[no common name] Beetle
(Rhadine exilis)
5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Austin Ecological Services Field Office
Austin, Texas
September 28, 2021

5-YEAR REVIEW

Species reviewed: [no common name] Beetle (*Rhadine exilis*)

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1.0 GENERAL INFORMATION

1.1 Reviewers:

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

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

Cooperating Field Office(s): N/A

Cooperating Regional Office(s): N/A

1.2 Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (Service or USFWS) is required by section 4(c)(2) of the Endangered Species Act (ESA) to conduct a status review of each listed species once every five years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing as endangered or threatened is based on the species' status considering the five threat factors described in section 4(a)(1) of the ESA. These same five factors are considered in any subsequent reclassification or delisting decisions. In the 5-year review, we consider the best available scientific and commercial data on the species and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process including public review and comment.

1.3 Methodology used to complete the review:

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 May 5, 2021 (86 FR 23976). 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 2011b, 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), 2020 digital aerial photography (ESRI 2021), 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.

1.4 Background:

1.4.1 FR Notice citation announcing initiation of this review:

86 FR 23976, May 5, 2021

1.4.2 Listing history:

Original Listing
FR notice: 65 FR 81419
Date listed: December 26, 2000
Entity listed: (no common name) Beetle (*Rhadine exilis*)
Classification: Endangered

1.4.3 Associated Rulemakings:

August 27, 2002 (67 FR 55064) Proposed critical habitat
April 8, 2003 (68 FR 17155) Final critical habitat
February 22, 2011 (76 FR 9872) Proposed revised critical habitat
August 2, 2011 (76 FR 46234) Extended comment period for proposed revised critical habitat
February 14, 2012 (77 FR 8450) Final revised critical habitat and not warranted 12-month finding on a petition to revise critical habitat designation by removing unit 13 from designation under the Act

1.4.4 Review History:

Status reviews for (no common name) Beetle (*Rhadine exilis*) were conducted in 2000 for the final listing of the species (65 FR 81419) and 2011 in a 5-year review (Service 2011c, entire). The 2011 5-year review recommended no change in classification of endangered (Service 2011c, p. 19).

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

2C

1.4.6 Recovery Plan or Outline

Name of plan or outline: Bexar County Karst Invertebrates Recovery Plan
Date issued: 2011

2.0 REVIEW ANALYSIS

Section 4 of the Act (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species meets the definition of "endangered species" or "threatened species." The Act defines an "endangered species" as a species that is "in danger of extinction throughout all or a significant portion of its range," and a "threatened species" as a species that is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The Act requires that we determine whether a species meets the definition of "endangered species" or "threatened species" due to any of the five factors described above.

The identification of any threat(s) does not necessarily mean that the species meets the statutory definition of an "endangered species" or a "threatened species." In assessing whether a species meets either definition, we must evaluate all identified threats by considering the expected response of the species, and the effects of the threats—in light of those actions and conditions that will ameliorate the threats—on an individual, population, and species level. We evaluate each threat and its expected effects on the species, then analyze the cumulative effect of all of the threats on the species as a whole. We also consider the cumulative effect of the threats in light of those actions and conditions that will have positive effects on the species—such as any existing regulatory mechanisms or conservation efforts. The Service recommends whether the species meets the definition of an "endangered species" or a "threatened species" only after conducting this cumulative analysis and describing the expected effect on the species now and in the foreseeable future.

2.1 Updated Information and Current Species Status

2.1.1 Biology and Habitat

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

No new information

2.1.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, birth rate, seed set, germination rate, age at mortality, mortality rate, etc.), or demographic trends:

No new information.

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

No new information.

2.1.1.4 Taxonomic classification or changes in nomenclature:

Barr (1974) classified the *Rhadine* genus into different species groups using morphological features, such as reduced eyes, that are found in troglobitic (i.e., cave-adapted) species and not found in epigean (i.e., surface dwelling) species (Barr 1974, pp. 4-6; Gomez et al. 2016, p. 171). *Rhadine exilis* is one of 18 species of troglobites (i.e., cave-adapted species) from Texas and two from Mexico placed in the *subterranea* group using these morphological characteristics (Barr 1974, pp. 4-25; Barr 1982, pp. 184-186; Reddell and Cokendolpher 2001, pp. 110-114; Reddell and Cokendolpher 2004, pp. 154-155, 158-161, Reddell and Dupérré 2009, p. 111-114; Gómez et al. 2016, p. 165). Based on genetic analyses, Gomez et al. (2016, entire) found that there are two major clades of *Rhadines.* Clade I is primarily composed of subterranean species, including all troglobitic Texas *Rhadine* and Clade II includes many surface-dwelling species; however, each clade includes both epigean and subterranean species (Gomez et al. 2016, pp. 167-172). This study redefined the *subterranea* group by including several macrophthalmous (i.e., large-eyed) species from both Texas and Mexico and removing the two troglobitic species from Mexico (Gomez et al. 2016, pp. 170-171).

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

At the time of the 2011 5-year review, our records indicated *Rhadine exilis* had been found in 51-53 caves in the Government Canyon, Helotes, UTSA, and Stone Oak Karst Fauna Regions (KFRs) in Bexar County, Texas (Service 2011a, p. 4-10). KFRs are geographic areas that were delineated based on potential discontinuity of karst habitat that may reduce or limit interaction between troglobite populations (Veni 1994, entire). We are using KFRs to serve as recovery units for these species. They are important to the species conservation because they include representation and potential genetic diversity of these species across their range (Service 2011b pp. 18-19). Since the last review, we have corrected several records and added new known and potential localities for this species including several records in the Culebra Anticline KFR. For this review, we are analyzing 65 caves or karst features in five KFRs (Figure 1).

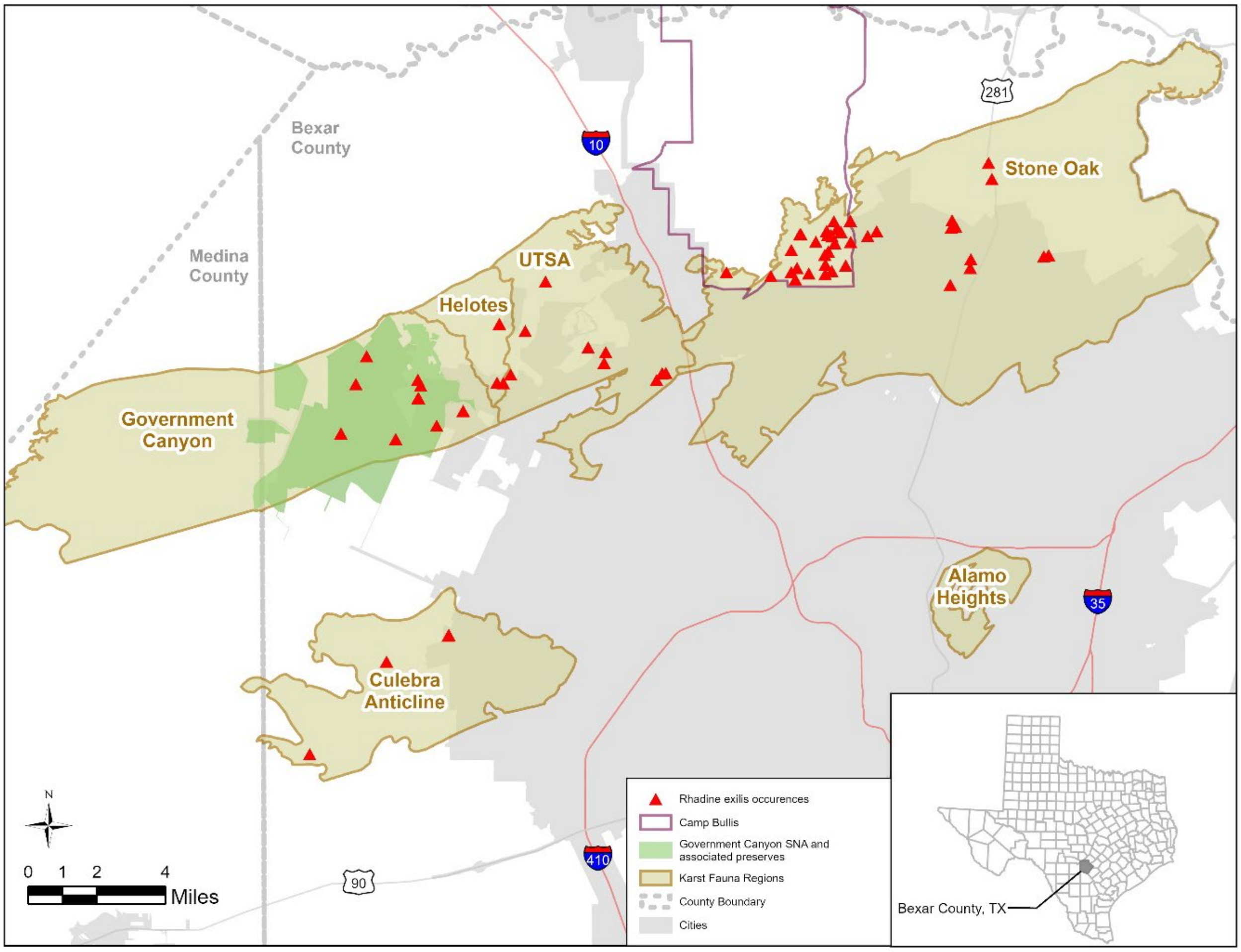

Figure 1. Current distribution of *Rhadine exilis* in Bexar County, Texas

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 *Rhadine exilis*, 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 *Rhadine exilis* dispersal distances may be greater or lesser than that value. Site specific geologic studies and genetic analyses would be necessary to provide more certainty regarding actual dispersal distances and connectivity between individual features.

For each cave occupied or potentially occupied by *Rhadine exilis*, 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 *Rhadine exilis* 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 *Rhadine exilis* occurrences into a total of 12 cave clusters and 25 individual caves (Table 1).

One exception to this methodology was Kamikazi Cricket Cave. Although it occurred within 600 m of Helotes Blowhole Cave, we maintained it as an individual cave site due to its location on the other side of Helotes Creek. This creek is the boundary between the Helotes and UTSA KFRs and may present a barrier or restriction to dispersal of species between these two caves.

Table 1. Cave clusters and individual caves by karst fauna region.

Cave Name	KFR	Cluster	Ownership
Karst Feature 211-C-1[1]	Culebra Anticline	Individual	Texas Department of Transportation (TxDOT)
Rattlesnake Pit[1]	Culebra Anticline	Individual	Private
Beat-the-Snakes Pit[1]	Culebra Anticline	SAWS Pump Station	San Antonio Water System
S-19 (SAWS) [2]	Culebra Anticline	SAWS Pump Station	San Antonio Water System
Big Dome Cave	Government Canyon	Individual	Texas Parks and Wildlife Department (TPWD)
Cowbell Cave	Government Canyon	Individual	Private
Government Canyon Bat Cave	Government Canyon	Individual	TPWD
Lithic Ridge Cave[2]	Government Canyon	Individual	TPWD
Sotol Pit	Government Canyon	Individual	TPWD
Surprise Sink[2]	Government Canyon	Individual	TPWD
Canyon Ranch Pit[2]	Government Canyon	Scenic Overlook Cave Cluster	Private
Creek Bank Cave[2]	Government Canyon	Scenic Overlook Cave Cluster	City of San Antonio
Pig Cave[2]	Government Canyon	Scenic Overlook Cave Cluster	City of San Antonio
San Antonio Ranch Pit	Government Canyon	Scenic Overlook Cave Cluster	City of San Antonio
Tight Cave	Government Canyon	Scenic Overlook Cave Cluster	City of San Antonio
Helotes Blowhole	Helotes	Helotes Hilltop Preserve	Private

Cave Name	**KFR**	**Cluster**	**Ownership**
Helotes Hilltop Cave	Helotes	Helotes Hilltop Preserve	Private
Christmas Cave	Helotes	Individual	Private
Logan^s Cave	Helotes	Individual	Private
40mm Cave	Stone Oak	40mm Cave and Strange Little Cave	Department of Defense (DOD)
Strange Little Cave	Stone Oak	40mm Cave and Strange Little Cave	DOD
Black Cat Cave[1]	Stone Oak	Black Cat Cave Cluster	Private
Encino Park Cave[1]	Stone Oak	Black Cat Cave Cluster	Private
Bunny Hole	Stone Oak	Bunny Hole, Platypus Pit, Josey Wales Cave Cluster	DOD
Josey Wales Cave	Stone Oak	Bunny Hole, Platypus Pit, Josey Wales Cave Cluster	DOD
Platypus Pit	Stone Oak	Bunny Hole, Platypus Pit, Josey Wales Cave Cluster	DOD
B-52 Cave	Stone Oak	Camp Bullis Main Cluster	DOD
Backhole	Stone Oak	Camp Bullis Main Cluster	DOD
Banzai Mud Dauber Cave	Stone Oak	Camp Bullis Main Cluster	DOD
Cross the Creek Cave	Stone Oak	Camp Bullis Main Cluster	DOD
Eagles Nest Cave	Stone Oak	Camp Bullis Main Cluster	DOD
Hanging Rock Cave	Stone Oak	Camp Bullis Main Cluster	DOD
Hold Me Back Cave	Stone Oak	Camp Bullis Main Cluster	DOD
Isocow Cave	Stone Oak	Camp Bullis Main Cluster	DOD

Cave Name	**KFR**	**Cluster**	**Ownership**
MARS Pit	Stone Oak	Camp Bullis Main Cluster	DOD
MARS Shaft	Stone Oak	Camp Bullis Main Cluster	DOD
Pain in the Glass Cave	Stone Oak	Camp Bullis Main Cluster	DOD
Record Fire 1 Pit	Stone Oak	Camp Bullis Main Cluster	DOD
Root Canal Cave	Stone Oak	Camp Bullis Main Cluster	DOD
Hairy Tooth Cave	Stone Oak	Hairy Tooth and Ragin' Cajun Cluster	Private
Ragin’ Cajun Cave	Stone Oak	Hairy Tooth and Ragin' Cajun Cluster	Private
281-163	Stone Oak	Individual	TxDOT
Blanco Cave	Stone Oak	Individual	TxDOT
Boneyard Pit	Stone Oak	Individual	DOD
Classen Feature 7A	Stone Oak	Individual	City of San Antonio
Dos Viboras Cave	Stone Oak	Individual	DOD
Headquarters Cave	Stone Oak	Individual	DOD
Hilger Hole	Stone Oak	Individual	DOD
Platynini Cave	Stone Oak	Individual	TxDOT
Poor Boy Baculum Cave	Stone Oak	Individual	DOD
Root Toupee Cave	Stone Oak	Individual	DOD
Up the Creek Cave	Stone Oak	Individual	DOD
Boulder Cave	Stone Oak	Panther Springs Preserve KFA	City of San Antonio
Lucy and Toto’s Cave	Stone Oak	Panther Springs Preserve KFA	City of San Antonio
Hornet^s Last Laugh Pit	Stone Oak	Springtail Crevice Cave Cluster	City of San Antonio
Kick Start Cave	Stone Oak	Springtail Crevice Cave Cluster	City of San Antonio

Cave Name	KFR	Cluster	Ownership
Springtail Crevice	Stone Oak	Springtail Crevice Cave Cluster	City of San Antonio
John Wagner Ranch Cave No. 3	UTSA	Individual	Private
Kamikazi Cricket Cave	UTSA	Individual	Private
Three Fingers Cave	UTSA	Individual	Private
Young Cave No. 1	UTSA	Individual	Private
La Cantera Cave No.1	UTSA	La Cantera Cluster	Private
La Cantera Cave No.2	UTSA	La Cantera Cluster	Private
Mastodon Pit	UTSA	La Cantera Cluster	Private
Hills and Dales Pit	UTSA	Robber's Cave and Hills and Dales Pit	Private
Robber’s Cave	UTSA	Robber's Cave and Hills and Dales Pit	City of San Antonio

[1] Specimen described as *Rhadine exilis*? Genetic/morphological analysis of additional specimens would allow these to be more confidently placed to species.
[2] Sight record – Either specimen records are missing, or the species has been seen and a specimen has not been collected from this cave. Collection or recollection of a voucher specimen and examination by a taxonomist would be necessary to provide confidence that this cave is occupied by *Rhadine exilis*.

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

The population needs of *Rhadine exilis* 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 *Rhadine exilis* 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 2020 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 basins, if known. As we lack maps of most caves' footprints, 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) using values generated for each habitat element (Service 2018, p. 53). Based on this evaluation, sites assigned to high and moderate resiliency are those located in larger tracts of open land (i.e., greater than 16 ha [40 ac]), less likely to be experiencing edge effects (i.e., greater than 120 m (394 ft) from an edge), with a greater potential to support cave cricket foraging (i.e., the area within 105 m (394 ft) of the cave footprint is not impacted by development). 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 *Rhadine exilis* 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 *Rhadine exilis* over the long-term.

Impacts to a cave's surface or subsurface drainage basin can be a significant source of stressors for *Rhadine exilis* 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 *Rhadine exilis* persistence.

Based on this review, 10 cave clusters and 13 individual caves are currently of high to moderate resiliency with potential to support *Rhadine exilis* populations over the long-term (Table 2). This includes one cave cluster and five individual caves in the Government Canyon KFR, one cave cluster in the Helotes KFR, five cave clusters and six individual caves in the Stone Oak KFR, two cave clusters and two individual caves in the UTSA KFR, and one cave cluster in the Culebra Anticline KFR. For the most part, these sites are in larger tracts of open space and have relatively unaltered cave cricket foraging areas and drainage basins. There is one cave in the Government Canyon KFR (Cowbell Cave) that we were unable to analyze because its location is uncertain.

Table 2. Current resiliency of *Rhadine exilis* sites (cave clusters and individual caves) by karst fauna region.

Karst Fauna Region	High	Moderate	Low	Impaired
Government Canyon	6	0	0	0
Helotes	0	1	1	1
UTSA	2	2	2	0
Stone Oak	9	2	2	5
Culebra Anticline	0	1	0	2
Total	17	6	5	8

2.1.1.7 Other:

No new information.

2.1.1.8 Conservation Measures:

Government Canyon Karst Fauna Region

<u>Government Canyon State Natural Area Karst Fauna Areas</u>

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 several areas containing caves with listed species. Government Canyon Bat Cave, Lithic Ridge Cave, Sotol Pit, and Surprise Sink all occur on Government Canyon State Natural Area, which is owned by Texas Parks and Wildlife Department. They occur in the approximately, 40 ha (100ac) Government Canyon Bat Cave KFA; 90 ha (223 ac) Lithic Ridge, Dancing Rattler, and Hackberry Sink KFA; 58 ha (144 ac) Surprise Sink and Bone Pile Cave KFA and 40 ha (100 ac) 10K Cave KFA respectively. Creek Bank Cave and Tight Cave occur on a 171 ha (423 ac) parcel purchased through the section 6 HCP Land Acquisition Program. Portions of this parcel, as well as a portion of an adjacent Government Canyon State Natural Area and a City of San Antonio parcel make up the 40 ha (100 ac) Tight KFA.

These preserves encompass the cave cricket foraging areas and are believed to include the surface and subsurface drainage basins of these caves. Management for these preserves are 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 inter-local 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 areas as high quality KFAs for *Rhadine exilis*.

Other Protected Caves

Big Dome Cave occurs on Government Canyon State Natural Area. Canyon Ranch Pit occurs 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). Pig Cave and San Antonio Ranch Pit 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 undeveloped and are believed to occur within the boundaries of these parcels. With confirmation of appropriate management and monitoring, there is enough area around these caves to meet the criteria for one or more high quality KFAs.

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.

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 may meet the definition of a high quality KFA.

John Wagner Ranch Cave No. 3

This privately owned cave is located on a 2-ha (4-ac) preserve. This preserve is adjacent to the Rancho Diana preserve, which is about 466 ha (1,152 ac) and is owned by the City of San Antonio. A portion of the cave cricket foraging area and subsurface drainage basins for this cave have been impacted by development on adjacent parcels. The John Wagner Ranch Preserve is managed per the La Cantera Habitat Conservation Plan (Service 2001, entire).

Stone Oak KFR

Panther Springs Preserve KFA

Boulder Cave and Lucy and Toto's Cave occur within a 37 ha (91 ac) preserve on Panther Springs Park which was donated by the San Antonio River Authority to the City of San Antonio in 2001. The cave cricket foraging area and surface and subsurface drainage basin for Boulder Cave are within the preserve boundaries. The surface and subsurface drainage basins for Lucy and Toto's cave have not been delineated and its footprint has not been mapped so it is unknown if these are within the preserve. The preserve is being managed by the City of San Antonio Parks and Recreation Department and the Service has recognized this preserve as a medium quality KFA for *Rhadine exilis* (Blair Wildlife Consulting 2018, entire).

Springtail Crevice Cave Cluster

Kick Start Cave, Springtail Crevice Cave, and Hornet's Last Laugh Pit occur on 67-ha (165-ac) park owned by the City of San Antonio. The cave cricket foraging area for two of the three caves is undeveloped. The normal surface drainage basins of Kick Start Cave and Hornet's Last Laugh are unaltered and included in the park. However, the park and caves are in a stormwater retention reservoir, which periodically floods these caves and the floodwater may come from outside the normal drainage basins as they are currently delineated. The surface drainage basin for Springtail Crevice is not included in the park. The subsurface drainage basins of all three caves are included in the park except for a small portion of the Springtail Crevice. With confirmation of appropriate management and monitoring, there is enough area around these caves to meet the criteria for a high quality KFAs, however, since the park is a stormwater retention reservoir, runoff that has entered this reservoir may have degraded the subterranean habitat quality of the caves.

Culebra Anticline KFR

San Antonio Water System (SAWS) Pump Station Preserve

Beat-the-Snakes Pit (formerly known as S-29 (SAWS)) and S-19 (SAWS) are located on an approximately 23.1 ha (57-ac) area protected by the San Antonio Water System through the San Antonio Water System Micron Pipeline and Water Resources Integration Program Habitat Conservation Plan (SWCA 2017, p. 56). The preserve currently includes the surface and subsurface drainage basins and most of the cave cricket foraging area for Beat-the-Snakes-Pit. SAWS has committed to perpetual management and monitoring of this preserve consistent with the Service's Karst Preserve Management and Monitoring Recommendations as a part of their habitat conservation plan (SWCA 2017, p. 60). This preserve could meet the criteria for a medium quality KFA with confirmation of protection of the cave cricket foraging area for Beat-the-Snakes Pit and receipt of a final karst management plan.

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

2.1.2.1 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 2,009,324 people (U.S. Census Bureau 1982, p. 8; U.S. Census Bureau 2021) and is expected to increase to 3,353,060 people 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).

Rhadine exilis, 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 *Rhadine exilis* population viability and the species' long-term persistence. Land conversion to residential and commercial development has already reduced and degraded surface habitats surrounding almost 40% of the known occupied sites. Given population and urbanized land growth projections (Texas Demographic Center 2018; Nowak and Greenfield 2018, p. 170), it is likely that much of the remaining surface and subsurface habitats will be impacted in the absence of management and protection.

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

No new information.

2.1.2.3 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). Suspected tawny crazy ant populations have been identified at several caves on Camp

Bullis. Additional research is needed to determine the potential for the tawny crazy ant to affect *Rhadine exilis* populations.

2.1.2.4 Inadequacy of existing regulatory mechanisms:

No new information.

2.1.2.5 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 (i.e.., RCP 4.5) the coldest years will feel like the warmest years today, and the warmest years will be about six degrees (Fahrenheit) warmer than the hottest year from the historical record (Runkle et al. 2017, p. 1). Warming under a higher emissions scenario (i.e., 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 *Rhadine exilis*, 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 *Rhadine exilis* populations.

2.2 Synthesis

Based on a review of available data, three of the five KFRs that *Rhadine exilis* occurs in have three or more areas currently of sufficient resiliency with the potential to support *Rhadine exilis* 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 *Rhadine exilis* 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.

Recovery criterion (1) in the Bexar County Karst Invertebrates Recovery Plan (Service 2011b, p. 25) recommends that at least three Karst Fauna Areas (KFAs) in each KFR 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, one preserve in the Stone Oak KFR meets the definition of a medium quality KFA and the Service is working with the City of San Antonio to recognize five additional areas in the Government Canyon KFR as high quality KFAs. At least one additional area the Government Canyon KFR one in the Helotes KFR, four in the UTSA, and one in the Culebra Anticline have the potential to meet either a high or medium quality KFA provided adequate management and protections can be put in place. There are at least an additional 10 potential high or moderate resiliency caves and cave clusters in the Stone Oak KFR; however, all of these occur on Department of Defense Lands. Although they are being monitored and managed, their permanent protection cannot be assured.

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. Given the current status of the species in relation to these ongoing threats and to the existing recovery criteria, we do not recommend a change in listing status for *Rhadine exilis* at this time.

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 (indicate if no change; see 48 FR 43098):

No Change Recommended

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. *Rhadine exilis* 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 efforts to establish karst fauna areas or other protected sites for *Rhadine exilis* throughout its range.
II. Apply recovery criterion 2 to karst fauna areas that qualify.
III. Gather additional specimens and morphological character and DNA data to further refine the species limits in the *subterranea* group and help resolve uncertainties of placement for *Rhadine exilis*? specimens.
IV. Continue collecting efforts to confirm *Rhadine exilis* occurrence in caves currently recorded as sight records.
V. 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.

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

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

Barr, T.C., Jr. 1974. Revision of *Rhadine* LeConte (Coleoptera: Carabidae) I. The subterranean group. American Museum Novitates 2539: 1-30.

Barr, T. C., Jr. 1982. The cavernicolous anchomenine beetles of Mexico (Coleoptera: Carabidae: Agonini). Pages 161-192 *in* J. Reddell, editor. Further studies on the cavernicole fauna of Mexico and adjacent regions. Association for Mexican Cave Studies Bulletin 8 and Texas Memorial Museum Bulletin 28. The Speleo Press, Austin.

Blair Wildlife Consulting, LLC. 2018. Southern Edwards Plateau Habitat Conservation Plan Panther Springs Preserve Karst Fauna Area. Report prepared for County of Bexar and City of San Antonio. 37 pp.

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.

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.

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 cylindrical 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.

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

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.

ESRI. 2021. World Imagery Basemap. https://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer.

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.

Gómez, R.A., J. Reddell, K. Will, and W. Moore. 2016. Up high and down low: molecular systematics and insight into the diversification of the ground beetle genus *Rhadine* LeConte. Molecular Phylogenetics and Evolution 98: 161-175.

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.

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.

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.

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

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.

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

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.

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.

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.

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.

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.

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

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

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.

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.

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.

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. A new species of troglobitic *Rhadine* (Coleoptera: Carabidae) from Texas. Texas Memorial Museum, Speleological Monographs 5: 109- 114.

Reddell, J.R. and J.C. Cokendolpher. 2004. New species and records of cavernicole *Rhadine* (Coleoptera: Carabidae) from Camp Bullis, Texas. Texas Memorial Museum, Speleological Monographs 6:153-162.

Reddell, J. R., and N. Dupérré. 2009. A new species of troglobitic *Rhadine* (Coleoptera: Carabidae) from Hays County, Texas. Texas Memorial Museum, Speleological Monographs 7:111–114.

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.

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.

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 invertebrate distribution. Austin Ecological Services Field Office. 13 pp.

Service (U.S. Fish and Wildlife Service). 2011b. Bexar County karst invertebrates recovery plan. USFWS, Southwest Region, Albuquerque, NM. 53 pp.31

Service (U.S. Fish and Wildlife Service). 2011c. *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.

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., 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.

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.

U.S. Census Bureau. 2021. Explore Census Data. Retrieved on September 27, 2021 at https://data.census.gov/cedsci/profile?g=0500000US48029.

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

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., 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.

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.

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 [no common name] Beetle (*Rhadine exilis*)

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, Austin Ecological Services Field Office

Approve Wade Harrell Digitally signed by Wade Harrell Date: 2021.09.28 13:09:39 -05'00' ____