

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

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5-YEAR REVIEW
[no common name] Beetle (*Rhadine infernalis*)

1.0 GENERAL INFORMATION

1.1 Reviewers:

Lead Regional Office: Southwest Regional Office, Region 2,
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Lead Field Office: Austin Ecological Services Field Office
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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 infernalis*)

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 infernalis*) 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 epigeal (i.e., surface dwelling) species (Barr 1974, pp. 4-6; Gómez et al. 2016, p. 171). *Rhadine infernalis* 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, Gómez 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 epigeal and subterranean species (Gómez 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 (Gómez et al. 2016, pp. 170-171). This study also indicated that *Rhadine infernalis* may be paraphyletic as currently delimited (Gómez 2016, pp. 169, 172). Additional genetic and morphological analyses of the troglobitic Texas *Rhadine* would be necessary to better understand the species limits for *Rhadine infernalis*.

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 infernalis* had been found in 39 caves in the Government Canyon, Helotes, UTSA, Stone Oak, and Culebra Anticline 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. For this review, we are analyzing 75 caves or karst features in five KFRs (Figure 1).

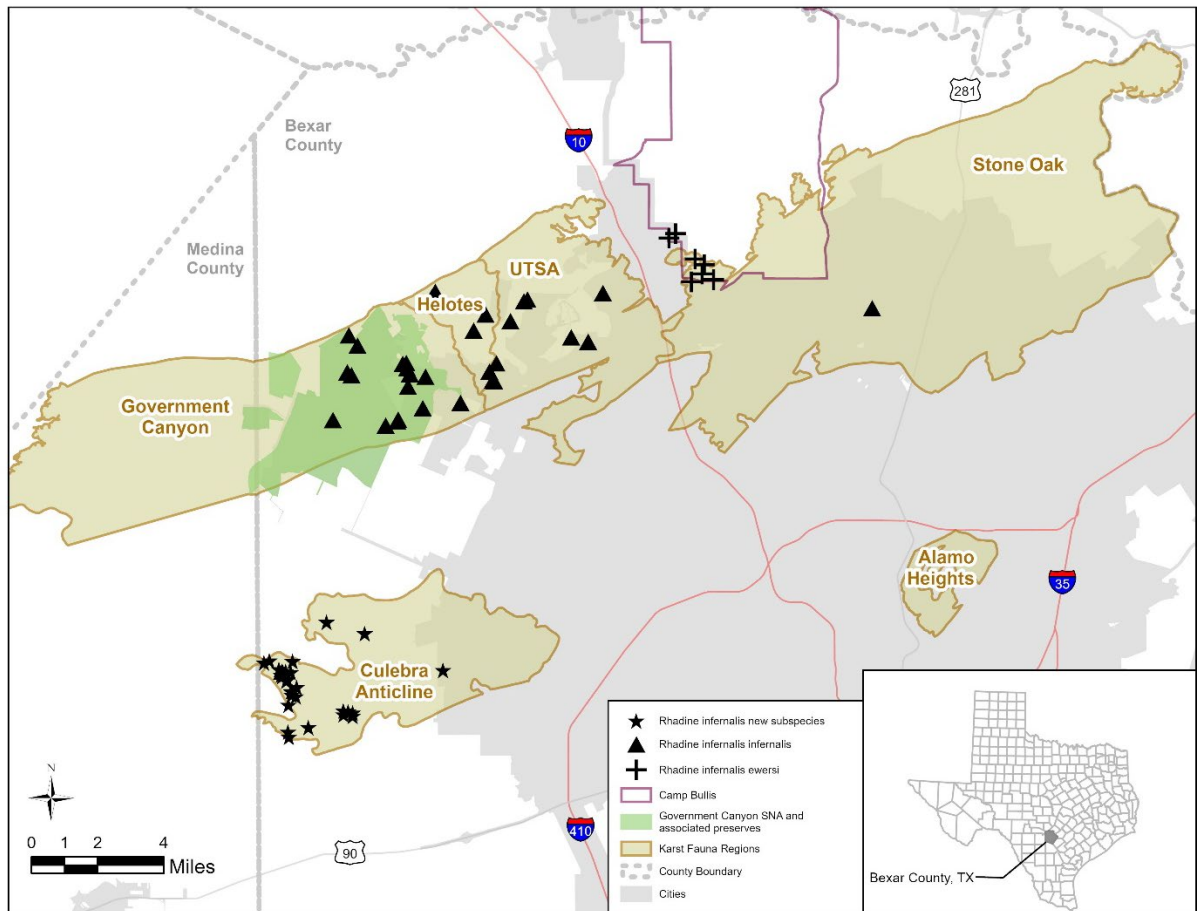


Figure 1. Current distribution of *Rhadine infernalis* in Bexar County, Texas

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 (Avisé 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 infernalis*, 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 infernalis* 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 infernalis*, 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 overlapped (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 infernalis* 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 infernalis* occurrences into a total of 12 cave clusters and 25 individual caves (Table 1).

Two exceptions to this methodology were Kamikazi Cricket Cave and Mattke Cave and Scorpion Cave Cluster. Although each of these occurred within 600 m (1968 ft) of Helotes Blowhole Cave, we maintained them as an individual sites due to their 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 sites.

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

Cave Name	Sub-species¹	KFR	Cluster	Ownership
Dancing Rattler Cave	I	Government Canyon	Dancing Rattler Cave and Hackberry Sink	Texas Parks and Wildlife Department (TPWD)
Hackberry Sink	I	Government Canyon	Dancing Rattler Cave and Hackberry Sink	TPWD
Canyon Ranch Pit	U	Government Canyon	Scenic Overlook Cave Cluster	Private
Fat Man's Nightmare Cave	I	Government Canyon	Scenic Overlook Cave Cluster	Private
Pig Cave	I	Government Canyon	Scenic Overlook Cave Cluster	City of San Antonio
San Antonio Ranch Pit	I	Government Canyon	Scenic Overlook Cave Cluster	City of San Antonio
Scenic Overlook Cave	I	Government Canyon	Scenic Overlook Cave Cluster	Private
Bone Pile Cave	I	Government Canyon	Surprise Sink and Bone Pile Cave	TPWD
Surprise Sink	I	Government Canyon	Surprise Sink and Bone Pile Cave	TPWD

Cave Name	Sub-species¹	KFR	Cluster	Ownership
10K Cave	I	Government Canyon	Individual	TPWD
Big Dome Cave	I	Government Canyon	Individual	TPWD
Continental Park Cave	I	Government Canyon	Individual	City Public Service (CPS)
Government Canyon Bat Cave	I	Government Canyon	Individual	TPWD
Government Canyon Blowhole	I	Government Canyon	Individual	TPWD
Lithic Ridge Cave	I	Government Canyon	Individual	TPWD
Sir Doug's Cave	U	Government Canyon	Individual	Private
Sure Sink ²	U	Government Canyon	Individual	TPWD
Tight Cave	I	Government Canyon	Individual	TPWD
Helotes Blowhole	I	Helotes	Helotes Hilltop Preserve	Private
Helotes Hilltop Cave ²	U	Helotes	Helotes Hilltop Preserve	Private
Logan's Cave	I	Helotes	Logan's Cave and Madla's Drop Cave	Private
Madla's Drop Cave	I	Helotes	Logan's Cave and Madla's Drop Cave	Private
Christmas Cave	I	Helotes	Individual	Private

Cave Name	Sub-species¹	KFR	Cluster	Ownership
Madla's Cave	I	Helotes	Individual	Private
Dirt in My Eye Cave	E	Stone Oak	Dirt in My Eye Cave and Peace Pipe Cave	Department of Defense (DOD)
Peace Pipe Cave	E	None	Dirt in My Eye Cave and Peace Pipe Cave	DOD
Constant Sorrow Cave	E	Stone Oak	Headquarters Cave Cluster	DOD
Furry Cave	E	Stone Oak	Headquarters Cave Cluster	DOD
Headquarters Cave	E	Stone Oak	Headquarters Cave Cluster	DOD
Flying Buzzworm Cave	E	Stone Oak	Individual	DOD
Genesis Cave	I	Stone Oak	Individual	Private
Low Priority Cave	E	Stone Oak	Individual	City of San Antonio
Huesta Cave	I	UTSA	Huesta Cave and Scharf Cave	City of San Antonio
Scharf Cave	I	UTSA	Huesta Cave and Scharf Cave	Private
Mattke Cave	I	UTSA	Mattke Cave and Scorpion Cave	Private
Scorpion Cave	I	UTSA	Mattke Cave and Scorpion Cave	Private

Cave Name	Sub-species¹	KFR	Cluster	Ownership
Cave 189 ²	U	UTSA	Individual	Private
Crownridge Canyon Cave	I	UTSA	Individual	City of San Antonio
John Wagner Ranch Cave No. 3	I	UTSA	Individual	Private
Kamikazi Cricket Cave	I	UTSA	Individual	Private
Porcupine Squeeze Cave ²	U	UTSA	Individual	Private
Robber's Cave	I	UTSA	Individual	City of San Antonio
Three Fingers Cave	I	UTSA	Individual	Private
Horsefly Cave	N	Culebra Anticline	Oak Meadow Lane Cluster	Private
Isopit	N	Culebra Anticline	Oak Meadow Lane Cluster	Private
Obvious Little Cave	N	Culebra Anticline	Oak Meadow Lane Cluster	Private
Wurzbach Bat Cave	N	Culebra Anticline	Oak Meadow Lane Cluster	Private
S-08 (Weingarten)	N	Culebra Anticline	SH 211 Cluster	Private
S-13 (Landon Ridge)	N	Culebra Anticline	SH 211 Cluster	Private
S-20 (Landon Ridge)	U	Culebra Anticline	SH 211 Cluster	Private
S-24 (Landon Ridge)	U	Culebra Anticline	SH 211 Cluster	Private

Cave Name	Sub-species¹	KFR	Cluster	Ownership
S-32 (Landon Ridge)	N	Culebra Anticline	SH 211 Cluster	Private
S-35 (Landon Ridge)	U	Culebra Anticline	SH 211 Cluster	Private
S99 (SH 211)	U	Culebra Anticline	SH 211 Cluster	Private
308 (SH211)	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
435 (Stevens Ranch)	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
445 (Stevens Ranch)	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
Bedrock Sink	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
Coon Pipe Sink	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
F 305 (SH 211)	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
F-32 (Stevens Ranch)	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
Game Pasture Cave No. 1	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
King Toad Cave	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
Max and Robert's Cave	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
P-12 (SH 211)	N	Culebra Anticline	Stevens Ranch Central Cluster	Private

Cave Name	Sub-species¹	KFR	Cluster	Ownership
Quarried Sink	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
S-205 (SH 211)	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
Senior Sink	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
Stevens Ranch Trash Hole Cave	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
Stone Pipe Sink	N	Culebra Anticline	Stevens Ranch Central Cluster	Private
318 (Stevens Ranch)	N	Culebra Anticline	Stevens Ranch North Cluster	Private
438 (Stevens Ranch)	N	Culebra Anticline	Stevens Ranch North Cluster	Private
Caracol Creek Coon Cave	N	Culebra Anticline	Individual	Private
Cave of the Bearded Tree	N	Culebra Anticline	Individual	Private
F-3a (Westpointe West)	N	Culebra Anticline	Individual	Private
Headstand Cave	N	Culebra Anticline	Individual	Private

¹Subspecies – *R. infernalis infernalis* (I), *R. infernalis ewersi* (E), *R. infernalis* n. subsp (N), Subspecies unknown (U)

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 infernalis*.

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

The population needs of *Rhadine infernalis* 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 infernalis* 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 (Pellegrini 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 infernalis* 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 infernalis* over the long-term.

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

Based on this review, 10 cave clusters and 14 individual caves are currently of high to moderate resiliency with potential to support *Rhadine infernalis* populations over the long-term (Table 2). This includes three cave clusters and eight individual caves in the Government Canyon KFR, two cave clusters and

one individual cave in the Helotes KFR, one cave clusters and two individual caves in the Stone Oak KFR, one cave cluster and two individual caves in the UTSA KFR, and three cave clusters in the Culebra Anticline KFR. One additional moderate cave cluster, Dirt in My Eye Cave and Peace Pipe Cave Cluster, occurs outside the currently mapped KFRs as it is just north of the Stone Oak 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 also one individual cave in the Government Canyon KFR and two in the UTSA KFR that we were unable to analyze because their locations are too uncertain. Therefore, they are not included in the table below. However, we believe it is likely these features have been impacted by adjacent development activities and would not contribute to high or moderate resiliency population numbers.

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

Karst Fauna Region	High	Moderate	Low	Impaired
Government Canyon	11	0	0	0
Helotes	2	1	0	1
UTSA	3	0	3	1
Stone Oak	2	1	0	1
Culebra Anticline	3	0	1	3
Outside mapped KFRs	0	1	0	0
Total	21	3	4	6

2.1.1.7 Other:

No new information.

2.1.1.8 Conservation Measures:

Government Canyon Karst Fauna Region

Government Canyon State Natural Area Karst Fauna Areas

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 in the Government Canyon State Natural Area, which is owned by Texas Parks and Wildlife Department. These caves are: Government Canyon Bat Cave, which occurs in the approximately 40 ha (100 ac) Government Canyon Bat Cave KFA; Dancing Rattler Cave, Hackberry Sink, and Lithic Ridge Cave, in the approximately 90 ha (223 ac) Lithic Ridge, Dancing Rattler, and Hackberry Sink KFA; Bonepile Cave and Surprise Sink, in the 58 ha (144 ac) Surprise Sink and Bone Pile Cave KFA; and 10K Cave, which occurs in the 40 ha (100 ac) 10K Cave KFA. Tight Cave occurs 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 of these caves and are believed to include their surface and subsurface drainage basins as well. Management for these preserves 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 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 infernalis*.

Other Protected Caves

Several other caves occur either on Government Canyon State Natural Area or nearby preserves. Big Dome Cave, Government Canyon Blowhole, and Sure Sink occur on Government Canyon State Natural Area. Canyon Ranch Pit, Fatman's Nightmare, and Scenic Overlook 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). Pig Cave and San Antonio Ranch Pit occur on a 171 ha (423 ac) parcel purchased through the Section 6 HCP Land Acquisition Program and Continental Park Cave occurs within a 36 ha (90 ac) parcel owned by City Public Service that was set aside as mitigation for a section 7 consultation. 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 additional 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. This preserve 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 Preserve

Madla's 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.

UTSA KFR

Crownridge Canyon Cave

Crownridge Canyon Cave occurs on the 85 ha (211 ac) Crownridge Canyon Natural Area owned by the City of San Antonio. The entire surface and most of the subsurface drainage basin of this cave is included within the preserve area. However, the cave cricket foraging area for this cave has been impacted by adjacent development. This area is not managed or monitored for karst invertebrates.

Huesta Cave

Huesta Cave occurs on the 465 ha (1149 ac) Rancho Diana Natural Area owned by the City of San Antonio. The surface and subsurface drainage basins of this cave have not been mapped so we are unsure whether they occur within the preserve. 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 and the drainage basins could be protected and managed in perpetuity.

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).

Robber's Cave

Robber's Cave occurs on the 62 ha (155 ac) 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.

Culebra Anticline KFR

S99

As a part of construction of SH 211, TXDOT is planning to set aside a nine-acre tract within their right of way to preserve portions of the cave cricket foraging area, the surface drainage basin, and a portion of the subsurface drainage basin of this cave.

Steven Ranch Central Proposed KFA

As a part of the Steven Ranch Master Development Plan, a 79 ha (195 ac) area surrounding at least 14 caves in the Stevens Ranch Central Cluster as well as a 16.2 ha (40 ac) area around Max and Roberts Cave has been proposed to be preserved. The surface and subsurface drainage basins and cave cricket foraging areas for most of the caves in the cluster would be contained within the 79 ha (195 ac) preserve. The preserve around Max and Roberts Cave would protect the surface and subsurface drainage basin and most of the cave cricket foraging area for Max and Roberts Cave. The Service has reviewed and approved the proposed preserve management plan and is working with the Texas Department of Transportation to protect the Max and Roberts Preserve as mitigation for impacts from State Highway 211 which will be built between the two preserves. Once completed, the two preserves together would form the 95.1 ha (235 ac) Stevens Ranch Central KFA. The preserves would be managed under the Karst Preserve Management Plan for the Stevens Ranch Preserves (Pape Dawson 2017, entire).

Stevens Ranch Northern KFA

The caves known as 318 (Stevens Ranch) and 438 (Stevens Ranch) are located on the 26.7 ha (66 ac) Stevens Ranch Northern KFA, recognized by the Service as a medium quality KFA for *Rhadine infernalis*. The surface and subsurface drainage basins for both features are within the area protected by this preserve as well as all of the cave cricket foraging area for 438 and a portion of the cave cricket foraging area for 318. The preserve is currently being managed under the Karst Preserve Management Plan for the Stevens Ranch Preserves (Pape Dawson 2017, entire).

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 infernalis, 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 infernalis* population viability and the species' long-term persistence. Land conversion to residential and commercial development has already reduced and degraded surface habitats surrounding over 30 percent of 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 infernalis* 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 (e.g., 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 (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). Troglotic arthropods, such as *Rhadine infernalis*, 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 infernalis* populations.

2.2 Synthesis

Based on a review of available data, all five of the KFRs that *Rhadine infernalis* occurs in currently have three or more areas of sufficient resiliency with the potential to support *Rhadine infernalis* 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 infernalis* 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 Culebra Anticline KFR meets the definition of a medium quality KFA. The Service is working with a developer and TxDOT to recognize one other high quality KFA in the Culebra Anticline and with the City of San Antonio to recognize five additional areas in the Government Canyon KFR as high quality KFAs. At least five additional areas in the Government Canyon KFR three in the Helotes KFR, three in the UTSA, and three in the Stone Oak KFR have the potential to meet either a high or medium quality KFA provided adequate management and protections can be put in place. However, two of the potential high or moderate resiliency caves and cave clusters in the Stone Oak KFR 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 unprotected 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 infernalis* 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
- 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 infernalis* 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 infernalis* 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 infernalis* specimens.
- IV. Continue collecting efforts to confirm *Rhadine infernalis* 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.

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U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW of [no common name] Beetle (*Rhadine infernalis*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

- Downlist to Threatened
- Uplist to Endangered
- Delist
- 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 _____