Critical habitat for the Cokendolpher Cave harvestman in Bexar County, Texas, occurs in Unit 20.

Unit 20 consists of 247 ac (100 ha) of private land located in north-central San Antonio, south of Loop 410 West, and primarily along Nacogdoches Road northeast of Broadway in the Alamo Heights KFR. This unit contains one known occupied cave, Robber Baron Cave, which is the only known cave for the Cokendolpher Cave harvestman. It is also one of only two caves known to be occupied by the Robber Baron Cave meshweaver (OB3 in Unit 25 is the other cave). Robber Baron Cave was occupied at the time of listing and is the longest cave in Bexar County, consisting of approximately 0.9 mi (1.5 km) of passages (Veni 2003, p. 19). The estimated footprint of the cave now underlies numerous residential and commercial developments. Veni (1997, p. 29) reported a slow decline in moisture in the cave over time. The Texas Cave Management Association (TCMA) now owns and manages the cave and about 0.5 ac (0.2 ha) surrounding the opening. The TCMA is a nonprofit organization dedicated to the study and management of Texas cave resources. Cave gates and modifications to the cave entrance have reduced airflow into the cave and the opportunity for cave crickets to move into and out of the cave. Installation of a new cave gate, removal of trash, and revegetation of a small area surrounding the entrance was completed in 2008 by TCMA (TCMA 2011, pp 2–3) and improved these issues for a portion of the cave. This unit was occupied at the time of listing and contains both PCEs. Surface vegetation within Unit 20 has been significantly reduced and degraded by urban development, although portions of primarily landscaped areas remain. The unit requires special management because of the high levels of residential and commercial development within the unit. Threats include the potential for destruction of habitat from vandalism, soil compaction from cave visitation, lack of a nutrient sources, contamination of the subsurface drainage area of the unit, drying of karst, and infestation of fire ants. Because of the extensive development, high levels of impervious cover, and diversion of storm water over the cave, intensive management may be needed to provide nutrients and water to the karst environment. The unit was delineated to encompass the estimated extent of the surface and subsurface drainage and all of the contiguous Karst Zone 1. We did not use the standard procedure that we used to delineate other units because the cave footprint and contiguous Karst Zone 1 are long and narrow, and because the overall size exceeds 100 ac (40 ha).

Primary Constituent Elements/Physical or Biological Features

The primary constituent elements of critical habitat for the Cokendolpher Cave harvestman are:

(i) Karst-forming rock containing subterranean spaces (caves and connected mesocaverns) with stable temperatures, high humidities (near saturation), and suitable substrates (for example, spaces between and underneath rocks for foraging and sheltering) that are free of contaminants; and

(ii) Surface and subsurface sources (such as plants and their roots, fruits, and leaves, and animal (e.g., cave cricket) eggs, feces, and carcasses) that provide nutrient input into the karst ecosystem.

Special Management Considerations or Protections

Developed lands that do not contain the subsurface primary constituent elements and that existed on the effective date of this rule are not considered to be critical habitat.

Threats to the nine Bexar County invertebrates include clearing of vegetation for commercial or residential development, road building, quarrying, or other purposes. Infestation by nonnative vegetation causes adverse changes in the plant and animal community and possibly in moisture availability. An increase in fire ants can occur with development and cause competition with and predation on other invertebrates in the karst ecosystem. In addition, filling cave features for construction, ranching, or other purposes can adversely affect the listed invertebrate species by reducing nutrient input, reducing small mammal access, and changing moisture regimes. Excavation for construction or operation of quarries can directly destroy karst features occupied by any of the nine Bexar County invertebrates, including the mesocaverns they use.

Examples of management that would alleviate these threats include: (1) Protecting vegetation around occupied karst features and overlying connected mesocaverns; (2) protecting subsurface karst habitat to allow movement of karst invertebrates through caves and mesocaverns; (3) controlling nonnative fire ants around cave features and within the karst cricket foraging area; (4) preventing unauthorized access to karst features by installing fencing and cave gates; and (5) keeping the surface and subsurface areas surrounding cave features and associated mesocaverns free from sources of contamination.

Life History

Feeding Narrative

Adult: Nutrients in most karst ecosystems are derived from the surface either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the karst invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller troglophiles and troglobites that grow on the leaves or feces rather than the original material itself. Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through karst fissures and solution features. Forpredatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave. The cave cricket (Ceuthophilus spp.) is a particularly important nutrient component and is found in most caves in Texas (USFWS 2011). Troglobytes typically have very slow metabolisms, an adaptation to the sparse amounts of food found in their environment. Because they are adapted to an environment with little food, pollution by the addition of large amounts of nutrients to the cave can actually be harmful to the species, because it allows invertebrates that are not cave adapted, such as cockroaches and a variety of flies to survive in the care and even-out-compete the cave species (USFWS 2000).

Reproduction Narrative

Adult: As K-selected species, cave invertebrates are described as more similar to large mammals than to their invertebrate cousins that live on the land surface. Like large mammals, they have few offspring and live relatively long lives (for invertebrates). This also means their populations are more sensitive to losing even fairly small numbers of individuals, and that it takes a long time for their population sizes to recovery from any catastrophe. May have 4 to 8 symphal instars to reach maturity; most have 6. Females may lay eggs up to 6 months after mating. Males may guard the eggs (laid by several partners); some species build nests. Gestation period is unknown, but depending on temperature, may be from 20 days to 6 months after eggs laid.

Geographic or Habitat Restraints or Barriers

Adult: Restricted to cave/karst environment

Spatial Arrangements of the Population

Adult: Unknown

Environmental Specificity

Adult: High

Tolerance Ranges/Thresholds

Adult: Unknown, but likely low do due environmental specificity

Site Fidelity

Adult: Unknown, but likely high due to restricted environment.

Dependency on Other Individuals or Species for Habitat

Adult: Unknown

Habitat Narrative

Adult: The six listed Bexar County arachnids are restricted to cave/karst habitat, and can be found in as few as one cave or as many as 20. How they may disperse, or be dispersed, to other caves is unknown. What is known is that the karst/cave system (shelter) is highly susceptible to degradation from outside influences. The species requires stable temperature and constant, high humidity; surface vegetation to provide nutrients from: (1) direct flow of plant material into the karst with water; (2) habitat and food sources provided for the animal communities that contribute nutrients to the karst ecosystem (such as cave crickets, small mammals); and (3) roots that extend into subsurface areas and may provide a major energy sources in shallow caves.

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: None

Dispersal

Adult: How they may disperse, or be dispersed, to other caves is unknown.

Immigration/Emigration

Adult: Unknown

Dependency on Other Individuals or Species for Dispersal

Adult: Unknown

Dispersal/Migration Narrative

Adult: The six listed arachnids are restricted to the cave/karst environment of the Edwards Aquifer in Bexar County, Texas. Very little is known about their dispersal/migration within/among the caves; how they may disperse, or be dispersed, to other caves is unknown.

Population Information and Trends

Population Trends:

Unknown

Species Trends:

Unknown

Resiliency:

Unknown, but likely low.

Representation:

Known from a single cave, so likely low.

Redundancy:

Known from a single cave, so likely low.

Population Growth Rate:

Unknown

Number of Populations:

Unknown, but known from a single cave.

Population Size:

Unknown, but known from a single cave, so likely low.

Minimum Viable Population Size:

Unknown

Resistance to Disease:

Unknown, but likley low due to isolation.

Adaptability:

Unknown, but likely low do to highly specialized environment requirements.

Population Narrative:

Population estimates are unavailable for any of the six troglobites listed as endangered in Bexar County due to a lack of adequate techniques, their cryptic behavior, and inaccessibility of habitat. While some troglobites are known from a few specimens, detailed studies suggest that "as a rule" most troglobites are not numerically rare and thus are not susceptible to the problems of small populations." However, considering the lack of population estimates and limited study of these species, data are insufficient to indicate whether Bexar County karst invertebrates are numerous enough to rule out small population concerns. The number of populations and size of the populations of this species is unknown, Resiliency, representation,growth rate, and redundancy are all likely to be low as the species is known from only one cave. Resistance to disease and adaptability are likely low due to isolation and highly specialized environmental requirements.

Threats and Stressors

Stressor: Edge effects
Exposure: impact native communities; disrupt natural systems; introduce non-native predators (such as fire ants)
Response: loses nutrients; competes for limited resources; death by predation
Consequence: Reduction in population numbers; decreased reproductive success

Narrative: Edge effects - "Edge effects" are changes to the floral and faunal communities where different habitats meet. The length and width of the edge, as well as the contrast between the vegetational communities, all contribute to the amount of impacts (Smith 1990, Harris 1984). Some types of edge effects include increases in solar radiation, changes in soil moisture due to elevated levels of evapotranspiration, wind buffeting (Ranny et al. 1981), changes in nutrient cycling and the hydrological cycle (Saunders et al. 1990), and changes in the rate of leaf litter decomposition (Didham 1998). These edge effects alter plant communities, which in turn impact the associated animal species. Edge effects can also affect animal species directly. The changes caused by edge effects can occur rapidly. Vegetation located 2 m (6.6 ft) from an edge can be visibly affected within days (Lovejoy et al. 1986). Edge effects associated with soil disturbance and disruption to native communities that accompany urbanization (for example, waste associated with housing) may attract redimported fire ants (RIFA)(discussed in factor C) or other surface species that prey on or compete with cave species (Reddell 1993). The invasion of RIFA is aided by "any disturbance that clears a site of heavy vegetation and disrupts the native ant community" (Porter et al. 1988) such as road building and urbanization. Development and edges often allow enough disruption for invasive or exotic species to displace native communities that had previously prevented their spread (Saunders et al. 1990, Kotanen et al. 1998, Suarez et al. 1998, Meiners and Steward 1999). (USFWS 2011a).

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Stressor: Contamination
Exposure: introduced pollutions, poisons to groundwater
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Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Contamination - Karst landscapes are particularly susceptible to groundwater contamination because water penetrates rapidly through bedrock conduits and little or no filtration occurs (White 1988). In some areas the water that moves through the habitat of these species percolates to the Edwards Aquifer below. The Edwards Aquifer is an important source of drinking water for 1.7 million people (Edwards Aquifer Authority 2008). So, information on

sources of water contamination of the Edwards Aquifer may also be indicative of sources of contamination of karst invertebrate habitat. The ranges of these species are becoming increasingly urbanized and thereby are becoming more susceptible to contaminants including sewage, oil, fertilizers, pesticides, herbicides, seepage from landfills, pipeline leaks, or leaks in storage structures and retaining ponds. Activities on the surface, such as disposing of toxic chemicals or motor oil, can also contaminate caves (White 1988). Continued urbanization will increase the likelihood that karst ecosystems are polluted by contamination from the leaks and spills, which have often occurred in Bexar County (see TWC 1989, TCEQ 2010a, TCEQ 2010b for information on contamination events). Texas Commission on Environmental Quality (TCEQ) (2010a) summarizes information on groundwater contamination reported by a number of agencies, and in 2010 they reported that 1,712 leaking petroleum storage tanks were located in Bexar County.

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Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of temperature, humidity, and nutrients that are washed into caves. To sustain these conditions, both natural surface and subsurface flow of water and nutrients should be maintained. Decreases in water flow or infiltration can result in excessive drying and may slow decomposition, while increases can cause flooding that drowns air-breathing species and carries away available nutrients. Alterations to surface topography, including decreasing or increasing soil depth or adding non-native fill, can change the nutrient flow into the cave and affect the cave community (Howarth 1983). Impermeable cover, collection of water in devices like storm sewers, increased erosion and sedimentation, and irrigation and sprinkler systems can affect water flow to caves and karst ecosystems. Altering the quantity or timing of water input to the karst ecosystem, or its organic content, may negatively impact the listed species. (USFWS 2011a).

Stressor: Quarrying and mining operations
Exposure: destroys/degrades habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Quarrying and mining operations - Quarries and mines exist in Bexar County, including the northern half, where the majority of the listed species occur. While quarrying activities have revealed some caves (which can lead to protecting these sites), they have also completely destroyed others (Elliott 2000). As caves and mesocavernous spaces are destroyed at mines and quarries, karst invertebrates, possibly including some listed species, will also be lost. (USFWS 2011a).

Stressor: Alterations of surface plant and animal communities -
Exposure: destroy/degrades habitat; introduces competition; introduces predators
Response: Loses habitat; competes for limited resources; is predated upon
Consequence:
Narrative: Alterations of surface plant and animal communities - Karst ecosystems are heavily reliant on surface plant and animal communities to maintain nutrient flows, reduce sedimentation, and resist exotic and invasive species. As the surface around a cave entrance

becomes developed, native plant communities are often replaced with impermeable cover or exotic plants from nurseries. The abundance and diversity of native animals may decline due to decreased food and habitat combined with increased competition and predation from urban, exotic, and pet species. The leaf litter and wood that make up most of the detritus may also be reduced or altered, resulting in a reduction of nutrient and energy flow into the cave. (USFWS 2011a).

Recovery

Reclassification Criteria:
(1) at least one high quality protected Karst Fauna Area (KFA) per Karst Fauna Region (KFR); (2) at least three total medium or high quality protected KFAs per KFR; (3) a minimum of six protected KFAs rangewide; (4) a minimum of three high quality KFAs; (5) all KFAs must at be of at least mediium or high quality.

Delisting Criteria:
In addition to the five downlisting criteria, monitoring and research will have to have been completed to conclude with a high degree of certainlty that KFA size, quality, configuration, and management are adquate to provide a high probably of the species survival (greater than 90 percdnt over 100 years). To assess adequacy, results should be measured over a long enough time that cause and effect can be inferred with a high degree of certainty.

Recovery Actions:
- Reduce threats to the species by securing an adequate quantity and quality of caves, including selecting caves or cave clusters that represent the range of the species and potential genetic diversity.

Conservation Measures and Best Management Practices:
- Not addressed. See recovery actions.

References

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SPECIES ACCOUNT: *Texella reddelli* (Bee Creek Cave harvestman)

Species Taxonomic and Listing Information

Listing Status: Endangered (USFWS 1988)

Physical Description

Troglobite (spends entire life in subterranean environment); small, essentially eyeless daddy long-legs; very long, thin legs and a small body;light yellowish-brown in color; does not have silk glands, so does not build webs; can swallow chunks of solid food, not just liquid; males have a penis (unlike other arachnids); all species lay eggs.

Taxonomy

Order Opiliones, not closely related to other arachnids, although often confused with spiders (order Araneae); aka Bee Creek Cave Harvestman; cave obligate, troglobite

Historical Range

Unknown, but likely similar to current distribution, unless cave systems have been destroyed historically

Current Range

Known from 8 caves (Spider Cave, Jest John Cave, Jester Estates Cave, Little Black Hole, Little Bee Creek Cave, Bee Creek Cave, Bandit Cave, and Startk's North Mine Cave) within 3 KRFs (Jollyville Plateau, Rollingwood, and McNeil/Round Rock) are known to contain T. reddelli in Travis Counties, Texas; <100-250 square km (less than about 40-100 square miles); distributed along a 34 km of the Edwards Plateau in Travis County in central Texas (USFWS, 1994).

Distinct Population Segments Defined

N/A for invertebrates

Critical Habitat Designated

Yes;

Life History

Feeding Narrative

Adult: Nutrients in most karst ecosystems are derived from the surface either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the karst invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller troglophiles and troglobites that grow on the leaves or feces rather than the original material itself. Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through karst fissures and solution features. For predatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave. The cave cricket (Ceuthophilus spp.) is a particularly important nutrient component and is found in most caves in Texas (USFWS 2011). Troglobites typically have very slow metabolisms, an adaptation to the sparse amounts of food found in their environment. Because they are adapted to an environment with little food, pollution by the addition of large amounts of nutrients to the cave can actually be harmful to the species, because it allows invertebrates that are not cave adapted, such as cockroaches and a variety of flies to survive in the care and even-out-compete the cave species (USFWS 2000).

Reproduction Narrative

Adult: Cave invertebrates are described as K-strategists -- more similar to large mammals than to their invertebrate cousins that live on the land surface. Like large mammals, they have few offspring and live relatively long lives (for invertebrates). This also means their populations are more sensitive to losing even fairly small numbers of individuals, and that it takes a long time for their population sizes to recovery from any catastrophe. Generally, female Harvestmen may lay eggs up to 6 months after mating. They have an unknown gestation rate, but depending on termperature, it may be from 20 days to 6 months after the eggs are laid. Males may guard the eggs (laid by several partners). They may have four to eight symphal instars to reach maturity, but most species have six. Most species live for 1 year. (USFWS 2000).

Geographic or Habitat Restraints or Barriers

Adult: Restricted to cave/karst environment

Spatial Arrangements of the Population

Adult: Unknown

Environmental Specificity

Adult: High

Tolerance Ranges/Thresholds

Adult: Unknown, but likely low

Site Fidelity

Adult: Unknown, but likely high

Dependency on Other Individuals or Species for Habitat

Adult: Unknown

Habitat Narrative

Adult: T. reddelli is restricted to cave/karst habitat, and has been recorded in eight caves (USFWS, 2009) in Travis and Williamson counties, Texas. The species is especially sensitive to drying and requires very moist, humid conditions (Elliott 1991a-f and unpublished data). Most individuals are found under large rocks, but are occasionally seen walking on moist floors. Individuals are typically found about 30m from the entrance in total darkness, where humidity is high; they seldom occur farther in the cave where there is less water and food. In the hottest part of the summer when many of the small caves warm up and become drier, individuals may retreat into the interstitium or may be found only in the coolest, dampest spots in the caves. This species feeds on microarthropods. One individual in Lake Line Cave was observed feeding on fungi growing on a dead raccoon. (USFWS 1994). The species requires habitat with surface vegetation to provide nutrients from: (1) direct flow of plant material into the karst with water; (2) habitat and food sources provided for the animal communities that contribute nutrients to the karst ecosystem (such as cave crickets, small mammals); and (3) roots that extend into subsurface areas and may provide a major energy sources in shallow caves. Troglobitic habitat includes caves and mesocavernous voids in karst limestone (a terrain characterized by landforms and subsurface features, such as sinkholes and caves, which are produced by solution of bedrock) in Travis and Williamson counties. Karst areas commonly have few surface streams; most water moves through cavities underground. Within this habitat this species depends on high humidity, stable temperatures, and nutrients derived from the surface. Examples of nutrient sources include leaf litter fallen or washed in, animal droppings, and animal carcasses. (USFWS 2007).

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: None

Dispersal

Adult: Currently known from 8 caves, distributed along a 40 km distance in Travis and Williamson counties in central Texas (USFWS, 1994).

Immigration/Emigration

Adult: Unknown

Dependency on Other Individuals or Species for Dispersal

Adult: Unknown

Dispersal/Migration Narrative

Adult: T. reddelli is restricted to the cave/karst environment of Travis and Williamson and counties, Texas. Very little is known about their dispersal/migration within/among the cave systems (USFWS, 2009).

Population Information and Trends

Population Trends:

Unknonwn

Species Trends:

Unknown

Resiliency:

Unknown, but likely low due to specialized habitat requirements

Representation:

Uknown, but likely low due to restricted occupation

Redundancy:

Unknown, but likely low as found to occur in only 8 caves in Texas

Population Growth Rate:
Unknown

Number of Populations:
Unknown; known from 8 caves

Population Size:
Unknown

Minimum Viable Population Size:
Unknown

Resistance to Disease:
Unknown, but likely low due to restricted habitat

Adaptability:
Unknown, but likely low due to specialization

Population Narrative:
Population trends and estimates are unavailable due to a lack of adequate techniques, its cryptic behavior, and inaccessibility of habitat. The species is currently known from 8 caves in Travis and Williamson counties, Texas. While some troglobites are known from a few specimens, detailed studies suggest that "as a rule" most troglobites are not numerically rare and thus are not susceptible to the problems of small populations." However, considering the lack of population estimates and limited study of these species, data are insufficient to indicate whether the Travis and Williamson counties karst invertebrates are numerous enough to rule out small population concerns (USFWS, 2011). The 2009 5-year review for the Bee Creek Cave harvestman listed eight caves with records of the species from three karst fauna regions in Travis County (Service 2009, pp. 2, 5, 7). This review documents 11 caves and three surface occurrences of the species in two karst fauna regions in Burnet and Travis counties (Table 2). The location for Stark's Mine North in the McNeil/Round Rock Karst Fauna Region was in error with that cave now mapped east of the Central Austin Karst Fauna Region near Interstate 35. As a result, the McNeil/Round Rock Karst Fauna Region is not included in the species range at present. The Jollyville Plateau and Rollingwood Karst Fauna Regions each contain four caves occupied by the Bee Creek Cave harvestman. Currently, these are the only two karst fauna regions known to host the species. Not including Stark's North Mine, five occurrences of the Bee Creek Cave harvestman occur outside of delineated karst fauna regions. A surface collection of this species occurred at the intersection of State Highway 71 and the Pedernales River in western Travis County (Ubick and Briggs 2004, p. 108). Ubick and Briggs (2004, pp. 107-108) extended the Bee Creek Cave harvestman's range into southeastern Burnet County with specimens taken from MVN and Waldman Caves as well as two surface sites along County Road 404 northwest of Spicewood. An important consideration for this 5-year review was whether occupied caves warranted consolidation into single populations based on geographic proximity (Service 2018, pp. 24, 49-50). Although there are no data specific to the Bee Creek Cave harvestman, research indicates that troglobitic arachnids and insects may disperse through networks of subterranean voids (e.g., mesocaverns). In central Texas, some troglobitic beetles (i.e., Rhadine), bristletails (i.e.,

Texoredellia), and spiders (e.g., Cicurina and Tayshaneta=Neoleptoneta) have exhibited genetic connectivity among occupied caves (Avise and Selander 1972, p.15; Paquin and Hedin 2004, p. 3250; Paquin and Hedin 2005, pp. 4-5, 14-15; Ledford et al. 2012, pp. 11, 18-23; Espinasa et al. 2016, pp. 233, 236, 238). Subterranean dispersal of troglobitic invertebrates, along with resultant gene flow in some cases, has been suggested to occur in cave systems of Australia (Moulds et al. 2007, pp. 8, 10), Brazil (Jaffé et al. 2016, pp. 11-12), and other regions of the United States (i.e., Kentucky; Turanchik and Kane 1979, pp. 6567). Ledford et al. (2012, pp. 11, 18-23, 51) documented significant genetic similarity (i.e., mitochondrial and nuclear DNA) among Tooth Cave spider (Tayshaneta myopica=Neoleptoneta myopica) populations at Gallifer, Root, Tooth Caves and Tight Pit in Travis County. Genetic similarity among Tooth Cave spiders sampled from those sites implies dispersal of individuals between caves over time through interconnected subterranean dispersal corridors such as fissures or mesocaverns (Ledford et al. 2012, pp. 11, 51). The greatest distance between genetically similar Tooth Cave spider populations at Tight Pit and Gallifer, Root, and Tooth Caves is approximately 292 m (958 ft). For our assessment, we assumed that populations of the Bee Creek Cave harvestman, given adequate geological connectivity, are capable of subterranean dispersal and gene flow among karst features. To account for potential genetic connectivity of populations, we assigned a maximum dispersal radius of 300 m (984 ft) from each cave occupied by the species. That value is a conservative estimate that is most similar to distances exhibited by the Tooth Cave spider. Given the extent of geological connectivity surrounding caves, actual Bee Creek Cave harvestman dispersal distances may be greater or less than that value. Genetic analyses would be necessary to provide more certainty regarding actual dispersal distances. We did not apply this methodology to surface sites given the lack of detailed data on habitat conditions at these locations. For each cave occupied by the Bee Creek Cave harvestman, we established a 300 m (984 ft) radius around individual sites in ArcGIS with the entrance as a center-point. If the respective radiuses of adjacent caves over-lapped (or caves were within 600 m (1968 ft) of each other), those sites were grouped into what we refer to as a cave cluster and those caves were assumed to be part of the same interconnected Bee Creek Cave harvestman population. If a cave's radius did not overlap with any other cave, we labeled that site an individual cave and considered it an isolated population. Based on that methodology, we grouped Bee Creek Cave harvestman occurrences into two cave clusters and seven individual caves (Table 2) (USFWS, 2018).

Threats and Stressors

Stressor: Edge effects
Exposure: impact native communities; disrupt natural systems; introduce non-native predators (such as fire ants)
Response: loses nutrients; competes for limited resources; death by predation
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Edge effects - "Edge effects" are changes to the floral and faunal communities where different habitats meet. The length and width of the edge, as well as the contrast between the vegetational communities, all contribute to the amount of impacts (Smith 1990, Harris 1984). Some types of edge effects include increases in solar radiation, changes in soil moisture due to elevated levels of evapotranspiration, wind buffeting (Ranny et al. 1981), changes in nutrient cycling and the hydrological cycle (Saunders et al. 1990), and changes in the rate of leaf litter decomposition (Didham 1998). These edge effects alter plant communities, which in turn impact the associated animal species. Edge effects can also affect animal species directly. The changes

caused by edge effects can occur rapidly. Vegetation located 2 m (6.6 ft) from an edge can be visibly affected within days (Lovejoy et al. 1986). Edge effects associated with soil disturbance and disruption to native communities that accompany urbanization (for example, waste associated with housing) may attract redimported fire ants (RIFA)(discussed in factor C) or other surface species that prey on or compete with cave species (Reddell 1993). The invasion of RIFA is aided by "any disturbance that clears a site of heavy vegetation and disrupts the native ant community" (Porter et al. 1988) such as road building and urbanization. Development and edges often allow enough disruption for invasive or exotic species to displace native communities that had previously prevented their spread (Saunders et al. 1990, Kotanen et al. 1998, Suarez et al. 1998, Meiners and Steward 1999). (USFWS 2011a).

Stressor: Human visitation and vandalism, including commercialization
Exposure: degrades/destroys habitat; introduces predators and competitors
Response: Loses habitat; competes for limited resources; death by predation; crushed
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Human visitation and vandalism - Visitation can impact caves by increasing soil compaction, trash deposition, and vandalism; altering airflow as entrances are expanded and excavated; scaring away trogloxenes (Culver 1986, Elliott 2000); and may also lead to direct mortality of cave organisms crushed by human disturbance (Crawford and Senger 1988). Commercialization of caves affects cave communities due to (1) competition with introduced surface species; (2) harmful effects of commercial lighting, for example increased temperature and decreased humidity near lights; (3) substrate changes around trails; (4) changes in microclimate due to cave ventilation; (5) and increases in the nutrient regime that favor surface species (Culver 1986, Northup 1988, Northup et al. 1988; Reddell 1993, Krejca and Myers 2005, Mulec and Kosi 2009). Conversely, some researchers have found high diversity and/or abundance of some species in show caves that have higher nutrient and water availability (Culver and Sket 2000, Paquin 2007). However, for the reasons stated above we believe that commercialization of caves is generally a threat because (1) these activities alter the natural habitat and nutrient regime of these species and (2) because most caves in Texas have limited nutrient and water availability. (USFWS 2011a)

Stressor: Contamination
Exposure: introduced pollutions, poisons to groundwater
Response: Loses habitat; direct poisoning
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Contamination - Karst landscapes are particularly susceptible to groundwater contamination because water penetrates rapidly through bedrock conduits and little or no filtration occurs (White 1988). In some areas the water that moves through the habitat of these species percolates to the Edwards Aquifer below. The Edwards Aquifer is an important source of drinking water for 1.7 million people (Edwards Aquifer Authority 2008). So, information on sources of water contamination of the Edwards Aquifer may also be indicative of sources of contamination of karst invertebrate habitat. The ranges of these species are becoming increasingly urbanized and thereby are becoming more susceptible to contaminants including sewage, oil, fertilizers, pesticides, herbicides, seepage from landfills, pipeline leaks, or leaks in storage structures and retaining ponds. Activities on the surface, such as disposing of toxic chemicals or motor oil, can also contaminate caves (White 1988). Continued urbanization will increase the likelihood that karst ecosystems are polluted by contamination from the leaks and spills, which have often occurred in Bexar County (see TWC 1989, TCEQ 2010a, TCEQ 2010b for

information on contamination events). Texas Commission on Environmental Quality (TCEQ) (2010a) summarizes information on groundwater contamination reported by a number of agencies, and in 2010 they reported that 1,712 leaking petroleum storage tanks were located in Bexar County.

Stressor: Alterations of Drainage Patterns
Exposure: degrades/destroys habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of Alteration of Drainage Patterns - Cave organisms are adapted to live in a narrow range of temperature, humidity, and nutrients that are washed into caves. To sustain these conditions, both natural surface and subsurface flow of water and nutrients should be maintained. Decreases in water flow or infiltration can result in excessive drying and may slow decomposition, while increases can cause flooding that drowns air-breathing species and carries away available nutrients. Alterations to surface topography, including decreasing or increasing soil depth or adding non-native fill, can change the nutrient flow into the cave and affect the cave community (Howarth 1983). Impermeable cover, collection of water in devices like storm sewers, increased erosion and sedimentation, and irrigation and sprinkler systems can affect water flow to caves and karst ecosystems. Altering the quantity or timing of water input to the karst ecosystem, or its organic content, may negatively impact the listed species. (USFWS 2011a).

Stressor: Quarrying and mining operations
Exposure: destroys/degrades habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Quarrying and mining operations - Quarries and mines exist in Bexar County, including the northern half, where the majority of the listed species occur. While quarrying activities have revealed some caves (which can lead to protecting these sites), they have also completely destroyed others (Elliott 2000). As caves and mesocavernous spaces are destroyed at mines and quarries, karst invertebrates, possibly including some listed species, will also be lost. (USFWS 2011a).

Stressor: Alterations of surface plant and animal communities -
Exposure: destroy/degrades habitat; introduces competition; introduces predators
Response: Loses habitat; competes for limited resources; is predated upon
Consequence:
Narrative: Alterations of surface plant and animal communities - Karst ecosystems are heavily reliant on surface plant and animal communities to maintain nutrient flows, reduce sedimentation, and resist exotic and invasive species. As the surface around a cave entrance becomes developed, native plant communities are often replaced with impermeable cover or exotic plants from nurseries. The abundance and diversity of native animals may decline due to decreased food and habitat combined with increased competition and predation from urban, exotic, and pet species. The leaf litter and wood that make up most of the detritus may also be reduced or altered, resulting in a reduction of nutrient and energy flow into the cave. (USFWS 2011a).

Stressor: Human Population Growth

Exposure:
Response:
Consequence:
Narrative: The Bee Creek Cave harvestman, and its subterranean habitat, is reliant on functional surface ecological systems. The plant communities that overlay and surround cave systems aid in buffering subterranean ecosystems from stressors, support nutrient flow, and aid in the maintenance of microclimatic conditions (Barr 1968, pp. 47-48; Poulson and White 1969, pp. 971-972; Howarth 1983, p. 376; Culver and Pipan 2009b, p. 23; Simões et al. 2014, p. 168; Pellegrini et al. 2016, pp. 28, 32-34). As a site is developed, native plant communities are often mechanically cleared and replaced with a highly modified urban to exurban landscape (Theobald et al. 1997, p. 26; McKinney 2002, pp. 884, 886; McKinney 2008, p. 168; Zipperer 2011, pp. 188-189). Construction activities may also modify cave entrances and other openings to the surface (Watson et al. 1997, p. 11; Veni et al. 1999, p. 55; Waltham and Lu 2007, p. 17; Frumkin 2013, pp. 61-62; Hunt et al. 2013, p. 97) which could affect climatic conditions within the cave as well as water infiltration (Pugsley 1984, pp. 403-404; Elliott and Reddell 1989, p. 7; Culver and Pipan 2009b, p. 202). The abundance and species richness of native animals may decline due to decreased foraging or sheltering habitat, increased predation, competition with non-native species, or lack of connectivity among populations (Rebele 1994, p. 177; McKinney 2002, pp. 885-886; Taylor et al 2007, pp. 2, 37, 41-44; Pellegrini et al. 2016, pp. 28, 34). Direct and collateral impacts to surface and subsurface habitat from urbanization have the potential to reduce Bee Creek Cave harvestman population viability and the species' long-term persistence. Given population and urbanized land growth projections (Texas Demographic Center 2014; Nowak and Greenfield 2018b, p. 170), it is likely that remaining surface and subsurface habitats will be impacted in the absence of management and protection (USFWS, 2018).

Stressor: Invasive Ant Species
Exposure:
Response:
Consequence:
Narrative: Since the 2009 5-year review, a new non-native invasive ant species has established colonies at sites in Travis County. The tawny crazy ant (Nylanderia fulva), native to South America, was documented in Texas in 2002 and has established populations along the state's Gulf Coast and some central Texas counties (Wang et al. 2016, p. 4). This ant has exhibited a potential to affect native animal and plant communities (LeBrun et al. 2013, p. 2439; Wang et al. 2016, p. 5). Tawny crazy ant colonies are often polygynous and can form dense infestations that dominate the local ant community (LeBrun et al. 2013, p. 2433). Arthropod species richness and abundance may decline in areas infested by tawny crazy ants (LeBrun et al. 2013, pp. 2434-2435; Wang et al. 2016, pp. 5, 7). Tawny crazy ants also appear capable of eliminating red-imported fire ants from areas where the species co-occur (LeBrun et al. 2013, pp. 2436-2437). Unlike redimported fire ants that generally prefer open-habitat types, the tawny crazy ant can reach high densities in forested habitats along with grasslands and other open-habitat types (LeBrun et al. 2013, pp. 2439-2440). Sites with dense canopies, therefore, would be afforded some decreased susceptibility to redimported fire ants but not the tawny crazy ant. Tawny crazy ants have established populations at Whirlpool and No Rent Caves in Travis County (LeBrun 2017, p. 3). LeBrun (2017, entire) assessed the effects of tawny crazy ants at these caves. Based on observations at these two sites, use of caves by ants was tied to surface temperatures and moisture with tawny crazy ants most prevalent in caves during hot, dry summer conditions (LeBrun 2017, p. 35). Tawny crazy ants preyed on cave crickets and other karst invertebrates

with one species, the spider Cicurina varians, experiencing decreased abundance associated with that ant's presence (LeBrun 2017, pp. 2122, 35-36). No declines were noted for other karst invertebrates examined, though sample size was small (LeBrun 2017, pp. 22, 35). Additional research is needed to determine the potential for the tawny crazy ant to affect karst invertebrates (USFWS, 2018).

Recovery

Reclassification Criteria:
Not available

Delisting Criteria:
According to recovery criterion (1) in USFWS 1994, 3 KFAs within each KFR should be protected. Protection is defined as an area sufficiently large to maintain the integrity of the karst ecosystem on which the species depends. These areas must also provide protection from threats such as RIFA, habitat destruction, and contaminants. Recovery criterion (2) requires at least 5 consecutive years of a cave meeting KFA status and that perpetual protection of these areas is in place.

Although T. reddelli is known from 8 caves occurring within 3 KFRs, at this time none of the karst preserves meet the definition of a protected KFABased on a review of available data, none of these caves currently meet this definition; however, with some additional data gathering and/or confirmation/implementation of certain activities, there is potential for two areas (with caves) in the Jollyville Plateau KFR to meet protected KFA status. In particular, more research is needed to delineate the subsurface drainage basin for caves in both of these areas. If a cave is determined to be a KFA, then information relating to recovery criterion (2) should be gathered and/or implemented to meet downlisting criteria; however, there does not appear to be enough potential KFAs per KFR to meet downlisting criteria. Until such time, we do not recommend a change in listing status for this species (USFWS 2009)

Recovery Priority Number: 2C

Recovery Actions:
- Determine the subsurface drainage basins for Jest John Cave and Spider Cave.
- Confirm and/or implement RIFA control at Jest John Cave and Spider Cave.
- Find more T. reddelli locations that could meet KFA status and protect them to meet downlisting criteria
- Considering the geographic distance between northern (Jollyville and McNeil/Round Rock KFRs) and southern (Rollingwood KFR) caves where this species occurs, the fact that they are separated by a major hydrologic divide (Colorado River), and that the northern caves occur within the range of the closely related Bone Cave harvestman (Texella reyesi), genetic analyses to confirm the presence of the Bee Creek Cave harvestman are needed.

Conservation Measures and Best Management Practices:
- RECOMMENDATIONS FOR FUTURE ACTIONS I. Obtain information for sites within the Balcones Canyonlands Preserve to include surface and subsurface drainage basins, potential development impacts, tract acreage, management, and perpetual protection mechanisms among others. Review information to determine the potential for sites to be recognized as karst fauna areas. II. Draft

quantitative delisting criteria for the Bee Creek Cave harvestman and other listed karst invertebrates in Travis and Williamson counties, Texas. III. Reassess the current karst fauna regions of Travis and Williamson counties, Texas using current data and revise regions as necessary to better inform recovery efforts. IV. Assess the relationship of Burnet County to existing or potentially new karst fauna regions. V. Assess genetic variation of Bee Creek Cave and Bone Cave harvestman populations across their range to evaluate species boundaries and relationships. VI. Conduct surveys for the Bee Creek Cave harvestman at reported surface collection sites to assess persistence and potential habitat use (USFWS, 2018).

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U.S. Fish and Wildlife Service (USFWS). 2011. Bexar County Karst Invertebrate Recovery Plan. Note: This Bexar County reference/material was used because it is more up to date than the general information contained in the 1994 Recovery Plan for Travis and Williamson Counties. and the threats are identical.

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SPECIES ACCOUNT: *Texella reyesi* (Bone Cave harvestman)

Species Taxonomic and Listing Information

Listing Status: Endangered, 1988

Physical Description

The Bone Cave Harvestman is a small, essentially eyeless "daddy long-legs" spider that spends its entire life in a subterranean environment (troglobite). It has very long, thin legs and a small body; is pale pale orange in color; does not have silk glands, so does not build webs; can swallow chunks of solid food, not just liquid; the males have a penis, unlike other arachnids; and all species lay eggs (USFWS 1993).

Taxonomy

Order Opiliones, which is not closely related to other arachnids, although often confused with spiders (order Araneae); originally listed as endangered in 1988 (USFWS 1988) as a part of the Bee Creek Cave Harvestman (Texella reddelli), which was subsequently re-classified into two species in 1993 (USFWS 1993).

Historical Range

Unknown, but likely similar to current distribution, unless cave systems have been destroyed historically (USFWS 1994).

Current Range

The Bone Cave Harvestman is known from 168 caves, spanning all 7 established Karst Fauna Regions (KFRs) in Travis and Williamson Counties, Texas; distributed along a 40 kilometer (km) distance in Travis and Williamson Counties in central Texas. (USFWS 1994)

Distinct Population Segments Defined

N/A for invertebrates

Critical Habitat Designated

Yes;

Life History

Feeding Narrative

Adult: Nutrients in most karst ecosystems are derived from the surface either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the karst invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller troglophiles and troglobites that grow on the leaves or feces rather than the original material itself. Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through karst fissures and solution features. For predatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave. The cave cricket (Ceuthophilus spp.) is a particularly important nutrient component and is found in most caves in

Texas (USFWS 2011). Troglobytes, like the Bone Cave Harvestman, typically have very slow metabolisms, an adaptation to the sparse amounts of food found in their environment. Because they are adapted to an environment with little food, pollution by the addition of large amounts of nutrients to the cave can actually be harmful to the species, because it allows invertebrates that are not cave adapted, such as cockroaches and a variety of flies to survive in the care and even out-compete the cave species (USFWS 2000).

Reproduction Narrative

Adult: Cave invertebrates are described as K-strategists -- more similar to large mammals than to their invertebrate cousins that live on the land surface. Like large mammals, they have few offspring and live relatively long lives (for invertebrates). This also means their populations are more sensitive to losing even fairly small numbers of individuals, and that it takes a long time for their population sizes to recovery from any catastrophe. Generally, female Harvestmen may lay eggs up to 6 months after mating. The gestation rate is unknown, but depending on the temperature, it may be from 20 days to 6 months after the eggs are laid. Males may guard the eggs (laid by several partners). They may have four to eight symphal instars to reach maturity, but most species have six. Most species live for 1 year. (USFWS 2000).

Geographic or Habitat Restraints or Barriers

Adult: Restricted to cave/karst environment

Spatial Arrangements of the Population

Adult: Unknown

Environmental Specificity

Adult: High

Tolerance Ranges/Thresholds

Adult: Unknown, but likely low

Site Fidelity

Adult: Unknown, but likely high due to restricted habitat

Dependency on Other Individuals or Species for Habitat

Adult: Unknown

Habitat Narrative

Adult: As a troglobite, the Bone Cave Harvestman is restricted to cave/karst habitat, and has been recorded in 168 caves (USFWS 2009). The species is especially sensitive to drying and requires very moist, humid conditions (Elliott 1991a-f and unpublished data). Most individuals are found under large rocks, but are occasionally seen walking on moist floors. In Temples of Thor Cave, individuals are typically found about 30m from the entrance in total darkness, where humidity is high; they seldom occur farther in the cave where there is less water and food. In the hottest part of the summer when many of the small caves warm up and become drier, individuals may retreat into the interstitium or may be found only in the coolest, dampest spots in the caves. This species feeds on microarthropods (USFWS 1994). They require surface vegetation to provide nutrients from: (1) direct flow of plant material into the karst with water; (2) habitat and food sources provided for the animal communities that contribute nutrients to the karst ecosystem (such as cave crickets, small mammals); and (3) roots that extend into subsurface areas and may provide a major energy sources in shallow caves. Troglobitic habitat includes caves and mesocavernous voids in karst limestone (a terrain characterized by landforms and subsurface features, such as sinkholes and caves, which are produced by solution of bedrock) in Travis and Williamson Counties. Karst areas commonly have few surface streams; most water moves through cavities underground. Within this habitat this species depends on high humidity, stable temperatures, and nutrients derived from the surface. Examples of nutrient sources include leaf litter fallen or washed in, animal droppings, and animal carcasses. (USFWS 2007).

Dispersal/Migration

Motility/Mobility

Adult: Low

Migratory vs Non-migratory vs Seasonal Movements

Adult: None

Dispersal

Adult: <100-250 sq km (< 40-100 sq mi) distributed along a 40 km distance in Travis and Williamson Counties in central Texas (USFWS 1994).

Immigration/Emigration

Adult: Unknown

Dependency on Other Individuals or Species for Dispersal

Adult: Unknown

Dispersal/Migration Narrative

Adult: The Bone Cave Harvestman is restricted to the cave/karst environment of Travis and Williamson and Counties, Texas. Very little is known about their dispersal/migration within/among the cave systems. (USFWS 2009)

Population Information and Trends

Population Trends:

Declining (USFWS, 2018).

Species Trends:

Unknown, but original threats have not been alleviated.

Resiliency:

Unknown, but likely low

Representation:

Unknown; currently known from 168 caves in Travis and Williamson Counties, Texas.

Redundancy:

Unknown

Population Growth Rate:
Unknown

Number of Populations:
Unknown

Population Size:
Unknown

Minimum Viable Population Size:
Unknown

Resistance to Disease:
Unknown, but likely low.

Adaptability:
Unknown, but likely low.

Population Narrative:
Population estimates for the Bone Cave Harvestman are unavailable because of a lack of adequate techniques, its cryptic behavior, and inaccessibility of habitat. The species is currently known from 168 caves in Travis and Williamson Counties, Texas. While some troglobites are known from a few specimens, detailed studies suggest that "as a rule" most troglobites are not numerically rare and thus are not susceptible to the problems of small populations." However, considering the lack of population estimates and limited study of these species, data are insufficient to indicate whether the Travis and Williamson Counties karst invertebrates are numerous enough to rule out small population concerns (USFWS, 2011).

Threats and Stressors

Stressor: Loss and degradation of habitat
Exposure: Edge effects
Response: Impact native communities; disrupt natural systems; introduce non-native predators (such as fire ants)
Consequence: Loses nutrients; competes for limited resources; death by predation; reduction in population numbers; decreased reproductive success
Narrative: “Edge effects” are changes to the floral and faunal communities where different habitats meet. The length and width of the edge, as well as the contrast between the vegetational communities, all contribute to the amount of impacts (Smith 1990, Harris 1984). Some types of edge effects include increases in solar radiation, changes in soil moisture due to elevated levels of evapotranspiration, wind buffeting (Ranny et al. 1981), changes in nutrient cycling and the hydrological cycle (Saunders et al. 1990), and changes in the rate of leaf litter decomposition (Didham 1998). These edge effects alter plant communities, which in turn impact the associated animal species. Edge effects can also affect animal species directly. The changes caused by edge effects can occur rapidly. Vegetation located 2 m (6.6 ft) from an edge can be visibly affected within days (Lovejoy et al. 1986). Edge effects associated with soil disturbance

and disruption to native communities that accompany urbanization (for example, waste associated with housing) may attract redimported fire ants (RIFA)(discussed in factor C) or other surface species that prey on or compete with cave species (Reddell 1993). The invasion of RIFA is aided by “any disturbance that clears a site of heavy vegetation and disrupts the native ant community” (Porter et al. 1988) such as road building and urbanization. Development and edges often allow enough disruption for invasive or exotic species to displace native communities that had previously prevented their spread (Saunders et al. 1990, Kotanen et al. 1998, Suarez et al. 1998, Meiners and Steward 1999). (USFWS 2011a).

Stressor: Loss and degradation of habitat
Exposure: Human visitation
Response: Degrades/destroys habitat; introduces predators and competitors
Consequence: Loses habitat; competes for limited resources; death by predation; crushed; reduction in population numbers; decreased reproductive success
Narrative: Human visitation can impact caves by increasing soil compaction, trash deposition, and vandalism; altering airflow as entrances are expanded and excavated; scaring away trogloxenes (Culver 1986, Elliott 2000); and may also lead to direct mortality of cave organisms crushed by human disturbance (Crawford and Senger 1988).

Stressor: Loss and degradation of habitat
Exposure: Commercialization
Response: Degrades/destroys habitat; introduces predators and competitors
Consequence: Loses habitat; competes for limited resources; death by predation; crushed; reduction in population numbers; decreased reproductive success
Narrative: Commercialization of caves affects cave communities due to (1) competition with introduced surface species; (2) harmful effects of commercial lighting, for example increased temperature and decreased humidity near lights; (3) substrate changes around trails; (4) changes in microclimate due to cave ventilation; (5) and increases in the nutrient regime that favor surface species (Culver 1986, Northup 1988, Northup et al. 1988; Reddell 1993, Krejca and Myers 2005, Mulec and Kosi 2009). Conversely, some researchers have found high diversity and/or abundance of some species in show caves that have higher nutrient and water availability (Culver and Sket 2000, Paquin 2007). However, for the reasons stated above we believe that commercialization of caves is generally a threat because (1) these activities alter the natural habitat and nutrient regime of these species and (2) because most caves in Texas have limited nutrient and water availability. (USFWS 2011a)

Stressor: Loss and degradation of habitat
Exposure: Contamination
Response: Introduced pollutions, poisons to groundwater
Consequence: Loses habitat; direct poisoning; reduction in population numbers; decreased reproductive success
Narrative: Karst landscapes are particularly susceptible to groundwater contamination because water penetrates rapidly through bedrock conduits and little or no filtration occurs (White 1988). In some areas the water that moves through the habitat of these species percolates to the Edwards Aquifer below. The Edwards Aquifer is an important source of drinking water for 1.7 million people (Edwards Aquifer Authority 2008); information on sources of water contamination of the Edwards Aquifer may also be indicative of sources of contamination of karst invertebrate habitat. The ranges of these species are becoming increasingly urbanized and thereby are

becoming more susceptible to contaminants including sewage, oil, fertilizers, pesticides, herbicides, seepage from landfills, pipeline leaks, or leaks in storage structures and retaining ponds. Activities on the surface, such as disposing of toxic chemicals or motor oil, can also contaminate caves (White 1988). Continued urbanization will increase the likelihood that karst ecosystems are polluted by contamination from the leaks and spills, which have often occurred in Bexar County (see TWC 1989, TCEQ 2010a, TCEQ 2010b for information on contamination events). Texas Commission on Environmental Quality (TCEQ) (2010a) summarizes information on groundwater contamination reported by a number of agencies, and in 2010 they reported that 1,712 leaking petroleum storage tanks were located in Bexar County.

Stressor: Loss and degradation of habitat
Exposure: Alterations of drainage patterns
Response: Degrades/destroys habitat
Consequence: Loses habitat; reduction in population numbers; decreased reproductive success
Narrative: Cave organisms are adapted to live in a narrow range of temperature, humidity, and nutrients that are washed into caves. To sustain these conditions, both natural surface and subsurface flow of water and nutrients should be maintained. Decreases in water flow or infiltration can result in excessive drying and may slow decomposition, while increases can cause flooding that drowns air-breathing species and carries away available nutrients. Alterations to surface topography, including decreasing or increasing soil depth or adding non-native fill, can change the nutrient flow into the cave and affect the cave community (Howarth 1983). Impermeable cover, collection of water in devices like storm sewers, increased erosion and sedimentation, and irrigation and sprinkler systems can affect water flow to caves and karst ecosystems. Altering the quantity or timing of water input to the karst ecosystem, or its organic content, may negatively impact the listed species. (USFWS 2011a).

Stressor: Quarrying and mining operations
Exposure: Destroys/degrades habitat
Response: Loses habitat
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Quarrying and mining operations - Quarries and mines exist in Bexar County, including the northern half, where the majority of the listed species occur. While quarrying activities have revealed some caves (which can lead to protecting these sites), they have also completely destroyed others (Elliott 2000). As caves and mesocavernous spaces are destroyed at mines and quarries, karst invertebrates, possibly including some listed species, will also be lost. (USFWS 2011a).

Stressor: Alterations of surface plant and animal communities
Exposure: Destroy/degrades habitat; introduces competition; introduces predators
Response: Loses habitat; competes for limited resources; is predated upon
Consequence: Reduction in population numbers; decreased reproductive success
Narrative: Alterations of surface plant and animal communities - Karst ecosystems are heavily reliant on surface plant and animal communities to maintain nutrient flows, reduce sedimentation, and resist exotic and invasive species. As the surface around a cave entrance becomes developed, native plant communities are often replaced with impermeable cover or exotic plants from nurseries. The abundance and diversity of native animals may decline due to decreased food and habitat combined with increased competition and predation from urban, exotic, and pet species. The leaf litter and wood that make up most of the detritus may also be

reduced or altered, resulting in a reduction of nutrient and energy flow into the cave. (USFWS 2011a).

Stressor: Predation
Exposure:
Response:
Consequence:
Narrative: Since the 2009 5-year review, a new non-native invasive ant species has established colonies at sites in Travis County. The tawny crazy ant (Nylanderia fulva), native to South America, was documented in Texas in 2002 and has established populations along the state's Gulf Coast and some central Texas counties (Wang et al. 2016, p. 4). This ant has exhibited a potential to affect native animal and plant communities (LeBrun et al. 2013, p. 2439; Wang et al. 2016, p. 5). Tawny crazy ant colonies are often polygynous and can form dense infestations that dominate the local ant community (LeBrun et al. 2013, p. 2433). Arthropod species richness and abundance may decline in areas infested by tawny crazy ants (LeBrun et al. 2013, pp. 2434-2435; Wang et al. 2016, pp. 5, 7). Tawny crazy ants also appear capable of eliminating red-imported fire ants from areas where the species co-occur (LeBrun et al. 2013, pp. 2436-2437). Unlike redimported fire ants that generally prefer open-habitat types, the tawny crazy ant can reach high densities in forested habitats along with grasslands and other open-habitat types (LeBrun et al. 2013, pp. 2439-2440). Sites with dense canopies, therefore, would be afforded some decreased susceptibility to redimported fire ants but not the tawny crazy ant. Tawny crazy ants have established populations at Whirlpool and No Rent Caves in Travis County (LeBrun 2017, p. 3), the latter cave occupied by the Bone Cave harvestman. LeBrun (2017, entire) assessed the effects of tawny crazy ants at these caves. Based on observations at these two sites, use of caves by ants was tied to surface temperatures and moisture with tawny crazy ants most prevalent in caves during hot, dry summer conditions (LeBrun 2017, p. 35). Tawny crazy ants preyed on cave crickets and other karst invertebrates with one species, the spider Cicurina varians, experiencing decreased abundance associated with that ant's presence (LeBrun 2017, pp. 21-22, 35-36). No declines were noted for other karst invertebrates examined, though sample size was small (LeBrun 2017, pp. 22, 35). Additional research is needed to determine the potential for the tawny crazy ant to affect Bone Cave harvestman populations (USFWS, 2018).

Recovery

Reclassification Criteria:
The Bone Cave harvestman will be considered for reclassification from endangered to threatened when:

(1) Three karst fauna areas (if at least three exist) within each karst fauna region in each species' range are protected in perpetuity. If fewer than three karst fauna areas exist within a given karst fauna region, then all karst fauna areas within that region should be protected. If the entire range of a given species contains less than three karst fauna areas, then they should all be protected for that species to be considered for downlisting (USFWS, 2018).

(2) Criterion (1) has been maintained for at least five consecutive years with assurances that these areas will remain protected in perpetuity (USFWS, 2018).

Delisting Criteria:

Three KFAs within each KFR should be protected. Protection is defined as an area sufficiently large to maintain the integrity of the karst ecosystem on which the species depends. These areas must also provide protection from threats such as RIFA, habitat destruction, and contaminants;

Perpetual protection of these areas is required to be in place for at least 5 consecutive years of a cave meeting KFA status. (USFWS 1994; USFWS 2009).

Recovery Actions:

- ? Within the Jollyville Plateau KFR, fulfillment of the following actions will meet qualifications for the creation of KFAs on City of Austin lands included in the CP:
- ? Delineate the subsurface drainage basin for Stovepipe Cave, Beard Ranch Cave, and McDonald Cave located in Cuevas (Tomen Park) tract;
- ? Verify footprint and subsurface drainage of Beard Ranch Cave.
- ? Determine the footprint, surface and subsurface drainage basins, and establish RIFA control, management of trespass, and monitoring of the Bone Cave Harvestman for Barker Ranch Cave No. 1, located in South Travis County KFR, owned by the City of Austin.
- ?To progress toward KFA status, work with landowners or organizations to confirm locations and tract acreage, determine footprints, and/or delineate surface and subsurface drainage basins for the following privately-owned caves:
- ? In North Williamson County KFR: Karankawa and Polaris; Shaman and Pow Wow; Red Crevice, Temples of Thor, and Thor; Jensen; Lobo's Lair; Wolf's Rattlesnake;
- ? In Georgetown KFR: Round Rock Breathing; Steam and Fence-line Sink;
- ? In McNeil/Round Rock KFR: Blessed Virgin; Weldon; Rockfall; Raccoon Lounge; Wyoming Springs Corridor; Chaos Cave Preserve;
- ? In Jollyville Plateau KFR: Four Points complex – MWA, Eluvial, Jollyville Plateau caves; Cuevas cave complex – Tooth, McDonald.
- ? Confirm and/or implement RIFA control and other management activities with the cooperation of landowners at the following privately-owned caves to progress toward attaining KFA status:
- ? In North Williamson County KFR: Karankawa and Polaris; Shaman and Pow Wow; Jensen; Lobo's Lair and Wolf's Rattlesnake;
- ? In Georgetown KFR: Round Rock Breathing; Steam and Fence-line Sink;
- ? In McNeil/Round Rock KFR: Blessed Virgin; Weldon; Rockfall; Raccoon Lounge; Wyoming Springs Corridor.
- ?Apply recovery criterion #2 to any caves that meet KFA status.
- ? Draft delisting criteria and revaluate the status of the species in accordance with those criteria.
- ? Considering the geographic distance between northern (North Williamson, Georgetown, McNeil/Round Rock, Cedar Park, Jollyville Plateau, Central Austin KFRs) and southern (South Travis KFR) cave where this species occurs, the fact that they are separated by a major hydrologic divide (Colorado River), and that some northern caves overlap with the range of the closely related Bee Creek Cave harvestman (Texella reddelli), genetic analyses to confirm the presence of the Bone Cave Harvestman are needed.

Conservation Measures and Best Management Practices:

- I. Following submission, review needed information to recognize Millennium, Shaman, and Wilco Karst Preserves as karst fauna areas (USFWS, 2018). II. Obtain information for nine sites within the Balcones Canyonlands Preserve (Jollyville Plateau Karst Fauna Region) to include surface and subsurface drainage basins, potential development impacts, tract acreage, management, and perpetual protection mechanisms among others. Review information to determine the potential for sites to be recognized as karst fauna areas (USFWS, 2018). III. Increase efforts to establish karst fauna areas or other protected sites for the Bone Cave harvestman in the Georgetown and McNeil/Round Rock Karst Fauna Regions. Protected areas in the latter region are especially needed to secure representation of the species across its range (USFWS, 2018). IV. Draft quantitative delisting criteria for the Bone Cave harvestman and other listed karst invertebrates in Travis and Williamson counties, Texas (USFWS, 2018). V. Apply recovery criterion 2 to karst fauna areas that qualify (USFWS, 2018). VI. Reassess the current karst fauna regions of Travis and Williamson counties, Texas using current data and revise regions as necessary to better inform recovery efforts (USFWS, 2018). VII. Assess genetic variation of Bone Cave harvestman populations across their range and evaluate in light of north to south morphological variation (USFWS, 2018).

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