U.S. Fish & Wildlife Service

Bexar County Karst Invertebrates

Recovery Plan

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BEXAR COUNTY KARST INVERTEBRATES

RECOVERY PLAN

Southwest Region
U.S. Fish and Wildlife Service
Albuquerque, New Mexico

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The biology, threats, and conservation needs of these species and the karst ecosystems they occur in are very similar to congeners (members of the same Genus) that occur in nearby Travis and Williamson counties, Texas. Literature on the Travis and Williamson county species, including the recovery plan for those species (Service 1994), was used extensively during the creation of this document, and we thank those authors.

The Service would also like to express its appreciation for the many individuals, groups, and agencies actively involved in the recovery of the federally endangered karst invertebrate species of Bexar County. We look forward to continued collaboration with these partners and new partners to conserve these species and the ecosystems on which they depend.

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EXECUTIVE SUMMARY

Species Status - Nine Bexar County karst invertebrates were listed as endangered species on 26 December 2000 (65 FR 81419 81433). These species inhabit caves and mesocaverns (humanly impassable voids in karst limestone) in Bexar County, Texas. *Rhadine exilis* is known from 51 caves, *R. infernalis* is known from 39 caves, *Batrisodes venyivi* is reported from eight caves (the location of three of these are unknown), *Texella cokendolpheri* is known from one cave, *Neoleptoneta microps* is known from one cave, *Cicurina baronia* is known from two caves, *C. madla* is known from 22 caves, *C. venii* is known from one cave, and *C. vespera* is known from one cave. Physical and biological features important for the species long-term survival have been impacted at some of these sites. Two of these species (*T. cokendolpheri* and *C. baronia*) have a recovery priority number of 5C because the likelihood that we can recover them is low considering that they are known from one and two caves respectively and they occur in an area that is highly urbanized. The remaining seven species have a recovery priority number of 2C. Recovery priority 2C indicates that these species face a high degree of threat with a high potential for recovery and there may be conflict between species recovery and economic development. Critical habitat was designated on April 8, 2003, for seven of the nine species, with the exception of *N. microps* and *C. vespera*. The Service is in the process of revising critical habitat and published a proposed rule on 22 February 2011.

Habitat Requirements and Limiting Factors - All of these invertebrates are troglobites, spending their entire lives underground. They are characterized by small or absent eyes and pale coloration. Their habitat includes caves and mesocavernous voids in karst limestone (landforms and subsurface features, for example, sinkholes and caves, produced by dissolution of bedrock). Within this habitat these animals depend on high humidity, stable temperatures, suitable substrates (for example, spaces between and underneath rocks), and surface-derived nutrients. Examples of nutrient sources include leaf litter fallen or washed in, animal droppings, and animal carcasses. It is imperative to consider that while these species spend their entire lives underground, their ecosystem is dependent on the overlying surface habitat.

The primary threat to these species is habitat destruction. Caves and karst habitat are destroyed or impacted in several ways, including but not limited to (1) completely filling the cave with cement during development, (2) by quarrying activities, and (3) by capping or sealing cave entrances. Other causes of habitat degradation include altering drainage patterns, altering native surface plant and animal communities, reducing or increasing nutrient flow, contamination, excessive human visitation, and threats from red-imported fire ants (*Solenopsis invicta*) including competition with cave crickets and predation on karst invertebrates, and competition from non-native, invasive vegetation species with native surface vegetation.

Recovery Strategy - The recovery strategy is to reduce threats to the species by protecting an adequate quantity and quality of karst areas to ensure a high probability of the species' long-term survival. This includes protecting caves or cave clusters and the associated mesocaverns necessary to support populations that represent the range of the species and their potential genetic diversity. Maintenance of these karst preserves involves keeping them free from contamination, excessive human visitation, and non-native fire ants; maintaining an adequate amount and composition of the surface plant and animal community; regular monitoring; and implementing adaptive management (when necessary) to control existing and new threats. Research is also a component of recovery. Many aspects of the population dynamics and habitat requirements of the species are not well understood. Therefore, recovery is dependent on incorporating research findings into adaptive management actions. Since several of these species are known to occur in fewer than six caves, additional surveys to find more locations are needed.

Recovery Goal - Delisting.

Recovery Criteria - Delisting any of these species should be considered when threats have been removed or reduced as indicated by the following:

Criterion 1- (downlisting) – The location and configuration of a least the minimum quality and number of karst fauna areas (KFAs)[1] in each karst fauna region (KFR)[2] for each species are preserved. Also, legally binding commitments are in place for perpetual protection and management of these KFAs.

Criterion 2 - (delisting) – In addition to the downlisting criterion, monitoring and research have been completed to conclude with a high degree of certainty that KFA sizes, quality, configurations, and management are adequate to provide a high probability of the species survival (greater than 90 percent over 100 years). To assess adequacy, results should be measured over a long enough time that cause and effect can be inferred with a high degree of certainty.

Actions Needed

(1) Habitat protection and management
(2) Monitoring, research, and adaptive management
(3) Education and outreach
(4) Post-delisting monitoring plan

Estimated Costs

Costs estimated below reflect what is needed for specific recovery actions for these species. Estimates do not include costs that agencies or other entities normally incur as part of their mission or normal operating expenses. The following table provides cost estimates for the recovery actions in the Implementation Schedule (section 4.0). Also, the costs are combined in two-year increments in the table.

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[1] Karst Fauna Area (KFA) - a geographic area known to support one or more locations of an endangered species. A KFA is distinct in that it acts as a system that is separated from other KFAs by geologic and hydrologic features and/or processes or distances that create barriers to movement of water, contaminants, and troglobitic fauna.

[2] Karst Fauna Region (KFR) - geographic areas delineated based on discontinuity of karst habitat that may reduce or limit interaction between troglobite populations.

Total Estimated Cost of Recovery by Recovery Action Priority:
(dollars by 1,000)

Years	Priority 1(a) Actions	Priority 1(b) Actions	Priority 2 Actions	Priority 3 Actions	Total
1 and 2	26,940	100	222	0	27,262
3 and 4	26,940	0	164	0	27,104
5 and 6	26,940	0	119	0	27,059
7 and 8	26,940	0	93	0	27,033
9 and 10	26,940	0	82	0	27,022
11 to 20	26,940	0	0	0	26,940
Total	161,640	100	679	0	162,420

Estimated Date of Recovery - If recovery actions are fully funded and carried out as outlined in this plan, criterion 1 (downlisting) could be met within 10 years. Upon the completion of recovery criterion 1, criterion 2 could be met in an additional 10 years if monitoring has also been occurring during the first 10 years. This means that these species could be delisted in 20 years.

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ACRONYMS

The following acronyms are used in this recovery plan:

BCo	Bexar County
BLT	Bexar Land Trust
COSA	City of San Antonio
EAA	Edwards Aquifer Authority
GCSNA	Government Canyon State Natural Area
KFA	Karst Fauna Area
KFR	Karst Fauna Region
RIFA	Red-imported Fire Ant
Service	U.S. Fish and Wildlife Service
SWRI	Southwest Research Institute
TCEQ	Texas Commission on Environmental Quality
TNC	The Nature Conservancy
TPL	Trust for Public Land
TPWD	Texas Parks and Wildlife Department
TSS	Texas Speleological Survey
TxDOT	Texas Department of Transportation
USGS	U.S. Geological Survey
UTSA	University of Texas at San Antonio
WKU	Western Kentucky University

1.0 BACKGROUND

1.1 Introduction

The Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.)(Act), establishes policies and procedures for identifying, listing, and protecting species of wildlife and plants that are endangered or threatened with extinction. The Act defines an "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." A "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." According to the Service's Interim Recovery Planning Guidelines (NMFS and Service 2010), recovery is defined as "the process by which listed species and their ecosystems are restored and their future is safeguarded to the point that protections under the ESA are no longer needed."

Day-to-day protection of endangered and threatened species under the Department of Interior's jurisdiction has been delegated to the Service. To help identify and guide species recovery needs, section 4(f) of the Act directs the Service to develop and implement recovery plans for listed species or **population**s (terms in bold are defined in the glossary). Recovery plans are advisory documents developed to provide recovery recommendations aimed at resolving the threats to the species and ensuring self-sustaining populations in the wild.

Section 4 of the Act and regulations (50 CFR Part 424) promulgated to implement listing provisions also set forth the procedures for reclassifying and delisting species. A species can be delisted if the Secretary determines that it no longer meets endangered or threatened status based upon the five listing factors in section 4(a)(1) of the Act. These factors are:

> **Factor A** - the present or threatened destruction, modification, or curtailment of its **habitat** or range;
> **Factor B** - overutilization for commercial, recreational, scientific, or educational purposes;
> **Factor C** - disease or predation;
> **Factor D** - the inadequacy of existing regulatory mechanisms; and
> **Factor E** - other natural or manmade factors affecting its continued existence.

This section (1.0) of the plan briefly describes the (1) status of the species; (2) **life history**; and (3) threats to the species. The purpose of the background section is to provide information needed to understand the recovery strategy; recovery goals, objectives, and criteria; and the recovery program. The recovery section (2.0) identifies a strategy with actions that are expected to be the most effective and most efficient way of achieving recovery for these species and specific criteria for measuring when recovery has occurred. The success of this plan depends upon the collaboration of many people and organizations to ensure the future existence of these species.

Reference is made throughout this plan for where more detailed information can be found. Information on karst invertebrate habitat and ecology, karst preserve design, karst preserve management, taxonomy, and distribution can be found at: (http://ecos.fws.gov/tess_public/). Information in these documents may be updated periodically, so please check the website for the most recent updates.

1.2 Legal Status and Brief Description of the Species

The intent of this recovery plan is to guide the recovery of the listed karst invertebrates of Bexar County, Texas. It covers nine endangered **karst** invertebrate species. Two of these species (*T. cokendolpheri* and *C. baronia*) have a recovery priority number of 5C because the likelihood that we can recover them is low considering that they are known from so few locations and they occur in an area that is highly urbanized. The remaining seven species have a recovery priority number of 2C, which means that these species face a high degree of threat, have a high potential for recovery, and there may be conflict between species recovery and economic development. They were listed as endangered on December 26, 2000 (Service 2000a). Critical Habitat was designated for all species except *N. microps* and *C. vespera* on April 8, 2003 (Service 2003). On February 22, 2011, the Service proposed a revision of the previous critical habitat designations and proposed critical habitat for *N. microps* and *C. vespera* as announced in a Federal Register notice (76 FR 9872). Please check our website for information on future revisions of critical habitat (http://www.fws.gov/southwest/es/austintexas/).

Rhadine exilis (no common name) and *R. infernalis* (no common name) are small, essentially eyeless ground beetles. *Batrisodes venyivi* (Helotes mold beetle) is a small, eyeless beetle. *Texella cokendolpheri* (Cokendolpher **cave** harvestman) is a small, eyeless harvestman (daddy-longlegs). *Cicurina baronia* (Robber Baron Cave meshweaver), *C. madla* (Madla Cave meshweaver), *C.venii* (Braken Bat Cave meshweaver), *C. vespera* (Government Canyon Bat Cave meshweaver), and *Neoleptoneta microps* (Government Canyon Bat Cave spider) are all small, eyeless or essentially eyeless spiders. The first three of these are insects: two ground beetles and one mold beetle. The remaining species are arachnids, including one harvestman and five spiders. While harvestmen are in the same class (Arachnidea) as spiders, they are in a different order (Araneae) because they are anatomically and evolutionarily distinct from spiders. Taxonomic verification of these species is usually not possible in the field and usually requires examination of adult specimens under a microscope. Identification often requires dissection of the genitalia by a taxonomic expert. These species range in size from 1 millimeter (mm) (0.039 in) to 1 centimeter (cm) (0.39 in). For more information, see the taxonomy document at http://ecos.fws.gov/tess_public/.

1.3 Population Status and Distribution

Current range - These species are only known from karst areas (see description below) in Bexar County. However, suitable karst habitat extends into Medina County, so these species could possibly be found there during future search efforts. For information on the current distribution of these species, please refer to our website (http://ecos.fws.gov/tess_public/). There you will find a list of the known locations for all of these species by cave. Our confidence in this site-specific location information is variable. For example, we have not verified the location information for each cave; many are on private property and have not been recently assessed by surveyors. However, some localities are regularly visited during biomonitoring; therefore, the cave's entrance has been well documented. Other sites have cryptic names that may be synonymous with other caves on the list, and others have unknown geographic locations; therefore, the status or continued existence of these caves is uncertain.

Historic range - Little information on these species is available prior to the 1960s, when the study of **biospeleology** began in earnest in Bexar County. Their historic ranges are unknown, but were likely similar to their present day ranges with the exception of caves that have been destroyed or severely impacted.

Karst Zones - The geologic context of the distribution of the nine species in this plan, as well as other **troglobite**s, was examined by Veni (1994), who delineated five karst zones (Figure 1 and at: http://www.fws.gov/southwest/es/austintexas/) to facilitate assessment of the probability of the presence of rare or **endangered** species. These zones are:

Zone 1. Areas known to contain listed karst invertebrate species.

Zone 2. Areas having a high probability of containing habitat suitable for listed karst invertebrate species.

Zone 3. Areas that probably do not contain listed karst invertebrate species.

Zone 4. Areas that require further research but are generally equivalent to Zone 3, although they may include sections that could be classified as Zone 2 or Zone 5 as more information becomes available.

Zone 5. Areas that do not contain listed karst invertebrate species.

Under contract with the Service, Veni (2002) re-evaluated and, where applicable, revised the boundaries of each karst zone originally delineated in Veni (1994). Revisions were based on current geologic mapping, further studies of cave and karst development, and current information available on the distribution of listed and non-listed karst species. For a full description of the methods used to delineate the karst zones, refer to Veni (2002) and Veni (1994).

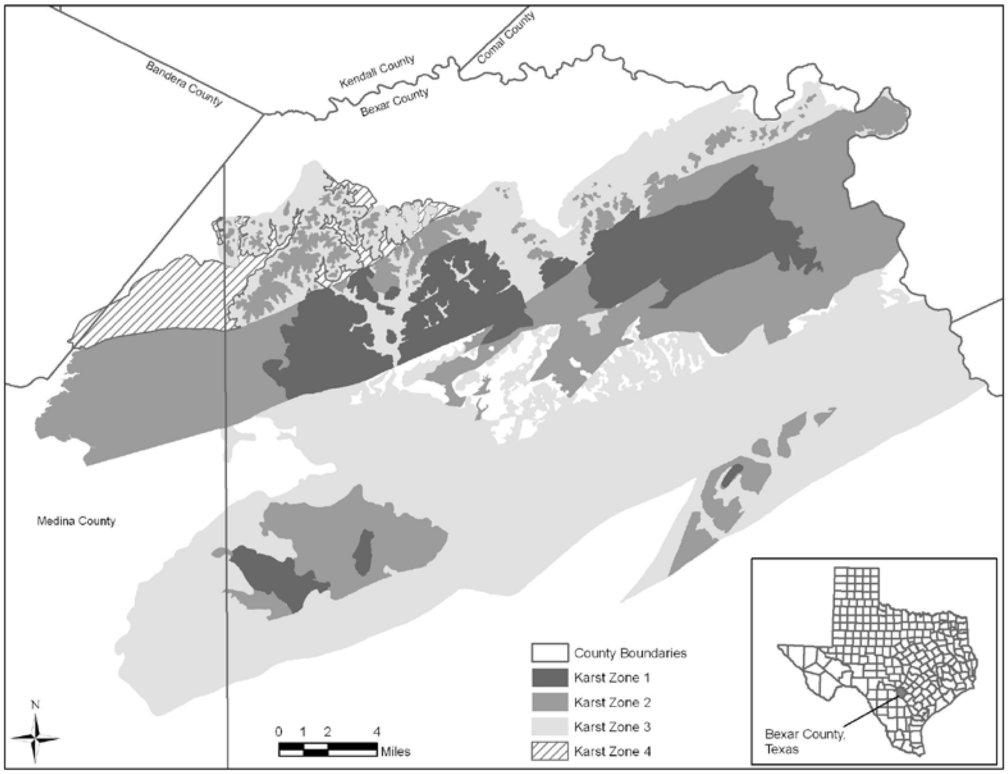

Figure 1. Karst Zones in the San Antonio area

Population estimates - Population estimates are unavailable for any of these species due to lack of adequate techniques, their cryptic behavior, inaccessibility of **mesocaverns**, and difficulty accessing cave and karst habitat. In known locations, one or two individuals are typically observed per survey event, and it is not uncommon to observe none at all (Krejca and Weckerley 2007). Results of point counts are available for some species at some localities in unpublished literature (for example, scientific permittee annual reports). Techniques that may be useful for population estimates of invertebrates include mark-recapture, such as have been used for cave crickets and troglobitic crustaceans (Knapp and Fong 1999, Taylor et al. 2005) but not for any of the listed species or their relatives.

Some of the nine listed species are known from only one location, despite the fact that a considerable amount of effort has been expended collecting cave species in Bexar County.

1.4 Life History and Habitat Characteristics

All of these invertebrates are troglobites, spending their entire lives underground. They are characterized by small or absent eyes. Their habitat includes karst limestone caves and mesocaverns, including suitable substrates, for example, spaces between and underneath rocks and uncompacted soil. The term "karst" refers to a type of terrain that is formed by the slow dissolution of calcium carbonate from limestone bedrock by mildly acidic groundwater. This process creates numerous cave openings, cracks, fissures, fractures, and **sinkholes**. Many karst features may contain habitat, including voids that are too small to be humanly passable. These voids are referred to as mesocaverns and are discussed below.

Physical factors in caves that influence the species include absence of sunlight, low nutrient flow (due to lack of primary production), and a stable environment with uniform temperatures and high humidity (Barr 1968, Poulson and White 1969, Culver 1986, Howarth 1983). These parameters favor the evolution of **troglomorphic** characteristics including reduction or loss of eyes and pigment, often coupled with enhancement of other sensory structures for example, attenuated limbs and olfactory organs, and 'k-selected' life history strategies for example, low metabolic and reproductive rates, and long life spans (Poulson and White 1969, Howarth 1983, Culver 1986, Culver et al. 1995, Jeffery 2001).

<u>Nutrients</u> - Nutrients in most karst ecosystems are derived from the surface (Barr 1968, Poulson and White 1969, Howarth 1983, Culver 1986) either directly (organic material washed in or brought in by animals) or indirectly, by feeding on the karst invertebrates that feed on surface-derived nutrients. In some cases, the most important source of nutrients for a target troglobite may be the fungus, microbes, and/or smaller **troglophiles** and troglobites that grow on the leaves or feces rather than the original material itself (Elliott 1994, Gounot 1994). Tree roots can penetrate into caves and may also provide direct nutrient input to shallow caves. In deeper cave reaches, nutrients enter through water containing dissolved organic matter percolating vertically through karst fissures and solution features (Howarth 1983, Holsinger 1988, Elliott and Reddell 1989). For predatory troglobites, accidental species of invertebrates (those that wander in or are trapped in a cave) may be an important nutrient source in addition to other troglobites and troglophiles found in the cave (Service 2000b).

The cave cricket (*Ceuthophilus* spp.) is a particularly important nutrient component (Barr 1968, Reddell 1993) and is found in most caves in Texas (Reddell 1966). It forages on the surface at night; one study documented travel distances (of *C. secretus*) up to 105 meters (m) (345 feet [ft]) from the cave entrance (Taylor et al. 2005). Typically, cave crickets exit a cave to forage when the ambient surface temperature is close to 15º Celsius (C) (59º Fahrenheit [F]) and the relative humidity is close to 100 percent (Lavoie et al. 2007). Cave crickets are generally known to return to the cave during the day, where they lay eggs and roost. A variety of troglobites are known to feed on cave cricket eggs (Mitchell 1971a), feces (Barr 1968, Poulson et al. 1995), and/or on the adults and **nymphs** directly (Elliott 1994). A radio tracking study showed that travel from cave to cave is not uncommon, and sometimes the crickets will spend their day on the surface away from a known cave, probably in a tiny crack or other protected **microhabitat** (Taylor et al. 2004). The nutrient input from foraging by tens to thousands of crickets is quite large, as it consists of deep cricket guano blanketing large parts of the floor of some cave passages. Research conducted by Taylor et al. (2007a) found that the total number of cave **taxa** was strongly correlated with the total number of cave crickets. This is an indicator of the importance of cave crickets to the karst ecosystem.

The most abundant recognized species of cave cricket in central Texas is *C. secretus*. There is at least one other widely recognized, but not formally described, species of cave cricket known as "*Ceuthophilus* species B." These species are known to exit caves at night and forage on the surface (Taylor et al. 2007b). A third species, *C. cunicularis*, is more troglomorphic and rarely exits caves (Taylor et al. 2007b).

<u>Mesocaverns</u> - It is conjectured that the majority of nutrients are located in humanly accessible caves with open entrances; therefore, they are foci of troglobitic populations that may occur in low densities throughout the karst. Since metabolic rates of troglobites are typically low, they may be able to sustain periods ranging from months to years existing on lower levels of food or no food (Howarth 1983). During temperature extremes, small mesocavernous spaces connected to caves may have a physical environment with more favorable humidity and temperature levels than the cave (Howarth 1983), but where the abundance of food may be less than in the larger cave passages. Troglobites may spend the majority of their time in such retreats, only leaving them during temporary forays into the larger cave passages to forage (Howarth 1987). For more information on mesocaverns see the document on karst invertebrate habitat requirements at: http://ecos.fws.gov/tess_public/.

Mesocaverns are important to karst invertebrate populations, and covering them with urbanization is detrimental; therefore, more effort should be put toward preserving contiguous karst areas. These areas are important for two reasons (1) they may be occupied, though they are extremely difficult to sample, and (2) they may serve as migration routes.

<u>Humidity and Temperature</u> - Terrestrial troglobites require stable temperatures and constant, high humidity (Barr 1968, Mitchell 1971b). The temperatures in caves are typically the average annual temperature of the surface habitat and vary much less than the surface environment (Howarth 1983, Dunlap 1995). Relative humidity in a cave is typically near 100 percent for caves supporting troglobitic invertebrates (Elliott and Reddell 1989, TPWD 2009, SWCA 2010). Many of these species have lost the adaptations needed to prevent desiccation in drier habitat (Howarth 1983) or the ability to detect and/or cope with more extreme temperatures (Mitchell 1971b). To maintain these conditions, it is important to maintain an adequate drainage area to supply moisture to the cave and connected karst areas and to maintain the surface plant communities that insulate the karst system from excessive drying and from more extreme temperature fluctuations.

Drainage Basins - Water primarily enters karst invertebrate habitat through (1) infiltration through soils and karst and (2) percolation through upland features (caves, sinkholes, and other open features) (Cowan et al. 2007, Veni and Associates 2008, Hauwert 2009). Therefore, caves and karst are susceptible to pollution from contaminated water entering the ground (Drew and Holtz 1999). Well-developed pathways, such as cave openings, fractures, and solutionally enlarged bedding planes, rapidly transport water through the karst with little or no purification (White 1988). The route that has the greatest potential to carry water-borne contaminants into the karst ecosystem is through the surface and subsurface **drainage basin**s of specific karst features (caves, sinkholes, etc.) that supply water to the ecosystem. Cave fauna require material brought in from the surface (including humanly inaccessible cracks) and high humidity; therefore, it is critical to have drainage basins with a natural quantity and quality of water. The surface drainage basin of karst features is dependent on topography. The subsurface or groundwater drainage basin is dependent on mesocaverns, subterranean streams, bedding planes, buried joints and sinkholes that have a connection to the surface that is not always observable from the surface. It is also important to note that the surface and subsurface drainage basins do not necessarily overlap. They may be of different size and direction. See discussion in Veni (2003) for more information on this topic.

Surface Vegetative Community - Surface plant communities provide nutrients to the subsurface by providing habitat that supports **trogloxene** and accidental species (species that may wander into a cave). They also provide nutrients to the subsurface by providing leaf litter that washes or falls into caves and through root masses that grow directly into caves (Howarth 1983, 1988, Jackson et al. 1999). Surface vegetation also acts as a buffer against drastic changes in the temperature and moisture regime. Also, a healthy native vegetation **community** may help prevent RIFA invasion since RIFA are attracted to disturbed areas. Further, vegetation serves to filter pollutants (to a limited degree) before they enter the karst system (Biological Advisory Team 1990). For more information on the importance of surface plant communities see: http://ecos.fws.gov/tess_public/.

1.5 Threats

The reasons for listing (threats) these species were described in the final rule (Service 2000a) and are still applicable today. Without proper management and protection, these threats will continue to impact these species. The information below consists of a brief discussion of existing threats, updated information on these threats, and new threats identified since the time of listing. Threats are discussed below in relation to the five factors (factors A-E) considered when listing or delisting a species. For more information on threats see the final rule (Service 2000a) and the most recent 5-year status review. Additionally, Elliott (2000) provides a thorough review of threats and conservation of North American cave species.

A. The present or threatened destruction, modification, or curtailment of its habitat or range

One of the main threats to the listed invertebrates is habitat loss due to increasing urbanization and human population growth. Effects of urbanization on the listed species include habitat loss from filling and collapsing caves, habitat degradation through alteration of drainage patterns, alteration of surface plant and animal communities, edge effects, contamination from pollutants, human visitation, vandalism, and activities associated with mining and quarrying. Bexar County is facing continued rapid population growth and associated urbanization. According to the U.S. Census Bureau (2009), the City of San Antonio grew by 12 percent from 2000 to 2006 and had 2,808 people per square mile. According to the San Antonio Planning Department (2005), the Bexar County population is forecasted to reach about 2.37 million people by 2050. Much of this growth is occurring in areas where endangered invertebrates are most likely to occur (Figure 1).

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

<u>Alterations of Surface Plant and Animal Communities</u> - Karst ecosystems are heavily reliant on surface plant and animal communities to maintain nutrient flows, reduce sedimentation, and resist exotic and invasive species. As the surface around a cave entrance becomes developed, native plant communities are often replaced with impermeable cover or exotic plants from nurseries. The abundance and diversity of

native animals may decline due to decreased food and habitat combined with increased competition and predation from urban, exotic, and pet species. The leaf litter and wood that make up most of the detritus may also be reduced or altered, resulting in a reduction of nutrient and energy flow into the cave.

A study by Taylor et al. (2007a) compared caves in urbanized areas to those in natural areas, and found significant differences in **isotope ratios** of cave species between the different levels of impact. This demonstrates that nutrient flows from the plant and animal communities are different in urbanized areas as compared to rural areas. The same study also found that impervious cover and modified vegetation explained large percentages (89 to 91 percent) of the variation of cave crickets and other cave species numbers, with significantly fewer individuals found at impacted sites. Further, a study at the Lakeline Cave in Travis County showed a decline in cave crickets as the area around the cave was developed (Zara Environmental 2008).

<u>Edge Effects</u> - "Edge effects" are changes to the floral and faunal communities where different habitats meet. The length and width of the edge, as well as the contrast between the vegetational communities, all contribute to the amount of impacts (Smith 1990, Harris 1984). Some types of edge effects include increases in solar radiation, changes in soil moisture due to elevated levels of evapotranspiration, wind buffeting (Ranny et al. 1981), changes in nutrient cycling and the hydrological cycle (Saunders et al. 1990), and changes in the rate of leaf litter decomposition (Didham 1998). These edge effects alter plant communities, which in turn impact the associated animal species. Edge effects can also affect animal species directly. The changes caused by edge effects can occur rapidly. Vegetation located 2 m (6.6 ft) from an edge can be visibly affected within days (Lovejoy et al. 1986).

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

<u>Contamination</u> - Karst landscapes are particularly susceptible to groundwater contamination because water penetrates rapidly through bedrock conduits and little or no filtration occurs (White 1988). In some areas the water that moves through the habitat of these species percolates to the Edwards Aquifer below. The Edwards Aquifer is an important source of drinking water for 1.7 million people (Edwards Aquifer Authority 2008). So, information on sources of water contamination of the Edwards Aquifer may also be indicative of sources of contamination of karst invertebrate habitat. The ranges of these species are becoming increasingly urbanized and thereby are becoming more susceptible to contaminants including sewage, oil, fertilizers, pesticides, herbicides,

seepage from landfills, pipeline leaks, or leaks in storage structures and retaining ponds. Activities on the surface, such as disposing of toxic chemicals or motor oil, can also contaminate caves (White 1988).

Continued urbanization will increase the likelihood that karst ecosystems are polluted by contamination from the leaks and spills, which have often occurred in Bexar County (see TWC 1989, TCEQ 2010a, TCEQ 2010b for information on contamination events). Texas Commission on Environmental Quality (TCEQ) (2010a) summarizes information on groundwater contamination reported by a number of agencies, and in 2010 they reported that 1,712 leaking petroleum storage tanks were located in Bexar County.

Human visitation and vandalism - Visitation can impact caves by increasing soil compaction, trash deposition, and vandalism; altering airflow as entrances are expanded and excavated; scaring away trogloxenes (Culver 1986, Elliott 2000); and may also lead to direct mortality of cave organisms crushed by human disturbance (Crawford and Senger 1988).

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

Quarrying and Mining Operations - Quarries and mines exist in Bexar County, including the northern half, where the majority of the listed species occur. While quarrying activities have revealed some caves (which can lead to protecting these sites), they have also completely destroyed others (Elliott 2000). As caves and mesocavernous spaces are destroyed at mines and quarries, karst invertebrates, possibly including some listed species, will also be lost.

B. Overutilization for commercial, recreational, scientific, or educational purposes

Besides the unintentional impacts and threats to habitat from recreational and commercial use of caves discussed under factors A and E, there are no known threats to these species from overuse of the species themselves, for commercial, recreational, scientific, or educational purposes.

C. Disease and Predation

Red-imported fire ants (RIFA) are a pervasive, non-native ant species originally introduced to the U.S. from South America (Vinson and Sorensen 1986) over 50 years ago (Porter and Savignano 1990). This ant is an aggressive predator and competitor that has spread across the southern United States. This predator often replaces native species, and evidence shows that overall **species richness** and abundance, drops in infested areas (Vinson and Sorenson 1986, Porter and Savignano 1990). Also, research has found that a number of rare and threatened ant species may be disproportionately impacted by RIFA (Porter and Savignano 1990). Some researchers conducting work on surface arthropods suggested that RIFA have less impact than originally thought and that over time their impacts decline (Morrison 2002, Morrison and Porter 2003, King and Tschinkel 2006). However, that research was not conducted on karst invertebrates or troglobitic species. For this reason and the ones discussed below, we believe that RIFA are a threat to karst invertebrates.

Karst invertebrates in central Texas are especially susceptible to RIFA predation because some of the caves that karst invertebrates inhabit are relatively short and shallow. The hot dry weather may also encourage RIFA to move into caves during summer months or seek refuge or prey in caves during colder periods in the winter. RIFA have been found within and near many caves in central Texas and have been observed feeding on dead troglobites, cave crickets, and other species within caves (Elliott 1992, 1994, 2000, Reddell 1993, Taylor et al. 2003). Reddell (1993) describes an instance in a cave where "hundreds of hard chitonous shells of the millipede *Cambala speobia* littered the floor of the cave. Fire ants were observed actively mining the millipedes…" A quantitative study of RIFA at six central Texas caves showed that they primarily used the entrance and **twilight zones**, but during cooler months were occasionally found deep into caves, not necessarily using human entrances as access points (Taylor et al. 2003). Of 36 caves Veni and Reddell visited during status surveys for the nine Bexar County karst invertebrates, RIFA were found inside 26 of them (Reddell 1993). Also, Krejca (pers. comm., 2010) reported that sticky traps placed in caves as part of endangered species presence/absence surveys commonly caught cave crickets, which were then quickly swarmed and devoured by RIFA even when they were still alive. Karst fauna life stages that are likely most vulnerable to RIFA predation are the immature stages, eggs, and slower-moving adults.

Besides direct predation, RIFA threaten listed invertebrates by reducing the nutrient input that fuels the karst ecosystem. Cave species rely on nutrients from the surface that are either washed in the entrance or carried in by trogloxenes like cave crickets. Taylor et al. (2003) found that at baits placed above ground at night, cave crickets often arrived at the food resource before RIFA, but the arrival of RIFA corresponded to the departure of cave crickets, indicating competition for at least some food resources. A study that assessed foraging behavior of cave crickets at Government Canyon State Natural Area (GCSNA), found less competition between cave crickets and RIFA (and among cave crickets) at caves that were managed to reduce RIFA mounds (Lavoie et al. 2007). Because RIFA are voracious, they can out-compete crickets for food resources (Taylor et al. 2003), leading to a reduction in overall productivity in the caves.

D. Inadequacy of existing regulatory mechanisms

Karst invertebrates and their habitat are not protected by State regulations. Invertebrates are not included on the Texas Parks and Wildlife Department's (TPWD) list of threatened and endangered species and are provided no protection by the State. Also, the TCEQ water quality regulations do not provide much protection to the species' habitat (see 65 FR 81419 - 81433 for more information). For example, while some TCEQ practices provide protection from water quality impacts, others, such as, sealing cave entrances for water quality reasons, can harm karst invertebrates.

The City of San Antonio (COSA) regulates development and impervious cover within the recharge area of the Edwards Aquifer through Ordinance #81491, made effective January 23, 1995. This ordinance limits types of development and impervious cover around critical environmental features (typically recharge features) within the city limits, the extraterritorial jurisdiction, and the recharge zone. Most of the caves known to contain the nine invertebrates are relatively small and do not provide much recharge, so it is uncertain how these caves would be considered under this ordinance (see 65 FR 81419 - 81433 for more information).

As of August 2009, the San Antonio City Council amended the Unified Development Code (Chapter 35 of the city code). This amendment states for any property owner "who submits an application to the City of San Antonio for development on/of a tract of land greater than 0.8 hectares (ha) (2 acres) in area shall submit a Habitat Compliance Form" to the city. By submitting this form, the property owner is attesting that they (1) have a section 10(a)(1)(B) incidental take permit; (2) have a section 7 biological opinion; (3) are participating in a regional habitat conservation plan; or (4) have submitted an endangered species survey to the Service attesting that no endangered species are on their property. This amendment pertains to properties located in karst zone one or two (Figure 1). Hence, this ordinance is expected to provide some protection to karst invertebrate habitat.

E. Other natural or manmade factors affecting their continued existence

<u>Small Population Size</u> - Frankham (2005) states, "loss of genetic diversity in small populations is expected to increase extinction risk by adversely affecting the ability of populations to evolve to cope with environmental change (evolutionary potential)." Although sample sizes are consistently small, it is not certain that these populations are at risk of losing genetic diversity. Culver et al. (2000) states that while some troglobites are known from a few specimens, detailed studies suggest that "as a rule" most troglobites "are not numerically rare and thus are not susceptible to the problems of small populations." However, considering the lack of population estimates and the available studies of these species, data are insufficient to indicate whether Bexar County karst invertebrates are numerous enough to rule out small population concerns. Further, due to inherently low sample sizes, it is difficult to detect population response to possible

impacts (Poulson and White 1969, Howarth 1983, Miller and Reddell 2005). These species may be threatened by small population sizes when coupled with other threats, making them more vulnerable to existing threats discussed throughout this section.

Climate Change - According to the Intergovernmental Panel on Climate Change (IPCC) (2007) "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." Average Northern Hemisphere temperatures during the second half of the 20th century were very likely higher than during any other 50-year period in the last 500 years and likely the highest in at least the past 1,300 years (IPCC 2007). It is very likely that over the past 50 years cold days, cold nights, and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent (IPCC 2007). It is likely that heat waves have become more frequent over most land areas and the frequency of heavy precipitation events has increased over most areas (IPCC 2007).

The IPCC (2007) predicts that changes in the global climate system during the 21st century are very likely to be larger than those observed during the 20th century. For the next two decades a warming of about 0.2°C (0.4°F) per decade is projected (IPCC 2007). Afterwards, temperature projections increasingly depend on specific emission scenarios (IPCC 2007). Various emissions scenarios suggest that by the end of the 21st century, average global temperatures are expected to increase 0.6°C to 4.0°C (1.1°F to 7.2°F) with the greatest warming expected over land (IPCC 2007).

Localized projections suggest the southwest may experience the greatest temperature increase of any area in the lower 48 States (IPCC 2007). The IPCC also predicts that hot extremes and heat waves will increase in frequency and that many semi-arid areas like the western United States will suffer a decrease in water resources due to climate change (IPCC 2007, p. 8). Milly et al. (2005) project a 10–30 percent decrease in precipitation in mid-latitude western North America by the year 2050 based on an ensemble of 12 climate models.

Although climate change was not identified as a threat to the Bexar County karst invertebrates in the original listing document, their dependence on stable temperatures and humidity indicate that these species may be affected by climatic change. The temperatures in caves are typically the average annual temperature of the surface habitat and vary much less than the surface environment (Howarth 1983, Dunlap 1995). If surface temperatures increase, this could result in increased in-cave temperatures, which will likely impact these species. Changes in vegetation and the surface environment may indirectly affect karst invertebrates by reducing food resource amounts and availability. Rainfall regime changes and increased severe weather events may also impact the cave environment (and some mesocaverns) by filling them with debris, flooding, drying them out more between floods, and affecting the amount and timing of nutrients washed into a cave. Further, all of the scenarios projected by the available climate change models indicate that mesocaverns may become more important as refuge habitats since they have more stable temperature and humidity. Another consideration is that during dry conditions karst invertebrates are more difficult to locate (Howarth 1983). Further, caves in arid regions have lower apparent invertebrate populations and diversity, due to less moisture and nutrient availability (G.Veni 2010, pers. comm.). Since karst invertebrates in central Texas are also sensitive to these habitat parameters, it is reasonable that climate change could cause these effects to occur here as well.

2.0 RECOVERY

The following sections present a strategy to recover the species, including objective and measurable recovery criteria to achieve downlisting and delisting, and site-specific management actions to monitor and reduce or remove threats to the Bexar County karst invertebrates, as required under section 4 of the ESA. The Recovery Plan also addresses the five statutory listing/recovery factors (section 4(a)(1) of the ESA) to demonstrate how the recovery criteria and actions will lead to removal of the Bexar County karst invertebrates from the lists of Threatened and Endangered Species.

2.1 Recovery Strategy

Habitat preservation, management, and research to refine our understanding of these species are key components of recovery. The recovery strategy for these species includes the perpetual protection and management of an adequate quantity and quality of habitat that spans the geographic range of each of the species.

An "adequate" quantity and quality of habitat means that needed to provided a high probability of species survival over the long term (for example, at least 90 percent probability over 100 years). Normally our preference would be a probability closer to 99 percent over 100 years. However, calculating a probability for these species may not be possible with much certainty due to the difficulty sampling for the population parameters that are necessary to calculate this probability. Therefore, since we will likely be estimating this probability based on best available scientific and expert judgment, we are suggesting that a probability of greater than 90 percent is a more reasonable target range to estimate.

Adequate quantity of habitat refers to both size and number of preserved and areas that are sufficient for supporting the karst ecosystems. The number of preserves called for in the criterion below provides redundancy to the species by providing a sufficient number of populations to provide a margin of safety for these species to withstand a catastrophic event (Schaffer and Stein 2000). The size of preserves should be adequate to ensure resiliency of the population so that they are large enough to withstand stochastic events (Schaffer and Stein 2000). Multiple **karst fauna areas** (KFAs) across the species' ranges should provide representation of the breadth of their genetic diversity to conserve their adaptive capabilities (Schaffer and Stein 2000).

Adequate quality of habitat refers to (1) the condition and orientation of preserved lands with respect to the known localities for the species and (2) the ability of the species' needs to be met to sustain **viable populations**.

Considering the rapid rate of development and habitat loss within these species' ranges, establishing these KFAs as soon as possible (ten years or less) is the highest priority action for this recovery strategy. Once KFAs are established, our second priority is increasing our knowledge about these species and adaptively managing. Please check our website for recommendations on designing preserves for these species (http://ecos.fws.gov/tess_public/). These recommendations may be updated as new information becomes available.

This section provides an overview of the number and distribution of preserves needed for recovery. For more information on how to design preserves see the karst preserve design document referred to above. The actions to accomplish recovery of these species are outlined in section 2.3 and are described in more detail in section 2.4.

Selecting Areas for Preservation

Conservative Estimates for Preserve Design - The basic strategy for designing a karst ecosystem preserve is to protect an adequate area to (1) meet the species needs to feed, breed, and have shelter and (2) to provide a high probability that karst invertebrate populations will survive and thrive over the long term. Basic preserve design features include protecting the surface and subsurface drainage basins of at least one occupied karst feature and adequate surface habitat to maintain native plant and animal communities, which provide nutrient input and a buffer to temperature and humidity extremes. Details of the minimum area needed to protect the population detected in a feature are difficult to define due to limited information on these species' life history and population dynamics. Furthermore, population trends of all the listed invertebrates are difficult to obtain due to small sample sizes. This means that the only way to determine with certainty that a preserve is insufficient to support karst invertebrates is to document the extinction of a population by observing no specimens over the course of many years.

Current knowledge indicates that these species cannot be reintroduced into existing habitat. Therefore, an attempt to re-establish a population after it has been extirpated is not a feasible method. In addition, if a preserve is later found to be insufficient to support the species due to surrounding developments being either too close or too dense, the potential for preserving additional land is lost (the potential for **adaptive management** will be gone). Because these species have relatively long life spans and low requirements for food, a decline in population size or even the complete extinction of the population may take years or even decades. Observations of a listed species over several years on a preserve that is too small for perpetual species preservation may not detect declines that are actually occurring. If these observations are used as evidence that a preserve size was adequate, then the potential for long-term preservation of that species may be lost due to irreversible development surrounding the preserve. Therefore, preserve sizes should be established precautiously and be large enough to account for the uncertainty in area requirements for a population.

To provide long-term conservation of these species, consideration needs to also be given to the population dynamics and population genetics of these species. To preserve the genetic diversity of the species, preserves should be established based on consideration of population genetics analyses (if available), subsurface barriers or restrictions to travel, and the species' ranges. Some species-level genetic work has been done on *Cicurina* (including *C. madla*, *C. vespera*, and several non-listed *Cicurina*) (Paquin and Hedin

2004); however, no population genetics research has been done on any of the species. The current process used to ensure that genetic diversity is conserved is based on (1) known and potential barriers and restrictions to travel and (2) on species distributions.

Karst Fauna Regions (KFR) - For the purpose of this plan, **karst fauna regions** (KFR) are geographic areas that were delineated based on potential discontinuity of karst habitat that may reduce or limit interaction between troglobite populations (Veni 1994). Six KFRs were established by Veni (1994) and are as follows: Stone Oak, UTSA, Helotes, Government Canyon, Culebra Anticline, and Alamo Heights (Figure 2).

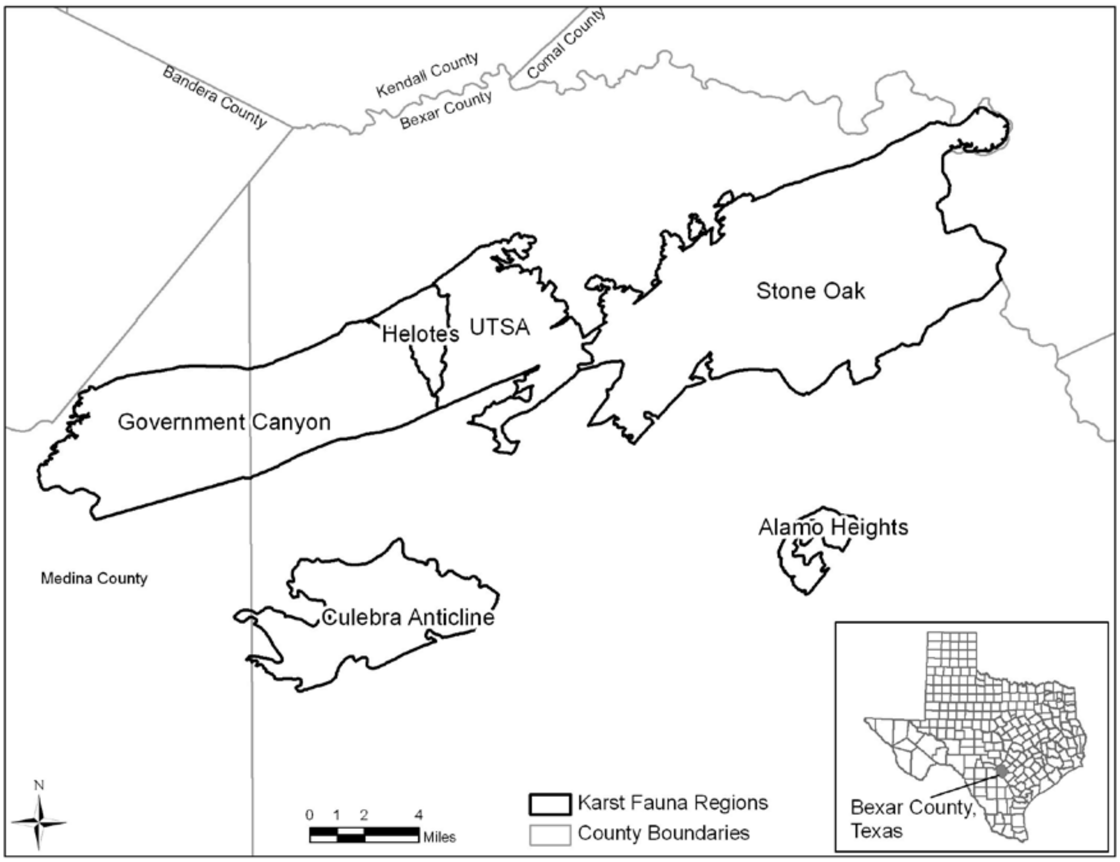

Figure 2. Karst Fauna Region boundaries in the San Antonio area

Recovery Units - A recovery unit is a special unit of the listed entity that is geographically or otherwise identifiable and is essential to the recovery and survival of the entire listed entity; that is, recovery units are individually necessary to conserve genetic robustness, demographic robustness, important life history stages, or some other feature necessary for long-term sustainability of the entire listed entity. Examples of recovery units include dispersed population units that represent the genetic diversity of a species necessary to provide adaptive flexibility and avoid inbreeding (NMFS and Service 2010). 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. Further, as mentioned above, having multiple KFAs (per KFR) across the species range provides (1) redundancy to the species by providing a sufficient number of populations to provide a margin of safety for these species to withstand a catastrophic event and (2) representation of the breadth of their genetic diversity to conserve their adaptive capabilities (Schaffer and Stein 2000). This is especially important for these species since they cannot easily move long distances to other areas to re-establish themselves and because this will allow more flexibility in coping with potential effects of climate change.

Some research, including Paquin and Hedin (2004) and White (2006), found that the distribution of *C. madla*, *C. vespera*, and several non-listed *Cicurina* species do not correlate well with the current KFRs per DNA analysis. Population level genetic information is needed for each species and would be helpful to reassess the recovery unit boundaries to ensure we are conserving a good representation of genetic diversity of each species throughout its range.

Karst Fauna Areas (KFA) - For the purpose of this plan, a karst fauna area (Service 1994) is a geographic area known to support one or more locations of an endangered species. A KFA is distinct in that it acts as a system that is separated from other KFAs by geologic and hydrologic features and/or processes or distances that create barriers to movement of water, contaminants, and troglobitic fauna. Karst Fauna Areas should be far enough apart that a catastrophic event (such as contaminants from a spill, pipeline leak, or flooding, etc.) that may kill species or destroy habitat in one area would be unlikely to impact species or habitat in other areas. As explained above in the KFR discussion, genetic interchange may occur over very large or small areas depending on geologic factors (White 2006). Therefore, the level of faulting or other geologic aspects (for example, stream incision or erosion) that may prohibit or allow genetic exchange should be assessed when considering areas as potential KFAs. All preserves should be either medium or high quality as defined in the karst preserve recommendations (http://ecos.fws.gov/tess_public/).

Full implementation of the recovery plan should lead to removal or reduction of threats to these species adequate to warrant downlisting and then to delisting the species. Since karst ecosystems cannot be recreated once destroyed, an adequate number of areas (KFAs) per portion of a species range (KFR) should be "protected" in perpetuity. For a KFA to be considered "protected" there must be a legally binding commitment in place that ensures that the KFA will be managed, monitored, and protected in perpetuity. Where development has precluded high quality KFAs, or where effects of urbanization and exotic species are impacting KFAs, increased management will be a critical component of recovery.

To be considered adequate to provide a high probability of species survival, a preserve should be sufficiently large and of adequate quality to maintain the integrity of the ecosystem on which the species depend and meet the guidelines in the karst preserve design document (http://ecos.fws.gov/tess_public/). The preserves should also have protection and management established in perpetuity and ensured to continue through a legally-binding mechanism.

Quantity and Quality of Karst Fauna Areas - To be considered for downlisting, each species should occur in six or more "protected" KFAs rangewide and be distributed as discussed below. Natureserve designates species that occur in five or fewer localities as critically imperiled (Natureserve Heritage 2010). Therefore, occurrence in at least 6 locations will ensure the species is not in Naturserve's critical (G1) designation. Ideally all KFAs would be high quality. However, we recognize that within KFRs opportunities will vary for recovering the karst invertebrates; therefore, various minimum distributions and qualities of KFAs in each KFR that would meet these criteria are discussed in Table 1. Overarching criteria, applied per species, that are reflected in each option in Table 1 include:

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

To understand Table 1, it may be helpful to also examine Table 2, which gives the actual number of KFRs that each species is known from. For example, a species that occurs in only one KFR, such as *Texella cokendolpheri*, would need at least six KFAs with at least three being high quality and the other three at least medium quality to be considered for downlisting (see the karst preserve design document (http://ecos.fws.gov/tess_public/) for description of high, medium, and low quality). High quality KFAs have a higher probability of long-term species survival, and by having three high quality KFAs in each KFR it provides for resiliency of the population enabling them to withstand stochastic events.

Table 1 shows options for the minimum number and qualities of KFAs that need to be preserved in each KFR for a species to be considered for downlisting. The left column indicates the number of KFRs in which each species could occur (see Table 2 for the number of KFRs from which each species is currently known). The center column illustrates the possible configurations of the minimum number and minimum quality of KFAs within the possible total number of KFRs. The right column indicates the total number of protected KFAs needed rangewide to be considered for downlisting. If species are more widely distributed (occur in more KFRs) more total KFAs are needed to meet recovery because we want to ensure we are conserving the genetic diversity of those species.

Table 1. Minimum quality and quantity of KFAs needed for recovery

<table>
<tr><th># of KFRs that species occurs in</th><th colspan="7">Combination of KFAs needed per KFR</th><th>Total No. of KFAs</th></tr>
<tr><td>1</td><td colspan="7">KFR #1: 3 High (H) + 3 Medium (M)</td><td>6</td></tr>
<tr><td>2</td><td>KFR #1: HHM</td><td colspan="6">KFR #2: HMM</td><td>6</td></tr>
<tr><td>3</td><td>KFR #1: HMM</td><td colspan="2">KFR #2: HMM</td><td colspan="4">KFR #3: HMM</td><td>9</td></tr>
<tr><td>4</td><td>KFR #1: HMM</td><td colspan="3">KFR #2: HMM</td><td>KFR #3:HMM</td><td colspan="2">KFR #4: HMM</td><td>12</td></tr>
<tr><td>5</td><td>KFR #1: HMM</td><td>KFR #2: HMM</td><td colspan="2">KFR #3: HMM</td><td>KFR #4: HMM</td><td colspan="2">KFR #5: HMM</td><td>15</td></tr>
</table>

Table 2. Estimated number of KFAs needed for recovery

Species	KFR	Number of KFAs to protect
Rhadine exilis	Government Canyon	12
	UTSA	
	Helotes	
	Stone Oak	
Rhadine infernalis	Government Canyon	15
	UTSA	
	Helotes	
	Stone Oak	
	Culebra Anticline	
Batrisodes venyivi	Government Canyon	6
	Helotes	
Texella cokendolpheri	Alamo Heights	6
Neoleptoneta microps	Government Canyon	6
Cicurina baronia	Alamo Heights	6
Cicurina madla	Government Canyon	12
	UTSA	
	Helotes	
	Stone Oak	
Cicurina venii	Culebra Anticline	6
Cicurina vespera	Government Canyon	6

The quality of preserved KFAs is defined based on probability of long-term survival of the species in that area. Ideally, all recovery KFAs would be high quality. High quality preserves are larger, tend to require less active management, and have a higher probability of maintaining the species long-term. Medium quality preserves have some compromised characteristics of a high quality preserve and while the probability of species survival is thought to be lower than in a high quality preserve, it is still presumed to be fairly high. Also, medium quality preserves may require increased management. Accepting any number of medium quality KFAs in place of high quality KFAs, is accepting a higher risk of extirpation of that population, and thus, a higher risk of extinction for the species. However, two reasons to accept a medium quality KFA (and a higher risk of extinction) are (1) often there are not six high quality habitat patches remaining, and (2) there is considerable uncertainty as to the exact probability of extinction at KFAs of various sizes and configurations. This uncertainty is due in part to lack of research on KFAs of intermediate sizes over the long term (decades).

In situations where the possibility for high and medium quality KFAs doesn't exist, we encourage the establishment of low quality karst preserves. While these preserves do not count towards meeting the recovery criteria, they still provide some chance of survival for these species.

It is important to base decisions about preserve size on data that demonstrate decades of success because the long-lived nature and difficulty in sampling these organisms and the current inability to detect population trends indicate there will likely be some time between an environmental cause and a detectable population effect (see section 2.4 for descriptions of recovery actions to clarify this uncertainty).

Management

It is also important to ensure that that preserves are managed in a way that is most conducive to ensuring the continued survival and recovery of the federally listed karst invertebrates in central Texas.

Management is needed at all KFAs and includes, but is not limited to:

- keeping the area free from contamination;
- controlling red-imported fire ant infestation;
- preventing excessive human visitation in the cave and preserve area;
- maintaining adequate populations of surface native plant and animal communities.

Currently, there are data gaps and uncertainty about how to best avoid impacts and ensure long-term survival of these species. Therefore, monitoring population status and applying adaptive management are critical components of the recovery strategy for these species (also see the management document [http://ecos.fws.gov/tess_public/]).

Research Needs

In a global context, cave fauna are not well-studied and these species are no exception. Generally, any given species has fewer than five peer-reviewed publications that even mention their names, and most of these species are represented in the scientific literature by only their species description. This lack of knowledge contrasts the high diversity of troglobites and high threats from habitat destruction that occur in central Texas. In a study that compared the **cavernicole** diversity of every single county in the 48 contiguous United States, Texas ranked among the highest for diversity locations of both troglobites and **stygobites** (aquatic troglobites) with Travis, Williamson, Bexar, Comal, and Hays counties suggested as the focus of conservation efforts due to the high diversity and concentration of taxa (Culver et al. 2000). This same study found that over 50 percent of troglobites occurred in less than 1 percent of the land area, stressing the importance of high diversity areas to the conservation of subterranean species.

Several research priorities detailed in section 2.4 could yield results that may change management recommendations or may prompt revision of downlisting and delisting criteria. Further, Table 3 below lists the threats to these species and the recovery actions that address them. The research actions identified in section 2.4 will fill gaps in our knowledge of these species and help us adapt our management and conservation efforts, as needed, to meet the recovery objectives and goal.

Table 3. Threats and recovery actions and criteria designed to address them

Listing factor	Threats associated with factor	Recovery actions that address threat	Recovery criteria that measures success at removing threat
A	Habitat destruction; habitat modification and degradation (including alteration of surface plant and animal community and surface or subsurface drainage basins); edge effects; contamination; human visitation and vandalism; quarrying and mining	All actions under 1.0, 2.0, 3.0, and 4.0	1 and 2
B	Besides the unintentional impacts and threats to habitat from recreational and commercial use of caves discussed under factors A and E, there are no known threats to these species from over-utilization of the species for commercial, recreational, scientific, or educational purposes.	N. A.	-
C	Red-imported fire ants	All actions under 1.2.1, 2.2, 2.3.3, 2.4.2, 2.4.3	1 and 2
D	Little to no regulatory protection is afforded to these species by state or local agencies	All actions under 1.2, 3.0, and 4.0	1 and 2
E	Small population size and climate change	All actions under 1.0, 2.0, and 4.0	1 and 2

2.2 Goals, Objectives, and Criteria

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

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

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

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

Criterion 1- (downlisting) – The location and configuration of a least the minimum number and quality[3] of KFAs in each KFR (Table 1) for each species are preserved. Also, legally binding commitments are in place for perpetual protection and management[4] of these KFAs.

Overarching criteria, applied per species, that are reflected in Table 1 include:

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

Criterion 2 - (delisting) – In addition to the downlisting criterion, monitoring and research have been completed to conclude with a high degree of certainty that KFA sizes, quality, configurations, and management are adequate to provide a high probability of the species survival (greater than 90 percent over 100 years). To assess adequacy, results should be measured over a long enough time that cause and effect can be inferred with a high degree of certainty.

The recovery criteria above are based on addressing threats (see section 1.5) to karst invertebrates. Cumulatively, they address the five listing factors (A-E) identified in section 4(a)(1) of the Act that were considered when these species were listed and any new threats since the time of listing (see section 1.5). The KFAs called for in recovery criterion 1 will need to be designed, established, and managed in such a way that the species' long-term survival is no longer threatened. The activities called for in the

[3] Preserve quality is defined in the karst preserve document at http://ecos.fws.gov/tess_public/,
[4] Management recommendations can be found at http://ecos.fws.gov/tess_public/.

second criterion will help confirm the adequacy of the KFAs and management in addressing the threats. The karst preserve design document and the management document (http://ecos.fws.gov/tess_public/) include guidance, based on best available science at this time, on how to design and manage preserves (KFAs) to address threats and assess their effectiveness. The Plan calls for an adaptive management approach to revise management, if necessary, to meet the recovery goals. Therefore, the two documents referenced above may be revised accordingly.

2.3 Recovery Program Outline

The actions needed to implement the recovery strategy for these species and meet recovery criteria are organized below into (1) habitat protection and management, (2) monitoring, research, and adaptive management, (3) outreach and education, and (4) post-delisting monitoring. Habitat, species, and threat monitoring and research will generate information that assists with management of the species and assessment of the recovery program success. Monitoring the implementation of habitat management and results to the species should ensure that management practices are appropriately and effectively addressing impacts and threats to the species. If the practices are not effective, then changes in management should be made and additional planning and scientific research may be necessary.

This section outlines actions necessary to achieve this plan's goals and objectives and provides a quick overview of the recovery program. The Narrative of Recovery Actions (section 2.4) describes the recovery actions in more detail and contains a table (Table 3) linking threats to the species with actions that address those threats and criteria to measure success. The listing factor(s) (see section 1.1) to be addressed by the recovery actions listed below are identified in parenthesis after each action. As discussed in section 1.1, implementation of this recovery plan is dependent on the voluntary participation and cooperation and commitment of numerous conservation partners.

Outline of Recovery Actions

1.0 Habitat Protection and Management

- 1.1 Identify/determine conservation areas (KFAs) needed to meet recovery criteria

- 1.2 Protect conservation areas (KFAs) needed to meet recovery criteria

  - 1.2.1 Purchase or otherwise implement measures to protect KFAs in perpetuity and provide for long-term management

  - 1.2.2 Develop a plan to protect non-cave/karst areas (mesocaverns) in between KFAs

  - 1.2.3 Work with regulatory agencies to ensure adequate protection of karst invertebrates

2.0 Monitoring, research, and adaptive management

- 2.1 Distribution information - conduct additional biospeleological surveys

- 2.2 Research to refine our understanding of habitat and population relationships and requirements to sustain viable populations

2.2.1 Research to refine our ability to measure and monitor species

2.2.1.1 Continue to assess the detectability of the listed karst invertebrates

2.2.1.2 Refine the appropriate interval(s) and protocols for monitoring

2.2.1.3 Develop marking techniques and conduct mark/recapture research

2.2.2 Research to refine our understanding of species response to influences

2.2.2.1 Refine our understanding of natural factors that affect populations

2.2.2.2 Refine our understanding of **anthropogenic** factors that affect populations

2.2.2.3 Design and implement a study to evaluate the appropriate size and quality of a KFA including (1) vegetation community size and composition needed to support karst invertebrates (and cave crickets) and (2) the interaction of surface plant and animal communities with the subsurface

2.2.3 Formulate population measures to indicate viability

2.3 Research to evaluate the effectiveness of KFA, KFR, and preserve design and management recommendations

2.3.1. Conduct genetics and other research to determine habitat connectivity, mesocavern use, and genetic diversity across the range

2.3.2 Conduct hydrogeologic research

2.3.3 Monitor KFAs of various sizes

2.4 Adaptive Management

2.4.1 Based on research and monitoring, reassess distribution of KFAs and KFRs

2.4.2 Based on research and monitoring, reassess delineation of KFAs and preserve design

2.4.3 Based on research and monitoring, reassess preserve management, and monitoring recommendations

3.0 Outreach and education

3.1 Educate the public about endangered karst invertebrates and their habitat

3.2 Provide instruction and information to private landowners

3.3 Provide educational opportunities for professionals regarding karst ecosystems and listed species, and work with agencies to ensure that their practices do not inadvertently cause impacts to karst invertebrates

4.0 Develop a post-delisting monitoring plan

2.4 Narrative of Recovery Actions

Underlined recovery actions represent the most stepped-down levels of the Recovery Program Outline and Narrative. These items are discrete, specific actions and are listed in the Implementation Schedule (section 4.0) with associated time and cost estimates and potential partners or responsible parties. The actions below include both status and trend monitoring (determines if a population or threat is increasing or decreasing) and cause and effect monitoring (tests hypothesis and determines if an action is effective) (NMFS and Service 2010).

1.0 Habitat Protection and Management

1.1 Identify/determine KFAs needed to meet recovery criteria

To assist with this task, the framework for delineating the number of KFAs can be found in Table 1, Table 2, and section 2.1 (recovery strategy). The characteristics and quality definitions of KFAs can be found in section 2.1 and the karst preserve design document (http://ecos.fws.gov/tess_public/). Known locations should be reviewed to (1) determine if they qualify as high or medium quality KFAs and (2) determine if they qualify as independent KFAs according to their proximity to each other and threats; therefore, their likelihood of being impacted by a catastrophic event. This action should be based on the best available information so that we can proceed with action 1.2.

1.2 Protect conservation areas (KFAs) needed to meet recovery criteria

To consider species for downlisting, the KFAs need to be protected in perpetuity.

1.2.1 Purchase or otherwise implement measures to protect KFAs in perpetuity and provide for long-term management

These properties could be acquired and protected in perpetuity by non-profit conservation groups or by governmental or private agencies. It is also possible to set aside KFAs as conservation easements on private property. Regardless of the owner, property use should restrict any activity that would threaten the species or their habitat.

KFAs require management, particularly those isolated from other patches of habitat. Management activities include (but are not limited to) invasive species control, restricting human visitation, and performing species monitoring that provides up-to-date feedback on the efficacy of management techniques. The guidelines in the management and monitoring document (http://ecos.fws.gov/tess_public/) should be followed. Based on new information these guidelines may be revised or updated in the future. Therefore funding should be in place for adaptive management.

1.2.2 Develop a plan to protect non-cave/karst areas (mesocaverns) in between KFAs

It is generally understood in the conservation community that single locality approaches to conservation are less valuable without a landscape based conservation vision. To this end, a plan should be developed that will conserve mesocavernous areas between known endangered species localities and preserved KFAs. These mesocaverns can serve as protection for mesocaverns that may support listed species or be corridors for migration, corridors for trogloxenes (for example, cave crickets), sources of genetic diversity for maintaining native flora and fauna in the KFAs, and buffers for overall water quality and quantity entering the subsurface. There is some thought that karst invertebrates may use mesocaverns more than caves, but are harder to detect in mesocaverns. Therefore, preserving mesocaverns is important as they may support unknown or existing populations that use a larger area than we realize. They may also serve as refugia during times of increased temperature or decreased humidity. There are many possible approaches to protecting mesocaverns, including limits on percentage of impervious cover for new development (particularly in karst zones 1 and 2), purchase of additional karst landscape, or other landscape level solutions. Another approach is to conduct community outreach to educate landowners to avoid pesticides or other products that could leach into mesocaverns and cause impacts.

1.2.3 Work with regulatory agencies to ensure adequate protection of karst invertebrates

The Service should work with regulatory agencies, such as, TCEQ and COSA, to help increase awareness of karst invertebrates and protect them from inadvertent impacts. For example, TCEQ regulations protect some features from water quality impacts; however, some of their practices (such as sealing a cave opening to protect water quality) could harm karst invertebrates and their habitat (see discussion in 65 FR 81419 81433).

2.0 Monitoring, research, and adaptive management

Status and trend monitoring of cave species, habitat parameters, and toxins should be conducted as part of the long-term management for KFAs. In addition, cause and effect research and monitoring, assessing what factors impact populations, should be performed. Many aspects of karst ecosystems in central Texas are poorly understood, particularly those relating to long-term survival of species in isolated KFAs. Ongoing research is essential to increase our confidence in estimations of the probability of survival in these KFAs. The research needs below are listed in no particular order, but some projects naturally follow others because the results of one will affect the design of another.

2.1 Distribution information – conduct additional biospeleological surveys

Efforts should be made to find additional localities of listed karst invertebrates. As properties are available for survey, quantified biospeleological inventories should be performed to help identify areas that may serve as karst fauna areas and to help determine which areas are most important for recovery. Due to the cryptic nature of karst invertebrates, additional surveys should be performed at previously surveyed caves, because it is possible to survey a site numerous times before discovering a listed species (Krejca and Weckerley 2007). As new locations are discovered, location and habitat information should be integrated into a central repository to keep the species known ranges up-to-date. Collection and observation data for each of the sites should be assembled according to the most recent Service 10(a)(1)(A) survey protocols.

2.2 Research to refine our understanding of habitat and population relationships and requirements to sustain viable populations

Research on what is necessary to provide for population viability should be assessed. The results from these studies should be used to adjust the basic monitoring and management of cave species, habitat, toxins, and other threats.

2.2.1 Research to refine our ability to measure and monitor species

Research should be conducted to refine our ability to measure and monitor these species both to evaluate their status and trends and to assess the effects of recovery efforts or threats (including impacts from RIFA). Some taxa may be more readily detected, while others are more cryptic. Therefore, different monitoring techniques may be needed. Further, recovery management decisions should be evaluated and supported by reliable monitoring results. These data can provide the scientific foundation to measure the progress of management decisions (NMFS and Service 2010).

2.2.1.1 <u>Continue to assess the detectability of the listed karst invertebrates</u>

To determine how reliable or meaningful population monitoring results are, it is important to determine the species detectability. Also, factors that affect populations may influence detection and should be considered for each taxa. Further, more information is needed on behavioral patterns that may influence detectability. For example, are the endangered karst invertebrates **nocturnal**, **diurnal**, or **crepuscular**? Most researchers enter caves during the day to conduct surveys. However, most cave organisms evolved from species that were pre-adapted to the cave environment, and one common pre-adaptation to low-light conditions is nocturnal behavior. Other behavior that may impact the interpretation of monitoring studies includes, but is not limited to, small-scale movement patterns (for breeding, feeding, territoriality, etc.) to microclimate habitat preferences, substrate preferences, and for reproductive behavior.

2.2.1.2 <u>Refine the appropriate interval(s) and protocols for monitoring</u>

Population monitoring intervals need to be determined and may be based on aspects of the species' biology, physiology, and population dynamics, for example, response time to introduction of toxins or loss of energy flow. This monitoring protocol should indicate an ideal monitoring interval that is frequent enough to detect population trends before they are catastrophic, but sparse enough to minimize the impact of researcher visitation due to substrate trampling or other effects. Also, species may have different characteristics that call for custom monitoring intervals.

2.2.1.3 Develop marking techniques and conduct mark/recapture research

Mark and recapture techniques are not commonly used with invertebrate species, but have been employed for some cave species (Knapp and Fong 1999, Taylor et al. 2005). Mark and recapture data can be used to estimate population size and migration. In addition to studies of the listed species (or **congener**s), further mark/recapture studies of cave cricket population dynamics are needed to determine habitat and area requirements to maintain viable populations of this food source.

2.2.2 Research to refine our understanding of species response to influences

Research should be conducted to assess the factors below and whether they have an effect on the species. This cause and effect research should test hypotheses, involve robust analyses, and generate reliable results. Further, this research should help us assess whether we are adequately managing KFAs.

2.2.2.1 Refine our understanding of natural factors that affect populations

Research to determine the influence of natural factors on invertebrate populations should be conducted. This research could include monitoring invertebrates and looking for correlations to physical characteristics of the cave, season and weather, microhabitat, nutrient quantity and quality, characteristics of the natural surface habitat (vegetation, **epigean** fauna, etc.), and proximity to source karst invertebrate populations. Other natural parameters that could be assessed include species assemblages, prey and predators (including RIFA competition and predation), and indicator species such as cave crickets (for healthy/diverse communities and impacted communities). Each of these factors may warrant an independent study or detailed analysis. A large dataset will likely be necessary to tease apart these factors and test how they affect cave communities and endangered species. These data will help refine population monitoring methods, including the ideal time of year and condition for presence/absence surveys, and to assess the adequacy of preserve design in sustaining these species.

2.2.2.2 Refine our understanding of anthropogenic factors that affect populations

Research on anthropogenic factors that may affect populations should be conducted. Factors that could be assessed for their influence on these species include things such as surface habitat fragmentation, impervious cover above the karst, non-native flora and fauna, changes in water quantity and quality that enters the cave, cave gates, and substrate compaction inside the cave. Effects from potential impacts need to be measured and analyzed using various methods (to compare results). Research on habitat fragmentation will increase understanding on how much fragmentation is tolerable within a properly designed KFA, or among karst preserves that may rely on one another as source populations.

Studying how varying levels of non-native flora and fauna affect cave populations will help guide karst preserve design and management. For example, some invasive plants and animals may be more important to control than others, particularly in smaller KFAs (and preserves) that are more impacted and may need more management. Determining which invasive species should be controlled and how will be important, especially for small KFAs.

Research on changes in water quantity and quality can indicate how these changes may be mitigated or avoided. For example, if part of a cave drainage basin will be crossed by a highway, should the drainage from that highway be routed elsewhere to prevent contamination, or is water quantity an equally or more important factor for the species? If so, should the drainage be maintained at the risk of contamination?

Cave gating is commonly used to limit human visitation in caves, and while the effect of gates has been examined for bats, research is needed to examine the effect that gates have on invertebrates and the cave environment (such as, temperature, humidity, and nutrient input) or the characteristics cave gates should have for invertebrate conservation.

Human visitation can cause impacts including soil compaction (for example, compacting loose soil, rocks with spaces underneath) and may have other impacts that are difficult to measure (for example, disturbance of normal behavior due to light, heat, or noise). A study is needed to specifically answer the question about how much impact is acceptable for the variety of substrates and conditions in central Texas caves. The results of this study may indicate the species tolerance to human visitation.

2.2.2.3 <u>Design and implement a study to evaluate the appropriate size and quality of a KFA including (1) vegetation community size and composition needed to support karst invertebrates and (2) the interaction of surface plant and animal communities with the subsurface</u>

During the first year of implementing this plan, a study should be designed to evaluate the adequacy of various characteristics (including size [acreage], setbacks, and other factors of a KFA) in meeting the objective of perpetual protection for the karst invertebrates. This should include species-specific research to determine the importance of grassland and woodland communities to conserving karst invertebrates. Data from this study should be assessed five years and ten years after the recovery plan is finalized. This will help ensure that we are adequately preserving these species.

Research is needed to assess the interaction of the surface plant and animal communities with subsurface ecosystems. For example, does surface plant diversity affect cave cricket foraging, and if so, how does this relationship influence nutrient input into a cave? Also, competition between RIFA and ground-foraging cave fauna should be further studied in areas with varying RIFA densities. This research should help determine if preserve size and configuration guidelines need revision.

2.2.3 Formulate population measures to indicate viability

Due to small sample sizes of karst invertebrates and the inability to generate population trends or conduct population viability analyses, measures need to be formulated that indicate the viability of these species. These indicators can be developed using information gathered under 2.2.1 above.

2.3 Research to evaluate the effectiveness of KFA, KFR, and preserve design and management recommendations

To ensure that we are effectively managing and protecting these species, the research below should be conducted to increase our confidence level about whether we are meeting the recovery objectives and goal of this plan.

2.3.1. Conduct genetics and other research to determine habitat connectivity, mesocavern use, and genetic diversity across the range

A major objective of the recovery strategy is to maintain adequate representation of the species to provide for long-term species viability and adaptability. Genetic diversity should be part of that consideration for each species. Factors that will influence the ability to maintain diversity across the range include the following: level of connectivity or migration between sites, population sizes, and area needed to support those populations. Population level genetic data would help evaluate adequacy of conservation units and answer questions, such as how much do karst invertebrates use mesocavern habitats around and between known caves and how much area is needed to support a viable population of these species? Answers to these questions may indicate whether more effort should be put toward preserving larger areas or intervening habitats.

Mesocaverns may be important corridors connecting KFAs, or may even be significant population centers. Efforts to assess populations in these spaces may include drilled boreholes, investigation of voids encountered during construction excavations, and population genetics. A set of guidelines should be established with multiple partners, such as TCEQ, COSA, or other site inspection entities, so that a construction site can be sampled for karst invertebrates by qualified personnel. Analysis of these data could help determine mesocavern use and contribute to population genetic analysis.

Genetics research (on the population and species level) is needed to help determine how KFAs should be distributed across the range and how well the KFR boundaries are contributing to meeting recovery objectives. The results of these projects should help address uncertainties about KFRs discussed in the recovery strategy section.

2.3.2 Conduct hydrogeologic research

Information on the evolution of caves in specific KFAs and their surface and subsurface drainage basins is important for preserving these sites. KFAs and especially areas closest to caves with listed species should be carefully searched for additional caves and karst features. These may be directly related biologically and hydrogeologically to known caves with listed species. The presence of hydrogeological characteristics is helpful to delineating surface and subsurface drainage basins, which are important to delineating KFAs.

Surface water drainage basins can usually be easily surveyed as land surface sloping down to cave entrances and karst features known to drain into caves. Subsurface drainage basins are determined by hydrogeologic assessment of the caves and karst features, mapping those features' interior conditions and layout of the cave or feature, evaluating the relationship of surface to subsurface features, and measuring and interpreting hydrogeologic features including strata, fractures, flow features, sediments, speleothems, distribution of animal bones that may have been carried by water, water flow, air flow, air quality, and resolution features. This information is used to determine the probable origin of the caves and karst features in order to gain insight into portions of the karst systems that are inaccessible to human exploration and probing, per the methodology proposed by Veni and Associates (1999). When possible, managers should use tracer testing and geophysical investigations to more accurately delineate the groundwater (subsurface) drainage areas.

2.3.3 Monitor KFAs of various sizes

Karst Fauna Areas of various sizes should be monitored for numerous years to refine our understanding of preserve size. Monitoring (and analyses) should include data on preserve size, listed species, non-listed troglobites, and RIFA from locations that do and do not meet recovery criteria. These analyses will provide information regarding extinction probabilities considering the state of conservation lands and help direct future recovery actions. This will help assess the effectiveness of our preserve design and mesocavern recommendations as to how much area is needed to adequately protect these species. Further, these data will help determine if the delisting recovery criterion has been met.

2.4 Adaptive Management

Results from the research and monitoring above should be used to adaptively manage these species as appropriate.

2.4.1 Based on research and monitoring, reassess distribution of KFAs and KFRs

Using the research results from above, we should reassess whether we have adequately distributed KFAs across these species' ranges. Also, based on research in action 2.3.1, we should be able to determine if the current KFR delineation adequately represents the species genetic diversity across the range. Results of this research could result in revisions to the current KFR boundaries or reveal the need to have a different distribution of KFAs.

2.4.2 Based on research and monitoring, reassess delineation of KFAs and preserve design

Based on research above, we should reassess whether we have adequately delineated KFAs. For example, based on research from action 2.2.2.3, we may make changes to preserve sizes to adequately protect the vegetation community that these species rely upon. Another example is that research from action 2.2.2.1 may provide information on what preserve size is needed to support the cave cricket metapopulation structure.

2.4.3 Based on research and monitoring, reassess preserve management, and monitoring recommendations

Based on research above, we should reassess whether we are adequately managing and monitoring these species. For example, research from actions 2.3.1 and 2.3.2 could indicate that management practices should be adjusted to adequately protect mesocaverns. Another example may be that research from actions under 2.2.1 above could indicate that a different monitoring regime is needed to accurately monitor these cryptic species.

3.0 Outreach and education

The Service by itself cannot recover these species; they occur on private, state, and federal lands. Therefore, successful recovery involves an outreach program that solicits and encourages support and participation from potential partners and others who could influence recovery implementation.

Outreach should include a focused effort by conservation partners, especially those managing parks and public lands. They can post kiosks, include information in their brochures, websites, and public presentations, and conduct field trips to non-vulnerable locations that highlight their endangered species protection efforts on their lands and for their communities. Educational opportunities could also be provided to private landowners and professionals regarding beneficial activities and how to avoid inadvertently impacting karst invertebrates.

3.1 Educate the public about endangered karst invertebrates and their habitat

Long-term survival of listed species depends on an educated and concerned public that recognize the importance of these species; therefore, it is important to develop programs to educate all ages of people about karst biology, geology, and ecology. These programs should disseminate information on creatures of the karst ecosystem and how they interact with each other and the surface, their relationship to the aquifer, and the threats to karst ecosystems. They should also detail how people can contribute to conservation efforts. Education efforts should occur in and around caves that do not contain endangered karst invertebrates to avoid impacts of human visitation to the habitat and species.

This can be accomplished via websites, brochures, signs (for example, at parks and preserves), workshops, classes, videos, and other avenues of public outreach. Existing programs could be used to distribute this information. For example, the San Antonio Virtual Nature Center (sponsored by the Bexar Audubon Society) or other similar websites may be useful venues for spreading information online, and classes on karst ecosystems may be incorporated into existing natural history courses such as the Texas Master Naturalist Program. Also, teachers can incorporate karst education into existing programs by creating new curricula that encompass aspects of the species biology, range, habitat requirements, and threats.

Preserve managers could partner with local caving clubs, government agencies, conservation organizations, schools, or landowners to provide similar, on-the-ground opportunities to teach people about karst ecosystems in Bexar County.

3.2 Provide instruction and information to private landowners

Programs and materials should be developed for private landowners in karst areas with listed species. These materials should contain much of the general information from 3.1, with an emphasis on landowners and specific management activities they can implement on their property that would benefit karst ecosystems or avoid negative impacts. Management guidelines should include information on how to identify a karst feature, avoidance of insecticides and pollutants, and the importance of native surface communities. This task can be accomplished through informational websites, classes, brochures, workshops, and other forms of outreach. Landowners should be instructed on where they can obtain additional information and ask questions relating to karst ecosystems.

3.3 Provide educational opportunities for professionals regarding karst ecosystems and listed species, and work with agencies to ensure that their practices do not inadvertently cause impacts to karst invertebrates

Develop educational programs for preserve managers, consultants, and other professionals to expand knowledge of karst ecosystems. Applied techniques should be taught to professionals including species identification, survey methodology, drainage basin delineations, and preserve design. These techniques should be covered using field visits whenever possible. Organizations such as universities, government agencies, the Texas Speleological Survey, and the Texas Cave Management Association may be of assistance with these efforts. Efforts should be made to work with agencies such as TCEQ and the COSA to ensure that their practices do not inadvertently cause impacts to karst invertebrates. For example, while some TCEQ practices provide protection from water quality impacts, others, such as sealing cave openings for water quality reasons, can harm karst invertebrates.

4.0 Develop a post-delisting monitoring plan

Section 4(g)(1) of the Act requires that the Service monitor the status of all recovered species for at least five years following delisting. In keeping with this mandate, a post-delisting monitoring plan should be developed by the Service in cooperation with TPWD, Federal agencies, academic institutions, and other appropriate entities. This plan should outline indicators that will be used to assess the status of the delisted species (considering population and threat monitoring), develop monitoring protocols for those indicators, and evaluate factors that may trigger consideration for relisting. Actions under 2.2 may be helpful in designing this plan and it should be developed in advance of delisting to provide for baseline monitoring.

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4.0 IMPLEMENTATION SCHEDULE

The Implementation Schedule follows the outline in section 2.3, includes the most stepped-down actions, and estimates costs for implementing this recovery plan. It is a guide for meeting the objectives discussed in the recovery section (section 2.2). This schedule indicates action priorities, action numbers, action descriptions, action durations, potential partners, and estimated costs. When these actions are complete they should accomplish the objectives of this plan. The Service has identified agencies and other potential partners to help implement the recovery of these species. While these potential partners are called "responsible parties" in the table, this plan does not commit any partners to actually carry out a particular recovery action or expend funds. Likewise, this schedule does not preclude or limit other agencies or parties from participating in the recovery program.

The Implementation Schedule contains the estimated monetary needs for all parties involved in recovery for the first 10 years only. Estimated funds for agencies include only project specific contracts, staff, and operations costs in excess of base budgets. They do not include budgeted amounts that support ongoing agency staff responsibilities.

Under "Duration," the term "continual" is used to denote actions that are expected to require constant attention throughout the recovery process and have an indefinite duration.

Priorities in column one of the Implementation Schedule are assigned using the following guidelines:

Priority 1(a) - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 1(b) - An action that by itself will not prevent extinction, but is needed to carry out a Priority 1(a) action.

Priority 2 - An action necessary to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.

Priority 3 - All other actions necessary to meet the recovery objectives.

Actions and action numbers are taken from the Recovery Action Outline and Recovery Action Narrative (sections 2.3 and 2.4). The terms and acronyms used for the potential partners for implementation are listed on p. x of the recovery plan.

Implementation Schedule for the Nine Bexar County Karst Invertebrates Recovery Plan (Species: *Rhadine exilis, R. infernalis, Batrisodes venyivi, Texella cokendolpheri, Neoleptoneta microps, Cicurina baronia, C. madla, C. venii, and C. vespera*)												
								Cost Estimate by FY (by $1,000s)				
Priority Number	Action Number	Action Description	Species Benefiting (if multi-species plan)	Action Duration (Years)	Responsible Parties	Is FWS Lead?	Total $1,000s	FY 1-2	FY 3-4	FY 5-6	FY 7-8	FY 9-10
1(b)	1.1	Identify/determine conservation areas (KFAs) needed to meet recovery criteria	all	2	Service and others	yes	20	20	0	0	0	0
1(a)	1.2.1	Purchase or otherwise implement measures to protect KFAs in perpetuity and provide for long-term management	all	10	Service and others	no	134,700	26,940	26,940	26,940	26,940	26,940
2	1.2.2	Develop recommendations to protect mesocaverns in between KFAs	all	2	Service and others	yes	0	0	30	0	0	0
2	1.2.3	Work with regulatory agencies to ensure adequate protection of karst invertebrates	all	8	TCEQ, COSA, Service	yes	10	5	2	2	1	0

Implementation Schedule for the Nine Bexar County Karst Invertebrates Recovery Plan (Species: *Rhadine exilis, R. infernalis, Batrisodes venyivi, Texella cokendolpheri, Neoleptoneta microps, Cicurina baronia, C. madla, C. venii, and C. vespera*)												
								Cost Estimate by FY (by $1,000s)				
Priority Number	Action Number	Action Description	Species Benefiting (if multi-species plan)	Action Duration (Years)	Responsible Parties	Is FWS Lead?	Total $1,000s	FY 1-2	FY 3-4	FY 5-6	FY 7-8	FY 9-10
2	2.1	Distribution information - conduct additional biospeleological surveys	all	10	Service and others	no	25	5	5	5	5	5
2	2.2.1.1	Continue to assess the detectability of the listed karst invertebrates	all	2	Service and others	no	40	40	0	0	0	0
2	2.2.1.2	Refine the appropriate interval(s) and protocols for monitoring	all	5	DOD, TPWD, Service, and others	no	60	30	30	0	0	0
2	2.2.1.3	Develop marking techniques and conduct mark/recapture research	all	3	DOD, TPWD, Service, and others	no	30	20	10	0	0	0
2	2.2.2.1	Refine our understanding of natural factors that affect populations	all	10	Service and others	no	50	10	10	10	10	10
2	2.2.2.2	Refine our understanding of anthropogenic factors that affect populations	all	10	Service and others	no	50	10	10	10	10	10

Implementation Schedule for the Nine Bexar County Karst Invertebrates Recovery Plan (Species: *Rhadine exilis, R. infernalis, Batrisodes venyivi, Texella cokendolpheri, Neoleptoneta microps, Cicurina baronia, C. madla, C. venii, and C. vespera*)												
								Cost Estimate by FY (by $1,000s)				
Priority Number	Action Number	Action Description	Species Benefiting (if multi-species plan)	Action Duration (Years)	Responsible Parties	Is FWS Lead?	Total $1,000s	FY 1-2	FY 3-4	FY 5-6	FY 7-8	FY 9-10
2	2.2.2.3	Design and implement a study to evaluate the appropriate size and quality of a KFA preserve including (1) vegetation community size and composition needed to support karst invertebrates and (2) the interaction of surface plant and animal communities with the subsurface	all	10	Service and others	no	20	10	0	5	0	5
2	2.2.3	Formulate population measures to indicate viability	all	3	DOD, TPWD, Service	no	60	0	0	30	20	10

Implementation Schedule for the Nine Bexar County Karst Invertebrates Recovery Plan (Species: *Rhadine exilis, R. infernalis, Batrisodes venyivi, Texella cokendolpheri, Neoleptoneta microps, Cicurina baronia, C. madla, C. venii, and C. vespera*)													
								Cost Estimate by FY (by $1,000s)				
Priority Number	Action Number	Action Description	Species Benefiting (if multi-species plan)	Action Duration (Years)	Responsible Parties	Is FWS Lead?	Total $1,000s	FY 1-2	FY 3-4	FY 5-6	FY 7-8	FY 9-10
1(b)	2.3.1	Conduct genetics and other research to determine habitat connectivity, mesocavern use, and genetic diversity across the range	all	3	DOD, TPWD, Service	no	80	80	0	0	0	0
2	2.3.2	Conduct hydrogeologic research	all	2	DOD, EAA, TPWD, SWRI, Service, USGS, and others	no	60	40	20	0	0	0
2	2.3.3	Monitor KFAs of various sizes	all	continual	Service, permit holders, preserve managers, and others	no	80	20	20	20	10	10
2	2.4.1	Based on research and monitoring, reassess distribution of KFAs and KFRs	all	5	Service and others	yes	15	0	0	5	5	5

Implementation Schedule for the Nine Bexar County Karst Invertebrates Recovery Plan (Species: *Rhadine exilis, R. infernalis, Batrisodes venyivi, Texella cokendolpheri, Neoleptoneta microps, Cicurina baronia, C. madla, C. venii, and C. vespera*)													
								Cost Estimate by FY (by $1,000s)				
Priority Number	Action Number	Action Description	Species Benefiting (if multi-species plan)	Action Duration (Years)	Responsible Parties	Is FWS Lead?	Total $1,000s	FY 1-2	FY 3-4	FY 5-6	FY 7-8	FY 9-10
2	2.4.2	Based on research and monitoring, reassess delineation of KFAs and preserve design	all	5	Service and others	yes	15	0	5	5	5	0
2	2.4.3	Based on research and monitoring, reassess preserve management, and monitoring recommendations	all	6	Service and others	yes	15	0	0	5	5	5
2	3.1	Educate the public about endangered karst invertebrates and their habitat	all	10	DOD, TPWD, UTSA, COSA, Service, and others	no	60	20	10	10	10	10
2	3.2	Provide instruction and information to private landowners	all	continual	EAA, TCMA, TPWD, Service	no	10	2	2	2	2	2

Implementation Schedule for the Nine Bexar County Karst Invertebrates Recovery Plan (Species: *Rhadine exilis, R. infernalis, Batrisodes venyivi, Texella cokendolpheri, Neoleptoneta microps, Cicurina baronia, C. madla, C. venii, and C. vespera*)												
								Cost Estimate by FY (by $1,000s)				
Priority Number	Action Number	Action Description	Species Benefiting (if multi-species plan)	Action Duration (Years)	Responsible Parties	Is FWS Lead?	Total $1,000s	FY 1-2	FY 3-4	FY 5-6	FY 7-8	FY 9-10
2	3.3	Provide educational opportunities for professionals regarding karst ecosystems and listed species, and work with agencies to ensure that their practices do not inadvertently cause impacts to karst invertebrates	all	continual	EAA, TCMA, TPWD, TSS, WKU, and others	no	50	10	10	10	10	10
3	4.0	Develop a post-delisting monitoring plan	all	1	Service, TPWD	yes	0	0	0	0	0	0

APPENDICES

Appendix A – Glossary

Adaptive management: An iterative learning process that produces improved understanding and management over time.
Anthropogenic: Caused or produced by humans.
Biospeleology: The study of subterranean living organisms, particularly in caves, karst, or groundwater.
Cave: A naturally occurring, humanly enterable cavity in the earth, at least 5m in length and/or depth, in which no dimension of the entrance exceeds the length or depth of the cavity. This definition is from the Texas Speleological Survey and is commonly used in central Texas to distinguish caves from other types of karst features or man-made openings.
Cavernicole: An animal that normally lives in caves for all or part of its life cycle.
Community: Interacting populations of various species in a common location.
Congener: Belonging to the same genus.
Crepuscular: Appearing or active in twilight (such as bats).
Dark zone: An area of a cave typified by total darkness, stable humidity and temperature, and troglobitic organisms.
Diurnal: Active during the daytime.
Drainage basin: A watershed; the area from which a stream, spring, or conduit derives its water.
Endemic: Peculiar to a country or district, and not native elsewhere. The species may be very limited in extent, for example, to a single cave system.
Epigean: Pertaining to, or living on, the surface of the Earth.
Habitat: The place or environment where a plant or animal naturally or normally lives and grows.
Isotope ratios: Ratio of carbon-12 to either of the less common isotopes, carbon-13 or carbon-14, or the reciprocal of one of these ratios; if not specified, the ratio refers to carbon-12/carbon-13.
Karst: A terrain characterized by landforms and subsurface features, such as sinkholes and caves, which are produced by dissolution of bedrock.
Karst fauna area: A geographic locale known to support one or more locations of an endangered species that is distinct because it is separated by geologic or hydrologic features and/or processes, or distance that creates barriers to the movement of water, contaminants, and troglobitic fauna.
Karst fauna region: A geographic area delineated based on hydrogeological barriers and/or restrictions to the migration of troglobites over evolutionary time, that result in speciation between regions and the creation of similar groups of troglobites within the caves of a particular area. The ranges of the nine federally listed species in San Antonio fall into six regions: Stone Oak, UTSA (University of Texas at San Antonio), Helotes, Government Canyon, Culebra Anticline, and Alamo Heights.
Life history: Typically refers to a species' life cycle.

Mesocavern: Includes all cavities in rock that are humanly inaccessible. Not large enough to be considered as a cave in the usual sense.
Microhabitat: A miniature habitat within a larger one; a restricted area where environmental conditions differ from those in the surrounding area.
Nocturnal: Active at night.
Nymph: Refers to the second life stage of cave crickets.
Population: A group of individuals of the same species living and interacting in the same geographic area at the same time.
Sinkhole: Sites of sinking water in a karst area.
Species richness: The simplest measure of biodiversity and is simply a count of the number of different species in a given area.
Stygobite: An aquatic troglobite restricted to subterranean waters and having troglomorphic features.
Taxa: (plural) Taxonomic categories, such as species, genus, etc.
Troglobite: A species of animal that is restricted to the subterranean environment and that typically exhibits morphological adaptations to that environment, such as elongated appendages and loss or reduction of eyes and pigment.
Troglomorphic: The physical characteristics of an obligate subterranean organism, including eyelessness, attenuated appendages, depigmentation, delicate exoskeleton, and greater development of some sensory structures.
Troglophile: A species of animal that may complete its life cycle in the subterranean environment but which may also be found in similar dark, moist environments on the surface.
Trogloxene: Species that spend part of their life underground (hibernation, shelter) and part on the surface (feeding, reproduction).
Twilight zone: An area of a cave typified by very little light and more stable humidity and temperatures than the entrance area.
Viable populations: Populations that are capable of continued existence.

SOURCES FOR DEFINITIONS IN APPENDIX A

The definitions in Appendix A come from the various sources below.

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Appendix B - Comments on the Draft Recovery Plan and Responses

Public Review

A draft of this recovery plan (hereafter referred to as "plan") was published and distributed for review to all interested parties. The Service published a notice in the Federal Register on May 16, 2008, (73 FR 28494) to announce that the document was available for public review and comment. The comment period lasted for 30 days and closed on July 15, 2008. An electronic version of the draft plan was also posted on the Service's Southwest Region website. We mailed and emailed 1,240 letters to interested parties announcing the availability of the document. We also distributed a press release to local news organizations and mailed out several hard copies of the plan upon request.

Peer Review

We asked 25 individuals to serve as peer reviewers of the document and 14 agreed to serve as a peer reviewer. Ten reviewers provided comments. Depending on their expertise, peer reviewers were asked to review and comment on 1) issues and assumptions relating to their scientific expertise (hydrological, karst preserve design, buffer areas, decision analysis, minimum viable population, or karst preserve management); 2) the scientific data regarding proposed recovery activities in the recovery criteria and recovery action outline; and 3) the quality and completeness of the data in the draft plan. The qualifications of the peer reviewers are in the administrative record for this plan.

Public Comments Received

We received 12 sets of comments from interested parties during the public comment period.

Responses to Comments

Some comments provided were supportive of the recovery plan overall and the preserve design. Many comments provided additional support and citations for information in the plan. One commenter suggested common names for *Rhadine infernalis* and *R. exilis,* which is outside the scope of this plan. Some commenters suggested editorial changes to the text of the plan and we have incorporated suggestions as appropriate. Some commenters suggested clarifications (for example, combining recovery actions), and where possible, we tried to clarify the document. The remaining substantive comments were taken into consideration in this final version of the plan, and specific responses are provided below. Several of the comments were similar in nature and were combined and summarized for brevity. Comments are arranged into seven categories based on the related topics of the comments: (1) background, (2) threats, (3) recovery, (4) preserve design, (5) preserve management, (6) miscellaneous technical comments, and (7) general comments.

A. Background

A.1 Comment: Please consider that these species may have evolved below ground, are inter-connected below ground, and have little or no use for above-ground linkages. Consideration needs to be given to the importance of nutrient input from above ground and whether there may be some alternative energy and nutrient fixing pathways (such as seen in deep marine environments) (peer review comment).

Response: Based on available literature (discussed in section 1.4) on central Texas karst ecology, we believe a vital link exists between the surface and karst ecosystems. However, we have included a recovery action to further investigate the links between the surface and subsurface.

A.2 Comment: Regarding **s**urvey procedures, personnel conducting karst invertebrate surveys should be trained by an expert collector and should ensure that any "take" (during surveys) is kept to a minimum. Also, in the discussion of where the species are found in a cave (entrance zone, twilight zone, and **dark zone**), the time spent searching for these species in each zone should be discussed under monitoring. Otherwise, these data may misrepresent true habitat preferences (peer review comments).

Response: Personnel conducting karst invertebrate surveys should be highly qualified and we have listed surveyor qualifications and discussed the amount of "take" anticipated during surveys in Appendix II of Service 2006 (karst survey procedures) (http://www.fws.gov/southwest/es/austintexas/). We have added language in our management and monitoring recommendations (http://ecos.fws.gov/tess_public/) regarding monitoring efforts throughout a cave (and time spent searching in each zone) in an effort to avoid survey bias.

B. Threats

B.1 Comment: This plan is too negative on the effects of commercialization of caves. For example, in Culver and Sket (2000), some of the ten biodiversity hotspots identified are show caves (peer review comment).

Response: We have added language regarding Culver and Sket's (2000) findings to section 1.5. The caves discussed in Culver and Sket (2000) have high levels of nutrient and moisture input. However, most central Texas caves have less nutrients and moisture; therefore, it is not as likely that the same levels of biodiversity will be found in central Texas.

B.2 Comment: Language should be added to the plan that considers RIFA habitat requirements and preferences for tree/ground canopy cover, soil moisture, and soil types because understanding seasonal movement patterns of RIFA in response to canopy cover changes may offer passive strategies for RIFA control by increasing plant cover (peer review and public comment).

B.3 Comment: The draft plan stated that Camp Bullis is located in large expanses of undeveloped land, and this may be why they had less RIFA infestation compared to caves in more urbanized areas (Veni and Associates 1999). However, La Cantera found more RIFA in the larger preserves than in smaller preserves. The larger preserves have open tree canopies and were heavily disturbed by humans and feral hogs before they were fenced. The smaller preserves have abundant tree canopy and were not disturbed by humans. This corresponds to

results found by King and Tschinkel (2006) and Plowes et al. (2007) that state that the degree of disturbance and canopy cover determines RIFA presence rather than the size of the area (public comment).
Response to B.2 and B.3: We have added language from the references above to the recovery plan and our management and monitoring recommendations at: (http://ecos.fws.gov/tess_public/).

B.4 Comment: King and Tschinkel (2006) found that RIFA do not suppress native ants through competition, rather it was ecological disturbance that suppressed native ant populations (public and peer review comment).
Response: We have added the following sentence: "Some researchers conducting work on surface arthropods suggested that RIFA have less impact than originally thought and that over time their impacts decline (Morrison 2002, Morrison and Porter 2003, King and Tschinkel 2006)."

B.5 Comment: The main point of the Morrison (2002) paper cited in the threats section is that native ants were able to rebound after the RIFA invasion. A better reference for the statement that RIFA "alters native ant species richness and abundances and displaces or eliminates rare ant species" is Porter and Savignano (1990). Further, RIFA impacts may decline over time as evidenced by Morrison (2002) (peer review comment).
Response: We have made the suggested changes.

B.6 Comment: Most references cited as evidence that RIFA threaten karst invertebrates are not peer-reviewed. There are no publications that scientifically demonstrate that karst invertebrates are negatively impacted by RIFA. Also, while there is evidence that boiling water treatment of RIFA reduces visible mounds, there is still no evidence that this treatment has benefitted karst invertebrates (public comment).
B.7 Comment: Porter and Savignano (1990) found that RIFA caused long-term impacts to surface arthropods. This study did not discuss karst invertebrates. However, the Service infers that the same impacts to surface arthropods by RIFA could occur to karst invertebrates (public comment).
Response to B.6 and B.7: We recognize that no peer-reviewed studies document direct predation of karst invertebrates by RIFA. However, RIFA have been observed feeding on dead troglobites within caves by species experts (see discussion in section 1.5). Also, by reducing the number of RIFA mounds on a preserve, it is likely that this will benefit karst invertebrates by reducing competition with cave crickets and by reducing the possibility of direct predation. This was corroborated by a study that assessed foraging behavior of cave crickets at Government Canyon State Natural Area (GCSNA). That study found that there was less competition between cave crickets and RIFA (and among cave crickets) at caves that were receiving boiling water treatments to reduce RIFA mounds (Lavoie et al. 2007). Also, karst invertebrates rely upon cave crickets and other surface arthropods to bring nutrient input into karst ecosystems. Cave crickets feed (in part) on surface arthropods (Taylor et al. 2005), hence there is a link from surface arthropods to karst invertebrates. Therefore, it is prudent to control RIFA around endangered karst invertebrate locations.

B.8 Comment: Observations made by SWCA found that (1) many arthropods compete with cave crickets; (2) cave crickets can cope with competition by taking food from competitors; and (3) competition for food is dependent on what is available during cave cricket emergence (public comment).
Response: There may be competition between cave crickets and some surface arthropods (aside from RIFA); however, we do not have enough information to consider them a major competitor with cave crickets.

B.9 Comment: The threats section should address global warming (peer review comment).
Response: We have added a section on climate change to section 1.5.

B.10 Comment: The discussion of the TCEQ optional water quality measures indicates that these measures only provide water quality protection. My understanding is that they provide assurances that the Service concurs that no "take" would result from development complying with the measures. "No take" is a broader measure than no "hydrologic effects" (public comment).
Response: The measures specifically state "If these practices are used, they are expected to result in 'no take' of these species from degradation of water quality by non-Federal landowners and other non-Federal managers." The Service concurred that if these optional water quality measures (TCEQ Appendix B) were followed, then karst invertebrates would incur "no take" from water quality issues only. "Take" caused by anything other than water quality is not covered by these measures. For information on these measures please see the TCEQ website (http://www.tceq.state.tx.us/).

B.11 Comment: The plan implies that all edges are negative. Edges between different plant communities are beneficial for some species for example, white-tailed deer (public comment).
Response: In section 1.5, we are referring to edge effects (increases in invasive species, pollutants, and changes in microclimate) that can impact natural communities that karst invertebrates rely upon. Also, we discuss the patchy nature of the woodland-grassland community (natural edges that are not harmful) of the Edwards Plateau in our karst preserve design document at: http://ecos.fws.gov/tess_public/.

C. Recovery

C.1 Comment: It is not appropriate to use the IUCN (2001) criteria for red list categories for the number of KFAs needed for recovery since it does not have a criterion for number of sites. However, the NatureServe Heritage Program ranking level does include a criterion for the number of sites and may provide the best available information to develop estimates of preserves (peer review comment).
Response: We have made the suggested change and refer to the NatureServe Heritage Ranking levels. This did not change the number of KFAs needed for recovery.

C.2 Comment: A requirement in a population viability analysis for a species to be delisted is that its chance of extinction is less than 5 percent in 100 years. The number of KFAs needed for recovery can only meet this criterion if there are low levels of demographic and environmental stochasticity. These sources of variation can greatly affect the minimum number of populations

required for species persistence and they should be discussed in the plan (two peer review comments).
Response: When developing the recovery criteria we considered that there are low levels of environmental stochasticity since these species rely on stable temperature and humidity. We did not consider demographic data (number of individuals per population) because those data are not available. We have accepted a certain amount of risk regarding the number and qualities of KFAs discussed in section 2.0. We think this risk is acceptable considering that the number of KFAs needed for recovery was (1) chosen to match the Natureserve Heritage ranking criteria and (2) provides redundancy as several KFAs across the species' ranges provides a buffer against a catastrophic event that could extirpate a population.

C.3 Comment: In section 1.3, it states that some of the invertebrates are known from one or very few specimens from a single or very few locations. Due to the rarity of these species, they will likely suffer from small population concerns. Should significant effort or expense be directed toward delisting them, except where their locations overlap with other species (peer review comment)?
Response: While six endangered Bexar County karst invertebrates (*Texella cokendolpheri*, *Cicurina baronia, C. venii, C. vespera, Neoleptoneta microps,* and *Batrisodes venyivi*) are very rare, we have developed a plan for their recovery as mandated by the Act. Also, future surveys may discover more locations of these species. However, we agree that attaining the recovery criteria for these species will be difficult. Therefore, we have changed the recovery priority number for two of these species, *T. cokendolpheri* and *C. baronia*, to 5c because the likelihood that we can recover them is very low considering that they occur in an area that is highly urbanized.

C.4 Comment: A limit on impervious cover over mesocaverns should be in the recovery strategy. Impervious cover amounts in excess of 10-15 percent increase the volume and velocity of stormwater runoff. This causes erosion and water quality degradation as pollutants are flushed off of paved areas into surface and groundwater supplies (Beach 2002; Brabec et al. 2002). Hence, an increased volume of contaminated runoff could enter karst features that contain endangered karst invertebrates (two peer review comments and one public comment).
Response: We do not have enough information to say how much mesocavernous area should be protected. However, recovery action 1.2.2 is to implement a plan for protecting mesocaverns between KFAs. This plan should help address this threat and could include impervious cover recommendations.

C.5 Comment: Given the discussion in the recovery narrative of the long life-spans of these species that prompts 25 years of monitoring to delist, it seems the 5-year monitoring period under the recovery action 4.0 is too short to determine the effectiveness of the recovery program without the legal and social pressure that the listed status provides a species (peer review comment).
C.6 Comment: If recovery means that the species are at a point where "the protections of the Act are no longer necessary", then why is there a need for post de-listing monitoring (public comment)?
Response to C.5 and C.6: We have built monitoring and adaptive management into the recovery plan, which should address any species declines that occur prior to delisting. Also, the

Act (section 4(g)(1)) requires the Service to effectively monitor the status of any recovered species for no less than five years. The goal of the post-delisting monitoring plan is to ensure that a species status does not deteriorate after the regulatory protections of the Act are removed. We are also directed by the Act (section 4(g)(2)) to promptly use our emergency listing authority to prevent a significant risk to the well-being to the species. In effect, post-delisting monitoring assesses the effectiveness of the recovery strategy and plan, and its implementation. Further, we removed the reference to monitor for 25 years in (criterion 2) because we are uncertain how long it will take to gather enough data to have a high degree of confidence that we are adequately protecting these species.

C.7 Comment: A review of the plan should be conducted within the first five years of its completion to evaluate its efficacy at securing the long-term survival of these species (public comment).
Response: An assessment of the status of the species is conducted during the five-year status review for these species. If information arises during any five-year review (or any other time) that the recovery plan is not adequate, then a revision to the plan may be warranted. Also, there are recovery actions for monitoring the effectiveness of the recovery strategy and plan, and for adaptive management. Our ability to implement the plan and monitor its effectiveness will depend on the availability of funding and partners.

C.8 Comment: While it is important to preserve genetic diversity, the KFR method of determining how that diversity is to be identified has been refuted by literature that is not fully addressed. For this plan to meet the standard of having considered the best available scientific information, Paquin and Hedin (2004), White et al. 2001, and White (2006) should be addressed. Further, geologic/geographic features, such as stream valleys and faults were hypothesized to (1) form barriers to karst invertebrate dispersal and distribution; (2) play roles in the species evolutionary development; and (3) define the ranges of individual troglobitic species or populations (Veni 1994). However, recent taxonomic revisions (Cokendolpher 2004a, 2004b, Elliott 2004, Reddell and Cokendolpher 2004, Ubick and Briggs 2004) do not conform to the KFR model. It is illogical that the KFR concept will make sense for nine species each with their own evolutionary history. It is more logical, and better supported, to suggest that separate phylogeographic ranges (roughly KFRs) should be developed for each of the nine species (public comment).
Response: In section 2.1, we referenced Paquin and Hedin (2004) and White (2006) regarding KFRs. We did not discuss White et al. (2001) because points of that paper are made in White (2006), which is a more comprehensive document. Also, the Karst Invertebrate Recovery Team had considerable discussion about this topic. We decided to use the existing KFR boundaries for now and to include a task in the plan to gather additional information to evaluate the KFRs and revise as warranted. Additional genetic data (particularly population level data) on all of the species (and possibly geological data) will add greatly to this evaluation.

C.9 Comment: There was no clear consensus among recovery team members on the minimum number of KFAs needed for recovery and preserve size. Further, the team's ability to provide guidance suffered from lack of funding for meetings and the opportunity for team members from other areas to become familiar with the local karst system (public comment).

Response: Based on the information that was available, the majority of the recovery team determined that the larger the size of the preserve the more likely it will be to provide for the long-term sustainability of these species. However, in part due to uncertainty about these species and their requirements, we have included recovery actions herein to conduct research and monitoring to (1) assess the effectiveness of preserve size and the minimum number of KFAs; and (2) to adaptively manage if needed, based on those results.

D. Preserve Design

D.1 Comment: It would be helpful to have an influence diagram that illustrates cause and effect relationships between ecosystem factors that went into the preserve design and how they interact and/or influence karst invertebrates (peer review comment).
Response: We have added an influence diagram to the karst preserve design document that illustrates how the ecosystem components influence karst invertebrates.

D.2 Comment: Since the entire Simple Multiple-Attribute Ranking Technique (SMART) was not used, it is more appropriate to state that expert opinion was surveyed to estimate performance values for a variety of ecosystem goals for preserve design (peer review comment).
Response: We deleted the reference to SMART.

D.3 Comment: Averaging the mean score of experts' opinion on the 12 goals to determine preserve design may not be the best approach because this does not address whether one of the 12 goals scored so low that it would result in extinction. Averaging or any other method of attribute ranking without considering each goal's independence and importance can unintentionally result in overweighting some factors (peer review comment).
Response: We reanalyzed the preserve design opinion results but rather than assessing the mean for all means, we assessed the lowest score for each preserve option for each team member, regardless of the ecosystem goal. This analysis resulted in a decrease from 17-25 percent for all options except 18, which was only 7 percent lower. Preserve options 6, 10, 14, and 18 continued to be the best preserve options. We also examined the lowest score overall for each option resulting in options 14 and 18 as the best preserve options. These results indicate that the larger a preserve is, the more likely it is to reach the 12 goals identified that are necessary to protect these species.

D.4 Comment: Explain why the preserve design threshold of 80 percent probability of attaining goals is acceptable, and how it relates to preserve quality and the 25-year timeframe to attain recovery and was not calculated based on any calculated probabilities. Also, what if some goals are below this threshold (peer review comment)?
Response: The 80 percent probability of attaining goals was relative to the options that were evaluated. It does not mean that an 80 percent probability of recovering these species is acceptable. Also, in the draft recovery plan, recovery criterion 2 states that research on population trends, population viability, habitat quality, and potential threats are to be completed over the course of at least 25 years to conclude with a high degree of certainty that preserve size, configuration, and management are adequate to provide a high probability of the species survival. We have deleted the 25 year timeframe because we are unsure how many years it will take to determine whether the preserve characteristics (goals) are adequate to support these

species for the long term. If one of the goals has not been met, we should be able to detect it (and address it) via research and monitoring.

D.5 Comment: A discussion of the Lakeline Mall cave cricket monitoring should be discussed in the plan. This work illustrates the impact of preserve size on cave crickets. Impacts to listed species can be inferred from these results (public comment).
Response: Information regarding the cave cricket monitoring at Lakeline Mall was incorporated into section 1.5.

D.6 Comment: Monitoring in karst preserves of various sizes with various levels of impact should be conducted to help determine adequate preserve size (public comment).
Response: This suggestion was incorporated into recovery action 2.3.3.

D.7 Comment: Reddell (2000) presents findings from five years of biological monitoring at caves in preserves of various sizes. This should be presented to the recovery team (along with Richardson-Verdoorn 1994) to assist in another preserve design analysis. The SMART analysis is essentially an opinion poll and is an inadequate substitute for data-based analysis. The team should review the Williamson County Regional Habitat Conservation Plan, which has a review of the KFA concept (public comment).
Response: The above reports, which do not contain preserve acreages for all preserves monitored, were presented to the recovery team and discussed at a meeting on January 28, 2009. Team members agreed that a data-based analysis should be conducted. This research should be conducted as part of recovery action 2.3.3.

D.8 Comment: Mesocaverns between cave locations should be included in preserves and a recovery action is needed to promote mesocavern protection. (two peer review comments) Perhaps the Service could: (1) specify acreages for mesocavern protection, (2) set an impervious cover limit over mesocaverns, and (3) define parameters to ensure mesocavern connectivity between caves (public comment).
Response: The preserve design recommendations consider mesocavernous areas associated with known occupied caves. Within preserves/protected KFAs, there should be practically no impervious cover (near zero). We are unsure, however, how much mesocavernous area is needed by the species between preserves/protected KFAs. There are actions in the recovery plan to address this question (recovery action 1.2.2).

D.9 Comment: TCEQ regulations were given in the draft recovery plan as an example of regulations that could be emulated to protect mesocaverns, but these methods include sealing cave entrances, which results in decreased moisture input that is critical to karst invertebrates. The COSA regulations were mentioned in the draft recovery plan as protecting mesocaverns too. They are not designed to protect karst invertebrate habitat either, except through protecting water quality. Also, staff at TCEQ and COSA are not always biologically trained or aware of karst invertebrates (peer review and public comment).
Response: The TCEQ regulations regarding impervious cover limits were discussed (under preserve design) because they protect some features from water quality impacts. It is not our intent to indicate that all TCEQ practices would provide karst invertebrate protection as discussed in the final rule listing these species, and we understand that some of their practices

could impact karst habitat (for example, sealing cave openings to protect water quality) (65 FR 81419 81433). In section 1.5, we acknowledge that TCEQ and COSA protections alone are not adequate to protect karst invertebrates from all threats. Further, we have added a recovery action to work with agencies such as TCEQ and the COSA to ensure that they do not inadvertently cause impacts to these species.

D.10 Comment: The reference to using best management practices (BMPs) in the preserve design discussion should not be relied on to mitigate impacts, as this term (BMP) has been misused, misunderstood, and has promoted counterproductive results. Additionally, many are using what was best years ago and is now the cheapest and least effective mitigation measure. Using the term "mitigation measures" over "BMPs" may be more accurate as it does not imply a false level of efficacy (public comment).
Response: We have deleted references to BMPs and incorporated language in the karst preserve document stating that if individuals are using mitigation measures, it is their responsibility to ensure that they are using the most up-to-date practice that is most protective of karst invertebrates.

D.11 Comment: The method used to determine the area needed to support the native plant community (Pavlik's recommendations for minimum viable populations (MVP) based on life history) was appropriate considering that demographic information is not available. However, variation in MVPs occurs among species with similar life histories, and closely related species may have different MVPs. Therefore, the more conservative, larger preserve size of 32 ha (80 acres) of woodland habitat should be used for establishing preserve design (peer review comment).
D.12 Comment: In the preserve design discussion, it states that a karst preserve should be at least 28 to 40 ha (69-99 acres) to protect the integrity of the plant and animal communities that support the karst ecosystem. These figures describe larger areas than the high quality KFA size 24 to 36 ha (60-90 acres). Why are the preserve options smaller than the areas necessary to sustain vegetation communities (peer review comment)?
Response to D.11 and D.12: Based on these two comments, we have revised our preserve design recommendations accordingly.

D.13 Comment: Protecting the quality of water recharging into karst features is not always an effective way to protect groundwater quality. Veni and Associates (2008) discuss water budget and tracer studies where up to about 20 percent of rainfall is recharged into mesocaverns without flowing into a karst feature and with the recharge appearing in underlying caves in as little as 15 minutes. In another study by the Edwards Aquifer Authority, water was discharged into a flat area with no karst features. Dye injected in that area was detected about 1.4 kilometers (0.87 miles) away. These studies, suggest that an influx of water and nutrients exists in mesocavernous areas between caves that is critical to maintain karst invertebrate habitat (public comment).
Response: These studies demonstrate the importance of not only protecting drainage basins of particular karst features such as caves, but also the areas that drain to mesocaverns. We have incorporated this information in our discussion of drainage basins in section 1.4. Recovery 1.2.2 is to develop recommendations to protect mesocaverns in between KFAs and action 2.3.2 is on

hydrogeologic research. These actions should increase our knowledge of drainage basins and mesocaverns and result in better mesocavern protection for karst invertebrates.

D.14 Comment: Present conditions, including fire suppression, livestock grazing, and high deer densities, tend to increase *Juniperus ashei* and alter community dynamics. Due to these dynamics, karst preserves may become stands of *J. ashei*. This change could cause negative effects to occur that may affect karst invertebrates. These effects could include lower nutrient availability and the loss of public support due to a perceived fire hazard. Vegetation management can abate these concerns and is more feasible in larger preserves that are more protective of surface species (peer review comment).
Response: We have added vegetation management techniques to maintain healthy vegetation communities in our management and monitoring recommendations. Further, recovery action 2.2.2.3 is to design and implement a study to evaluate the appropriate size and quality of a KFA including (1) vegetation community size and composition to support karst invertebrates and (2) research the interaction of surface plant and animal communities with the subsurface. Results of this research should increase our understanding of how to adequately preserve and manage the vegetation community that supports karst invertebrates.

D.15 Comment: Low Quality KFAs should be called something else to avoid confusion with the Travis and Williamson County recovery plan that does not recognize differences in quality among KFAs. If a preserve doesn't count toward recovery, then it's not a KFA (public comment).
Response: Preserves that are too small to qualify as at least a medium quality KFA and that do not count toward meeting the recovery criteria, will be called low quality KFAs. We believe that changing this terminology would confuse more partners. While these preserves do not meet recovery criteria, they are still important to the conservation of these species because they increase their probability of surviving beyond what it would be if they did not exist.

D.16 Comment: Competition between RIFA and ground-foraging cave fauna should be further studied in areas with high and low RIFA densities (peer review comment).
Response: This research can be conducted as part of recovery 2.2.2.1, which is to research natural factors that may affect populations.

E. Preserve Management

E.1 Comment: Additional information on predator-prey relationships (between cave crickets and karst invertebrates) should be discussed under preserve management and monitoring because (1) karst invertebrates rely upon cave crickets and (2) cave crickets are an indicator species for the health of the karst ecosystem. Without a healthy population and foraging success of cave crickets, their nutrient input is reduced, which directly impacts the food base of karst invertebrates. For more information see discussion in Abrams and Ginzburg (2000) (peer review comment).
Response: We discuss the importance of cave crickets to karst invertebrates in section 1.4 and in our karst invertebrate habitat document found at http://ecos.fws.gov/tess_public/. Further, we have added methods to conduct cave cricket exit counts in our management and monitoring recommendations at http://ecos.fws.gov/tess_public/.

E.2 Comment: Preserve sizes were partially based on life history extrapolations of plant species to determine the minimum area needed to sustain the plant community. Therefore, monitoring plans should be developed for the dominant woody species so that management can be used to bolster these species if their populations drop below a MVP (peer review comment).
Response: We have added vegetation monitoring information in our management and monitoring recommendations.

E.3 Comment: Many invasive plant species were introduced for landscaping and require more water than most native plants. Karst features near seepages, streams, and areas of high moisture are susceptible to invasion. Since many of these plant species are bird-dispersed, they are not limited to edges. Their effects on litter, shading, water runoff, etc. are mostly unknown, but may impact karst invertebrates. Mechanical control is the best option to control invasive plants near karst features (peer review comment).
Response: We have added language about this issue to our management and monitoring recommendations.

E.4 Comment: We encourage the Service to develop a more concise list of conservation practices and land management activities that will benefit the recovery of these species (public comment).
Response: We have modified our management and monitoring recommendations (at http://ecos.fws.gov/tess_public/) to be more concise. We believe that this approximately 10-page document is user-friendly and easy to understand.

E.5 Comment: Rather than conducting mound counts to monitor RIFA, perhaps baits could be used. This would give a broader estimation of RIFA densities since mounds vary seasonally. The use of mound counts to assess RIFA populations is based on studies in areas dominated by the monogyne social form that builds larger mounds as colonies grow; however, in Texas RIFA are polygyne with multiple queens, and these populations tend to bud-off into new satellite colonies as the colony grows (peer review comment).
Response: We understand that most RIFA colonies in Texas are polygyne; however, one of the main purposes for monitoring RIFA (identified in the management document) is to manage this threat by applying boiling water on mounds. Therefore, locating mounds is important. While using baits to assess RIFA densities may be beneficial, it may not be practical for many preserve managers due to the time and expense of setting up bait transects and monitoring them in addition to boiling water treatments.

E.6 Comment: The arbitrary threshold of 80 RIFA mounds per 50 m (164 ft) radius around a cave entrance that triggers additional RIFA treatment (in addition to the biannual RIFA treatment) is about 41.3 mounds an acre. The number of mounds per unit area does not indicate the size of the colony or the extent of ant foraging – the direct cause of predation and competition with other arthropods (three public comments).
Response: We have changed the RIFA mound treatment area to 80 m (262 ft) from a cave entrance. This distance was chosen to treat the area where the majority of cave crickets forage. The threshold for the area within 80 m (262 ft) of an entrance, that would trigger additional RIFA treatment, should be determined by the preserve manager by observing declines in cave

crickets or an increase in the number of mounds. The threshold for the area within 10 m (33 ft) of an entrance is 1 mound and if this threshold is reached, mounds should be treated in 15 days. Further, recovery action 2.2.2.1 is to assess what natural factors affect these species. Based on research and design from that (in part), action 2.6.3 is to reassess KFA and preserve management and monitoring recommendations. This should refine our understanding of RIFA so that we may improve RIFA management techniques.

E.7 Comment: We received several public and peer review comments on RIFA control techniques.
Response: We considered the effectiveness of past techniques, labor and costs for landowners and managers, and the potential for toxic chemicals to impact non-target species. Based on these considerations we provide RIFA control techniques in our management and monitoring recommendations. We believe those techniques are the most protective to karst invertebrates and have less risk than other methods. We have recovery actions that should assess these techniques and allow us to adaptively manage as needed.

E.8 Comment: In the discussion on karst management it states that when a karst preserve is less than the minimum area needed to maintain a high probability of long-term survival then more frequent human intervention may be needed to minimize threats. Please explain how the need for more frequent intervention is determined since additional management may be costly. Further, more human intervention will cause disturbance and potentially increase RIFA; thus, benefits of disturbance or increased management should be considered as it may have negative impacts (public comment).
Response: The need for more frequent intervention can be determined by RIFA monitoring to determine if mound thresholds have been reached. This can also be determined by observing declines in cave cricket abundance or an increase in the number of RIFA mounds. Further, we have added language to the management and monitoring recommendations regarding routine inspections. During these inspections, managers can determine whether activities such as, eradicating non-native plants and animals, planting native flora, or performing prescribed burns should occur. Managers should always consider the ecological costs and benefits to karst invertebrates before they conduct any management activities. Managers should also look for ways to passively manage for RIFA including increasing canopy cover (see the management document for details).

E.9 Comment: Rather than a generic approach, the plan should encourage ecological analysis of individual preserves and then develop management activities accordingly (public comment).
Response: There are certain overarching management recommendations and goals in the management and monitoring recommendations that are common to all preserves. We recognize that there are site-specific considerations and this is why we recommend individual karst preserve management plans. For example, protecting caves from impacts from vandalism or unauthorized access is a management objective that should be in all management plans. This protection can be accomplished with a cave gate or a fence depending on the site-specific considerations. Managers can use results from routine inspections, in-cave monitoring, and RIFA monitoring to adaptively manage karst preserves.

F. Miscellaneous Technical Comments

F.1 Comment: How important are bats as sources of energy input for the Bexar County caves (peer review comment)?
Response: Bats are not thought to be a major source of nutrient input for karst invertebrates.

F.2 Comment: The holotype (the only specimen collected) for *C. venii* has been lost, which reduces the efficacy of identifying other individuals. However, some blind *Cicurina* have been observed in nearby caves. These caves should be surveyed to determine if there are more locations for this species (public comment).
Response: This should be accomplished as part of recovery action 2.1.

F.3 Comment: The plan has no provision for handling taxonomic revisions (public comment).
Response: The plan states in the disclaimer that "Approved recovery plans are subject to modification as dictated by new information, changes in species status, and the completion of recovery actions."

F.4 Comment: The genetic barcoding technique for identifying immature *Cicurina* spp. (Paquin and Hedin 2004) should be counted separately in the "Conservation Measures to Date" section (public comment).
Response: We acknowledge that the techniques developed by Paquin and Hedin (2004) have contributed to our knowledge of these species. We have removed the "Conservation Measures to Date" section from the plan, but may put this section on our website (http://ecos.fws.gov/tess_public/) in the future where the research by Paquin and Hedin (2004) may be discussed.

G. General Comments

G.1 Comment: Other than offering insight into the aquifer ecosystem status, what do these species do for humanity? Considering what else is going on in the world today, it seems that the money spent on recovering these species could be spent on things that benefit humanity (public comment).
Response: We understand that there are many things that benefit humans and that it is difficult to find money to address all of these issues. The Act (Section 2(a)(3)) recognizes that species are of aesthetic, ecological, educational, historical, recreational, and scientific value to the nation and its people. One ecological benefit of these species to humans is that they are an indicator species to the health and quality of our subterranean ecosystems and aquifer.

G.2 Comment: In addition to their value as living beings, it should be stated that the endangered karst invertebrates are indicator species for the health of the Edwards Aquifer, which is the drinking water source for 1.1 million Texans. The same risk of contamination from urbanization that threatens these species, also threatens the water quality of the aquifer. Therefore, protecting these species will also preserve the aquifer (public comment).
Response: We have incorporated some of the language above into the plan.

G.3 Comment: Why weren't range maps for each species included in the plan (public comment)?
Response: The range of these species is provided in Table 2, which indicates the KFRs that each species occurs in. Range maps were not included in the plan because as more surveys are conducted it is likely that the species distribution will change. Also, we were concerned that range maps may give a false impression that species may not be found in other locations outside of their current range in the future. We have included information on distribution on our website at (http://ecos.fws.gov/tess_public/), where we can more easily update that document as new information becomes available.

G.4 Comment: In several locations the reader is directed to source documents that are not available to the public. We believe that these documents should be made available and that the public comment period should be extended or re-opened for a sufficient period of time that those documents can be considered (public comment).
Response: Any reference cited in the plan is available upon request from the Service or is available at a public library. These documents were also available during the public comment period.

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