Madla Cave Meshweaver
(*Cicurina madla*)

5-Year Review:
Summary and Evaluation

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

5-YEAR REVIEW

Madla Cave Meshweaver (*Cicurina madla*)

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office: Southwest Regional Office, Region 2
Janess Vartanian, Recovery Biologist, 505-248-6657

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

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 new information on the status of the species (e.g., life history, habitat conditions, and threats). Data for this status review were solicited from interested parties through a Federal Register notice announcing this review on July 26, 2019 (84 FR 36113). No new information was received from this solicitation. The Austin Ecological Services Field Office conducted this review and considered both new and previously existing information from federal and state agencies, municipal and county governments, non-governmental organizations, academia, and the public. Primary sources of information used in this review were recovery criteria and guidelines from the Bexar County Karst Invertebrates Recovery Plan (Service 2011a, pp. 16-26), Karst Preserve Design Recommendations (Service 2012, entire), and Karst Preserve Management and Monitoring Recommendations (Service 2014, entire). Unless otherwise noted, all acreage and distance estimates were calculated using Geographic Information Systems (GIS), 2019 digital aerial photography (Digital Globe 2019), and 2019 Bexar County parcel data (Strategic Mapping Program 2019). These estimates are subject to typical margins of error (about 30 meters (m) [94.4 feet (ft)]) associated with Global Positioning Systems (GPS) units, GIS, and transferring data from paper sources to digital media.

1.3 Background:

The purpose of a 5-year review is to ensure that the Madla Cave meshweaver has the appropriate level of protection under the Endangered Species Act. The 5-year review examines new relevant information and documents a determination by the Service regarding whether the species status has changed since the last status review. The review also provides updated information on the current threats to the species, ongoing conservation efforts, and the priority needs for future conservation actions.

The Madla Cave meshweaver (Arachinida: Araneae: Hahnidae: *Cicurina madla* [Gertsch 1992]) is a small, eyeless, troglobitic spider endemic to a restricted range in the karst landscape of northern Bexar County, Texas (Gertsch 1992, p. 109; Cokendolpher 2004, pp. 25, 42-46, 52; Paquin and Dupérré 2009, pp. 28-29, 52-53; Hedin et al. 2018, p. 68). 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 2009, 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 2009, pp. 5-8; Stafford et al. 2014, pp. 8-18). Rising waters (i.e., hypogenic) from depth have also played a role in cave formation in this region (Schindel and Gary 2018, pp. 80, 83-85).

The Madla Cave meshweaver is one of 58 currently recognized species of eyeless *Cicurina* described within the subgenus *Cicurella,* all but four of which are found in Texas (Gertsch 1992, pp. 97-98, pp. 97-120; Cokendolpher 2004, pp. 38-56; Paquin and Dupérré 2009, pp 9-62; Hedin et. al. 2018, p. 50). Nine of the species found in Texas, including the Madla Cave meshweaver, are found only in Bexar County (Gertsch 1992, pp. 101, 103, 109, 111; Cokendolpher 2004, pp. 38-44, 46, 47-48, 51-56; Paquin and Dupérré 2009, pp. 15-17, 27-29, 33-34, 38, 52-53).

The eyeless species of *Cicurina* in Bexar County, including the Madla Cave meshweaver, are all troglobites (i.e., species that spend their entire life-cycle underground) and exhibit morphological adaptation to subterranean environments (i.e., troglomorphy) including the lack of eyes, large size, longer appendages, and lighter coloration (Cokendolpher 2004, p. 23). They all inhabit dark, moist areas of caves and other subterranean voids and do not occur at or very near twilight zones (Cokendolpher 2004, p. 20).

Studies indicate that troglobitic arthropods display preferences for higher relative humidity and/or lower air temperatures, underscoring a dependence on deep cave conditions (Bull and Mitchell 1972, pp. 375, 386; Yoder et al. 2011, p. 599; Mammola et al. 2015, pp. 246-247; Mammola and Isaia 2017, p. 3). Thus, the Madla Cave meshweaver likely requires subterranean habitats with high humidity and stable temperatures. 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. 558-560; 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).

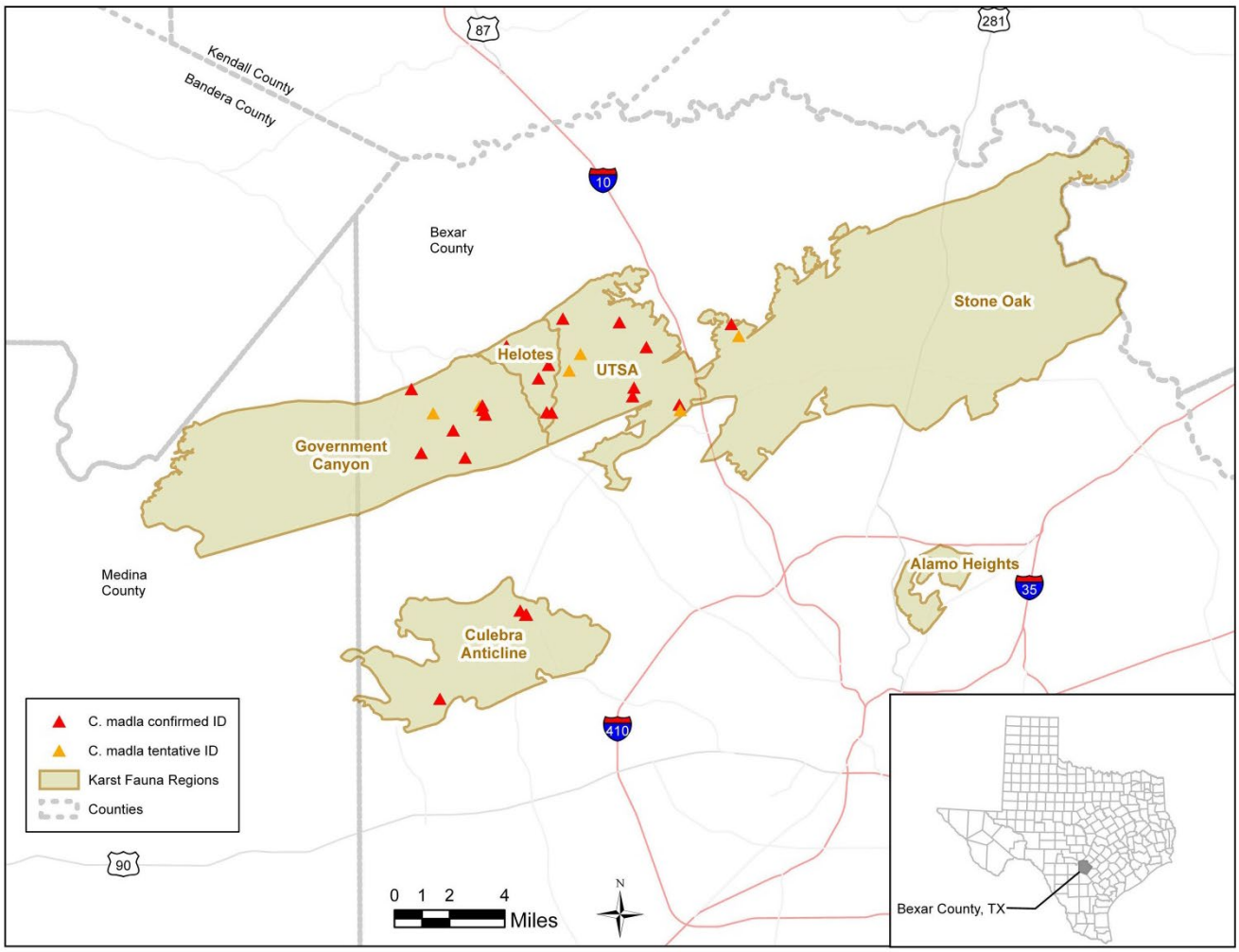
Cicurinas are predators, biting and holding their prey with their chelicerae (jaw-like appendages) while the venom acts (Cokendolpher 2004, p. 21). Cricket nymphs and a range of other cavernicolous invertebrates, including *Brackenridgia* isopods, *Texoreddellia* silverfish, *Cambala* and Speodesmus millipedes, and *Pseudosinella* springtails found in the dark zone of caves, are potential food for the eyeless *Cicurinas* (Cokendolpher 2004, p. 21).

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 2009, p. 23; Jasinska et al. 1996, p. 518). 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; Culver and Pipan 2009, 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). 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).

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; 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; 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).

Known from six caves at the time, the Madla Cave meshweaver was listed as endangered on December 26, 2000, due to its restricted distribution and threats from urban development (65 FR 81419-81433). The stressors that most influence the Madla Cave meshweaver viability are habitat destruction, degradation, and fragmentation that results from urban development.

Figure 1. Current Distribution of the Madla Cave Meshweaver in Bexar County, Texas.



1.3.1 FR Notice citation announcing initiation of this review:

84 FR 36113, July 26, 2019

1.3.2 Listing history

<u>Original Listing</u>
FR notice: 65 FR 81419
Date listed: December 26, 2000
Entity listed: Madla Cave meshweaver (*Cicurina madla*)
Classification: Endangered

1.3.3 Associated rulemakings:

Critical habitat was designated for seven of the nine listed Bexar County karst invertebrates, including the Madla Cave meshweaver, as announced in an April 8, 2003, Federal Register notice (68 FR 17156). In this critical habitat designation, the Service began using the new common names for six of the listed Bexar

County invertebrates, due to changes in the common names of these species as a result of a meeting of the Committee on Common Names of Arachnids of the American Arachnological Society in 2000 (Breene et al. 2001, pp. 10, 12, 14, 15). Accordingly, we changed the common name of the Madla's cave spider to the Madla Cave meshweaver (Breene et al. 2001, p. 14).

On February 22, 2011, the Service proposed a revision of the previous critical habitat designations (68 FR 17156) and proposed critical habitat for the Government Canyon Bat Cave spider (*Neoleptoneta=Tayshaneta myopica*) and the Government Canyon Bat Cave meshweaver (*Cicurina vespera*) (76 FR 9872). A notice extending the comment period on the proposed revisions was published on August 2, 2011 (76 FR 46234), and the final notice announcing the revised designated critical habitat was published on February 14, 2012 (76 FR 8540).

1.3.4 Review history:

Status reviews for the Madla Cave meshweaver were conducted in 2000 for the final listing of the species (65 FR 81419) and 2011 in a 5-year review (Service 2011b, entire). The 2011 5-year review recommended no change in classification of endangered (Service 2011b, p. 19).

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: Bexar County Karst Invertebrates Recovery Plan
Date issued: September 2011

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.

2.2.2 Adequacy of recovery criteria.

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

Yes.

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

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:

Goal - The goal of the recovery plan is to reduce or remove threats to the species such that their long-term survival is secured in the wild, the species are no longer endangered or threatened, and can be delisted.

Objective 1 - Perpetually preserve a sufficient amount and configuration of habitat areas (karst fauna areas or KFAs) to preserve populations that span the range and provide representation of the genetic diversity of the species. This will help conserve their adaptive capabilities and will help protect the species survival in the event of catastrophic or other stochastic influences. When preserved, ensure these areas have a high probability of the species survival in perpetuity.

Objective 2 - Manage these areas to remove threats to the species' survival.

The following criteria were developed to measure our successes at accomplishing the objectives and reaching the goal above.

Criterion 1 (downlisting) - The location and configuration of at least the minimum quality and number of KFAs in each karst fauna region (KFR) for each species are preserved. Also, legally binding commitments are in place for perpetual protection and management of these KFAs. Overarching criteria that are applied per species include:

(1) at least one high quality protected KFA per KFR;
(2) at least three total medium or high quality protected KFAs per KFR;
(3) a minimum of six protected KFAs rangewide per species;
(4) a minimum of three high quality KFAs;
(5) all KFAs at least medium or high quality.

Criterion 2 - (delisting) - In addition to the downlisting criterion, monitoring and research have been completed to conclude with a high degree of certainty that KFA sizes, quality, configurations, and management are adequate to provide a high probability of the species survival (greater than 90 percent over

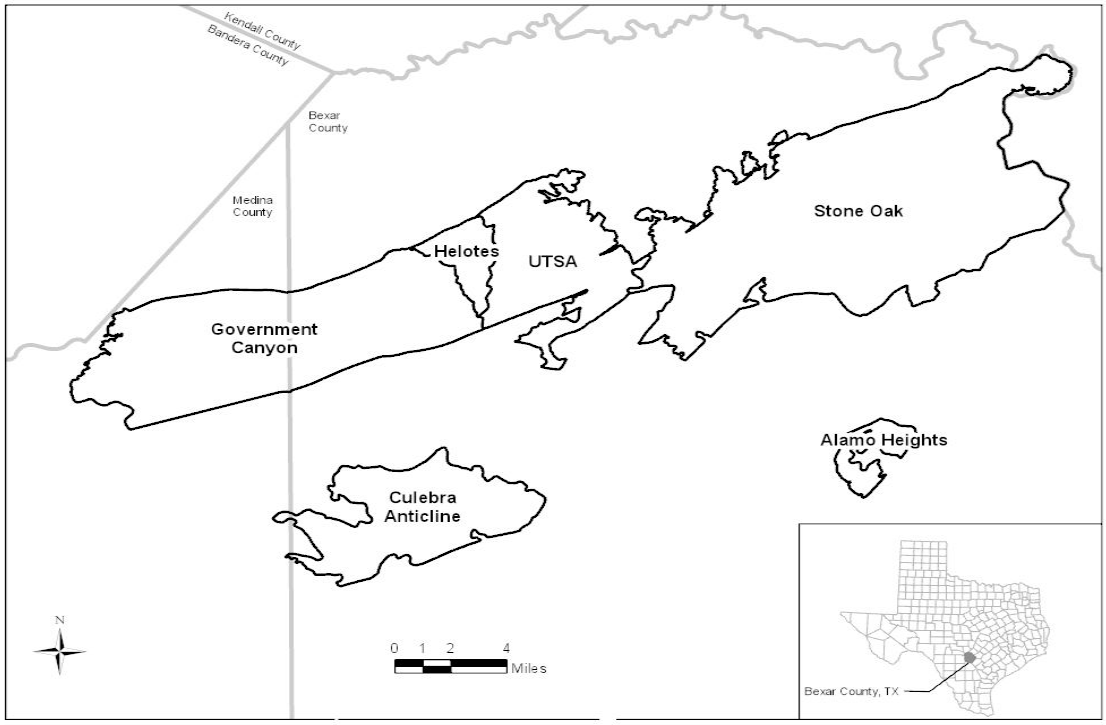
100 years). To assess adequacy, results should be measured over a long enough time that cause and effect can be inferred with a high degree of certainty.

For the purposes of the recovery program, a KFA is an area known to support one or more locations of a listed species. A KFA is distinct in that it acts as a system that is separated from other KFAs by geologic and hydrologic features and/or processes that create barriers to the movement of water, contaminants, and troglobitic fauna. Karst fauna areas should be far enough apart so that if a catastrophic event (for example, contamination of the water supply, flooding, disease) were to destroy one of the areas, that event would not likely destroy any other area occupied by that species.

To be considered adequate to contribute to meeting the recovery criteria, a KFA must be sufficiently large to maintain the integrity of the karst ecosystem on which the species depend(s). In addition, to be considered "protected" these areas must provide protection in perpetuity from threats such as RIFA, habitat destruction, and contaminants.

There are six KFRs in Bexar County that contain listed species. These regions are delineated based on geologic continuity, hydrology, and the distribution of rare troglobites (Veni 1994, entire). These six KFRs were used in the final rule to define the ranges of the listed species and are as follows: Stone Oak, University of Texas at San Antonio (UTSA), Helotes, Government Canyon, Culebra Anticline, and Alamo Heights (Figure 2).

Figure 2. Karst Fauna Regions of Bexar County, Texas.



Based on current information, the Madla Cave meshweaver occurs in five recovery regions. It occurs the Government Canyon, Helotes, UTSA, Stone Oak and Culebra Anticline KFRs. In order to meet Criterion 1 (downlisting), there would need to be at least three protected KFAs in each KFR, with at least one KFA in each KFR meeting the criteria for a high quality KFA (Table 1).

Table 1. KFAs needed per KFR

KFR	Minimum number of KFAs needed	Minimum number of high quality KFAs needed (out of the total)
KFR 1	3	1
KFR 2	3	1
KFR 3	3	1
KFR 4	3	1
KFR 5	3	1
Total	**15**	**5**

Brief summary of preserve design principles:

Much of the conservation and recovery of the Madla Cave meshweaver 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; Culver et al. 2004, pp. 1222-1223; 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; 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, p. 83; Jiménez-Valverde et al. 2017, p. 10213; Sendra et al. 2017a, p. 101; Sendra et al. 2017b, p. 49). Therefore, conservation strategies for the Madla Cave meshweaver focus on the delineation, protection, and management of occupied karst fauna areas.

The Bexar County Karst Invertebrate Recovery Plan provides guidelines on habitat conditions that are important to karst invertebrates (Service 2011a, pp. 6-8). Scientific information and additional karst preserve guidelines are further detailed in the 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 temperatures

- 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 m (345 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 2011 5-year review for the Madla Cave meshweaver, no karst fauna areas had been established for this species. The species was confirmed or or potentially found in 25 caves in four KFRs. There were four potential high quality KFAs in each of the Government Canyon and UTSA KFRs and two potential high quality and one potential medium quality KFAs in the Helotes KFR. No areas had the potential to meet the KFA criteria in the Stone Oak KFR.

Currently, there are 29 caves or karst features known to contain or potentially contain the Madla Cave meshweaver in five karst fauna regions. These occur in one cave cluster and five individual caves in the Government Canyon KFR, two cave clusters and five individual caves in the Helotes KFR, two cave clusters and five individual caves in the UTSA KFR, one individual cave in the Stone Oak KFR, and one cave cluster and one individual cave in the Culebra Anticline KFR. For simplicity, we will refer to all caves and karst features as caves although some of these may not meet the definition of a cave (karst features that consist of a natural opening in solid rock larger than 20 centimeters (cm) [> 8 inches (in)] in diameter or cross-sectional dimension (Howarth 1983, p. 370; Culver and Pipan 2009, p. 4)).

Based on a review of known locations and available data, the Service is working with the City of San Antonio to recognize four areas in the Government Canyon KFR as high quality KFAs. One additional area in that KFR has the potential to meet the definition of a medium quality KFA but could meet the definition of a high with additional monitoring and protection. In the Helotes KFR, there is a potential for two areas to meet the definition of a high quality KFA and one has the potential to be a medium quality KFA. In the UTSA KFR, five areas have sufficient undeveloped acreage to potentially meet the definition of a high quality KFA. There are no areas in either the Stone Oak KFA or the Culebra Anticline KFA that could be developed into a high or medium quality KFA (Table 2).

Table 2. 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)**
Government Canyon	1	4	0
Helotes	3	0	0
UTSA	5	0	0
Stone Oak	0	0	0
Culebra Anticline	0	0	0

Below is a discussion of these areas with a description of how they have the potential to contribute to meeting recovery criteria.

Government Canyon KFR

Government Canyon State Natural Area KFAs

Government Canyon Bat Cave, Lithic Ridge Cave, Lost Pothole, and Surprise Sink all occur on the Government Canyon State Natural Area which is owned by Texas Parks and Wildlife Department. As mitigation for the Southern Edwards Plateau Habitat Conservation Plan, the City of San Antonio has worked with Texas Parks and Wildlife Department to establish high quality preserves surrounding all four of these caves. They occur in the approximately 40 ha (100 ac) Government Canyon Bat Cave KFA; the 90 ha (223 ac) Lithic Ridge, Dancing Rattler, and Hackberry Sink KFA; the 40 ha (100 ac) Lost Pothole KFA; and the 58 ha (144 ac) Surprise Sink and Bone Pile Cave KFA respectively. These preserves encompass the cave cricket foraging area and surface and subsurface drainage basins of all four of these caves and management is being conducted under the Southern Edwards Plateau Habitat Conservation Plan Government Canyon State Natural Area Karst Fauna Areas Management and Monitoring Plan (Bowman Consulting 2017, entire) and through an interlocal agreement between Texas Parks and Wildlife Department and the City of San Antonio. The Service is working with the City of San Antonio to recognize these as high quality KFAs for the Madla Cave meshweaver.

Scenic Overlook Cave Cluster

Scenic Overlook Cave and Fatman's Nightmare Cave both occur on a 30 ha (75 ac) privately-owned parcel set aside and managed as part of the mitigation for the La Cantera Habitat Conservation Plan (Service 2001, entire). San Antonio Ranch Pit and Pig Cave occur on an adjacent 171 ha (423 ac) parcel purchased through the Section 6 HCP Land Acquisition Program. The cave cricket foraging areas and surface and subsurface drainage basins for these caves are all undeveloped and occur within the boundaries of these two parcels, with the exception of Pig Cave. Although undeveloped, its cave cricket foraging and subsurface drainage basins extend onto an adjacent 36 ha (90 ac) City Public Service (CPS) parcel and a 237 ha (587 ac) parcel owned by the City of San Antonio. There is enough area around Scenic Overlook Cave and Fatman's Nightmare Cave to meet the definition of a medium KFA and with additional management and monitoring on adjacent parcels, this area could potentially meet the definition of a high quality KFA.

Helotes KFR

Helotes Hilltop Preserve

This 10 ha (25 ac) privately-owned preserve contains two caves, Helotes Blowhole and Helotes Hilltop Cave, and was set aside and is being managed as part of the mitigation for the La Cantera Habitat Conservation Plan (Service 2001,

entire). The surface drainage basins of both caves are within the preserve, however, the subsurface drainage basins and cave cricket foraging areas are not. The cave cricket foraging area and subsurface drainage basin of Helotes Blowhole have been impacted by residential development but those of Helotes Hilltop Cave do not appear to have been impacted. With additional acreage and protection of the drainage basin and cave cricket foraging area of Helotes Hilltop Cave in perpetuity, this area could potentially meet the definition of a medium quality KFA.

Madla's Cave

This cave occurs within a 2 ha (5 ac) conservation easement on a 12 ha (30 ac) privately-owned parcel. The easement was set aside and is managed as a part of the La Cantera Habitat Conservation Plan (Service 2001, entire). The surface and subsurface drainage basins for the cave and a portion of the cave cricket foraging area are within the conservation easement. The cave cricket foraging area is currently undeveloped and there is sufficient undeveloped land surrounding the cave to meet the definition of a high quality KFA provided it could be protected and managed in perpetuity.

Madla's Drop Cave

Madla's Drop Cave occurs on a private parcel in an area of large residential lots. The cave cricket foraging area and surface and subsurface drainage basins for this cave are predominantly undeveloped except for a few jeep roads that have the potential to be remediated. This area has adequate undeveloped acreage to be considered a high quality KFA if enough area could be combined, managed, monitored, and protected in perpetuity.

UTSA KFR

Hills and Dales Pit and Robber's Cave Cluster

Hills and Dales Pit and Robber's Cave occur on a 28 ha (70 ac) preserve and an adjacent 62 ha (155 ac) natural area respectively. The 28 ha (70 ac) Hills and Dales Preserve is a privately-owned parcel set aside and managed as part of the mitigation for the La Cantera Habitat Conservation Plan (Service 2001, entire). It includes most of the subsurface drainage basin and a portion of the surface drainage basin and the cave cricket foraging for Hills and Dales Pit. Robber's Cave occurs on the adjacent Faye and William Sinkin Natural Area owned by the City of San Antonio. The surface and subsurface drainage basins of this cave have been mapped and are included within the preserve area. The cave footprint, however, has not been mapped so we are unsure how far it occurs from the edge of the preserve. In addition, this area is not managed or monitored for karst invertebrates. If the cave footprint for Robber's Cave was mapped and a sufficient area was permanently protected and managed, this area could meet the definition of a high quality KFA.

Breathless Cave

Breathless Cave occurs on an 85 ha (210 ac) preserve that is owned by the City of San Antonio. A portion of the cave cricket foraging area for this cave is on the preserve but the cave occurs in a linear strip of the parcel that is only about 54.8 m (180 ft) wide. We do not have a delineated cave footprint for this cave but based on the cave entrance, the cave cricket foraging area is currently undeveloped. In addition, the surface and subsurface drainage basins have not been delineated so their status is unknown. This area could meet the definition of a high quality KFA if the surface and subsurface drainage basins were delineated and protected, along with the remainder of the cave cricket foraging area, and permanent protection and management were assured.

Crane Bat Cave

Crane Bat Cave occurs on private property in a largely undeveloped area. The cave footprint has not been mapped and the drainage basins have not been delineated for this cave. There is sufficient area surrounding this cave to potentially meet the definition of a high quality KFA, however the cave footprint and surface and subsurface drainage basins would need to be delineated and protected and permanent protection and management would need to be assured.

Feature 50

Feature 50 occurs on about a 40 ha (100 ac) parcel of undeveloped land that is owned by University of Texas at San Antonio. The cave cricket foraging area is currently undeveloped, however, we do not have maps of the cave footprint so we are unsure how far it is from an edge. The surface and subsurface drainage basins for Feature 50 have not been delineated so we are unsure if they have been impacted. We also do not know if these caves receive any management. This area has the potential to meet the definition of a high quality KFA if the cave footprint and surface and subsurface drainage basins were delineated and protected and permanent protection and management were assured.

Scharf Cave

Scharf Cave occurs on private property in a largely undeveloped area. A portion of the cave cricket foraging area occurs on Rancho Diana Natural Area, which is owned by the City of San Antonio. The cave footprint has not been mapped and the drainage basins have not been delineated for this cave. There is sufficient area surrounding this cave to potentially meet the definition of a high quality KFA, however the cave footprint and surface and subsurface drainage basins would need to be delineated and protected and permanent protection and management would need to be assured.

Stone Oak KFR

There are no areas in the Culebra Anticline KFR that meet or may meet the definition of a high or medium quality KFA.

Culebra Anticline KFR

There are no areas in the Culebra Anticline KFR that meet or may meet the definition of a high or medium quality KFA.

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:

No new information.

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.):

Hedin (2015, entire) developed an integrative approach to species delimitation questions for troglobitic *Cicurina* including comparisons of multiple independent lines of evidence (e.g. mtDNA data, nuclear data, and morphology) for selected species in Travis and Williamson counties. This included next-generation sequencing methods, such as sequence capture of ultra-conserved elements. Hedin et al. (2018, entire) extended theses sequencing methods with some success to ethanol preserved spider museum specimens as well while utilizing this integrative approach to address species delimitation questions in Bexar County.

2.3.1.4 Taxonomic classification or changes in nomenclature:

Garrison et al. (2016, entire) conducted a phylogenomic analysis of spider relationship using a transcriptome-based data set comprising 70 ingroup spider taxa. In this analysis, *Cicurina* represented the Dictynidae family which was placed as a sister group to Hahiindae (Garrison et al. 2016, p. 25). Wheeler et al. (2017, entire), however, conducted a phylogenetic analysis of spiders using a dataset of 932 spider species, representing 115 families. Using six markers from the mitochondrial and nuclear genomes analyzed by multiple methods, *Cicurina* was moved from Dictynidae to Hahniidae (Wheeler et al. 2017, p. 598). The placement of *Cicurina* in Hahnidae was accepted by the World Spider Catalog (World Spider Catalog 2019).

The Madla Cave meshweaver was originally described in 1992 from a single female specimen found in Madla's Cave in 1963 (Gertsch 1992, p. 109). One of only four cave-dwelling spiders of the genus *Cicurina* described from Bexar County at the time (Gertsch 1992, p. 98), it was

differentiated from other *Cicurina* based on geographic location and specific morphological characters of the female epigyna (Gertsch 1992, p. 111).

Spider taxonomy in general relies largely on genitalic differences in adult specimens using a combination of male and female morphology to delimit species (Paquin and Hedin, 2004, p. 3240; Paquin et al. 2008, p. 139; Paquin and Dupérré 2009, p. 5; Hedin 2015, p. 347). Delimiting trogolobitic *Cicurina* species based on morphology is particularly difficult not only because of the inaccessibility of their habitat for gathering adequate samples (Moseley 2009, pp. 47-48, Paquin and Dupérré 2009, p. 4) but because most collections return immature specimens (Gertsch 1992, p. 80; Cokendolpher 2004, p. 15; Paquin and Hedin, 2004, p. 3240; Paquin et al. 2008, p. 140; Paquin and Dupérré 2009, pp. 5, 64). In addition, the few adults that are collected are disproportionately female (Cokendolpher 2004, pp. 14, 15, 17-18; Paquin and Dupérré 2009, pp. 5, 64; Hedin 2015, p. 347). As females of troglobitic *Cicurina* exhibit variability in genitalic characters within and between caves, this makes it difficult to determine whether an individual represents a distinct species or intraspecific variation based on morphology alone (Cokendolpher 2004a, pp. 30-32; Paquin and Dupérré 2009, pp. 5-6; Paquin et al. 2008, pp. 140, 143, 147; Paquin and Dupérré 2009, pp.4-6, 63-64).

Problems with species delimitation in *Cicurinas* utilizing genetic methods can also arise, such as extreme population genetic structuring found with constrained gene flow in cave restricted species and rare to non-existent cases of sympatry, making it difficult to test reproductive isolation, among others (Hedin 2015, p. 347). In order to address difficulties in species delimitation of troglobitic *Cicurinas*, Hedin et al. (2018, entire) combined morphological, mitochondrial, and nuclear phylogenomic data to address phylogenetic and species delimitation questions with particular focus on the four listed Bexar County species including the Madla Cave meshweaver.

Nuclear phylogenomic analyses recovered two primary eyeless clades corresponding to previously described morphological groups based on the shape of the spermathecum in adult females (Hedin et al. 2018, pp. 55, 61). These include mostly elongate (ME) and rounded (R) spermathecae groups with the exception of two species represented by large even-sized rounded spermathecum (Cokendolpher 2004, pp. 23-24, Paquin and Dupérré 2009, p. 9, Hedin et al. 2018, p. 55). Consistent with previous studies, measurements of degree of troglomorphy, as measured by a ratio of leg length to body length, also supported the ME and R clade lineages with the ME clade having a higher troglomorphic index than the R clade (Cokendolpher 2004, p. 18; Hedin et al. 2018, pp. 63-64).

Unexpectedly, both UCE and COI results placed several specimens of *Cicurina* with ME morphology from the Culebra Anticline in the Madla

Cave meshweaver clade (Hedin et al. 2018, pp. 55-57). This result included one specimen formerly assigned to the Braken Bat Cave meshweaver (*C. venii*) based on geographic location and female morphology (Cokendolpher 2012, pp. 4-5; Hedin et al. 2018, pp. 55-57). Although, at the time, it was noted that the morphology of that specimen was similar to a Madla Cave meshweaver from a cave in the UTSA KFR (Cokendolpher 2012, pp. 4-5).

Genetic material could not be retrieved from the holotype specimen of the Braken Bat Cave meshweaver for this study (Hedin et al. 2018, p. 51). However, based on comparison to the holotype specimen of the Braken Bat Cave meshweaver, the female morphology and the troglomorphic index values of this specimen were found to be like the Madla Cave meshweaver (Hedin et al. 2018, p. 67). Previously, these species were separated on the basis of slight morphological variations and geographic allopatry with the Braken Bat Cave meshweaver occurring in the Culebra Anticline KFR and the Madla Cave meshweaver listed as occurring in the Government Canyon, Helotes, UTSA, and Stone Oak KFRs (Cokendolpher 2004, pp. 28, 42-46, 52-53; Paquin and Dupérré 2009, pp. 28-29, 52-53). Evidence exists, however, for species distribution across these KFRs as another troglobitic spider, *Tayshaneta whitei* (no common name) also occurs in the Government Canyon KFR and the Culebra Anticline KFR (Hedin et al. 2018, pp. 55-56; Ledford et al. 2012, pp. 63, 65).

Based on morphologic characteristics and mitochondrial and nuclear DNA results Hedin et al. (2018, pp. 68-71), synonomized the Braken Bat Cave meshweaver under the Madla Cave meshweaver. This synonomy was accepted by the World Spider Catalog (World Spider Catalog 2019).

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.):

When the Madla meshweaver was originally listed, it was thought to occur in six caves, one cave in the Government Canyon KFR, three in the Helotes KFR, one in the UTSA KFR, and one in the Stone Oak KFR. Using morphological, mitochondrial, and nuclear phylogenomic data, Hedin et al. (2018) synonomized the Braken Bat Cave meshweaver, which occurred in the two Caves in the Culebra Anticline, with the Madla Cave meshweaver, which was not previously known from the Culebra Anticline KFR.

For this 5-year review, we considered a site occupied by the Madla Cave meshweaver if multiple lines of evidence supported identification of a specimen. Confirmed locations included those where a vouchered specimen of an adult female or male was identified morphologically and supported by either mitochondrial or nuclear genetic results or both and

locations with unsexed juvenile specimens where both mitochondrial and nuclear results were available and agreed. Juveniles confirmed only by mitochondrial or nuclear genetics but not both are considered tentative at this time until additional work to determine the extent of the agreement between mitochondrial and nuclear genetic results across the range of the species can be completed. In addition to the above specimens, we also included two locations as confirmed in this review where a female specimen was collected and identified morphologically by a taxonomist. We will continue to pursue genetic confirmation of these specimens. Including identifications of individuals formerly known as the Bracken Bat Cave meshweaver, the Government Canyon Bat Cave meshweaver is now confirmed from 23 caves and tentatively identified from six more across five KFRs (Table 3).

One exception to including unsexed juvenile records with mitochondrial genetic results that fall within the Madla Cave meshweaver clade in this 5-year review is Margaritaville Cave in Uvalde County. Caves in intervening counties (Bob Clark Cave in Bandera County and Fern Cave in Medina County) were placed in *C. cf. madla*, a potential sister group of the Madla Cave meshweaver based on nuclear genetic results (Hedin et al. 2018, p. 66). Absent corroborating nuclear results, including collections of samples from cave habitats in the geographic region between the Government Canyon KFR and the above more westerly cave locations, we did not include this cave in our analysis.

There is also some uncertainty regarding the holotype locality for the Braken Bat Cave meshweaver. The specimen from Braken Bat Cave is the only ME clade specimen known from that area with other caves surrounding the area falling in the R clade (Hedin et al. 2018, p. 67). One hypothesis is that the specimen for the Braken Bat Cave meshweaver was incorrectly labeled and does not occur in Braken Bat Cave (Hedin et al. 2018, p. 67). Another is that specimens of Government Canyon Bat Cave meshweaver and Braken Bat Cave meshweaver (*Cicurina venii*) were switched at some point in the past and that the Braken Bat Cave meshweaver was actually first collected in Government Canyon Bat Cave (Hedin et al. 2018, p. 67). Because the actual extent of the Madla Cave meshweaver range in the Culebra Anticline is unknown and evidence exists for sympatry between the Madla Cave meshweaver and the Government Canyon Bat Cave meshweaver (Hedin et al. 2018, p. 66), for purposes of this 5-year review, we are maintaining the record of the Madla Cave meshweaver in Braken Bat Cave. Additional studies to confirm or correct this record are recommended in Section 4.0.

An important consideration for this 5-year review was whether occupied caves warranted consolidation into single populations based on geographic proximity. 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 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. 958, 960), 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 populations at Gallifer, Root, and 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 (e.g., 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). Greater distances between genetically similar troglomorphic *Tayshaneta* (i.e., *T. anopica* and *T. sandersi*) species were noted by Ledford et al. (2012, pp. 11, 18-23) in Travis and Williamson counties. Individuals of *T. sandersi* sampled from three caves (i.e., District Park Cave, Slaughter Creek, and Whirlpool Caves) in Travis County were found to be genetically identical, with an average distance of 698 m (2,290 ft) between those karst features (Ledford et al. 2012, p. 57).

For our assessment, we assumed that populations of the Madla Cave meshweaver, 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. Given the extent of geological connectivity surrounding caves, actual Madla Cave meshweaver dispersal distances may be greater or lesser than that value. Genetic analyses would be necessary to provide more certainty regarding actual dispersal distances.

For each cave occupied by the Madla Cave meshweaver, 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 Madla Cave meshweaver 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 Madla Cave meshweaver occurrences into a total of five cave clusters and 14 individual caves (Table 3).

Table 3. Cave clusters and individual caves by karst fauna region.

Karst Fauna Region	Cave Name	Ownership
Government Canyon		
Cave Clusters		
Scenic Overlook Cave Cluster	Fatman's Nightmare Cave	Texas Parks and Wildlife Department (TPWD)
	Pig Cave	City of San Antonio
	Scenic Overlook Cave	TPWD
	San Antonio Ranch Pit	City of San Antonio
Individual Caves		
	Government Canyon Bat Cave	TPWD
	Hernandez Cave	Private
	Lithic Ridge Cave	TPWD
	Lost Pothole	TPWD
	Surprise Sink	TPWD
Helotes		
Cave Clusters		
Helotes Hilltop and Helotes Blowhole	Helotes Blowhole	Private
	Helotes Hilltop Cave	Private
Individual Caves		
	Christmas Cave	Private
	Madla's Cave	Private
	Madla's Drop Cave	Private
UTSA		
Cave Clusters		
La Cantera Cave Cluster	Feature 50	Private
	La Cantera Cave No. 1	Private
Hills and Dales Pit and Robber's Cave	Hills and Dales Pit	Private
	Robber's Cave	City of San Antonio
Individual Caves		
	Breathless Cave	City of San Antonio
	Crane Bat Cave	Private
	Crownridge Canyon Cave	City of San Antonio
	John Wagner Ranch Cave No. 3	Private
	Scharf Cave	Private
Stone Oak		
Individual Caves		
	Headquarters Cave	Department of Defense

Karst Fauna Region	Cave Name	Ownership
Culebra Anticline		
Cave Clusters		
SH 151 at Loop 1604	151-010	TXDOT[a]
	151-014	TXDOT[a]
	151-019	TXDOT[a]
	151-021	TXDOT[a]
Individual Caves		
	Braken Bat Cave	Private

[a] Cave has been destroyed

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

The population needs of the Madla Cave meshweaver 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 Madla Cave meshweaver 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 and drainage basins) surrounding a cave as surrogates to assess population resiliency. For a full discussion of this methodology, see Service (2018, pp. 49-53).

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 2019 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 and surface and subsurface drainage basin, if known. As we lack maps of every cave's footprint, cave entrances served as center-points for measurements where they are missing.

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. 53). We also 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 Madla Cave meshweaver 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 Madla Cave meshweaver over the long-term.

Impacts to a cave's surface or subsurface drainage basin can be a significant source of stressors for Madla Cave meshweaver 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 all occupied sites. If drainage basins have been delineated for a cave, we used those areas. For those whose drainage basins have not been delineated, 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 Madla Cave meshweaver persistence.

Based on this review, four cave clusters and 12 individual caves are currently of high to moderate resiliency with potential to support Madla Cave meshweaver populations over the long-term (Table 4). For the most part, these sites are located in larger tracts of open space and have relatively unaltered cave cricket foraging areas and drainage basins. Two individual caves that ranked with a moderate resiliency from the UTSA KFR using this approach were not considered as potential KFAs due to permanent impacts to their cave cricket foraging areas and mapped drainage basins. In addition, one high resiliency individual cave in the Stone Oak KFR was not considered for potential to become a KFA as it occurs on Department of Defense land. Although it is being monitored and managed, its permanent protection cannot be assured.

Of the remaining four cave clusters and nine individual caves of high or moderate resiliency based on this methodology, the Government Canyon KFR has four high resiliency individual caves and one high resiliency cave cluster. The four individual caves are discussed under the Government Canyon State Natural Area KFAs and the cave cluster is discussed under the Scenic Overlook Cave Cluster in 2.2.3 above. The two high resiliency individual caves and one moderate resiliency cave cluster in the Helotes KFR are also discussed above under Madla's Cave, Madla's Drop Cave and the Helotes Hilltop Preserve respectively. The UTSA KFR has two high resiliency cave clusters and three individual caves. The three individual caves are discussed under Breathless Cave, Crane Bat Cave and Scharf Cave above and the two clusters are discussed under the Helotes Hilltop Preserve and Feature 50. Feature 50 is the only high resiliency cave in the La Cantera Cave Cluster.

Table 4. Current resiliency of Madla Cave meshweaver sites (cave clusters and individual caves) by karst fauna region.

Karst Fauna Region	High	Moderate	Low	Impaired	Destroyed
Government Canyon	5	0	1	0	0
Helotes	2	1	0	1	0
UTSA	5	2	0	0	0
Stone Oak	1	0	0	0	0
Culebra Anticline	0	0	0	1	1
Total	**13**	**3**	**1**	**2**	**1**

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 species' range in Bexar County which also includes a portion of the City of San Antonio continues to experience substantial human population growth and development (Neumann and Bright 2008, pp. 8-11, 13; Frey 2012, pp. 7, 8, 11; Potter and Hoque 2014, p. 5). During the period from 2007 to 2010, the San Antonio area was among the fastest growing metropolitan areas in the United States (Frey 2012, p. 8). In the period from 2010 to 2018, San Antonio grew from 1,326,768 people to 1,532,233 people (U.S. Census Bureau 2019).

Population projections from the Texas State Data Center predict many of the large urban counties will continue to experience high growth rates with Bexar County being one of the counties expected to add a million more people by the year 2050 (You et al. 2019, pp. 5-6). Bexar County is also one of three counties expected to grow faster than the state (You et al. 2019, p. 2). The human population in Bexar County increased between 1980 and 2018, from 988,800 people to 1,986,049 people (U.S. Census Bureau 1982, p. 8; U.S. Census Bureau 2019) and is expected to increase to 3,353,060 by the year 2050 (Texas Demographic Center 2018).

Increased conversion of natural surface habitat to development or infrastructure has accompanied human population growth in Bexar County. Numbers of single and multi-family housing units in Bexar County increased by 281% over a 48-year period, from 249,025 units in 1970 to

700,132 units in 2018 (U.S. Census Bureau 2012, p. 6; U.S. Census Bureau 2018).

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. 12, 18-19; Scheer 2001, pp. 31-35; Oguz et al. 2008, pp. 11-12; Landis 2009, pp. 157, 165).

The Madla Cave meshweaver, 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 2009, 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 2009, 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 Madla Cave meshweaver population viability and the species' long-term persistence. Land conversion to residential and commercial development has already reduced and degraded surface habitats surrounding a number of occupied sites. Given population and urbanized land growth projections (Texas Demographic Center 2018; Nowak and Greenfield 2018, p. 170), it is likely that many of the 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 2011 5-year review, a new non-native invasive ant species has established colonies at sites in Bexar 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, pp. 2430, 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.

LeBrun (2017, entire) assessed the effects of tawny crazy ants at two caves in Travis County, Texas. 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, although results may be limited by the small sample size (LeBrun 2017, pp. 22, 35). Additional research is needed to

determine the potential for the tawny crazy ant to affect Madla Cave meshweaver populations.

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:

A National Oceanic and Atmospheric Administration (NOAA) report assessing the effect of climate change on Texas asserts that by the end of the 21st century even under lower emissions scenarios (e.g., RCP 4.5) the coldest years will feel like the warmest years today, and the warmest years will be about 6 degrees (Fahrenheit) warmer than the hottest year from the historical record (Runkle et al. 2017, p. 1). Warming under a higher emissions scenario (RCP 8.5) would lead to higher temperatures (Runkle et al. 2017, p. 1).

Model projections of future climate in southwestern North America also show a transition to a more arid climate that began in the late 20th and early 21st centuries (Seager et al. 2007, pp. 1,183). Milly et al. (2005, p. 349) project a 10% to 30% decrease in stream flow in mid-latitude western North America by the year 2050 based on an ensemble of 12 climate models.

Based on downscaling global models of climate change, Texas is expected to receive up to 20 percent less precipitation in winters and up to 10 percent more precipitation in summers (Jiang and Yang 2012, p. 238). However, most regions in Texas are predicted to become drier as temperatures increase (Jiang and Yang 2012, pp. 240–242).

Extreme droughts in Texas are now much more probable than they were 40 to 50 years ago (Rupp et al. 2012, pp. 1,053–1,054). In both moderate and high greenhouse gas emissions scenarios, Cook et al. (2015, pp. 5-6) predict that the Central Plains and Southwest regions of the United States will experience a drought in the second half of the 21st century (2050-2099) more severe than any other in the past 1,000 years.

The climatic conditions of caves, while relatively stable compared to surface habitats, are subject to variation in prevailing relative humidity and air temperature (Culver 1982, p. 9; Culver and Pipan 2009, pp. 3-4). Cave morphology (e.g., size, shape, and volume), number and size of entrances, seasonal changes in airflow, and annual range of surface temperatures among other factors interact to influence subterranean climates (Tuttle and Stevenson 1978, pp. 110-120; de Freitas and Littlejohn 1987, p. 568). Troglobitic arthropods, such as the Madla Cave meshweaver, may respond to seasonal shifts by moving to microclimates with higher humidity (i.e., mesocaverns) during dry conditions or into larger subterranean voids (i.e., macrocaverns) during wet periods (Park 1960, p. 99; Howarth 1983, p. 373; Crouau-Roy et al. 1992, p. 17; Mammola et al. 2015, p. 246); however, the

exact limits of its temperature and humidity physiological tolerance for this species are unknown.

With increasing distance into the cave, climatic conditions stabilize within a narrow range of humidity and temperature (Poulson and White 1969, p. 972; Howarth 1980, p. 398; Howarth 1993, p. 69; Prous et al. 2004, pp. 377-378; Tobin et al. 2013, p. 206). These temperatures, however, are affected by the average local temperature of the area within which the cave occurs (Badino 2010, p. 429; Covington and Perne 2015, p. 365, Mammola et al. 2017, p. 7-EV). Thus, as average annual surface temperatures increase, it is reasonable to predict that increases in temperatures in caves will follow. However, the length of the lag time for this correlation under climate change scenarios, as well as the detailed mechanistic relationship between climate change and changes in temperatures for individual caves is not easy to predict. If surface temperature increases and longer dry periods and reduced soil moisture lead to changes in the climate of the deep cave zones, this could reduce or eliminate available habitat within occupied caves, thus affecting the Madla Cave meshweaver.

2.4 Synthesis

Based on a review of available data, three of the five KFRs that the Madla Cave meshweaver occurs have three or more areas currently of sufficient resiliency with the potential to support Madla Cave meshweaver 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 Madla Cave meshweaver populations at these sites, however, are 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 Bexar County area will continue to grow from 1,986,049 people in 2018 to 3,353,060 people in 2050 (Texas Demographic Center 2018). 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 2018, 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 the Bexar County Karst Invertebrates Recovery Plan (Service 2011a, p. 25) recommends that at least three KFAs in each karst fauna region be protected, with at least one in each KFR being high quality in order to ensure the species' long-term survival in the wild is secure. 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) recommends conducting sufficient

research to conclude that these areas provide a high probability of species long-term survival.

Currently, only one area in the Government Canyon KFR meets the definition of a high quality KFA as defined in recovery criteria (1) and four are proposed. Three areas in the Helotes and five in the UTSA KFR have the potential to meet either a high or medium quality KFA provided adequate management and protections are put in place. No areas in the Stone Oak or Culebra Anticline have the potential to meet either a high or medium quality KFA. At present, recovery criteria for the Madla Cave meshweaver have not been achieved and threats from increasing development due to rapidly growing human populations in Bexar County are projected to continue. At this time, we do not recommend a change in listing status for the Madla Cave meshweaver.

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 Madla Cave meshweaver 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. Continue genetics work on C*icurina* specimens to ensure multiple lines of evidence exist to support species delimitation in known and new locations.

II. Gather additional specimens and conduct genetics work to determine range of *C. cf. madla* and other *Cicurina* species versus the Madla Cave meshweaver in counties west of Government Canyon KFR.

III. Resolve uncertainty around the Braken Bat Cave locality. This includes collecting/locating additional specimens of *Cicurina* in and around Braken Bat Cave, including juvenile museum specimens, and using genetic tests and measurements of troglomorphic index (when appropriate) to determine extent of ME clade in Culebra Anticline.

IV. Continue efforts to establish karst fauna areas or other protected sites for the Madla Cave meshweaver throughout its range.

V. Apply recovery criterion 2 to karst fauna areas that qualify.

VI. Reassess the current karst fauna regions of Bexar County, Texas using current data and revise regions as necessary to better inform recovery efforts.

5.0 REFERENCES

Avise, J.C. and R.K. Selander. 1972. Evolutionary genetics of cave-dwelling fishes of the genus *Astyanax*. Evolution 26(1): 1-19.

Barr, T.C., Jr. 1968. Cave ecology and the evolution of troglobites. Evolutionary Biology 2: 35-102.

Badino, G. 2010. Underground meteorology – "What's the weather underground?" Acta Carsologica 39: 427-448.

Bichuette, M.E., A.R. Nascimento, D.M. von Schimonsky, J.E. Gallão, L.P.A. Resende, and T. Zepon. 2017. Neotropical Biology and Conservation 12(2): 75-90.

Bowman Consulting Group, Ltd. 2017. Southern Edwards Plateau Habitat Conservation Plan Government Canyon State Natural Area Karst Fauna Areas Management and Monitoring Plan. February 2017. 42 pp.

Brueckner, J.K. 2000. Urban sprawl: diagnosis and remedies. International Regional Science Review 23(2): 160-171.

Bull, E. and R.W. Mitchell. 1972. Temperature and relative humidity responses of two Texas cave-adapted millipedes, *Cambala speobia* (Cambalida: Cambalidae) and *Speodesmus bicornourus* (Polydesmida: Vanhoeffeniidae). International Journal of Speleology 4: 365-393.

Cohen, L. 1996. From town center to shopping center: the reconfiguration of community marketplaces in postwar America. The American Historical Review 101(4): 1050-1081.

Cokendolpher, J.C. 2004. *Cicurina* spiders from caves in Bexar County, Texas. Texas Memorial Museum Speleological Monographs, 6. Studies on the cave and endogean fauna of North America IV: 13–58.

Cokendolpher, J.C. 2012. Adult female *Cicurina* spider identifications Features 151-015 and 151-019 HWY 151 at Loop 1604, Bexar County, Texas. Unpublished report for Texas Department of Transportation. 8 pp.

Cook, B.I., T.R. Ault., and J.E. Smerdon. 2015. Unprecedented 21st century drought risk in the American Southwest and Central Plains. Science Advances 1 (1): e1400082.

Covington, M.D. and M. Perne. 2015. Consider a cynlindrical cave: A physicist's view of cave and karst science. Acta Carsologica 44: 363-380.

Cowley J.S. and S.R. Spillete. 2001. Exurban residential development in Texas. Real Estate Center, Texas A&M University, Technical report 1470. 22 pp.

Crouau-Roy, B., Y. Crouau, and C. Ferre. 1992. Dynamic and temporal structure of the troglobitic beetle *Speonomus hydrophilus* (Coleoptera: Bathysciinae). Ecography 15(1): 12-18.

Culver, D.C. 1982. Cave life: Evolution and Ecology. Harvard University Press, Cambridge, MA, USA. 189 pp.

Culver, D.C. and T. Pipan. 2009. The biology of caves and other subterranean habitats. Oxford University Press. 256 pp.

Culver, D.C., M.C. Christman, B. Sket, and P. Trotelj. 2004. Sampling adequacy in an extreme environment: species richness patterns in Slovenian caves. Biodiversity and Conservation 13: 1209-1229.

de Freitas, C.R. and R.N. Littlejohn. 1987. Cave climate: assessment of heat and moisture exchange. Journal of Climatology 7: 553-569.

Digital Globe. 2019. EnhancedView Web Hosting Service (EV-WHS). Accessed August 2019 from https://evwhs.digitalglobe.com/myDigitalGlobe.

Elliott, W.R. 1994. Community ecology of three caves in Williamson County, Texas: a three-year summary. 1993 Annual Report for Simon Development Co., Inc., U.S. Fish and Wildlife Service and Texas Parks and Wildlife.

Elliott, W.R. and J.R. Reddell. 1989. The status and range of five endangered arthropods from caves in the Austin, Texas, Region. A report on a study supported by the Texas Parks and Wildlife Department and the Texas Nature Conservancy for the Austin Regional Habitat Conservation Plan. 75 pp.

Espinasa, L., N.D. Bartolo, D.M. Centone, C.S. Haruta, and J.R. Reddell. 2016. Revision of genus *Texoreddellia* Wygodzinsky, 1973 (Hexapoda, Zygentoma, Nicoletiidae), a prominent element of the cave-adapted fauna of Texas. Zootaxa 4126(2): 221-239.

Ferreira, R.L., R.P. Martins, and D. Yanega. 2000. Ecology of bat guano arthropod communities in a Brazilian dry cave. Ecotropica 6(2): 105-116.

Frey, W.H. 2012. Population growth in metro America since 1980: putting the volatile 2000s in perspective. Metropolitan Policy Program, The Brookings Institution, Washington, D.C. 27 pp.

Frumkin, A. 2013. Caves and karst hydrogeology of Jerusalem, Israel. Pages 60-65 in Filippi, M. and P. Bosák, editors. Proceedings of the 13th International Congress of Speleology. 453 pp.

Garrison, N.L., J. Rodriguez, I. Agnarsson, J.A. Coddington, CE. Griswold, C.A. Hamilton, M. Hedin, K.M. Kocot, J.M. Ledford, and J.E. Bond. 2016. Spider phylogenomics: untangling the Spider Tree of Life. PeerJ 4:e1719; DOI10.7717/peerj.1719.

Gertsch, W.J. 1992. Distribution patterns and speciation in North American cave spiders with a list of the troglobites and revision of the cicurinas of the subgenus *Cicurella*. Texas Memorial Museum Speleological Monographs 3. Studies on the endogean fauna of North America 2: 75–122.

Hansen, A.J., R.L. Knight, J.M. Marzluff, S. Powell, K. Brown, P.H. Gude, and K. Jones. 2005. Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. Ecological Applications 15(6): 1893-1905.

Hauwert, N. 2009. Groundwater flow and recharge within the Barton Springs segment of the Edwards Aquifer, southern Travis and northern Hays counties, Texas. University of Texas at Austin Dissertation. 645 pp.

Hedin, M. 2015. High stakes species delimitation in eyeless cave spiders (*Cicurina*, Dictynidae, Araneae) from central Texas. Molecular Ecology 24: 346–361. https://doi.org/10.1111/mec.13036.

Heimlich, R.E. and W.D. Anderson. 2001. Development at the urban fringe and beyond: Impacts on agriculture and rural land. Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 803. 80 pp.

Holsinger, J.R. 1988. Troglobites: The evolution of cave-dwelling organisms. American Scientist 76: 147-153.

Howarth, F.G. 1980. The zoogeography of specialized cave animals: a bioclimatic model. Evolution 34(2): 394-406.

Howarth, F.G. 1983. Ecology of cave arthropods. Annual Review of Entomology 28: 365-389.

Howarth, F.G. 1993. High-stress subterranean habitat and evolutionary change in cave inhabiting arthropods. The American Naturalist 142: 65-77.

Hunt, B.B., B.A. Smith, M.T. Adams, S.E. Hiers, and N. Brown. 2013. Cover-collapse sinkhole development in the cretaceous Edwards Limestone, central Texas. Pages 89-102 in Land, L, D.H. Doctor, and J.B. Stephenson, editors. Proceedings of the 13th Multidisciplinary Conference, May 6-10, Carlsbad, New Mexico: NCKRI Symposium 2. Carlsbad (NM): National Cave and Karst Research Institute. 480 pp.

Huxel, G.R. and A. Hastings. 1999. Habitat loss, fragmentation, and restoration. Restoration Ecology 7(3): 309-315.

Jaffé, R., X. Prous, A. Calux, M. Gastauer, G. Nicacio, R. Zampaulo, P.W.M. Souza-Filho, G. Oliveira, I.V. Brandi, and J.O. Siqueira. 2018. Conserving relics from ancient underground worlds: assessing the influence of cave and landscape features on obligate iron cave dwellers from the eastern Amazon. PeerJ 6:e4531:DOI 10.7717/peerj.4531.

Jaffé, R., X. Prous, R. Zampaulo, T.C. Giannini, V.L. Imperatriz-Fonesca, C. Maurity, G. Oliviera, I.V. Brandi, J.O. Siqueira. 2016. Reconciling mining with the conservation of cave biodiversity: a quantitative baseline to help establish conservation priorities. PLoS ONE 11 (12): e0168348. doi:10.1371/journal.pone.0168348.

Jasinska, E.J., B. Knott, and A.J. McComb. 1996. Root mats in ground water: a fauna-rich cave habitat. Journal of the North American Benthological Society 15(4): 508-519.

Jiang, X. and Z. Yang. 2012. Projected changes of temperature and precipitation in Texas from downscaled global climate models. Climate Research 53: 229-244.

Jiménez-Valverde. A., A. Sendra, P. Garay, and A.S.P.S. Reboleira. 2017. Energy and speleogenesis: key determinants of terrestrial species richness in caves. Ecology and Evolution 7: 10207-10215.

Kane, T.C. and T.L. Poulson. 1976. Foraging by cave beetles: spatial and temporal heterogeneity of prey. Ecology 57(4): 793-800.

King, J.R. and W.R. Tschinkel. 2013. Experimental evidence for weak effects of fire ants in a naturally invaded pine-savanna ecosystem in north Florida. Ecological Entomology 38: 68-75.

Krejca, J.K. and F.W. Weckerly. 2007. Detection probabilities of karst invertebrates. Report prepared for Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service. 27 pp.

Landis, J. 2009. The changing shape of metropolitan America. Annals of the American Academy of Political and Social Science 626: 154-191.

Lavoie, K.H., K.L. Helf, and T.L. Poulson. 2007. The biology and ecology of North American cave crickets. Journal of Cave and Karst Studies 69: 114-134.

LeBrun, E. 2017. Mitigating impact of tawny crazy ant populations on endangered karst invertebrates: quantifying harm and designing environmentally safe control methods. Final Performance Report Grant No. TX E-172-R. Texas Parks and Wildlife Department. 41 pp.

LeBrun, E. G., J. Abbott, and L. E. Gilbert. 2013. Imported crazy ant extirpates imported fire ant, diminishes and homogenizes native ant and arthropod assemblages. Biological Invasions DOI 10.1007/s10530-013-0463-6.

LeBrun, E.G., R.M. Plowes, and L.E. Gilbert. 2012. Imported fire ants near the edge of their range: disturbance and moisture determine prevalence and impact of an invasive social insect. Journal of Animal Ecology 81: 884-895.

Ledford, J., P. Paquin, J. Cokendolpher, J. Campbell, and C. Griswold. 2012. Systematics, conservation and morphology of the spider genus *Tayshaneta* (Araneae, Leptonetidae) in central Texas caves. ZooKeys 167: 1-102.

Longley, G. 1981. The Edwards Aquifer: Earth's most diverse groundwater ecosystem? International Journal of Speleology 11: 123-128.

Mammola, S. and M. Isaia. 2016. The ecological niche of a specialized subterranean spider. Invertebrate Biology 135(1): 20-30.

Mammola, S. and M. Isaia. 2017. Spiders in caves. Proceedings of the Royal Society of Biology 284: 1-10.

Mammola, S., E. Piano, P.M. Giachino, and M. Isaia. 2015. Seasonal dynamics and micro-climatic preference of two Alpine endemic hypogean beetles. International Journal of Speleology 44(3): 239-249.

Martín, J.L. and P. Oromí. 1986. An ecological study of Cueva de los Roques lava tube (Tenerife, Canary Islands). Journal of Natural History 20: 375-388.

Marzluff, J.M. and K. Ewing. 2001. Restoration of fragmented landscapes for the conservation of birds: a general framework and specific recommendations for urbanizing landscapes. Restoration Ecology 9(3): 280-292.

McKinney, M.L. 2002. Urbanization, biodiversity, and conservation. BioScience 52(10): 883-890.

McKinney, M.L. 2008. Effects of urbanization on species richness: a review of plants and animals. Urban Ecosystems 11: 161-176.

Mitchell, R.W. 1971. Food and feeding habits of the troglobitic carabid beetle *Rhadine subterranea*. International Journal of Speleology 3: 249-270.

Milly, P.C.D, K.A. Dunny, and A.V. Vecchia. 2005. Global pattern of trends in streamflow and water availability in a changing climate. Nature 438: 347-350.

Mosely, M. 2009. Estimating diversity and ecological status of cave invertebrates: some lessons and recommendations from Dark Cave (Batu Caves, Malaysia). Cave and Karst Science 35: 47-52.

Moulds, T.A., N. Murphy, M. Adams, T. Reardon, M.S. Harvey, J. Jennings, and A.D. Austin. 2007. Phylogeography of cave pseudoscorpions in southern Australia. Journal of Biogeography 34(6): 951-962.

Neumann, M. and E. Bright. 2008. Texas urban triangle: framework for future growth. Report to the Southwestern Region University Transportation Center. 34 pp.

Nowak, D.J. and E.J. Greenfield. 2018. US urban forest statistics, values, and projections. Journal of Forestry 116(2): 164-177.

Oguz, H., A.G. Klein, and R. Srinivasan. 2008. Predicting urban growth in a US metropolitan area with no zoning regulation. International Journal of Natural and Engineering Sciences 2(1): 9-19.

Pape-Dawson Engineers, Inc. (Pape-Dawson). 2017. Karst Preserve Management Plan for the Stevens Ranch Preserves. 29 pp.

Pape, R.B. and B.M. O'Connor. 2014. Diversity and ecology of the macro-invertebrate fauna (Nemata and Arthropoda) of Kartchner Caverns, Cochise County, Arizona, United States of America. Check List 10(4): 761-794.

Paquin, P. and N. Dupérré. 2009. A first step towards the revision of *Cicurina*: redescription of type specimens of 60 troglobitic species of the subgenus *Cicurella* (Araneae: Dictynidae), and a first visual assessment of their distribution. Zootaxa 2002: 1-67.

Paquin, P. and M. Hedin. 2004. The power and perils of 'molecular taxonomy': a case study of eyeless and endangered *Cicurina* (Araneae: Dictynidae) from Texas caves. Molecular Ecology 13(10): 3239–3255.

Paquin, P. and M. Hedin. 2005. Genetic and morphological analysis of species limits in *Cicurina* spiders (Araneae, Dictynidae) from southern Travis and northern Hays counties (TX), with emphasis on *Cicurina cueva* Gertsch and relatives. Special report for the Department of Interior, United States Fish & Wildlife Service Contract No. 201814G959. Revised version 10 May 2005. 12 pp.

Park, O. 1960. Cavernicolous pselaphid beetles of the United States. The American Midland Naturalist 64(1): 66-104.

Peck, S.B. 1976. The effect of cave entrances on the distribution of cave-inhabiting terrestrial arthropods. International Journal of Speleology 8: 309-321.

Peck, S.B. and J.J. Wynne. 2013. *Ptomaphagus parashant* Peck and Wynne, new species (Coleoptera: Leiodida: Cholevinae: Ptomaphagini): the most troglomorphic cholevine beetle known from western North America. The Coleopterist's Bulletin 687(3): 309-317.

Pellegrini, T.G., L.P. Sales, P. Aguiar, and R.L. Ferreira. 2016. Linking spatial scale dependence of land-use descriptors and invertebrate cave community composition. Subterranean Biology 18: 17-38.

Potter, L.B. and N. Hoque. 2014. Texas population projections, 2010 to 2050. Office of the State Demographer. 5 pp.

Poulson, T.L. and W.B. White. 1969. The cave environment. Science 165: 971-981.

Poulson, T.L., K.H. Lavoie, and K. Helf. 1995. Long-term effects of weather on the cricket (*Hadenoecus subterraneus*, Orthoptera, Rhaphidophoridae), guano community in Mammoth Cave National Park. American Midland Naturalist 134: 226-236.

Prous, X., R.L. Ferreira, and R.P. Martins. 2004. Ecotone delimitation: epigean-hypogean transition in cave ecosystems. Austral Ecology 29: 374-382.

Pugsley, C. 1984. Ecology of the New Zealand glowworm, *Arachnocampa luminosa* (Diptera: Keroplatidae), in the Glowworm Cave, Waitomo. Journal of the Royal Society of New Zealand 14(4): 387-407.

Rebele, F. 1994. Urban ecology and special features of urban ecosystems. Global Ecology and Biogeography Letters 4: 173-187.

Reddell, J.R. and J.C. Cokendolpher. 2001. Ants (Hymenoptera: Formicidae) from the caves of Belize, Mexico, and California, and Texas (U.S.A.). Texas Memorial Museum, Speleological Monographs 5: 129-154.

Runkle, J., K. E. Kunkel, J. Nielson-Gammon, R. Frankson, S. Champion, B. C. Stewart, and L. Romolo. 2017. Texas State Climate Summary. NOAA Technical Report NESDIS, NOAA National Centers for Environmental Information.

Rupp, D.E., Mote, P.W., Massey, N., Rye, C.J., Jones, R., M.R. Allen. 2012. Did human influence on climate made the 2011 Texas drought more probable? In Explaining Extreme Events of 2011 from a Climate Perspective, pp. 1052-1054. Peterson, T.C., Stott, P.A., and Herring, S., eds. American Meteorological Society.

Scheer, B.C. 2001. The anatomy of sprawl. Places 14(2): 28-37.

Schindel, G. M., and M. Gary. 2018. The Balcones Fault Zone Segment of the Edwards Aquifer of South-Central Texas. Pages 78-85 in Stafford, K. W., and G. Veni, editors. Hypogene Karst of Texas. Texas Speleological Survey, The University of Texas at Austin. Austin, Texas.

Schneider, K. 2009. How the availability of nutrients and energy influence the biodiversity of cave ecosystems. Ph.D. Dissertation. University of Maryland, College Park. 174 pp.

Schneider, K. and D.C. Culver. 2004. Estimating subterranean species richness using intensive sampling and rarefaction curves in a high density cave region in West Virginia. Journal of Cave and Karst Studies 66 (2): 39-45.

Seager, R., M. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H. Huang, N. Harnik, A. Leetmaa, N. Lau, C. Li, J. Velez, and N. Naik. 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. Science 316: 1181-1184.

Sendra, A., A. Jíménez-Valverde, J. Rochat, V. Legros, S. Gasnier, and G. Cazanove. 2017a. A new and remarkable troglobitic *Lepidocampa* Oudemans, 1890 species from La Réunion Island, with a discussion on troglobiomorphic adaptations in campodeids (Diplura). Zoologischer Anzeiger 266: 95-104.

Sendra, A. B. Sket, and P. Stoev. 2017b. A striking new genus and species of troglobitic Campodeidae (Diplura) from central Asia. Subterranean Biology 23: 47-68.

Service (U.S. Fish and Wildlife Service). 2001. Environmental assessment/habitat conservation plan for issuance of an Endangered Species Act Section l0(a)(1)(B) permit for the incidental take of two troglobitic ground beetles (*Rhadine exilis* and *Rhadine infernalis*) and Madla Cave meshweaver (*Cicurina madla*) during the construction and operation of commercial development on the approximately 1,000-acre La Cantera property, San Antonio, Bexar County, Texas. 93 pp.

Service (U.S. Fish and Wildlife Service). 2011a. Bexar County karst invertebrates recovery plan. USFWS, Southwest Region, Albuquerque, NM. 53 pp.

Service (U.S. Fish and Wildlife Service). 2011b. *Rhadine exilis* (no common name), *Rhadine infernalis* (no common name), Madla Cave meshweaver (*Cicurina madla*), Braken Bat Cave meshweaver (*C. venii*), Government Canyon Bat Cave meshweaver (*C. vespera*), Robber Baron Cave meshweaver (*C. baronia*), Cokendolpher cave harvestman (*Texella*

cokendolpheri), Government Canyon Bat Cave spider (*Neoleptoneta microps*), and Helotes mold beetle (*Batrisodes venyivi*) 5-year review: Summary and evaluation. USFWS, Austin Ecological Services Field Office Austin, TX. 23pp.

Service (U.S. Fish and Wildlife Service). 2012. Karst preserve design recommendations. Austin Ecological Services Field Office. 25 pp.

Service (U.S. Fish and Wildlife Service). 2014. Karst preserve management and monitoring recommendations. Austin Ecological Services Field Office. 12 pp.

Service (U.S. Fish and Wildlife Service). 2018. Species status assessment for the Bone Cave harvestman (*Texella reyesi*). Version 1.0 April 2018. Austin, TX. 157 pp.

Simões, M.H., M. Souza-Silva, and R.L. Ferreira. 2014. Cave invertebrates in northwestern Minas Gerais State, Brazil, Endemism, threats and conservation priorities. Acta Carsologica 43(10): 159-174.

Souza, M.F.V.R. and R.L. Ferreira. 2016. Two new troglobitic palpigrades (Palpigradi: Eukoeneniidae) from Brazil. Zootaxa 4171(2): 246-258.

Stafford, K.W., K. Arens, A. Gluesenkamp, O. Knox, J. Mitchell, J. Reddell, A.M. Scott, J. Kennedy, M. Miller, W.H. Russell, P. Sprouse, and G. Veni. 2014. Karst of the Urban Corridor: Bell, Bexar, Comal, Hays, Travis, and Williamson Counties, Texas. Karst Awareness and Education Series, 1: Austin, Texas, Texas Speleological Survey. 110 pp.

Stoev, P., N. Akkari, A. Komerički, G.D. Edgecombe, and L. Bonato. 2015. At the end of the rope: *Geophilus hadesi* sp. n. – the world's deepest cave-dwelling centipede (Chilopoda, Geophilomorpha, Geophilidae). ZooKeys 510: 95-114.

Strategic Mapping Program (StratMap). 2019. Land Parcels, 2019-04-08. Retrieved on July 31, 2019 from https://data.tnris.org/collection/2679b514-bb7b-409f-97f3-ee3879f34448.

SWCA Environmental Consultants (SWCA). 2017. San Antonio Water System Micron Pipeline and Water Resources Integration Program Habitat Conservation Plan. November 2017. 228 pp.

Taylor, S.J., K. Hackley, J. Krejca, M.J. Dreslik, S.E. Greenberg, and E.L. Raboin. 2004. Examining the role of cave crickets (Rhaphidophoridae) in central Texas cave ecosystems: isotope ratios (δ 13C, δ15N) and radio tracking. Illinois Natural History Survey, Center for Biodiversity Technical Report 2004 (9): 1-128.

Taylor, S.J., J.K. Krejca, and M.L. Denight. 2005. Foraging range and habitat use of *Ceuthophilus secretus* (Orthoptera: Rhaphidophoridae), a key trogloxene in central Texas cave communities. American Midland Naturalist 154: 97-114.

Taylor, S.J., J.K. Krejca, and K. Hackley. 2007. Examining possible foraging distances in urban and rural cave cricket populations: carbon and nitrogen isotope ratios (δ13C, δ15N) as indicators of trophic level. Illinois Natural History Survey Technical Report 2007(59): 1-97.

Texas Demographic Center. 2018. Texas population projections data tool result: Bexar County. Retrieved on August 20, 2019 from https://demographics.texas.gov/Data/TPEPP/Projections/Tool.

Theobald, D.M., J.R. Miller, and N.T. Hobbs. 1997. Estimating the cumulative effects of development on wildlife habitat. Landscape and Urban Planning 39: 25-36.

Tobin, B.W., B.T. Hutchins, and B.F. Schwartz. 2013. Spatial and temporal changes in invertebrate assemblage structure from the entrance to deep-cave zone of a temperate marble cave. International Journal of Speleology 42(3): 203-214.

Trajano, E., J.E. Gallão, and M.E. Bichuette. 2016. Spots of high diversity of troglobites in Brazil: the challenge of measuring subterranean diversity. Biodiversity and Conservation 25: 1805-1828.

Turanchik, E.J. and T.C. Kane. 1979. Ecological genetics of the cave beetle *Neaphaenops tellkampfii* (Coleoptera: Carabidae). Oecologia 44(1): 63-67.

Tuttle, M.D. and D.E. Stevenson. 1978. Variation in the cave environment and its biological implications. Pages 108-121 in Zuber, R. J. Chester, S. Gilbert, and D. Rhodes, editors. 1977 National Cave Management Symposium Proceedings. Adobe Press, Albuquerque, New Mexico. 140 pp.

U.S. Census Bureau. 1982. 1980 Census of Population, Characteristics of the Population, Chapter A Number of Inhabitants, Part 45 Texas. U.S. Government Printing Office, Washington, D.C. 49 pp.

U.S. Census Bureau. 2012. 2010 Census of Population and Housing, Population and Housing Unit Counts, CPH-2-45, Texas. U.S. Government Printing Office, Washington, D.C.

U.S. Census Bureau. 2018. Bexar County: annual estimates of housing units for the United States, regions, divisions, states, and counties: April 1, 2010 to July 1, 2018. Retrieved on July 3, 2019 at https://factfinder.census.gov.

U.S. Census Bureau. 2019. Bexar County: annual estimates of the resident population: April 1, 2010 to July 1, 2018. Retrieved on July 3, 2019 at https://factfinder.census.gov.

Veni, G. 1994. Geologic controls on cave development and the distribution of endemic cave fauna in the San Antonio, Texas, region. Report prepared for Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service. 99 pp.

Veni, G. 2003. Delineation of hydrogeologic areas and zones for the management and recovery of endangered karst invertebrate species in Bexar County, Texas. Report for U.S. Fish and Wildlife Service, Austin, Texas. Dated 23 December 2002 with minor revisions submitted 12 April 2003. 75 pp.

Veni, G., J.R. Reddell, and J.C. Cokendolpher. 1999. Management plan for the conservation of rare and endangered karst species, Camp Bullis, Bexar and Comal counties, Texas. Report prepared for Garrison Public Works, Fort Sam Houston, Texas. 160 pp.

Wakefield, K.R. and K.S. Zigler. 2012. Obligate subterranean fauna of Carter State Natural Area, Franklin County, Tennessee. Speleobiology Notes 4: 24-28.

Waltham, T. and Z. Lu. 2007. Natural and anthropogenic rock collapse over open caves. Pages 13-21 in Parise, M. and J. Gunn, editors. Natural and Anthropogenic Hazards in Karst Areas: Recognition, Analysis and Mitigation. Geological Society, London, Special Publications. 202 pp.

Wang, Z., L. Moshman, E.C. Kraus, B.E. Wilson, N. Acharya, and R. Diaz. 2016. A review of the tawny crazy ant, *Nylanderia fulva*, an emergent ant invader in the southern United States: is biological control a feasible option? Insects 7(4): 1-10.

Watson, J., E. Hamilton-Smith, D. Gillieson, and K. Kiernan. 1997. Guidelines for cave and karst protection. International Union for Conservation of Nature and Natural Resources. 53 pp.

Wheeler, W.C., J.A. Coddington, L.M. Crowley, D. Dimitrov, P.A. Goloboff, C.E. Griswold, G. Hormiga, L. Prendini, M.J. Ramírez, P. Sierwald, L. Almeida-Silva, F. Alvarez-Padilla, M.A. Arnedo, L.R. Benavides Silva, S.P. Benjamin, J.E. Bond, C.J. Grismado, E. Hasan, M. Hedin, M.A. Izquierdo, F.M. Labarque, J. Ledford, L. Lopardo, W.P. Maddison, J.A. Miller, L.N. Piacentini, N.I. Platnick, D. Polotow, D. Silva-Dávila, N. Scharff, T. Szűts, D. Ubick, C.J. Vink, H.M. Wood, and J. Zhang. 2017. The spider tree of life: phylogeny of Araneae based on target-gene analyses from an extensive taxon sampling. Cladistics, 33: 574-616. doi:10.1111/cla.12182

World Spider Catalog. 2019. World Spider Catalog. Version 20.0. Natural History Museum Bern. (accessed on 8/15/2019) http://wsc.nmbe.ch.

Wynne, J.J. 2013. Inventory, conservation, and management of lava tubes at El Malpais National Monument, New Mexico. Park Science 30(1): 45-55.

Yoder, J.A., J.B. Benoit, M.J. LaCagnin, H.H. Hobbs III. 2011. Increased cave dwelling reduces the ability of cave crickets to resist dehydration. Journal of Comparative Physiology B 181: 595-601.

You, H. L., L. Potter, L. Valencia, and S. Robinson. 2019. Texas Population Projections 2010-2050. Texas Demographic Center. 7 pp. https://demographics.texas.gov/Resources/publications/2019/20190128_PopProjectionsBrief.pdf

Zipperer, W.C. 2011. The process of natural succession in urban areas. Pages 187-197 in Douglas, I., D. Goode, M. Houck, and R. Wang, editors. The Routledge Handbook on Urban Ecology. Routledge Taylor and Francis Group, London. 688 pp.

U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW of the Government Canyon Bat Cave meshweaver (*Cicurina vespera*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

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

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

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve _____ Date 9/10/2019