Bee Creek Cave Harvestman
(*Texella reddelli*)

5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Austin Ecological Services Field Office
Austin, Texas

5-YEAR REVIEW
Bee Creek Cave Harvestman (*Texella reddelli*)

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office: Southwest Regional Office, Region 2
Jennifer Smith-Castro, Recovery Biologist, 281-286-8282 ext. 234

Lead Field Office: Austin Ecological Services Field Office
Michael Warriner, Supervisor, Listing and Recovery Branch 512-490-0057 ext. 236
Jenny Wilson, Listing and Recovery Biologist, 512-490-0057 ext. 231

1.2 Methodology used to complete the review:

The U.S. Fish and Wildlife Service (Service) conducts status reviews of species on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.12) as required by section 4(c)(2)(A) of the Endangered Species Act (16 U.S.C. 1531 et seq.). The Service provides notice of status reviews via the Federal Register and requests information on the status of the species. Data for this status review were solicited from interested parties through a Federal Register notice announcing this review on May 31, 2018 (83 FR 25034-25038). This review was conducted by the Austin Ecological Field Services Office using methodology developed for a species status assessment completed for the Bone Cave harvestman (Service 2018, pp. 31-32). We considered both new and previously existing information from federal and state agencies, municipal and county governments, non-governmental organizations, academia, and the general public. Recovery criteria and guidelines from the Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas (Service 1994, pp. 48-58, 86-88), Bexar County Karst Invertebrates Recovery Plan (Service 2011, pp. 19-22), Karst Preserve Design Recommendations (Service 2012, entire), and Karst Preserve Management and Monitoring Recommendations (Service 2014, entire) also informed this 5-year review.

1.3 Background:

The Bee Creek Cave harvestman (Opiliones: Laniatores: Phalangodidae: *Texella reddelli* Goodnight and Goodnight 1967) is one of 28 species within the North American genus *Texella* (Ubick and Briggs 1992, entire; Ubick and Briggs 2004, entire). Until 1967, the genus contained a single species, *T. mulaiki* (Goodnight and Goodnight 1967, pp. 6-7) endemic to Hays, Travis, and Williamson counties, Texas. Goodnight and Goodnight (1967, pp. 7-8) described the Bee Creek Cave harvestman from specimens collected from Travis and Williamson counties.

Ubick and Briggs (1992, entire) revised the genus *Texella* resulting in the re-description of the Bee Creek Cave harvestman and *T. mulaiki* as well as descriptions of 18 new species from California, New Mexico, Oregon, and Texas. Williamson County was removed from the Bee Creek Cave harvestman's range as specimens collected from that county, along with some sites in Travis County, were determined to represent a new species, *T. reyesi*, the Bone Cave harvestman (Ubick and Briggs 1992, pp. 209, 211). Ubick and Briggs (2004, pp. 107-108) expanded the Bee Creek Cave harvestman's range into southeastern Burnet County along with additional records for Travis County.

The Bee Creek Cave harvestman is endemic to a restricted range in the Balcones Canyonlands ecoregion of Texas, specifically portions of Burnet and Travis counties (Figures 1 and 2; Ubick and Briggs 2004, pp. 107-108, 113). The Balcones Canyonlands form the eastern to southeastern boundary of the Edwards Plateau, where the activity of rivers, springs, and streams has resulted in the formation of an extensive karst landscape of canyons, caves, and sinkholes (Griffith et al. 2007, p. 49). The term "karst" refers to a type of terrain that is formed by the slow dissolution of calcium carbonate from surface and subsurface limestone, and other soluble rock types (e.g., carbonites and evaporates), by mildly acidic groundwater (Holsinger 1988, p. 148; Culver and Pipan 2009b, pp. 5-15; Stafford et al. 2014, pp. 4-5). Flow of groundwater through conduits leads to the formation of an interconnected system of subterranean voids that become larger as bedrock is dissolved (Culver and Pipan 2009b, pp. 5-8; Stafford et al. 2014, pp. 8-18).

Eighteen of the 23 *Texella* species in Texas have some association with caves and exhibit varying degrees of troglomorphy, or adaptations to subterranean environments (Ubick and Briggs 1992, pp. 165, 167-170; Ubick and Briggs 2004, pp. 114, 116). Traits possessed by troglomorphic *Texella* species include increased length of legs, increased number of tarsomeres, loss or reduction of eyes, reduction of exoskeletal protuberances, and reduced pigmentation (Goodnight and Goodnight 1960, pp. 35-36; Ubick and Briggs 1992, pp. 165-168). Ubick and Briggs (1992, pp. 155-156, 165, 167-169, 208) considered the Bee Creek Cave harvestman to be slightly troglomorphic with well-developed eyes (i.e., retina and cornea) and relatively shorter legs, among other characters.

Research indicates that cave-dwelling arthropods often display preferences for higher relative humidity and/or relatively narrow temperature regimes underscoring a dependence on subterranean conditions (Bull and Mitchell 1972, pp. 375, 386; Howarth 1980, pp. 397-399; Howarth 1987, pp. 5-7; Weinstein 1994, pp. 369-370; Doran et al. 1999, pp. 258-259; Lavoie et al. 2007, p. 121; Yoder et al. 2011, p. 15; Mammola and Isaia 2014, p. 350; Mammola et al. 2015, pp. 246-247). Humidity, in particular, is an important influencer of harvestman spatial ecology (Edgar 1971, pp. 47-49; Martín and Oromí 1986, p. 384; Hillyard and Sankey 1989, pp. 26-27; Almeida-Neto et al. 2006, pp. 370-371; Bragagnolo et al. 2007, p. 397; Machado et al. 2007, p. 8; Stašiov 2008 p. 162; Chelini et al. 2011, pp. 396-397; Schönhofer et al. 2015, p. 49). These arachnids are considered very susceptible to desiccation and exhibit preferences for habitats that offer higher humidity (Curtis and Machado 2007, pp. 285-286; Machado and Macías-Ordóñez 2007, p. 409; Willemart et al. 2009, p. 219).

Bee Creek Cave harvestmen likely require subterranean habitats with high humidity and relatively stable temperatures (Curtis and Machado 2007, pp. 285-286; Machado and Macías-Ordóñez 2007, p. 409; Willemart et al. 2009, p. 219). Intact networks of subterranean voids provide living space and a buffer or refugia from the effects of humidity and temperature extremes (Howarth 1980, pp. 397-398; Howarth 1983, p. 373; Martín and Oromí 1986, p. 384; Holsinger 1988, p. 147; de Freitas and Littlejohn 1987, pp. 559-560; Crouau-Roy et al. 1992, pp. 13-15; Tobin et al. 2013, p. 206; Mammola et al. 2015, pp. 243, 246; Mammola and Isaia 2016, pp. 26-27). Functional surface and subsurface drainage basins supply water that aids in the maintenance of high relative humidity (Hauwert 2009, p. 84; Veni 2003, p. 7).

The Bee Creek Cave harvestman also requires a source of food in the form of invertebrates or other organic matter (Acosta and Machado 2007, pp. 310-320). The majority of nutrients that support subterranean ecosystems originate from surface habitats, specifically the natural communities that overlay these systems (Barr 1968, pp. 47-48; Poulson and White 1969, pp. 971-972; Howarth 1983, p. 376; Culver and Pipan 2009b, p. 23). Availability of surface nutrients is an important factor in the maintenance of species richness in caves with greater amounts of nutrients supporting higher species richness (Jaffé et al. 2016, pp. 6, 9, 11; Jiménez-Valverde 2017, pp. 10210-10212).

Nutrients may take the form of animal or plant material washed in by water, blown by wind, or transported by animals (Barr 1968, pp. 51, 53; Howarth 1983, pp. 376-377; Holsinger 1988, p. 147; Jasinska et al. 1996, p. 518; Culver and Pipan 2009b, pp. 24, 27-39). Deposited organic matter provides a resource base for bacteria, fungi, and invertebrates that serve as prey for other invertebrates as well as vertebrates in caves (Barr 1968, pp. 53-60; Kane and Poulson 1976, pp. 799-800; Longley 1981, pp. 126-127; Howarth 1983, pp. 378-379; Ferreira et al. 2000, pp. 108-109).

Cave crickets are contributors of nutrients in some subterranean ecosystems, including those of the Edwards Plateau (Barr 1968, pp. 51, 53; Peck 1976, p. 315; Veni et al. 1999, pp. 45-46; Sharrat et al. 2000, p. 123; Reddell and Cokendolpher 2001, pp. 132-133; Taylor et al. 2004, pp. 9, 28, 31; Lavoie et al. 2007, p. 131; Peck and Wynne 2013, p. 314). Cave crickets roost in caves during the day, leaving at night to forage on animal and/or plant matter in the surrounding plant communities (Taylor et al. 2004, pp. 37-38; Taylor et al. 2005, p. 105). Nutrients obtained during foraging are transferred into the cave through defecation (i.e., guano), laying of eggs, predation of living crickets, and carcasses of dead crickets (Barr 1968, p. 53; Mitchell 1971, p. 259; Elliott 1994, p. 16; Poulson et al. 1995, pp. 226, 229; Taylor et al. 2003, p. 47; Lavoie et al 2007, p. 131). Natural foraging habitat surrounding a cave is vital to the maintenance of cave cricket populations (Taylor et al. 2007, pp. 2, 37, 43). Declines in cave cricket populations can potentially lead to decreased abundances for other karst invertebrates (Taylor et al 2007, pp. 2, 37, 41-44).

The Bee Creek Cave Harvestman was listed as endangered on September 16, 1988, due to its restricted distribution and threats from urban development (53 FR 36029-36033). The stressors that most influence Bee Creek Cave harvestman viability are habitat destruction, degradation, and fragmentation that results from urban development. The species' range in Travis County has experienced substantial human population growth and development (Theobald 2005, pp. 15, 22; Berube et al. 2006, p. 12; Neumann and Bright 2008, pp. 8-11, 13; Torrens 2008, pp. 8-9, 16, 33; Frey 2012, pp. 4, 14; Potter and Hoque 2014, pp. 2, 5; Urban Land Institute 2016, p. 9).

In Travis County, the human population increased between 1980 and 2017, from 419,573 people to 1,226,698 people (U.S. Census Bureau 1982, p. 10; U.S. Census Bureau 2018b). Expansion of urban, suburban, and exurban developments has led to loss and fragmentation of natural habitat in this county. Numbers of single and multi-family housing units in Travis County increased by 394% over a 46-year period, from 100,882 units in 1970 to 499,062 units in 2016 (U.S. Census Bureau 2012, p. 9; U.S. Census Bureau 2018a). Burnet County is less populated than Travis County and has not experienced the same magnitude of human population (17,803 people in 1980 to 46,804 people in 2017) and housing growth (5,945 units in 1970 to 22,031 units in 2016) (U.S. Census Bureau 1982, p. 8; U.S. Census Bureau 2012, p. 6; U.S. Census Bureau 2018c; U.S. Census Bureau 2018d).

Figure 1. Distribution of the Bee Creek Cave harvestman in Travis County, Texas.

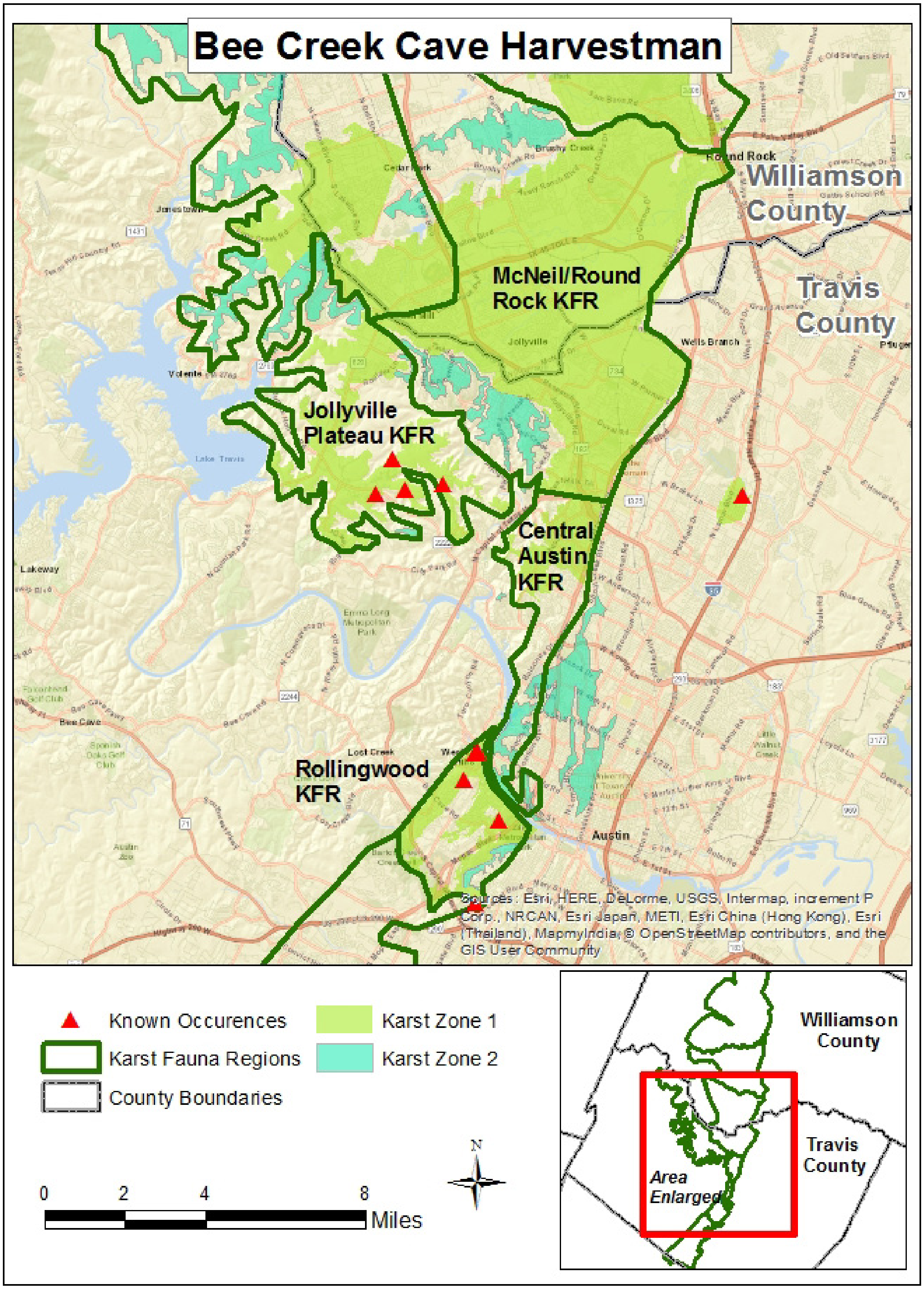
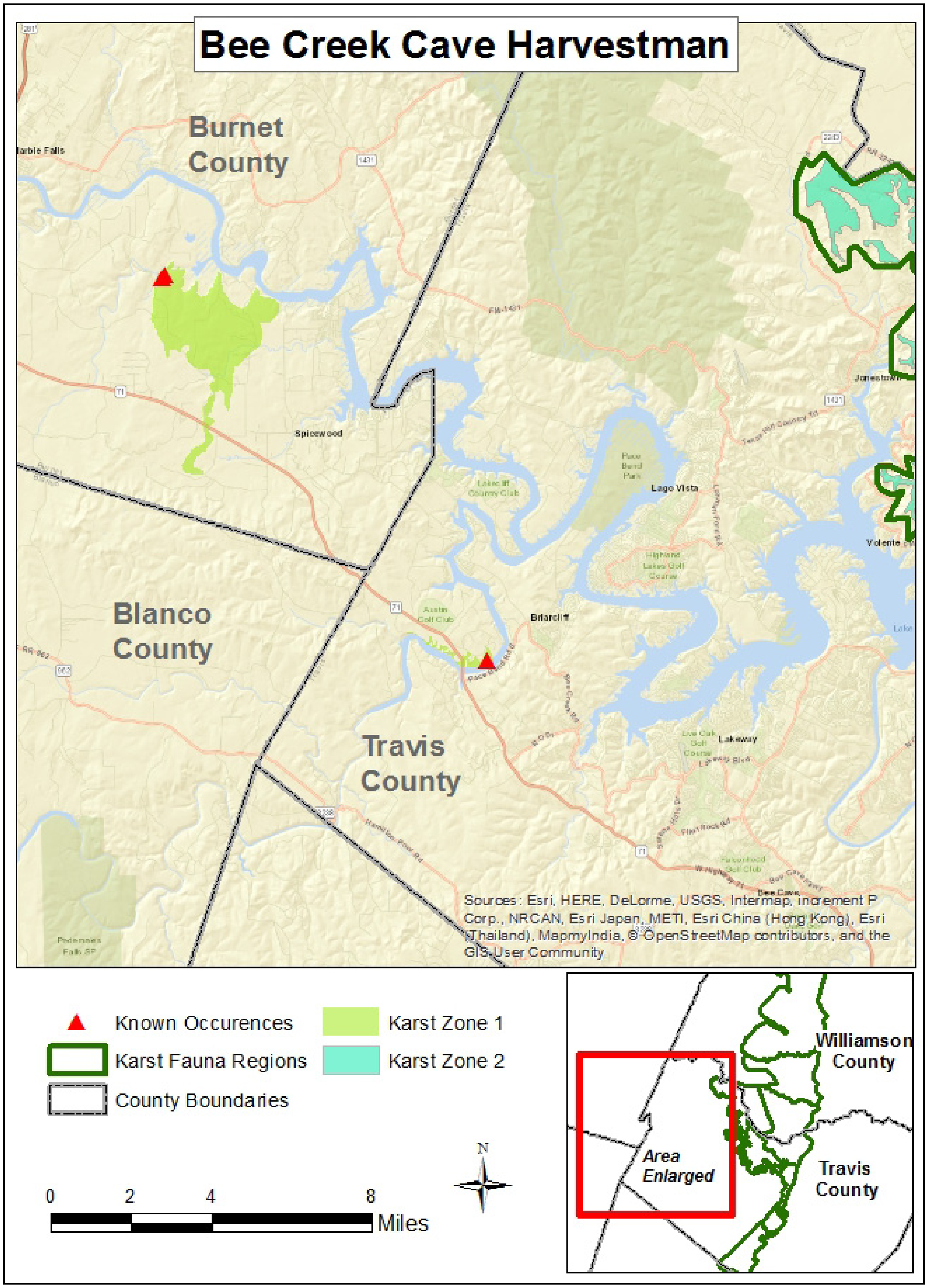


Figure 2. Distribution of the Bee Creek Cave harvestman in Burnet and Travis counties, Texas.



1.3.1 FR Notice citation announcing initiation of this review:

83 FR 25034, May 31, 2018

1.3.2 Listing history

Original Listing
FR notice: 53 FR 36029
Date listed: September 16, 1988
Entity listed: Bee Creek Cave harvestman (*Texella reddelli*)
Classification: Endangered

1.3.3 Associated rulemakings:

Not applicable.

1.3.4 Review history:

Status reviews for the Bee Creek Cave harvestman were conducted in 1988 for the final listing of the species (53 FR 36029), 1994 for the Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas (Service 1994, entire), and 2009 for a 5-year review (Service 2009, entire).

1.3.5 Species' Recovery Priority Number at start of 5-year review:

2C

1.3.6 Recovery Plan or Outline

Name of plan or outline: Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas
Date issued: 1994

2.0 REVIEW ANALYSIS

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

2.1.1 Is the species under review a vertebrate?

No, this species is an invertebrate, so the DPS policy does not apply.

2.2 Recovery Criteria

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

Yes. The recovery plan identifies downlisting criteria; however, no delisting criteria were identified in the recovery plan.

2.2.2 Adequacy of recovery criteria.

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

No. After the recovery plan was completed, additional work on other karst invertebrates lead to the development of delisting criteria which may be applicable to this species as well.

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

Yes.

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

The Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas (Service 1994, pp. 86-88) only provides criteria for downlisting from endangered to threatened. The Bee Creek 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.
>
> (2) Criterion (1) has been maintained for at least five consecutive years with assurances that these areas will remain protected in perpetuity.

Karst geologic areas were established for Travis and Williamson counties by Veni and Associates (1992, p. 52) and incorporated as karst fauna regions into the Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas (Service 1994, pp. 28-34). Geologic continuity, hydrology, and the distribution of rare karst invertebrates informed delineation of these regions (Service 1994, p. 76). The Bee Creek Cave harvestman occurs primarily within two of the eight karst fauna regions demarcated for Travis and Williamson counties (Figure 1). Regions occupied by the harvestman are the Jollyville Plateau and Rollingwood Karst Fauna Regions (Service 1994, p. 33).

Five occurrences of the Bee Creek Cave harvestman fall outside of established karst faunal regions boundaries. There are three localities with records for the species in southeastern Burnet County and two in Travis County (Ubick and Briggs, 2004, pp. 107-108). Although Veni (1992, pp. 2-3, 17, 19, 29-31, 42) defined an isolated karst fauna region, the Post Oak Ridge, in eastern Burnet and western Travis counties, this area does not correspond with occurrences of the Bee Creek Cave harvestman. Southeastern Burnet and western Travis counties merit attention regarding their relationship to existing or potentially new karst fauna regions.

A karst fauna area is a geographic area known to support one or more locations of an endangered karst invertebrate species (Service 1994, p. 87). A karst fauna area is distinct in that it acts as a system separated from other karst fauna areas by geologic and hydrologic features and/or processes or distances that create barriers to movement of water, contaminants, and troglobitic invertebrate fauna. Karst fauna areas should be far enough apart that a catastrophic event (e.g., contaminants from a spill, pipeline leak, or flooding, etc.) that may kill karst invertebrates or destroy habitat in one karst fauna area would be unlikely to affect karst invertebrates or habitat in other karst fauna areas. Within each karst fauna region, an established karst preserve may be considered a karst fauna area if it meets preserve design criteria.

Brief summary of preserve design principles:

Much of the conservation and recovery of the Bee Creek Cave harvestman depends upon the long-term protection of surface and subsurface habitat. The study of troglobitic invertebrates is complicated by their cryptic nature, low observed abundances, and difficulty in accessing and adequately surveying subterranean habitats (Veni et al. 1999, p. 28; Sharratt et al. 2000, pp. 119-121; Culver et al. 2004, p. 1223; Schneider and Culver 2004, pp. 42-43; Krejca and Weckerly 2007, pp. 8-10; Mosely 2009, pp. 50-51; Paquin and Dupérré 2009, pp. 6, 64; Schneider 2009, pp. 125-128; Wakefield and Zigler 2012, p. 25; Wynne 2013, p. 53; De Ázara and Ferreira 2014, p. 272; Pape and O'Connor 2014, p. 785; Stoev et al. 2015, p. 108; Souza and Ferreira 2016, p. 257; Trajano et al. 2016, p. 1822; Bichuette et al. 2017, pp. 82-83; Jiménez-Valverde et al. 2017, p. 10213; Sendra et al. 2017a, p. 101; Sendra et al. 2017b, p. 49; Nae et al. 2018, p. 22). Therefore, conservation strategies for the Bee Creek Cave harvestman focus on the delineation, protection, and management of occupied karst fauna areas.

The Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas provides guidelines on habitat conditions that are important to karst invertebrates, including maintaining stable humidity and temperatures, nutrient input from surface plant communities, preventing surface and subsurface contamination, controlling the invasion of non-native species (i.e., red-imported fire ants), and allowing for potential nutrient and karst invertebrate movement through subterranean interstitial spaces (Service 1994, pp. 48-58). Scientific information and additional karst preserve guidelines are further detailed in the Bexar County Karst Invertebrates Recovery Plan (Service 2011, pp. 19-22), Karst Preserve Design Recommendations (Service 2012, entire), and the Karst Preserve Management and Monitoring Recommendations (Service 2014, entire).

According to the Karst Preserve Design Recommendations, karst fauna areas should meet the following objectives (Service 2012, p. 1):

- Provide adequate quality and quantity of moisture to karst ecosystems
- Maintain stable in-cave temperature
- Reduce or remove red-imported fire ant predation/competition
- Provide adequate nutrient input to karst ecosystems
- Protect mesocaverns to support karst invertebrate population needs, including adequate gene flow and population dynamics
- Ensure resiliency of karst invertebrate populations by establishing preserves large enough to withstand random or catastrophic events
- Provide a high probability of viable karst invertebrate population persistence in each preserve
- Minimize the amount of active management needed for each preserve

For a karst fauna area to count toward meeting recovery criteria that area must be of a certain quality (i.e., high or medium). A legally binding mechanism must also assure management and perpetual protection of the area. The quality of a preserve is an indicator of how likely species are to survive for the long-term. Details regarding preserve quality are as follows (Service 2012, p. 3):

I. High Quality Preserve:

High quality preserves have a higher probability of long-term survival of karst invertebrates. A high quality preserve is at least 40 hectares (ha) (100 acres [ac]) and includes the following components:

- The entire surface and subsurface drainage basin of caves and karst features
- The native surface plant and animal communities
- The cave or karst feature footprint, which should be over 105 meters (m) [345 feet (ft)] from the preserve edge

II. Medium Quality Preserve:

A medium quality preserve is 16 to 40 ha (40 to 99 ac) and includes the following components:

- The entire surface and subsurface drainage basin of caves and karst features
- The native surface plant and animal communities
- The cave or karst feature footprint, which should be over 105 m (345 ft) from the preserve edge

III. Low Quality Preserve:

A low quality preserve is less than 16 ha (40 ac). Low quality preserves should only be established in areas where conditions for high or medium quality preserves do not exist. While these preserves will not contribute to meeting the recovery criteria set forth for endangered karst invertebrate species, they help increase their probability of overall survival beyond what it would be without them; so they do have some value.

Analysis regarding whether downlisting criteria have been met:

At the time of the Bee Creek Cave harvestman's 2009 5-year review, no karst fauna areas had been established for the species (Service 2009, p. 5). The 5-year review identified two sites (i.e., Jest John and Spider Caves) in the Jollyville Plateau Karst Fauna Region that had the potential to meet the definition of karst fauna area (Service 2009, pp. 5-12). However, insufficient information was available regarding surface and subsurface drainage basin delineations, confirmation of Bee Creek Cave harvestman presence, tract acreage, management and perpetual protection mechanisms to determine if those sites met qualifying criteria.

As of 2018, no karst fauna areas have been established for the Bee Creek Cave harvestman (Table 1). Eight caves with records for the species receive some level of protection within the Balcones Canyonlands Preserve (Balcones Canyonlands Preserve 2014, pp. 7-10). Ownership of these tracts varies from City of Austin, Travis County, to private holdings (Table 2). An additional cave, not within the Balcones Canyonlands Preserve, is owned by the City of Austin. Of those tracts subject to some level of protection, four sites (i.e., Bee Creek and Little Bee Creek Cave Cluster, Merkin Hole, Spider and RI-1 Caves) have potential as karst fauna areas based on current quality or resiliency. One site on private land in Burnet County also has potential as a karst fauna area based on resiliency. To receive that recognition, we would need additional information to determine if these sites meet qualifying criteria including surface and subsurface drainage basin delineations, cave location(s), confirmation of Bee Creek Cave harvestman presence, tract acreage, management and perpetual protection mechanisms, among others. Recovery criteria have not been achieved in the two karst fauna regions occupied by the species.

Table 1. Potential, proposed, and protected karst fauna areas by karst fauna region.

Karst Fauna Region	Potential Karst Fauna Area(s)	Proposed Karst Fauna Area(s)	Protected Karst Fauna Area(s)
Jollyville Plateau	3	0	0
Rollingwood	1	0	0
Undefined	1	0	0

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history:

Prior to 2004, the Bee Creek Cave harvestman was known only from larger subterranean voids (i.e., caves or macrocaverns), with the species collected from two caves in Burnet County and six caves in Travis County (Ubick and Briggs 1992, p. 209; Ubick and Briggs 2004, pp. 107-108). Ubick and Briggs (2004, pp. 107-108) identified *Texella* specimens collected from surface, or epigean, localities in Burnet (i.e., two sites) and Travis (i.e., one site) counties as the Bee Creek Cave harvestman (Ubick and Briggs 2004, pp. 107-108). Individuals from cave and surface sites were generally similar in morphology, but did differ in a character considered a sensitive indicator of troglomorphy, ratio of leg II/scute length (Ubick and Briggs 2004, p. 107). Troglomorphic *Texella* species display higher leg II/scute lengths compared to the lower values of surface species (Ubick and Briggs 1992, pp. 165, 167, 169). Bee Creek Cave harvestman from surface sites exhibited shorter leg II/scute lengths, 3.10-3.11 millimeters (mm) [0.12 inches (in)], than individuals from caves, 3.8-5.2 mm (0.15-0.20 inches [in]) (Ubick and Briggs, 2004, p. 107).

Detailed descriptions of habitat conditions at surface collection sites in Burnet and Travis counties are unavailable. Ubick and Briggs (2004, p. 107) only note that one Bee Creek Cave harvestman was taken from "talus" in Burnet County. Surface sites in Burnet County are in close proximity to MVN Cave, 6.4-9.7 kilometers (km)[4-6 miles (mi)] northwest of Spicewood, Texas; a subterranean site occupied by the Bee Creek Cave harvestman (Ubick and Briggs 2004, p. 107). MVN Cave also contains the troglobitic spider, *Eidmannella rostrata* (Cokendolpher and Reddell 2001, p. 31).

Talus, and other natural accumulations of rocky debris, can represent subterranean ecosystems potentially connected to larger, deeper subterranean voids (Negrea and Boitan 2001, p. 389; Mammola et al. 2016, pp. 5-7). Culver and Pipan (2009, pp. 5-11) grouped a number of near surface, aphotic (i.e., absence of light) subterranean habitats into what they term superficial subterranean habitats. Superficial subterranean habitats include epikarst (i.e, air- or water-filled voids in the upper portions of karst rock), lava fissures and tubes, the milieu souterrain superficiel (i.e., mesovoid shallow substratum), along with talus and scree (Culver and Pipan 2009a, pp. 7-9; Culver 2016, pp. 104-105).

Superficial subterranean habitats share many characteristics in common with deep subterranean systems such as absence of light, higher humidity and more stable temperatures than surface habitats, surface input of nutrients, and the presence of troglomorphic invertebrates (Crouau-Roy et al. 1992, pp. 13-16; Culver and Pipan 2009a, p. 11; Deltshev et al. 2011, p. 43; Pipan et al. 2011, pp. 268-270; Růžička et al. 2013, pp. 135-136; Jiménez-Valverde et al. 2015, pp. 717, 720; Espinasa et al. 2016, p. 238; Dorobat and Dobrescu 2017, p. 191; Mammola et al. 2017, pp. 13-14, 36; Tuf et al. 2017, p. 377). Mammola et al. (2016, entire) reviewed the ecology of mesovoid shallow substratum. Those researchers define mesovoid shallow substratum (Mammola et al. 2016, p. 5) as:

> " In general terms, an MSS [Mesovoid shallow substratum] consists of a system of empty air-filled voids within rocky fragments (Juberthie et al. 1980a, b, 1981a, Uéno 1987), usually regarded as suitable for the survival of troglobionts organisms (Uéno 1987; Giachino and Vailati 2010). Accumulations of rocky fragments may have different structures. The most common one is a sandwich-like structure, in which the MSS lies between the edaphic area (soil and rhizosphere) and the deep hypogean domain (Milieu Souterrain Profond or MSP according to Juberthie 1983; Ortuño and Gilgado 2010), represented by caves and the system of deep fissures."

In this sense, accumulations of rocky debris lie between the soil and deep subterranean voids, comprising an extension of the latter to the surface (Negrea and Boitan 2001, p. 389; Culver and Pipan 2009a, pp. 8-9, Mammola et al. 2016, pp. 11-13). Soil may not necessarily overlay mesovoid shallow substratum, but can be exposed to the surface as with boulder fields, scree, and talus (Mammola et al. 2016, pp. 9-10). Intersection with underlying networks of fissures facilitates dispersal and occupation by invertebrates with varying levels of troglomorphy (i.e., troglobites, troglophiles, to trogloxenes) as well as surface species (Mammola et al. 2016, pp. 6, 9, 22). In central Texas, Espinasa et al. (2016, p. 238) suggested that identical mitochondrial DNA haplotypes among cave populations of *Texoredellia* species (i.e., springtails), was attributable to dispersal through fissures and smaller cavities in epikarst.

Since meosvoid shallow substratum are near the surface, nutrient availability and input may be higher in these systems than deeper subterranean voids (Mammola et al. 2016, pp. 13-14). Jiménez-Valverde et al. (2015, pp. 717, 720) surveyed a rocky debris field in Spain and found that mites (i.e., Acari) and springtails (i.e., Collembola) dominated samples and were likely the primary source of nutrients for predators, including a troglomorphic harvestman species. Greater nutrient availability in the mesovoid shallow substratum may comprise higher quality foraging habitat for some subterranean predators. Růžička et al. (2013, pp. 136-137) captured several spider species in both cave and scree sites in the Czech Republic, suggesting that connections exist between those subterranean habitats.

Other *Texella* species (i.e., *T. dimopercula* and *T. reyesi*) have been taken or observed from habitats described as talus (Ubick and Briggs 1992, p. 211; Ubick and Briggs 2004, p. 111). Another slightly troglomorphic *Texella* species known from caves in Hays and Travis counties, *T. grubbsi*, has been collected from three surface localities in Burnet County (Ubick and Briggs 2004, p. 110). Those *T. grubbsi* collections are in the same area of southeastern Burnet County as surface occurrences of the Bee Creek Cave harvestman. The potential use of mesovoid shallow substratum, and other superficial subterranean habitats, by *Texella* species has not been well-defined and merits further examination. Use of these habitats by terrestrial invertebrates in Texas has largely gone unstudied. Surface collections of the Bee Creek Cave harvestman in Burnet and Travis counties should be revisited to determine if the species persists at those sites and, if so, what specific habitats are utilized by the species.

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

No new information.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Some occurrences of the Bee Creek Cave harvestman in the Jollyville Plateau Karst Fauna Region are located in close proximity to caves occupied by the Bone Cave harvestman. Genetics analyses are needed to clarify species distributions in this area.

2.3.1.4 Taxonomic classification or changes in nomenclature:

No new information.

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

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. 65-67).

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).

Table 2. Bee Creek Cave harvestman cave clusters and individual caves.

Karst Fauna Region	County	Ownership
Jollyville Plateau		
Individual Cave(s)		
Jester Estates Cave	Travis	City of Austin
Merkin Hole	Travis	City of Austin
RI-1 Cave	Travis	Travis County
Spider Cave	Travis	City of Austin
Rollingwood		
Cave Cluster(s)		
Bee Creek and Little Bee Creek Cave Cluster	Travis	City of Austin/Private
Individual Cave(s)		
Bandit Cave	Travis	Private
Little Black Hole	Travis	City of Austin
Outside Regions		
Cave Cluster(s)		
MVN and Waldman Cave Cluster	Burnet	Private
Individual Cave(s)		
Stark's Mine North	Travis	City of Austin
Surface Occurrences		
County Road 404, 8 km (5 mi) NW Spicewood	Burnet	Unknown
County Road 404 10 km (6 mi) NW Spicewood	Burnet	Unknown
Pedernales River and State Highway 71	Travis	Unknown

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

The population needs of the Bee Creek Cave harvestman are the factors that provide for a high probability of population persistence over the long-term at an occupied location (e.g., low degree of threats and high survival and reproduction rates). Since population estimates for the Bee Creek Cave harvestman are unavailable, nor do we know what reproductive rates sustain a healthy population, we applied measures of surface habitat elements (i.e., area of naturally vegetated open space, distance of cave entrance to nearest edge, and status of cave cricket foraging area) surrounding a cave as surrogates to assess population resiliency. For a full discussion of this methodology, see Service (2018, pp. 31-32).

Variables related to surface land uses and native vegetation can influence cave invertebrate communities, even at some distance (i.e., 50-250 m [164-820 ft]), from a cave's entrance (Pellegrini et al. 2016, pp. 23-34). Jaffé et al. (2018, pp. 9, 11) found that anthropogenic land use, in the form of agriculture, within 50 m (164 ft) of a cave significantly reduced troglobitic invertebrate species richness. Those researchers partially attributed reductions to chemical contamination in the form of herbicide, pesticide, and/or fertilizer use (Jaffé et al. 2018, p. 17). Reduction of nutrients into caves, due to loss of surrounding native vegetation to agricultural conversion, was cited as another potential contributor to reduced species richness (Jaffé et al. 2018, p. 17). It is likely that urbanization may have similar impacts on cave systems (Pelligrini et al. 2016, p. 28).

Construction of development projects (e.g., single- or multi-family housing, commercial buildings, and paved roadways) often entails the partial or complete mechanical removal of natural vegetation, and potentially topsoil, from a site (Theobald et al. 1997, p. 26; Zipperer 2011, pp. 188-189) followed by replacement with built structures, impervious cover, and/or non-native, managed landscaping (McKinney 2002, pp. 884, 886; McKinney 2008, p. 168). Once completed, such urban landscape features can have long-term impacts on surrounding natural communities (Theobald et al. 1997, pp. 27-28, 31-33). Compared to some other anthropogenic drivers of species decline, including agriculture, forestry, or grazing, the impacts of urbanization on native habitats are more persistent resulting in highly modified sites with decreased potential for maintenance or reestablishment of native species (Rebele 1994, p. 177; Theobald et al. 1997, p. 33; Huxel and Hastings 1999, p. 312; Marzluff and Ewing 2001, p. 281; McKinney 2002, pp. 883-886, 889; Hansen et al. 2005, pp. 1899-1900).

For this review, we evaluated 2016 aerial imagery of areas surrounding occupied caves in ArcGIS for the following habitat elements: amount of open space with natural vegetation contiguous with a cave entrance, distance of the cave entrance to nearest edge, and status of the cave cricket foraging area (Service 2018, p. 51). As we lack maps of every cave's footprint, cave entrances served as centerpoints for measurements. We did not apply this methodology to surface sites given the lack of detailed data on habitat conditions at these locations. We assigned each cave cluster and individual cave site to one of four resiliency categories, high, moderate, low, or impaired, based on values generated for each habitat element (Service 2018, p. 52). Finally, we noted whether a site possessed legally binding perpetual protection along with the amount of acreage protected, if that information was available.

Habitat elements at high and moderate resiliency sites provide the greatest probability for persistence of Bee Creek Cave harvestman populations and the associated karst ecosystem. However, a sites' continued status as high or moderate resiliency is dependent on the perpetuation of the needed surface and subsurface habitat elements. A cave cluster with a high or moderate resiliency designation may contain an individual cave or caves with lower resiliency, but if at least one cave in the cluster was potentially capable of supporting a high to moderate resiliency population, we assigned that higher resiliency category to the entire cluster. Low resiliency and impaired cave clusters and individual caves potentially lack habitat elements of sufficient quality to support persistent populations of Bee Creek Cave harvestman over the long-term.

Impacts to a cave’s surface or subsurface drainage basin can be a significant source of stressors for Bee Creek Cave harvestman populations. To characterize habitat for a particular site, it is important to determine whether development activities are affecting drainage basins, altering either the quantity or quality of hydrologic inputs into the karst ecosystem. At this time, however, we do not have adequate assessments of drainage basins for most occupied sites. Therefore, we did not include an assessment of actual impacts to drainage basins in this evaluation. For these analyses, we assumed that larger tracts of open space were more likely to include intact drainage basins, particularly when the cave entrance was some distance from the edge. In using this approach, we recognize that drainage basin impacts may be occurring undetected even in high and moderate resiliency sites. Thus, it would be important to delineate and protect these areas in the future to ensure Bee Creek Cave harvestman population.

Based on our review, five of the eight cave clusters and individual caves are currently of high resiliency with potential to support Bee Creek Cave harvestman populations over the long-term (Table 3). For the most part, these sites are located in larger tracts of open space and have relatively unaltered cave cricket foraging areas. Four high resiliency cave clusters and individual caves in Travis County, either within the Balcones Canyonlands Preserve or owned outside of that preserve system by the City of Austin or Travis County, may approximate karst fauna areas given further assessment. In the absence of protection, it is unlikely that the current resiliency of those sites can be maintained over the long-term given rapid human population growth and increasing development pressures. A high resiliency cave cluster in southeastern Burnet County is potentially of sufficient resiliency to support persistent Bee Creek Cave harvestman populations. This portion of the species range is not expected to experience increased population growth or development, however. Four individual caves are impaired due to small areas of open space, potential edge effects, and degraded cave cricket foraging areas. We do not expect these sites to increase in resiliency in the future. These sites are adjacent to commercial development, single and multi-family housing, and/or roadways that are unlikely to be restored to natural or semi-natural habitats.

Table 3. Current resiliency of Bee Creek Cave harvestman sites (cave clusters and individual caves) by karst fauna region.

Cave Cluster or Individual Cave	Open Space Area ha (ac)	Distance of Cave to Nearest Edge m (ft)	Percent of Cave Cricket Foraging Area Impacted	Current Resiliency
Jollyville Plateau Karst Fauna Region				
Individual Cave(s)				
Jester Estates Cave	1 (3)	<120 (<394)	75-100%	Impaired
Merkin Hole	>40 (>100)	>120 (>394)	0%	High
RI-1	>40 (>100)	>120 (>394)	0%	High
Spider Cave	>40 (>100)	>120 (>394)	0%	High
Rollingwood Karst Fauna Region				
Cave Cluster(s)				
Bee Creek Cave and Little Bee Creek Cave Cluster				High
Bee Creek Cave	>40 (>100)	<120 (<394)	0-25%	Moderate
Little Bee Creek Cave	>40 (>100)	>120 (>394)	0-25%	High
Individual Cave(s)				
Bandit Cave	0.3 (0.8)	<120 (<394)	75-100%	Impaired
Little Black Hole	7 (18)	<120 (<394)	75-100%	Impaired
Outside Regions				
Cave Cluster(s)				
MVN Cave and Waldman Cave Cluster				High
MVN Cave	>40 (>100)	>120 (>394)	0%	High
Waldman Cave	>40 (>100)	>120 (>394)	0%	High
Individual Cave(s)				
Stark's North Mine	4 (12)	<120 (<394)	25-50%	Impaired

2.3.1.7 Other:

No new information.

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

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

The range of the Bee Creek Cave harvestman in Travis County has experienced significant human population growth (Neumann and Bright 2008, pp. 8-11, 13; Potter and Hoque 2014, pp. 2, 5). During the period from 1980 to 2010, the Austin-Round Rock area was among the fastest growing metropolitan areas in the United States (Frey 2012, p. 4). In 2018, the U.S. Census Bureau (2018a) rated the Austin-Round Rock area as the ninth fastest growing metropolitan area in the United States.

In Travis County, the human population grew substantially between 1980 and 2010, from 419,573 people to 1,024,266 people (144% increase over 30 years; U.S. Census Bureau 1982, p. 10; U.S. Census Bureau 2012, p. 9). The county's largest city, the City of Austin, grew from 345,890 people in 1980 to a projected 949,587 people in 2017 (174% increase over 37 years; City of Austin 2016). From 2010 to 2017, the population of Travis County increased to 1,226,698 people (U.S. Census Bureau 2018b), an increase of 192% since 1980.

Increased conversion of natural surface habitat to development or infrastructure has accompanied human population growth in Travis County. Based on data from the U.S. Census Bureau (2012, p. 9), numbers of single and multi-family housing units in Travis County more than tripled over a forty-year period from 1970 to 2010, from 100,882 units to 441,240 units. From 2010 to 2016, number of housing units increased to 499,062 units (U.S. Census Bureau 2018a), an increase of 394% since 1970. Burnet County is less populated than Travis County and has not experienced the same magnitude of human population (17,803 people in 1980 to 46,804 people in 2017) and housing growth (5,945 units in 1970 to 22,031 units in 2016) [U.S. Census Bureau 1982, p. 8; U.S. Census Bureau 2012, p. 6; Texas; U.S. Census Bureau 2018c; U.S. Census Bureau 2018d].

Installation of infrastructure projects and non-residential commercial development can be expected to follow establishment of new housing units further expanding the urban, suburban, and exurban footprint (Cohen 1996 pp. 1051-1053; Brueckner 2000, pp. 166-167; Cowley and Spillette 2001, pp. 8-9; Heimlich and Anderson 2001, pp. 15, 18-19; Scheer 2001, pp. 31-35; Oguz et al. 2008, pp. 11-12; Landis 2009, pp. 157, 165). From 2009-2015, Texas was among states with the greatest annual loss in tree cover (8,413 ha/yr [20,790 ac/yr]) and greatest annual net increase in impervious cover (12,092 ha/yr [29,880 ac/yr]) in urbanized areas (Nowak and Greenfield 2018a, p. 37).

Population projections for Travis County indicate substantial increases will continue over the next several decades (i.e., through 2050). Projections from the

Texas Demographic Center (2014) estimate that Travis County will increase in population from 1,099,512 people in 2017 to either 1,612,674 people (One-half 2000-2010 Migration (0.5) Scenario) or 2,011,009 people (2000-2010 Migration (1.0) Scenario) in 2050, a 47% or 83% increase over 33 years, respectively. The City of Austin's population is expected to reach 1,367,879 people by 2045 (City of Austin 2016), an increase of 44% over 27 years. Burnet County is projected to grow less rapidly from 46,186 people in 2017 to either 60,532 people (One-half 2000-2010 Migration (0.5) Scenario) or 79,985 people (2000-2010 Migration (1.0) Scenario) in 2050 (Texas Demographic Center 2014).

Nowak and Greenfield (2018b, pp. 168-171) developed projections for urbanized land growth in the United States from 2010 to 2060. Texas is projected to gain the second highest amount of urbanized land in the country at 3,004,386 ha (7,424,000 ac) over that 50-year period (Nowak and Greenfield 2018b, p. 169). Percentage of urbanized land in Travis County is projected to increase from 25.1%-40% in 2010 to 60.1%-80% in 2060 (Nowak and Greenfield 2018b, p. 170). Urbanized land in Burnet County is not projected to increase significantly, only expanding from 1.1%-2.5% in 2010 to 2.6%-5% in 2060 (Nowak and Greenfield 2018b, p. 170).

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.

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

No new information.

2.3.2.3 Disease or predation:

Recent research underscores the importance of human disturbance to red-imported fire ant invasion. Although habitat disturbance facilitates red-imported fire ant establishment in affected natural communities (LeBrun et al. 2012, pp. 891-893; King and Tschinkel 2013, p. 73), the absence of disturbance does not preclude invasion of undisturbed areas. In southern Texas, LeBrun et al. (2012, pp. 891-892) noted that red-imported fire ants were able to establish colonies in undisturbed grassland and achieve abundances comparable to dominant native ant species. The prevalence of this non-native ant in those grasslands, however, was lower than in disturbed grasslands (LeBrun et al. 2012, p. 888). Red-imported fire ant prevalence can decline following the cessation of disturbance but several decades may be required before populations reach the lower levels observed in undisturbed habitats (LeBrun et al. 2012, p. 892).

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 red-imported 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 red-imported 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. 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 karst invertebrates.

2.3.2.4 Inadequacy of existing regulatory mechanisms:

No new information.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

No new information.

2.4 Synthesis

The Bee Creek Cave harvestman occurs at two cave clusters and seven individual caves in Burnet and Travis counties. Occurrences for the species also exist at three surface sites in Burnet and Travis counties. Four individual cave sites are impaired. Development in the rapidly growing Austin-Round Rock metropolitan area has resulted in loss and degradation of surface and subsurface habitats and is an ongoing stressor for the species. Open space with native vegetation has been reduced at impaired sites with tracts fragmented and isolated from one another. These sites may be unable to support viable populations of the Bee Creek Cave harvestman over the long-term.

There are currently two cave clusters and three individual caves of high resiliency with potential to support viable Bee Creek Cave harvestman populations over the long-term. Larger tracts of open space with natural vegetation surround these caves, providing higher quality cave cricket foraging habitat and greater potential for connectivity among karst features to support cricket populations. Persistence of Bee Creek Cave harvestman populations at these sites is dependent upon management and perpetual protection that maintains adequate open space, sufficient buffering from edge effects, intact foraging areas for cave crickets, and sufficient quantity and quality of water from intact drainage basins.

Projections indicate that the human population of Travis County will grow from 1,599,419 people in 2017 to between 2,605,488 and 3,987,967 people in 2050, an increase of 63%-149% over 33 years (Texas Demographic Center 2014). Such significant human population growth is projected to result in increased conversion of natural surface habitat to urban land uses through 2060 (Nowak and Greenfield 2018b, p. 170). If adequate protections are not enacted, land clearing, residential and commercial construction, and installation of infrastructure will accompany this growth and degrade the resiliency of high and moderate resiliency sites over time.

Recovery criterion (1) in Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas (Service 1994, pp. 86-88) states that three karst fauna areas within each karst fauna region 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 habitat destruction, red-imported fire ants, and contaminants. Recovery criterion (2) requires at least five consecutive years of a cave meeting karst fauna area status and that perpetual protection of these areas is in place.

The Balcones Canyonlands Preserve contributes significantly to the current resiliency of the following four sites, Bee Creek and Little Bee Creek Cave Cluster, Merkin Hole, RI-1, and Spider Caves. These Bee Creek Cave harvestman sites are located in areas of Travis County that have experienced substantial urban development. The protections provided by the preserve system have maintained large amounts of open space surrounding most of these caves and the integrity of cave cricket foraging habitat. If Merkin Hole, RI-1, and Spider Caves qualified and were recognized as karst fauna areas, recovery criterion 1 could be met for the Jollyville Plateau Karst Fauna Region. If those sites are determined to be karst fauna areas, information related to recovery criterion 2 (i.e., criterion (1) has been maintained for at least five consecutive years with assurances that these areas will remain protected in perpetuity) should be gathered and implemented if achieved. In the Rollingwood Karst Fauna Region, Bee Creek Cave and Little Bee Creek Cave Cluster has potential to be recognized as a karst fauna area given protection of sufficient open space surrounding these caves and intact drainage basins.

The occurrence of Bee Creek Cave harvestman outside of currently delineated karst fauna regions requires examination and likely merits a reassessment of karst fauna regional boundaries across the species range. The genetic relationship and taxonomic status of Bee Creek Cave and Bone Cave harvestmen in the Jollyville Plateau Karst Fauna Region requires evaluation to determine if these species do exist in close proximity or if those occurrences represent a single species. We also need detailed information on surface collection sites of the Bee Creek Cave harvestman, specifically the surface and/or subsurface microhabitats the species may rely upon.

At present, recovery criteria for the Bee Creek Cave harvestman have not been achieved. No karst fauna areas exist for this species in any occupied karst fauna region. In Travis County, threats from increasing development due to rapidly growing human populations are projected to continue. At this time, we do not recommend a change in listing status for the Bee Creek Cave harvestman given the lack of protected karst fauna areas.

3.0 RESULTS

3.1 Recommended Classification:

____ **Downlist to Threatened**
____ **Uplist to Endangered**
____ **Delist (*Indicate reasons for delisting per 50 CFR 424.11):***
  ____ *Extinction*
  ____ *Recovery*
  ____ *Original data for classification in error*
__X__ **No change is needed**

3.2 New Recovery Priority Number:

No change (2C).

Brief Rationale: A Recovery Priority Number of 2C is indicative of a taxon with a high degree of threat, a high recovery potential, and the taxonomic standing of a species. The C indicates that the species' recovery conflicts with water demands, development projects, or other forms of economic activity. The Bee Creek Cave harvestman continues to be threatened by a high degree of habitat destruction, disturbance, and degradation across its range. However, we consider this species' potential for recovery to be feasible through the concerted efforts of Service personnel and our partners to restore, enhance, and protect habitat.

4.0 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.

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of the Bee Creek Cave Harvestman (*Texella reddelli*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

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

Review Conducted By: Michael Warriner and Jenny Wilson, Austin Ecological Services Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, ~~Fish and Wildlife Service~~

Approve ______________________________ Date July 6, 2018