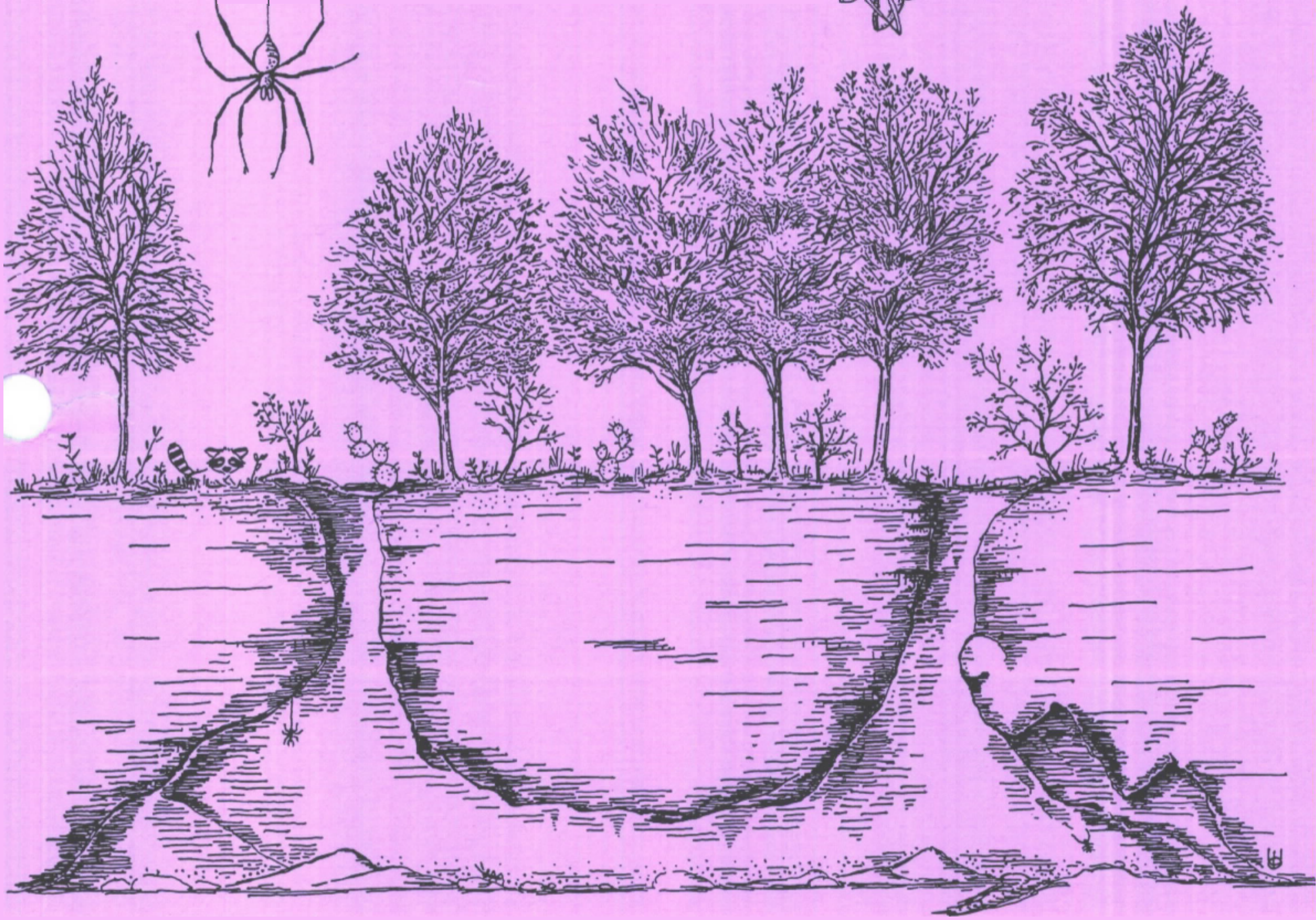
ENDANGERED KARST INVERTEBRATES

(TRAVIS AND WILLIAMSON COUNTIES, TEXAS)

RECOVERY PLAN



U.S. Fish and Wildlife Service
Region 2, Albuquerque, New Mexico
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RECOVERY PLAN
FOR
ENDANGERED KARST INVERTEBRATES
IN TRAVIS AND WILLIAMSON COUNTIES, TEXAS

Prepared by:

Lisa O'Donnell
U.S. Fish and Wildlife Service
611 E. 6th Street, Room 407
Austin, Texas 78701

William R. Elliott, Ph.D.
12102 Grimsley Drive
Austin, Texas 78750

and

Ruth A. Stanford
U.S. Fish and Wildlife Service
611 E. 6th Street, Room 407
Austin, Texas 78701

Edited by:

Alisa Shull
U.S. Fish and Wildlife Service
611 E. 6th Street, Room 407
Austin, Texas 78701

For:

U.S. Fish and Wildlife Service
Region 2

Approved: John G. Rogers
Regional Director, U.S. Fish and Wildlife Service

Date: 25 August 1994

DISCLAIMER

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. Because the potential for complete recovery and delisting is uncertain, the goal of this plan is downlisting. Thus, the estimated costs and date of recovery presented in this plan are for downlisting, not delisting.

Plans are published by the U. S. Fish and Wildlife Service (USFWS), sometimes prepared with the assistance of recovery teams, contractors, State agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service. They represent the official position of the U.S. Fish and Wildlife Service **only** after they have been signed by the Regional Director or Director as **approved**. Approved recovery plans are subject to modification as dictated by new findings, changes in species' status, and the completion of recovery tasks.

LITERATURE CITATIONS

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ACKNOWLEDGMENTS

The study of caves and karst in Texas is a continuing process. Much of the information presented in this plan was derived from research in progress. Besides William R. Elliott, who prepared the initial draft of this plan, contributors include James R. Reddell, George Veni, Mike Warton, and Bill Russell. James Reddell and George Veni provided significant comments to William Elliott in the early development stages of this plan.

EXECUTIVE SUMMARY OF THE RECOVERY PLAN FOR ENDANGERED KARST INVERTEBRATES IN TRAVIS AND WILLIAMSON COUNTIES, TEXAS

Current Species' Status: All seven species (*Texella reddelli, Texella reyesi, Tartarocreagris texana, Neoleptoneta myopica, Rhadine persephone, Texamaurops reddelli,* and *Batrisodes texanus)* are endangered. They spend their entire lives underground and are endemic to karst formations (caves, sinkholes, and other subterranean voids) in Travis and Williamson counties, Texas. Five of these listed invertebrate species occur in only four to seven caves, while *Rhadine persephone* and *Texella reyesi* occupy wider ranges. The total number of individuals is unknown, as are many aspects of their biology. Most localities are imminently threatened by land development, pollution, vandalism, and/or red imported fire ants (*Solenopsis invicta*).

Habitat Requirements and Limiting Factors: All tend to occur in the dark zone of caves, but occasionally in deep twilight. All prefer relative humidities near 100%, but some may be less sensitive to drying than others. Presumably all are predators upon small or immature arthropods, or, as in the case of the ground beetle, possibly cave cricket eggs.

Recovery Objective: Downlisting.

Recovery Criteria: To be considered for downlisting to threatened, the following criteria should be met for each species:

1. Three karst fauna areas within each karst fauna region (as defined in the Recovery Strategy) in each species' range should be protected in perpetuity. If fewer than three karst fauna areas exist within a given karst fauna region of a given species' range, then all karst fauna areas within that region should be protected. If a species' *entire range* contains less than three karst fauna areas, then all karst fauna areas where that species occurs should be protected. At least two karst fauna areas should exist and be protected for that species to be considered for downlisting.

2. Criteria 1 should be maintained for at least 5 consecutive years with assurances that these areas will remain protected in perpetuity before downlisting.

Actions Needed:

1. Identify, delineate, and protect karst fauna areas targeted for recovery and determine conservation measures necessary to maintain the integrity of the karst ecosystems.
2. Eliminate or control threats from habitat destruction, predation by fire ants, and other factors.
3. Develop and conduct a program to monitor each species' status.
4. Develop educational programs on biospeleology and karst hydrogeology to train professionals and increase public awareness.

Total Estimated Cost of Recovery: (dollars x 1000)

Year	Priority 1● tasks	Priority 1 tasks	Priority 2 tasks	Priority 3 tasks	Total
1995	60	160	45	85	350
1996	75	260	100	80	515
1997	60	260	110	50	480
1998-2014	380	3,920	1,275	400	5,975
Total:	575	4,600	1,530	615	7,320

Date of Recovery: Current downlisting requirements should be met by 2014, assuming steady funding and progress toward full implementation of this plan. Since the time required to downlist each species may vary, each species may be downlisted separately. More information is needed to determine the potential for complete recovery and delisting. Therefore, time of delisting is uncertain.

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I. INTRODUCTION AND BACKGROUND

[Appendix A contains a glossary of terms used in this recovery plan. Terms defined in the glossary are indicated by **BOLD** face type in the text.]

This recovery plan covers seven species of karst invertebrates and their ecosystems. The seven species are *Texella reddelli* (Bee Creek Cave harvestman), *Texella reyesi* (Bone Cave harvestman), *Tartarocreagris texana* (Tooth Cave pseudoscorpion), *Neoleptoneta myopica* (Tooth Cave spider), *Rhadine persephone* (Tooth Cave ground beetle), *Texamaurops reddelli* (Kretschmarr Cave mold beetle), and *Batrisodes texanus* (Coffin Cave mold beetle). Five species (*Texella reddelli*, *Tartarocreagris texana*, *Neoleptoneta myopica*, *Rhadine persephone*, and *Texamaurops reddelli*) were listed as endangered on September 16, 1988 (53 FR 36029). A refinement of the **taxonomy** has expanded this group into seven distinct species (58 FR 43818). Because *Texella reyesi* and *Batrisodes texanus* were considered to be populations of *Texella reddelli* and *Texamaurops reddelli*, respectively, at the time of listing, they are also considered to be listed as endangered under the Endangered Species Act (58 FR 43818).

Of the seven listed species, three are insects (one ground beetle and two mold beetles) and four are arachnids (one pseudoscorpion, one spider, and two harvestmen). All are **troglobites**, which spend their entire lives underground and have small or absent eyes, elongated appendages, and other adaptations to the subterranean environment. Although troglobites must complete their life cycles underground, they are dependent on moisture and nutrient inputs from the surface. Troglobites typically inhabit the

dark zone of the cave where temperature and humidity are relatively constant. Most are usually found under rocks. All seven species appear to be predators and are found in relatively small numbers. Each species may have a different preferred microhabitat and may depend on certain prey species for survival. Troglobites tend to be rare and limited in distribution and are of special interest to evolutionary biologists, ecologists, biogeographers, and educators. Their limited distributions combined with low reproductive rates, ecological specialization, and other factors, make troglobites especially vulnerable to habitat destruction, fire ant infestations, pollution, and other factors.

A. Taxonomic and Legal Classification, and Description

Note on Common Names and Arthropod Systematics

Few invertebrates have common names. Common names are often used for convenience sake and may become standardized for well-known or commonly studied species. The common names for the karst invertebrates included in this recovery plan are given in this section (A). However, because there are no official common names for these invertebrates, because taxonomy is most clearly understood in terms of scientific names, and because most biologists working with these species refer to them by scientific name, we use scientific names throughout this plan.

Scientific names are sometimes changed by scientists according to the International Code of Zoological Nomenclature. As taxonomists study certain groups, they publish descriptions of new or previously unrecognized species or assign known species to different groups. For example, the spider *Leptoneta myopica* was reassigned to the New World genus *Neoleptoneta* (Brignoli 1977), and *Batrisodes texanus* was described from specimens previously assigned to *Texamaurops reddelli* (Chandler 1992). It is widely recognized that most invertebrate species have yet to be described and catalogued (May 1992). In the future some of the invertebrate species discussed in this plan may be redescribed to include several distinct species, especially as **DNA** studies are increasingly used to determine the genetic and evolutionary relationship of different populations.

All of the listed species are members of the Phylum Arthropoda. With some arthropods, it is important to obtain mature male specimens for study. In many cases, as in the mold beetles and harvestmen, species are identified based on the structure of the male genitalia. These structures are highly species-specific and believed to be under genetic control. Often a first collection from a cave contains only immature and female specimens. Other species, such as the ground beetles, pseudoscorpions, and several species of spiders (including *Neoleptoneta myopica*), can be differentiated based on male or female structures (such as the ovipositor), as long as an adult specimen is obtained.

SPECIES 1 – Scientific name: *Neoleptoneta myopica* (Gertsch), formerly *Leptoneta myopica* Gertsch

Common Name: Tooth Cave spider

Taxonomic Classification: Class Arachnida (arachnids), Order Araneae (spiders), Infraorder Araneomorphae (true spiders), Family Leptonetidae. Spiders and other arachnids are not insects. Unlike insects, arachnids possess four pairs of legs, **pedipalps**, and **chelicerae**, and lack antennae. Insects have three pairs of legs, mandibles, and antennae. Leptonetids are minute spiders with six eyes, commonly found in caves and similar habitats. Some leptonetid spiders in Europe and the United States are completely eyeless, but members of this family typically have small eyes.

Original Description: Gertsch (1974)

Type Specimen: Male **holotype**, Tooth Cave, Travis County, Texas, March 30, 1965. Collected by James R. Reddell. Female specimen described but not designated as **paratype**. Type specimens are deposited in the American Museum of Natural History.

Other Taxonomic Literature: Brignoli (1972) erected the genus *Neoleptoneta* for all New World leptonetid spiders and reserved the genus *Leptoneta* for other regions. In 1977, Brignoli formally removed *Leptoneta myopica* to *Neoleptoneta*. The validity of *Neoleptoneta* was further supported by Platnick (1986). This recovery plan follows these two authorities in using the name *Neoleptoneta*.

Selected characteristics: A small, whitish, long-legged troglobitic spider with six **obsolescent eyes**. Eyes medium sized, without dark pigment; front eye row moderately recurved; eyes **subcontiguous** and subequal in size; posterior eyes subcontiguous, set back from anterior lateral eyes. First leg in both sexes 6.1 times as long as **carapace**. Body length 1.6 mm, carapace 0.7 mm long and 0.5 mm wide, abdomen 0.9 mm long and 0.5 mm wide. **Tibia** of male palpus with thin **retrolateral** process set with curved spine.

Intraspecific Variation: Not known.

Distinctiveness: *Neoleptoneta myopica* is related to several other troglobites in the Balcones Fault Zone of Texas: *N. anopica* (eyeless) from Cobb Caverns, Williamson County; *N. coeca* from two caves in Comal County; *N. concinna* from a cave and a mine in Travis County; *N. devia* from one cave in Travis County; and *N. microps* from one cave in Bexar County. Geographically, the *Neoleptoneta* species closest to *N. myopica* is *N. devia* from McDonald Cave (Schulze Cave), only 2.5 km from Stovepipe Cave and 4 km from Tooth Cave, the type locality. *Neoleptoneta devia* is dull yellow with a whitish abdomen and the eyes enclose a dusky field, whereas *N. myopica* is whitish and has very reduced eyes that are not set in a dusky field. *Neoleptoneta devia* and *N. concinna*, the other two species in Travis County, have much shorter legs. Gertsch (1974) did not discuss evolutionary relationships among the six Texas species of Leptoneta that he described.

Listed: Endangered; September 16, 1988; 53 FR 36029.

Recovery Priority: 2C. According to the U. S. Fish and Wildlife Service's (USFWS) criteria (48 FR 51985) this indicates a species with a high degree of threats, high potential for recovery, and in conflict with construction or development projects or other forms of economic activity.

SPECIES 2 – Scientific name: *Tartarocreagris texana* (Muchmore), formerly *Microcreagris texana* Muchmore.

Common Name: Tooth Cave pseudoscorpion

Taxonomic Classification: Class Arachnida (arachnids), Order Pseudoscorpiones (pseudoscorpions), Family Neobisiidae. Pseudoscorpions are quite distinct from scorpions in lacking a postabdomen (tail), stinger, and **book lungs**. Most pseudoscorpions are no more than a few mm long.

Original Description: Muchmore (1969).

Type Specimen: Female holotype, Tooth Cave, Travis County, Texas, May 16, 1965. Collected by James R. Reddell. Deposited in American Museum of Natural History. Male known from Amber Cave (Muchmore 1992).

Other Taxonomic Literature: Muchmore (1992) reassigned *Microcreagris texana* to *Tartarocreagris*, a genus described by Curcic (1984), based on the female holotype of *M. infernalis* from Inner Space Cavern, Williamson County. After Muchmore examined recently collected males of both species, it became clear that *M. texana* also belonged in *Tartarocreagris*. Curcic (1989) had previously reassigned *M. texana* to *Australinocreagris* Curcic (1984), which is based on *M. grahami* from California, but Muchmore (1992) found that classification to be incorrect based on internal male genitalia. Muchmore (1992) described a new species of *Tartarocreagris*, *T. comanche*, from New Comanche Trail Cave 1.8 km southwest of Tooth Cave, and reassigned *M. reddelli*, from McDonald Cave, Travis County, to *Tartarocreagris*. In Muchmore (1992), all four Texas *Microcreagris* species were reassigned to *Tartarocreagris*. The genus *Microcreagris* is no longer believed to occur in the New World. The four species of *Tartarocreagris* are extremely limited in distribution. Three of the species occur within 4.9 km of each other in the vicinity of the RM 2222 and RM 620 intersection on the central Jollyville Plateau in travis County, Texas. *T. infernalis* occurs in Inner Space Cavern and a few caves, all locations no more than 1.4 km apart in Williamson County, Texas.

Selected Characteristics: A large (female body length 4.1 mm), eyeless pseudoscorpion with **attenuated** appendages. Carapace, chelicerae, and palps golden brown, body and legs light tan. Carapace about 1/3 longer than broad. No eyes or eyespots present. Chelicera about 2/3 as long as carapace, 1.95 times as long as broad. Palps relatively long and **slender**; **femur** 1.5 and chela 2.55 times as long as carapace.

Intraspecific Variation: Male very similar to female in most respects – male body length 3.96 mm.

Distinctiveness: *Tartarocreagris texana* can be distinguished from its closest relatives only by microscopic inspection. *Tartarocreagris comanche* from New Comanche Trail Cave has four poorly developed eyes and relatively **robust** appendages, whereas the others are eyeless and more slender. Among the species of *Tartarocreagris* there are many minor differences in **tergal chaetotaxy** and in the proportions of the palps. Confirmation of the species may require dissection and study of the female **spermathecae** or the male internal genitalia.

Listed: Endangered; September 16, 1988; 53 FR 36029.

Recovery Priority: 2C

SPECIES 3 – Scientific name: *Texella reddelli* Goodnight and Goodnight

Common Name: Bee Creek Cave harvestman

Taxonomic Classification: Class Arachnida (arachnids), Order Opiliones (opilionids, or harvestmen), Suborder Laniatores, Family **Phalangodidae**. Harvestmen are anatomically and evolutionarily quite distinct from spiders (Order Araneae) and are not properly referred to as "spiders". Phalangodid harvestmen are predaceous. Other North American genera are *Banksula* in California (to which *Texella* is most closely related), *Sitalcina*, *Calicina*, and *Phalangodes*. Many harvestmen are **cavernicoles** (soil dwellers). *Texella* is the most widespread genus with 21 species from Texas, New Mexico, California, and Oregon. Several **species groups**, **subgroups**, and **infragroups** are recognized.

Original Description: Goodnight and Goodnight (1967)

Type Specimen: Male holotype, Bee Creek Cave (= "Pine Creek Cave"), Travis County, Texas, October 2, 1963. Collected by James Reddell and David McKenzie. Deposited in the American Museum of Natural History. Redescription by Ubick and Briggs (1992) is based on holotype, female **paratopotype**, and 14 other specimens deposited in the American Museum of Natural History, Texas Memorial Museum, California Academy of Sciences, Darrell Ubick collection, and Marie Goodnight collection.

Other Taxonomic Literature: Goodnight and Goodnight (1942), Ubick and Briggs (1992). The genus *Texella* was erected by Goodnight and Goodnight (1942) on the basis of one troglomorphic individual, described as *Texella mulaiki*, from Hays County, Texas. This specimen probably was from Ezell's Cave. Ubick and Briggs (1992) revised the genus and recognized 15 species in the *mulaiki* species group of Central Texas.

<u>Selected Characteristics</u>: Body length 1.90-2.18 mm, **scute** length 1.21-1.66 mm, leg II length 4.92-7.59 mm, leg II/scute length 3.81-5.20 mm (N = 16). Color orange. Body of medium **rugosity**. **Eye mound** broadly conical, eyes well developed. Male (holotype) – **Postopercular process** length 0.44; penis: ventral plate prong with two dorsal, 10 lateral, and three ventral **setae**; **apical** spine curved, apically pointed; glans: basal knob slender; middle lobe present; **parastylar** lobes claw-like; **stylus spatulate**, basal fold present. Female (paratopotype) – **Ovipositor cuticle** intricately folded; one pair of apical teeth present.

<u>Intraspecific Variation</u>: Juveniles are white to yellowish-white (as in most *Texella*); adults are orange. The tarsal count (number of **tarsomeres**) and the leg-to-body-length ratio (leg II/scute length) may vary from the south to north part of the species' range, with the least troglomorphic (cave-adapted) population being in Cave Y (south of the Colorado River) and the most troglomorphic in Jester Estates Cave (north of the Colorado River). The origin of this species is not easily explainable in that it is distributed on both sides of the Colorado River, which is a major barrier to other terrestrial troglobites. **Troglomorphy** in this genus is marked by increased leg/body ratio, greater number of tarsomeres,

depigmentation, reduction of **protuberances**, and loss of retinas followed by loss of corneas.

Distinctiveness: Goodnight and Goodnight (1942) described *Texella mulaiki* from Hays County (probably Ezell's Cave), but in 1967 reported it from Cotterell Cave in Travis County as well as Man-With-A-Spear Cave and Beck's Tin Can Cave (Beck Sewer Cave) in Williamson County. In 1967 they also described *T. reddelli*, but the genitalia were not studied and the only differences from *T. mulaiki* noted were the shorter legs, the differently-shaped spine on the **genital operculum**, and a few minor characteristics. The authors also reported *T. reddelli* from Bee Creek Cave, Tooth Cave, and Weldon Cave, Travis County; and Bone Cave, Williamson County. Lacking detailed data and material, they did not note that the distribution patterns of the two species were incongruously mixed. Apparently the identifications were based more on leg length than other characters. Ubick and Briggs (1992) examined more specimens from more caves and **epigean** sites and in their revision distinguished *T. reddelli* from *T. reyesi* (below). They described 18 new species and transferred one species from *Sitalcina* to *Texella*. Sixteen of the 21 *Texella* species are cavernicoles and five are troglobites. Fifteen of the species occur along the Balcones Escarpment in Central Texas.

T. reddelli can be distinguished in the field from its closest relative, *T. reyesi* by its shorter legs, its well developed eyes (versus extremely small or no eyes in *T. reyesi*), and its color, which is more orange. The species is not "without eyes" as noted by Goodnight and Goodnight but has "eye mound broadly conical, eyes well developed" (Ubick and Briggs 1992).

Such details can be seen with the naked eye or a hand lens in the field. However, confirmation of the species must be made microscopically by a qualified systematist on a preserved, adult specimen.

In their redescription of the *Texella* species, Ubick and Briggs (1992) state that *Texella reddelli* and *Texella reyesi* "are clearly very closely related and, using the standards of genitalia distinctness applied to other *Texella* species, may even be considered conspecific." However, given that the two groups can be distinguished, and are considered separate in the taxonomic description, the USFWS follows Ubick and Briggs and considers the two species separately.

Listed: Endangered; September 16, 1988; 53 FR 36029.

Recovery Priority: 2C

SPECIES 4 – Scientific name: *Texella reyesi* Ubick and Briggs

Common Name: Bone Cave harvestman

Taxonomic Classification: Class Arachnida (arachnids), Order Opiliones (opilionids, or harvestmen), Suborder Laniatores, Family Phalangodidae.

Original Description: Ubick and Briggs (1992). This paper describes 18 new species of *Texella*, with a total of 21 species in three species groups in Texas, New Mexico, California, and Oregon. The highest species diversity (15 species) is along the Balcones Escarpment in Central Texas.

Type Specimen: Male holotype, Bone Cave, Williamson County, Texas, 4 June 1989. Collected by William Elliott, James Reddell, and Marcelino Reyes. Male paratype, Tooth Cave, and female paratopotype, Bone Cave. All specimens are deposited at the California Academy of Sciences.

Other Taxonomic Literature: Goodnight and Goodnight (1942, 1967). The genus *Texella* was erected by Goodnight and Goodnight (1942). In 1967 they described *Texella reddelli*, which at that time included some populations of *Texella reyesi*.

Selected Characteristics: A long-legged, blind, pale orange harvestman. Body length 1.41-2.67 mm, scute length 1.26-1.69 mm, leg II length 6.10-11.79 mm, leg II/scute length 4.30-8.68 mm (N = 85). Body finely rugose. Few small **tubercles** on eye mound; eye mound broadly conical, retina absent, cornea variable (well developed, reduced, or absent). Penis with ventral plate prong round apically; two dorsal, 17 lateral, and four ventral setae; apical spine bent, apically pointed, length 0.05 mm. Glans with basal knob narrowly conical; middle lobe long; parastylar lobes claw-shaped. Stylus long, curved, ventrally **carinate**, apically spatulate; basal fold well developed.

Intraspecific Variation: Juveniles are white to yellowish-white. Adults are pale orange. Elliott (unpublished data) has observed an adult with a pale green abdomen in Man-With-A-Spear Cave, Williamson County, and an adult with a yellowish abdomen in Temples of Thor Cave, Williamson County. These colorations may have been due to eggs in the ovaries. This species is extremely **polymorphic**, most notably in troglomorphic characters, which increase toward the northern populations. Northern populations tend to be more troglomorphic; that is, longer-legged and smoother, with reduced or absent corneas.

Distinctiveness: *Texella reyesi* can be distinguished from its closest relative *T. reddelli* by its longer legs, its lack of retinas (versus well developed eyes in *Texella reddelli*), and its color, which is pale orange. Such differences can be seen with the naked eye or a hand lens in the field. However, confirmation of the species must be made microscopically by a qualified systematist on a preserved adult.

Listed: Because *Texella reyesi* was considered to be *Texella reddelli* before Ubick and Briggs' redescription (1992) and five localities (Tooth, McDonald, Weldon, Bone, and Root caves) of *T. reyesi* were included with *T. reddelli* at the time *T. reddelli* was listed as endangered on September 16, 1988 (53 FR 36029), *T. reyesi* is considered to be listed as endangered under the Endangered Species Act. The USFWS has reviewed the taxonomic change (Ubick and Briggs 1992) and other available information on this species and determined it should remain listed as endangered (58 FR 43818).

Recovery Priority: 2C

SPECIES 5 – Scientific name: *Rhadine persephone* Barr

Common Name: Tooth Cave ground beetle

Taxonomic Classification: Class Insecta (insects), Order Coleoptera (beetles), Suborder Adephaga, Family Carabidae (ground beetles), Tribe Agonini (agonines). Many troglobitic ground beetles have evolved in Texas and other parts of the world. The genus *Rhadine* contains more than 60 eyed and eyeless species in the Great Plains westward to California and south to Oaxaca, Mexico. Eleven species are troglobites found mostly in caves of the Balcones Escarpment of Texas and are members of the *subterranea* species group, a **monophyletic assemblage**. The *subterranea* group is closely related to the *perlevis* group, which contains eyed, troglophilic members found in caves of the Edwards Plateau. The *subterranea* species group contains a "robust", or heavy-bodied, subgroup, which is generally found south of the Colorado River, but which includes *R. persephone* north of the river. A "slender" subgroup, including *R. subterranea*, is widely distributed on both sides of the river. At least three different species pairs coexist in some caves, consisting of a robust species and a slender species in each case. In most situations the robust species is more abundant. These data suggest that the ranges of the various species may overlap broadly, but that minimal **niche** overlap occurs between robust and slender species, which allows the two species to coexist in some caves.

Original Description: Barr (1974a)

Type Specimen: Holotype male, Tooth Cave, Travis

County, Texas, May 16, 1965. Collected by R.W. Mitchell, T.C. Barr, Jr., and W.M. Andrews. Deposited in American Museum of Natural History.

Selected Characteristics: A moderately robust and convex beetle, more so than other species of the *subterranea* group. Reddish-brown, head and **pronotum** shining. Head half as wide as long, neck about 0.57-0.59 of greatest head width. Eye rudiment larger than in other species of *subterranea* group. Pronotum about 0.7 as wide as long, widest in apical three-eighths, slightly wider than head. Antenna about 0.85 total body length, attaining apical third of **elytra** when laid back. **Aedeagus** very large for *subterranea* group, 1.24-1.31 mm long, elongate, **feebly arcuate**, basal bulb slender and set off by slight constriction, keel prominent, apex attenuate and slightly produced; internal sac with **proximal** patch of numerous scales. Body length 8.0 mm, head 2.17 mm long by 1.08 mm wide, pronotum 1.80 mm long by 1.18 mm wide, elytra 4.46 mm long by 2.29 mm wide, antenna 6.8 mm long. Fifty paratypes and four specimens from Kretschmarr Cave with length 7.2-8.7 mm, mean 7.8.

Intraspecific Variation: Not known.

Distinctiveness: *Rhadine persephone* is distinguished from *R. subterranea* by its more robust build and its shorter and wider pronotum (the most distinguishing characteristic). The two species are about the same length. Tenerals (young adult beetles that have recently emerged) of all *Rhadine* species are pale yellow but soon darken to reddish brown. Other species that can be confused with *R. persephone* include *R. austinica* (southern Travis County), *R.*

noctivaga (northern Williamson County) and *R. russelli* (Post Oak Ridge area of Burnet, Travis, and Williamson counties). All three of these species are in the "slender" subgroup. Other related species occur in other parts of Central Texas. Identification of *Rhadine* species must be confirmed by microscopic examination of preserved specimens by a qualified systematist.

<u>Listed</u>: Endangered; September 16, 1988; 53 FR 36029.

<u>Recovery Priority</u>: 2C

SPECIES 6 – Scientific name: *Texamaurops reddelli* Barr and Steeves

Common Name: Kretschmarr Cave mold beetle

Taxonomic Classification: Class Insecta (insects), Order Coleoptera (beetles), Suborder Polyphaga, Family **Pselaphidae** (mold beetles), Tribe Batrisini. Pselaphids, or short-winged mold beetles, are a group of small beetles found under stones and logs, in rotting wood, moss, ant and termite nests, and caves. The European and North American cave faunas include many species. The genus *Texamaurops* was erected for one species, *T. reddelli*, from Kretschmarr Cave, Travis County, by Barr and Steeves in 1963. *Texamaurops* remains a monotypic genus found only in a few Texas caves.

Original Description: Barr and Steeves (1963)

Type Specimen: Female holotype, Kretschmarr Cave, Travis County, Texas, March 2, 1963. Collected by James R. Reddell and David McKenzie. Deposited in the Field Museum of Natural History, Chicago. Found under a rock in the second room of the cave, about 10 m from the entrance.

Other Taxonomic Literature: The first pselaphid described from a Texas cave was *Batrisodes schneiderensis* Park (1960), based on a single female from Schneider Ranch Cave in Kendall County. Barr (1974b) classified a male pselaphid from Inner Space Cavern as *Texamaurops reddelli*, but the specimen is now recognized by Chandler (1992) as *Batrisodes texanus* (below).

Selected Characteristics: A small, long-legged beetle with short elytra leaving five abdominal **tergites** exposed; **metathoracic wings** absent. Body length 2.72-3.08 mm. Color reddish-brown, shiny; pubescent hairs pale, moderately abundant and partially laid back; general body surface sparsely and weakly dotted with small pits. Ventral surface of head heavily pubescent. Eyes absent, but represented by small knobs with six **vestigial** eye **facets**. Antennae 11-segmented, simple.

Intraspecific Variation: Chandler (1992) noted that the holotype female from Kretschmarr Cave and the male from Stovepipe Cave differ from all other specimens in having only two basal **foveae** (pits) on each elytron, whereas the others have three equal foveae. All others features appear to be similar.

Distinctiveness: *Texamaurops reddelli* can only be distinguished from other pselaphid beetles by a qualified systematist upon microscopic study. The species is "superficially similar to *Batrisodes texanus* by the greatly elongated antennae and legs, as well as body size" (Chandler 1992), but can be definitively separated from *Batrisodes texanus* by its **ocular knobs** and its lack of the pencil of setae on the metatibia. Chandler (1992) stated that "based on the form of the aedeagus and antennal characters *Texamaurops* is probably best considered a lineage derived from *Batrisodes* that has lost the **metatibial pencil of setae**." In life *Texamaurops reddelli* is a tiny, long-legged form that can be confused with other species such as *Tachys ferrugineus*, which is an eyed, short-legged, shiny, fast-moving **carabid** beetle with full-length elytra; and *Batrisodes uncicornis*, an eyed species occurring in many caves in Central Texas. Other pselaphids, both blind and eyed, occur in caves outside the range of this species (Chandler 1992).

Listed: Endangered; September 16, 1988; 53 FR 36029.

Recovery Priority: 1C. Indicates a monotypic genus with a high degree of threats, high potential for recovery, and in conflict with construction or development projects or other forms of economic activity (48 FR 51985).

SPECIES 7 – Scientific name: *Batrisodes texanus* Chandler

Common Name: Coffin Cave mold beetle

Taxonomic Classification: Class Insecta (insects), Order Coleoptera (beetles), Suborder Polyphaga, Family Pselaphidae (mold beetles), Tribe Batrisini. Mold beetles are generally minute (about 2 or 3 mm long) rounded beetles with short elytra (wing covers), which expose the posterior half of the abdomen.

Original Description: Chandler (1992)

Type Specimen: Male holotype from Inner Space Cavern, Williamson County, Texas, May 23, 1965. Collected by William H. Russell. Deposited in Field Museum of Natural History, Chicago. Female paratypes from Inner Space Cavern and Off Campus Cave, Williamson County (deposited in Donald S. Chandler collection) and Coffin Cave, Williamson County (deposited in Texas Memorial Museum). The Coffin Cave paratype was the first collected on November 3, 1963, by James Reddell.

Other Taxonomic Literature: Barr (1974b) classified a male pselaphid from Inner Space Cavern as *Texamaurops reddelli*, but the specimen is now recognized by Chandler (1992) as *Batrisodes texanus*.

Selected Characteristics: A small, long-legged beetle with short elytra leaving five abdominal tergites exposed; metathoracic wings absent. Body length 2.60-2.88 mm. Male with vague groove across the head anterior to antennal bases. Sides of head smoothly curved and flat with a few granules present where eyes should be.

Intraspecific Variation: In females, the **transverse impression** anterior to the antennal bases is absent, and the tenth antennal segment is barely wider and longer than the ninth. In males the tenth is twice as wide as the ninth. No geographical variation has been noted.

Distinctiveness: *Batrisodes texanus* can only be distinguished from other pselaphid beetles by a qualified systematist upon microscopic study. The species can be definitively separated from *Texamaurops reddelli* by its lack of ocular knobs and the presence of a pencil of setae on the metatibia. In life the beetle is a tiny, long-legged form that can be confused with other species such as *Tachys ferrugineus*, which is an eyed, short-legged, shiny, fast-moving carabid beetle with full-length elytra; and *Batrisodes uncicornis*, an eyed species occurring in many caves in Central Texas. Other pselaphids, both blind and eyed, occur in caves outside the range of this species (Chandler 1992).

Listed: Because *Batrisodes texanus* was considered to be *Texamaurops reddelli* before Chandler's redescription (1992) and one locality (Coffin Cave) of *B. texanus* was included with *Texamaurops reddelli* at the time *Texamaurops reddelli* was listed as endangered on September 16, 1988, (53 FR 36029), *B. texanus* is considered to be listed as endangered under the Endangered Species Act. The USFWS has reviewed the species description (Chandler 1992) and other available information on this species and determined it should remain listed as endangered (58 FR 43818).

Recovery Priority: 2C

B. Distribution

Population estimates: No population estimates are currently available for any of the species due to their secretive habits, rarity, and inaccessibility. Generally, no more than one or two individuals of each species are seen on a visit to a cave and often none are observed, even in caves where they are considered relatively abundant. Some of the species, such as the pseudoscorpion and mold beetles, are so secretive that finding an individual is a rare event (Elliott, pers. observation). Current mark-recapture methods are of little use with such small populations.

Historic range: Since karst surveys and biospeleological studies in the Austin area were not initiated until the early 1960's, there is no information on the species' ranges prior to that time. Further, the status of some of the caves from which listed species have been collected is unknown. Some of these caves may have been filled or destroyed due to land development. For example, attempts to relocate Coffin Cave, which contains *Batrisodes texanus*, have been unsuccessful (James Reddell, Texas Memorial Museum, pers. communication).

Current range: The level of interest and effort in conducting karst and biospeleological surveys greatly increased with the listing of the invertebrate species in 1988. Regional studies were funded by the USFWS, the Texas Parks and Wildlife Department (TPWD), the Texas Department of Transportation, the Texas Nature Conservancy (TNC), and the City of Georgetown (Elliott and Reddell 1989, Reddell 1989, Reddell 1991, Reddell and Elliott 1991, Veni & Associates 1988a,b). Additional surveys have been done by developers, financial institutions, and private landowners.

These studies have assisted in clarifying the range and taxonomy of each species. Although additional localities for each species may still be discovered with continuing survey efforts, the species' ranges are now fairly well-defined, particularly for those species that are restricted to the Jollyville Plateau (*Neoleptoneta myopica*, *Tartarocreagris texana*, and *Texamaurops reddelli*).

Some specimens collected from certain localities have been tentatively identified as listed species (Tables 1 and 2). Positive identification of these specimens is contingent upon identification by a qualified systematist and/or additional collections including well-preserved, intact adult specimens. The information in these tables will be revised and updated as positive identifications are made.

Figure 1 shows all the caves in Travis and Williamson counties currently known to contain one or more of the listed species or from which tentative identifications have been made. Figure 2 shows the seven karst fauna regions (corresponding to the karst fauna areas in Figure 19 of Veni & Associates 1992) that support one or more of the listed species. The South Travis County region is included in the figure even though it is not currently known to have listed species. It is included in the event that future surveys locate any listed species in this region. To date, no listed species have been found in the caves that have been surveyed in the South Travis County region. However, local biospeleologists believe that portions of the South Travis County karst fauna region warrant further investigation to determine whether there are karst features inhabited by listed species, particularly along the south side of Barton Creek. The species most likely to occur in this region is *Texella reddelli*, which occurs in the

Table 1. Endangered Karst Invertebrate Locations in Travis County, Texas. Compiled by William R. Elliott and James R. Reddell, July 12, 1993. Cave numbers correspond to numbers in Figure 1 and Figures 3-8. TARTEX = *Tartarocreagris texana* pseudoscorpion, TEXRED = *Texella reddelli* harvestman, TEXREY = *Texella reyesi* harvestman, NEOMYO = *Neoleptoneta myopica* spider, RHAPER = *Rhadine persephone* beetle, TMPRD = *Texamaurops reddelli* beetle, BATTEX = *Batrisodes texanus* beetle. X = present, P = tentative identification. FIREANTS = *Solenopsis invicta* imported fire ant. Fire ant notes have been partially updated since October 1991: blank = unknown, 0 = no ants seen, 1 = ants in entrance only, 2 = moderate infestation, 3 = severe infestation, X = ants present but severity unknown, R = ants reported but not confirmed, T = treated October 1991. COA = City of Austin, LLMHCP = Lakeline Mall Habitat Conservation Plan.

	CAVE NAME	PRESERVE STATUS	KARST FAUNA REGION	TARTEX	TEXRED	TEXREY	NEOMYO	RHAPER	TMPRED	BATTEX	FIREANTS
1	Broken Arrow Cave		Cedar Park					X			
2	Rolling Rock Cave	LLMHCP	Cedar Park					X			0
3	McNeil Bat Cave		McNeil/Round Rock			X					
4	Weldon Cave		McNeil/Round Rock			X					
5	Fossil Garden Cave		McNeil/Round Rock			X					3
6	No Rent Cave		McNeil/Round Rock			X					0
7	Beer Bottle Cave		McNeil/Round Rock			X					
8	Hole-In-The-Road		McNeil/Round Rock			X					
9	Cold Cave		McNeil/Round Rock			X					
10	Fossil Cave	COA, filled	McNeil/Round Rock			X					
11	McDonald Cave		Jollyville Plateau			X					
12	Stovepipe Cave		Jollyville Plateau	P		P	P	X	X		0
13	Amber Cave		Jollyville Plateau	X					X		1
14	Kretschmarr Double Pit		Jollyville Plateau	P	P			P			0
15	Kretschmarr Cave		Jollyville Plateau					X	X		2T
16	Gallifer Cave		Jollyville Plateau			X	P	P			2T
17	North Root Cave		Jollyville Plateau					X			3T
18	Root Cave		Jollyville Plateau			X		X			3T
19	Tooth Cave		Jollyville Plateau	X		X	X	X	X		1T
20	Tardus Hole (Kretschmarr Fluted Sink)		Jollyville Plateau					X			
21	New Comanche Trail Cave		Jollyville Plateau			X	X				3T
22	Spider Cave		Jollyville Plateau			P		P			0
23	Beard Ranch Cave		Jollyville Plateau			X					
24	Jester Estates Cave	Protected by owner	Jollyville Plateau		X						0
25	Cotterell Cave	COA	Central Austin			X					3T
26	West Rim Cave		Central Austin			X					
27	Bee Creek Cave		Rollingwood		X						
28	Bandit Cave		Rollingwood		P						0
29	Cave Y		Rollingwood		P						1
30	Lamm Cave		Jollyville					X			
31	Jest John Cave	COA	Jollyville		X						
32	Little Bee Creek Cave	COA	Rollingwood		X						
33	Millipede Cave		McNeil/Round Rock			X					

Table 2. Endangered Karst Invertebrate Locations in Williamson County, Texas. Compiled by William R. Elliott and James R. Reddell, July 12, 1993. Cave numbers correspond to numbers in Figures 1, 6, 7, 9. See legend for Table 1.

	CAVE NAME	PRESERVE STATUS	KARST FAUNA REGION	TARTEX	TEXRED	TEXREY	NEOMYO	RHAPER	TMPRED	BATTEX	FIREANTS
1	Coffin Cave		North Williamson Co.							X	
2	Sore-ped Cave		North Williamson Co.			X					0
3	Texella Cave		North Williamson Co.			X					3
4	Pussy Cat Cave		North Williamson Co.			X					0
5	Unemployment Cave		North Williamson Co.			P					1
6	Red Crevice	LLMHCP	North Williamson Co.			X				X	3
7	Temples of Thor Cave	LLMHCP	North Williamson Co.			X					3T
8	Williams Cave No. 1		North Williamson Co.			P					3T
9	Flat Rock Cave		North Williamson Co.			X					3
10	Waterfall Canyon Cave		North Williamson Co.			X					3
11	Lobo's Lair		North Williamson Co.			X					1
12	Wolf's Rattlesnake Cave		North Williamson Co.			X					0
13	Coon Scat Cave		Georgetown			X					3
14	Off Campus Cave		Georgetown			X				X	0
15	On Campus Cave		Georgetown			X				P	1
16	Sierra Vista Cave		Georgetown			X					1
17	Fence-Line Cave		Georgetown			P					2
18	Steam Cave		Georgetown			X					
19	Inner Space Cavern	commercial cave	Georgetown			X				X	0
20	Man-With-A-Spear Cave		Georgetown			X					3T
21	Bone Cave		Georgetown			X					3T
22	Elm Cave		Georgetown			P					
23	Brown's Cave		Georgetown			X					
24	Flint Wash Cave		McNeil/Round Rock			X					1
25	Easter Cave		McNeil/Round Rock			P					2
26	Cat Hollow Cave #1		McNeil/Round Rock			X					2
27	Cat Hollow Cave #2		McNeil/Round Rock			X					3
28	Beck Ranch Cave		McNeil/Round Rock			X					R
29	Beck Sewer Cave		McNeil/Round Rock			X					2
30	Beck Bat Cave		McNeil/Round Rock			X					
31	Beck Blowing Well		McNeil/Round Rock			X					
32	Beck Horse Cave		McNeil/Round Rock			X					
33	Beck Pride Cave		McNeil/Round Rock			X					
34	Beck Tex-2 Cave		McNeil/Round Rock			X					
35	Marigold Cave		Cedar Park					X			2
36	Bluewater Cave #2		Cedar Park					X			2
37	Boulevard Cave		Cedar Park					X			
38	Cedar Elm Sink		Cedar Park					X			3R
39	Good Friday Cave		Cedar Park					X			3T
40	Harvestman Cave		Cedar Park					P			3
41	Hideaway Cave		Cedar Park					X			R
42	Nelson Ranch Cave		Cedar Park					X			1
43	T.W.A.S. A Cave		Cedar Park					X			0
44	Testudo Tube	LLMHCP	Cedar Park					X			0
45	Raccoon Cave		Cedar Park					X			X

Table 2. Endangered Karst Invertebrate Locations in Williamson County, Texas (Continued)
Cave numbers correspond to numbers in Figures 1, 6, 7, 9. See legend for Table 1.

	CAVE NAME	PRESERVE STATUS	KARST FAUNA REGION	TARTEX	TEXRED	TEXREY	NEOMYO	RHAPER	TMPRED	BATTEX	FIREANTS
46	Underline Cave	To be filled, LLMHCP	Cedar Park			X					0
47	LakeLine Cave	LLMHCP	Cedar Park			X		X			1T
48	McNeil Quarry Cave		McNeil/Round Rock			P					
49	Well Trap #6 (corehole)	LLMHCP, Filled	Cedar Park					X			
50	Abused Cave		North Williamson Co.			X					
51	Beck Bridge Cave		McNeil/Round Rock			X					
52	Beck Rattlesnake Cave		McNeil/Round Rock			X					
53	Broken Zipper Cave		McNeil/Round Rock			X					
54	O'Connor Cave		McNeil/Round Rock			X					
55	Stonewall Cave		McNeil/Round Rock			X					
56	Vault Cave		McNeil/Round Rock			X					
57	Little Lake Cave		McNeil/Round Rock			X					
58	Buttercup Creek Cave		Cedar Park					X			
59	Treehouse Sink		Cedar Park					X			
60	Formation Forest Cave		Georgetown			X					
61	Ominous Entrance Cave		Georgetown			X					
62	Step Down Cave		Georgetown			X					
63	Stalagroot Cave		North Williamson Co.			X					
64	Lineament Cave		McNeil/Round Rock			X					
65	Mustard Cave		McNeil/Round Rock			X					
66	Rock Fall Cave		McNeil/Round Rock			X					

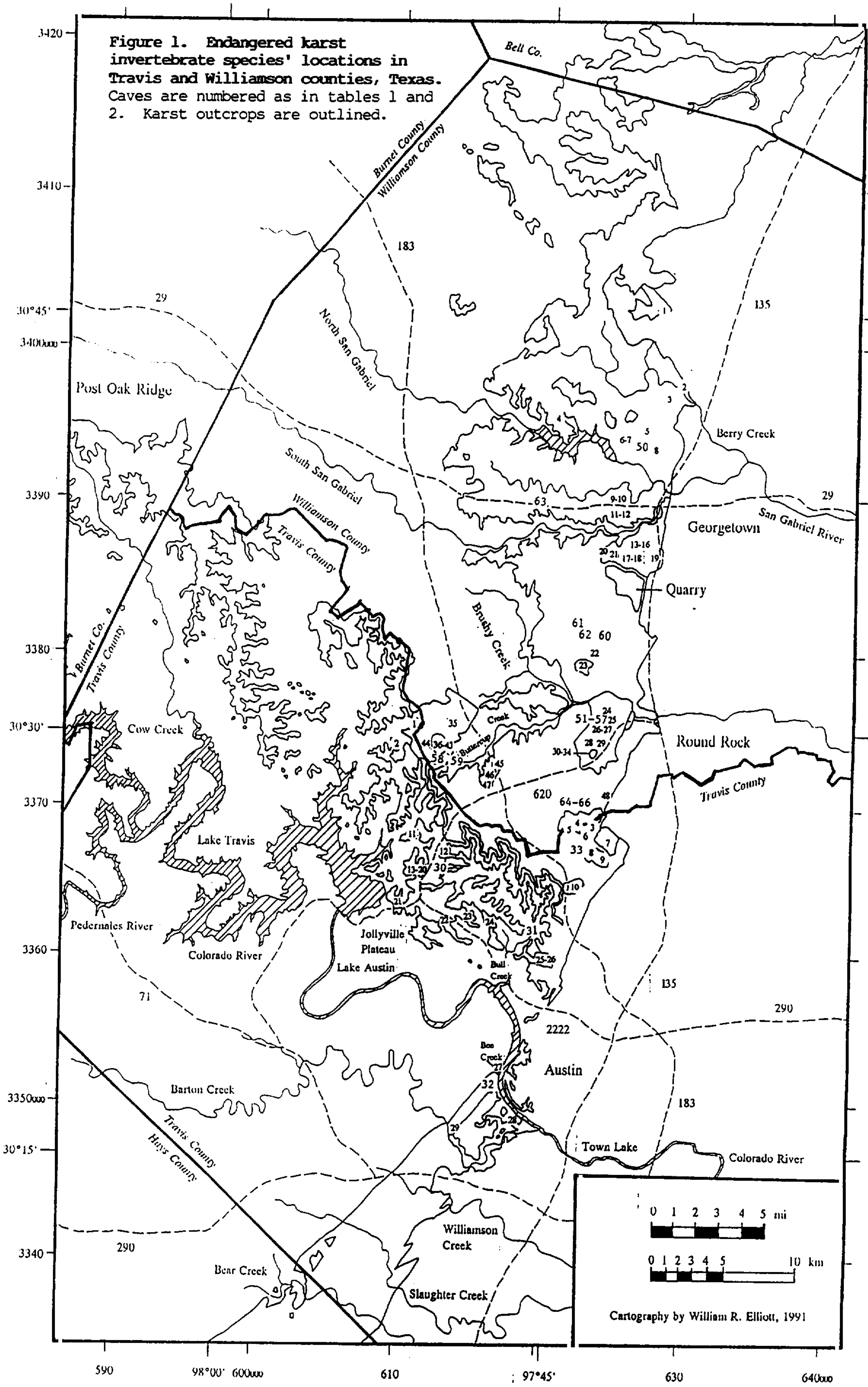
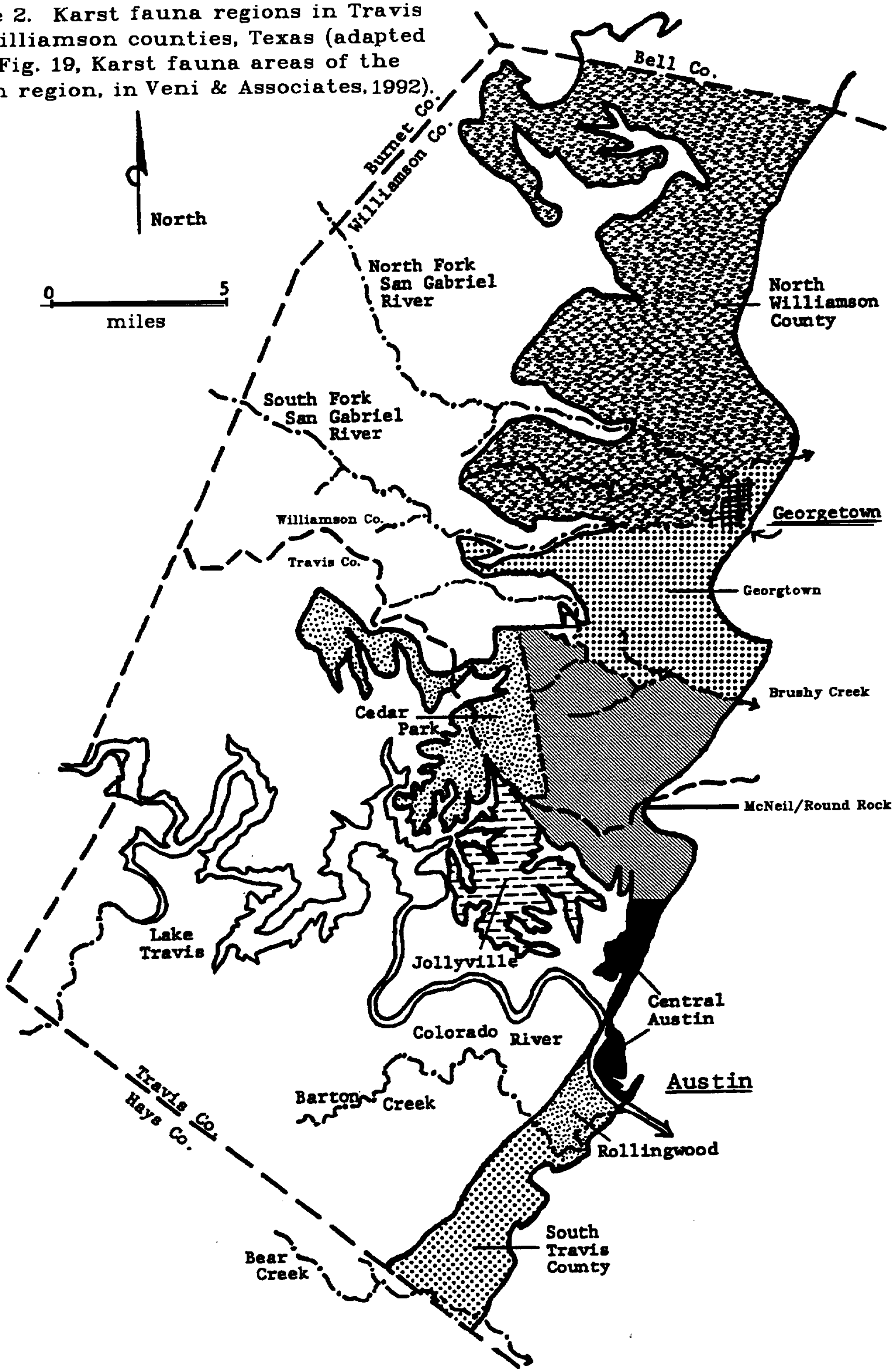


Figure 1. Endangered karst invertebrate species' locations in Travis and Williamson counties, Texas. Caves are numbered as in tables 1 and 2. Karst outcrops are outlined.

Figure 2. Karst fauna regions in Travis and Williamson counties, Texas (adapted from Fig. 19, Karst fauna areas of the Austin region, in Veni & Associates, 1992).



adjacent Rollingwood karst fauna region. Since this species' current distribution occurs on both sides of the Colorado River, it may also occur on both sides of Barton Creek, which separates the Rollingwood and South Travis County karst fauna regions.

Two karst fauna regions from Veni's 1992 report, the McNeil and Round Rock regions, have been combined for the purposes of this plan (hereafter referred to as the McNeil/Round Rock karst fauna region), since they contain virtually the same species and present no significant geologic barriers to troglobitic migration between them (Veni, in litt., 1993).

The distribution of each species is as follows:

SPECIES 1 - *Neoleptoneta myopica*: Known to occur in two caves and tentatively identified from two additional caves within a 4.5 km stretch in the Jollyville Plateau karst fauna region, Travis County, Texas (Table 1, Figure 3).

SPECIES 2 - *Tartarocreagris texana*: Known to occur in two caves and tentatively identified from two additional caves within a 1.3 km radius in the Jollyville Plateau karst fauna region, Travis County, Texas (Table 1, Figure 4).

SPECIES 3 - *Texella reddelli*: Occurs in three caves (one positive, two tentative identifications) in the Jollyville Plateau karst fauna region and four caves (one positive, three tentative identifications) in the Rollingwood karst fauna region, Travis County, Texas (Table 1, Figure 5). Previously reported from Tooth,

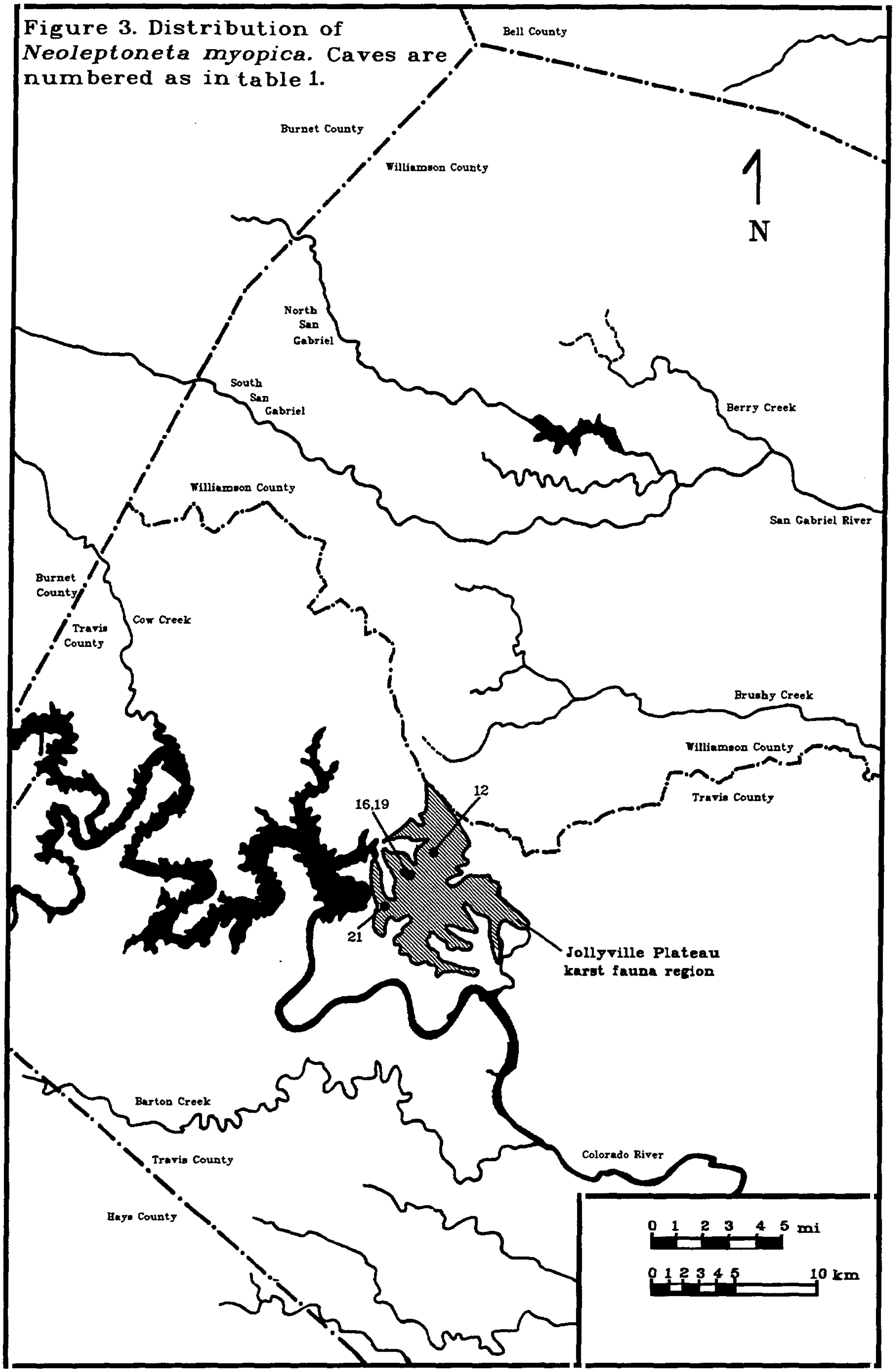


Figure 3. Distribution of *Neoleptoneta myopica*. Caves are numbered as in table 1.

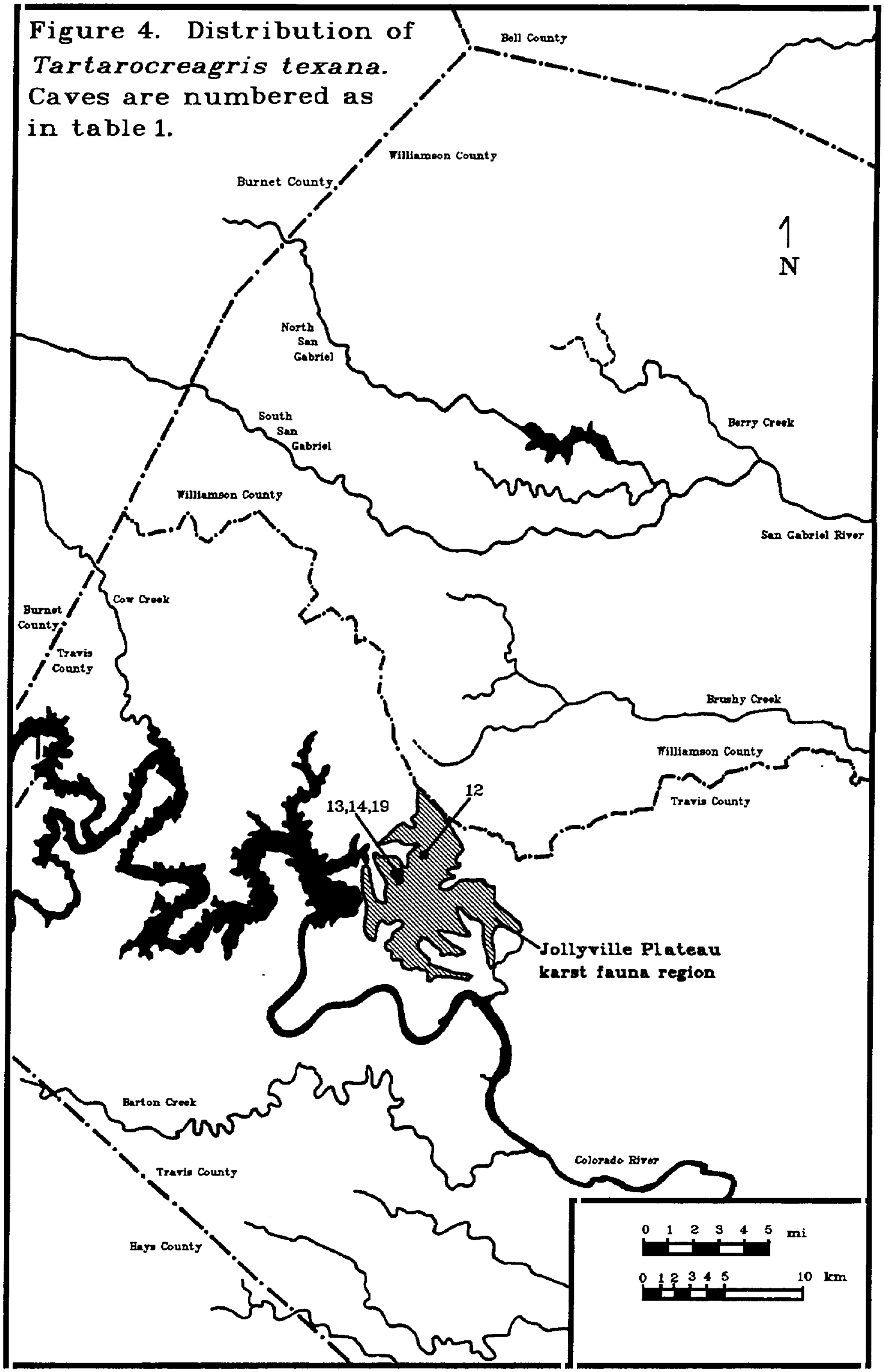
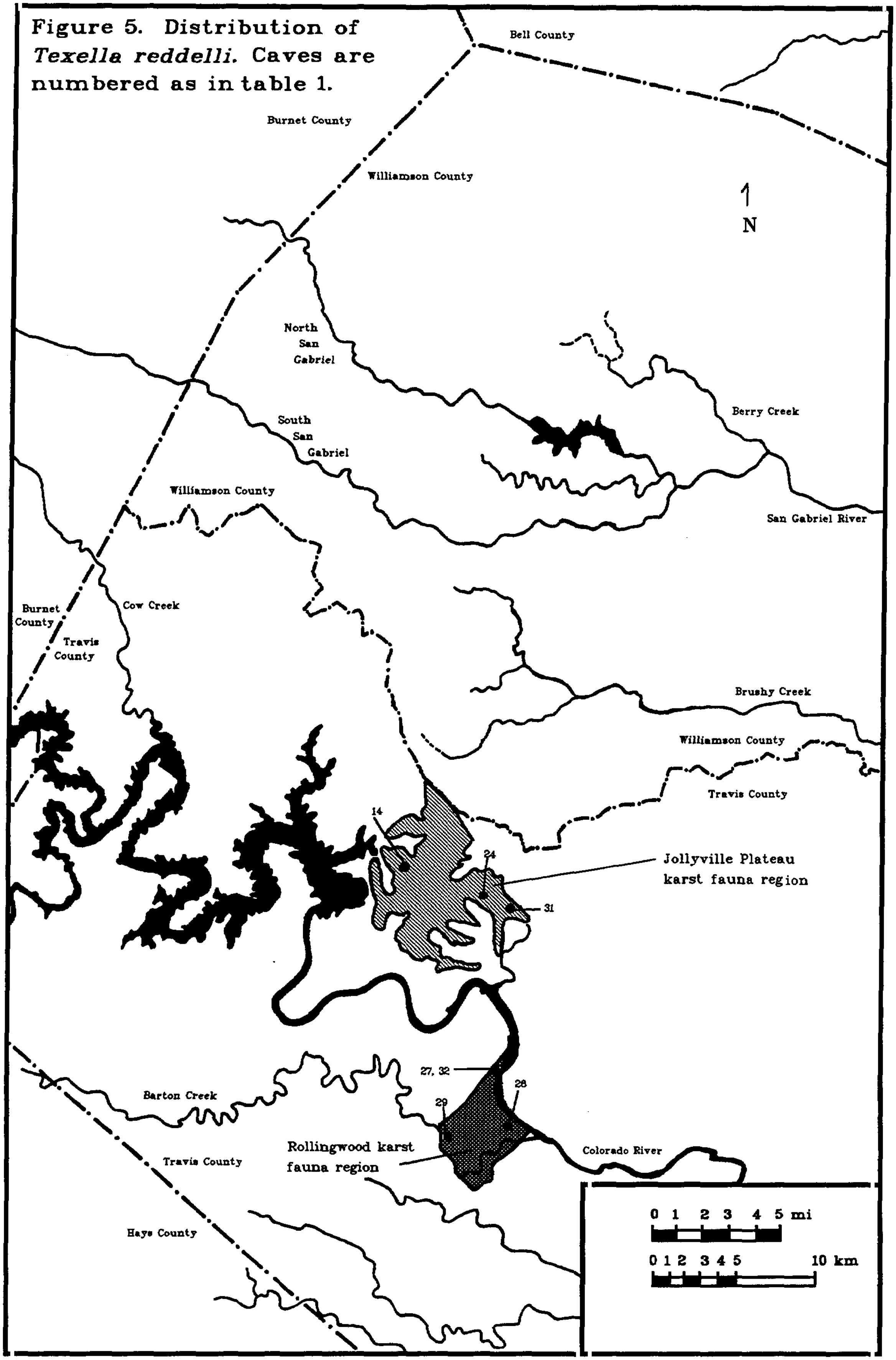


Figure 4. Distribution of *Tartarocreagris texana*. Caves are numbered as in table 1.

Figure 5. Distribution of *Texella reddelli*. Caves are numbered as in table 1.



McDonald, Weldon, and Root caves, Travis County (53 FR 36029), but these populations have been redescribed as *Texella reyesi* (Ubick and Briggs 1992) (58 FR 43818). Kretschmarr Double Pit, Jest John Cave, and Jester Estates Cave are north of the Colorado River on the Jollyville Plateau. The other four caves are located in the Rollingwood karst fauna region, south of the Colorado River. The Cave Y and Bandit Cave collections do not include the male specimens necessary to confirm the occurrence of this species. However, the females are similar to the females collected from Bee Creek Cave and Jester Estates Cave. Isolation of this species in caves on opposite sides of the Colorado River and in different blocks of limestone may be an indication that the populations are genetically distinct.

SPECIES 4 - *Texella reyesi*: Occurs in 69 caves (60 confirmed, 9 tentative identifications) from northern Travis to northern Williamson County, a distance of 40 km (Tables 1 and 2, Figure 6). This species occurs in six karst fauna regions (Jollyville, Central Austin, Cedar Park, McNeil/Round Rock, Georgetown, and North Williamson County). When Goodnight and Goodnight (1967) described *Texella reddelli* they included four populations, three of which are now recognized as *Texella reyesi* (Tooth Cave and Weldon Cave, Travis County; and Bone Cave, Williamson County). The Goodnight and Goodnight (1992) redescription of *Texella mulaiki* included four populations, three of which are now recognized as *Texella reyesi* (Cotterell Cave, Travis County; Man-With-A-Spear Cave and Beck's Tin Can Cave (= Beck Sewer Cave), Williamson County (58 FR 43818)).

SPECIES 5 - *Rhadine persephone*: Occurs in ten caves (8 positive, 2 tentative identifications) in the Jollyville Plateau karst fauna region (Travis County) and 17 localities (16 positive, 1 tentative identifications) in the Cedar Park karst fauna region (Travis and Williamson counties) (Tables 1 and 2, Figure 7), with a total distance of about 14 km between the northern and southernmost locations. **Sympatric** in at least four caves with a slender species, *R. subterranea*.

SPECIES 6 - *Texamaurops reddelli*: Known to occur in four caves within a 2 km radius in the Jollyville Plateau karst fauna region, Travis County, Texas (Table 1, Figure 8). Previously reported from Coffin Cave, Williamson County (53 FR 36029), but the Coffin Cave population has been redescribed as *Batrisodes texanus* (Chandler 1992) (58 FR 43818).

SPECIES 7 - *Batrisodes texanus*: Occurs in two caves in the North Williamson County karst fauna region (both positive identifications) and three caves (two positive, one tentative identification) in the Georgetown karst fauna region, Williamson County, Texas (Table 2, Figure 9). All localities occur within a 17 km stretch.

Figure 6. Distribution of *Texella reyesi*. Caves are numbered as in tables 1 and 2.

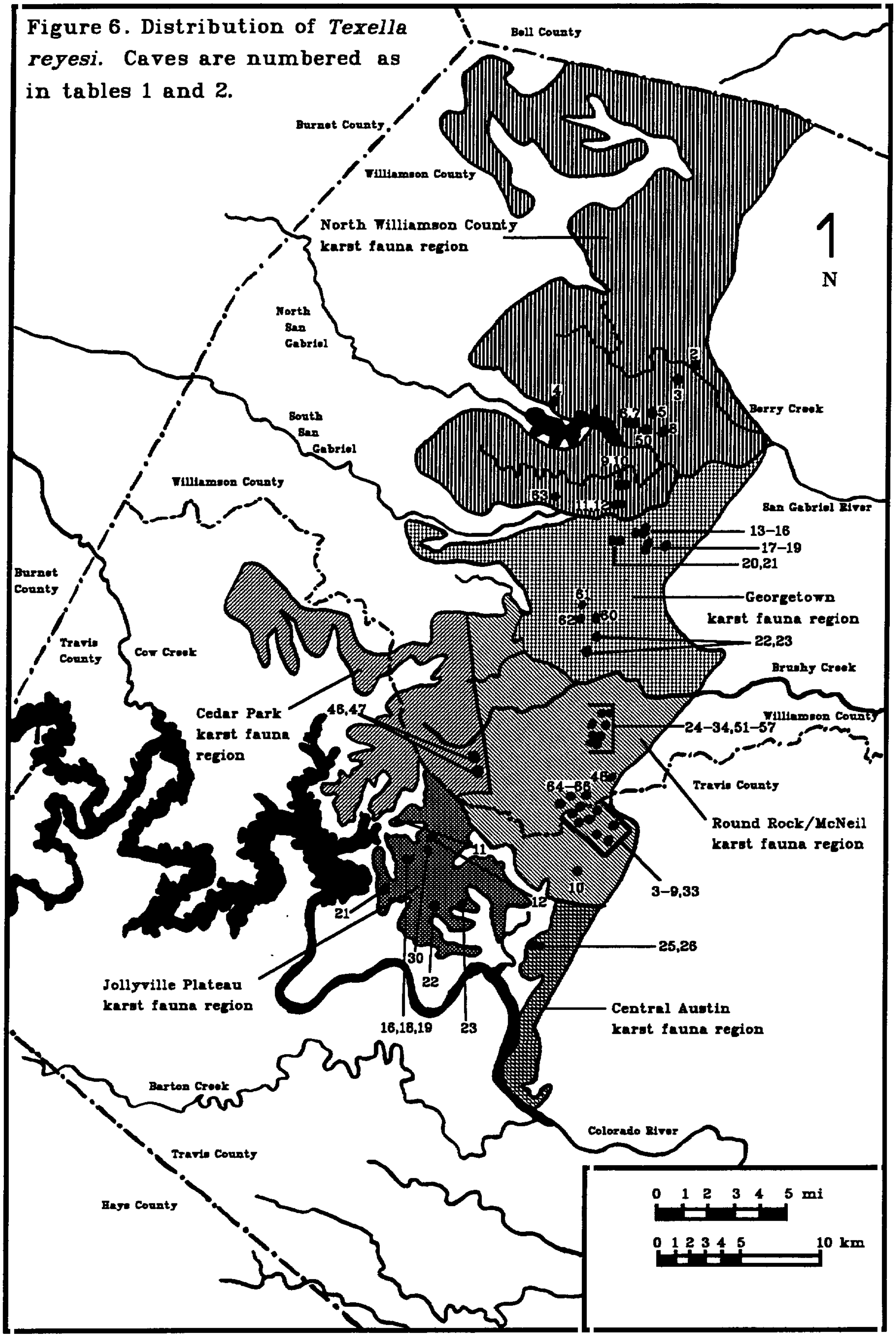


Figure 7. Distribution of *Rhadine persephone*. Caves are numbered as in tables 1 and 2.

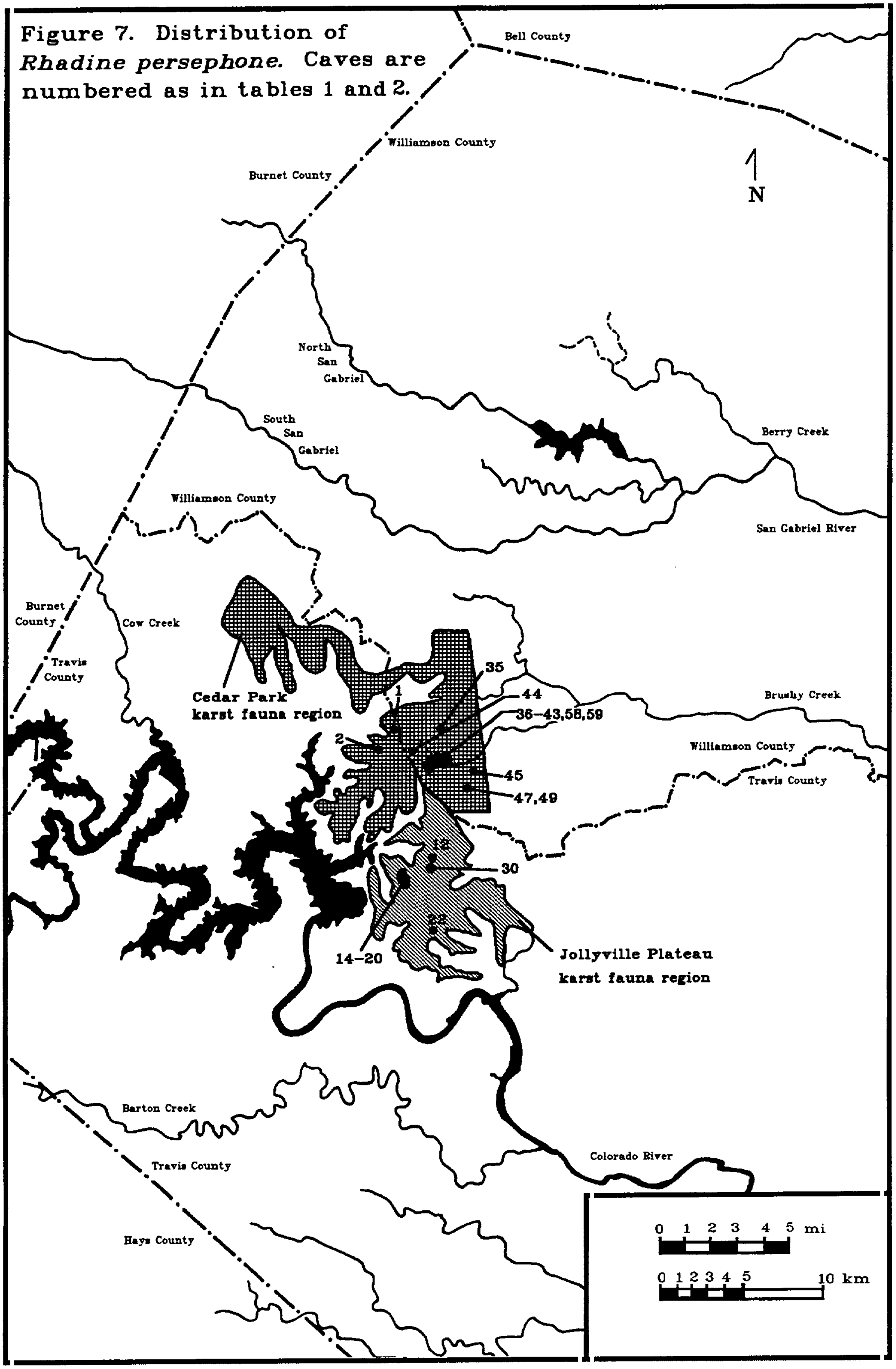


Figure 8. Distribution of *Texamaurops reddelli.* Caves are numbered as in table 1.

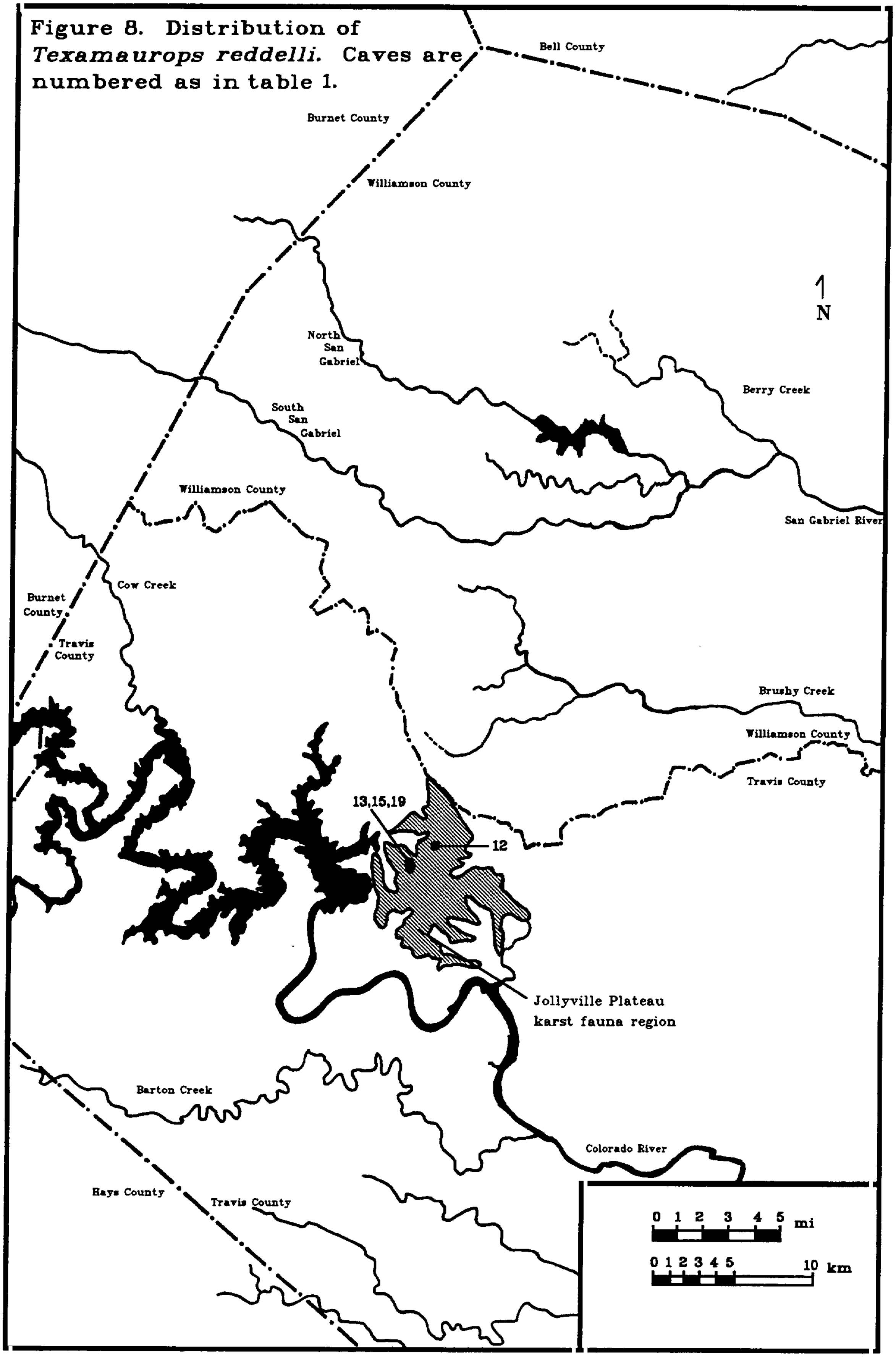
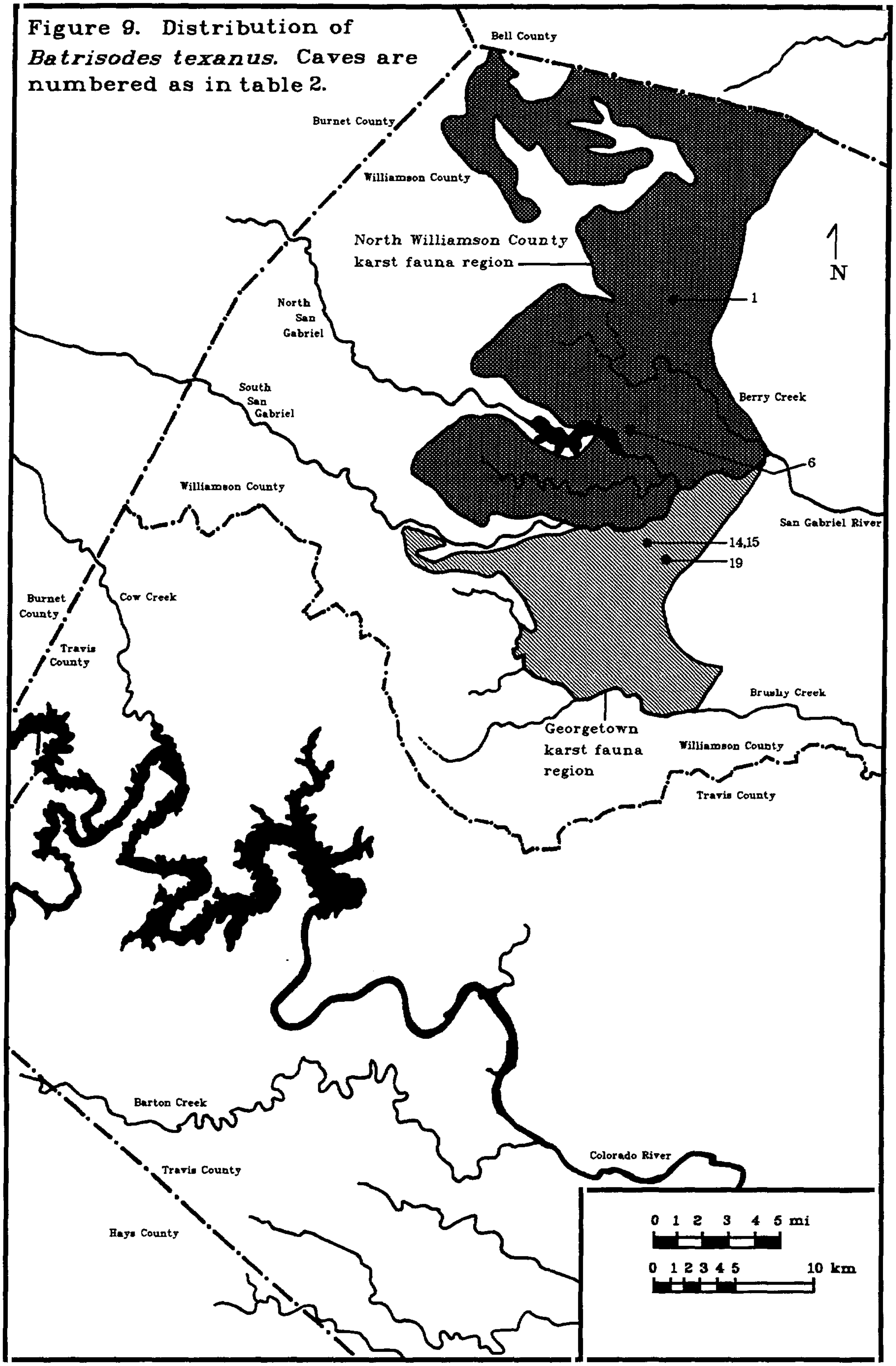


Figure 9. Distribution of *Batrisodes texanus.* Caves are numbered as in table 2.



Of the seven listed species, *Rhadine persephone* and *Texella reyesi* are the only two known from more than seven sites. *Rhadine persephone* appears to be restricted to sites within the Cedar Park and Jollyville Plateau karst fauna regions (Figure 7). *Texella reyesi* has both the greatest number of sites and the widest distribution, occurring in six karst fauna regions (Figure 6). *Texella reddelli* is the only species that occurs both north and south of the Colorado River.

Except for *Batrisodes texanus*, which occurs only in Williamson County, all or portions of the listed species' ranges include the Jollyville Plateau karst fauna region in Travis County. Three of the species' ranges (*Neoleptoneta myopica*, *Tartarocreagris texana*, and *Texamaurops reddelli*) occur entirely within this region. One cave cluster, located in the vicinity of the RM 2222 and RM 620 intersection in a proposed residential subdivision, harbors six of the listed species. This cluster supports one of the most diverse, terrestrial, cave-adapted faunas in the southwestern United States. Only the large, integrated cave systems, such as Mammoth Cave in Kentucky, contain more diverse faunas. Tooth Cave occurs in this cave cluster and contains five of the listed species. Stovepipe Cave, located to the northeast, also contains five of the listed species.

Many of the reconnaissance studies conducted since 1988 have resulted in the discovery of new localities for the listed species as well as new **endemic** species. Because current methods of locating karst features are time-intensive and require on-site inspections, many areas within each karst fauna region have not yet been surveyed. As surveying efforts continue, new localities may be discovered in all karst fauna regions. To date, karst fauna regions that have received the least amount of study are the South Travis County and northwest portion of the North Williamson County karst fauna regions. The northwestern part of Cedar Park also warrants additional study. A large knowledge gap also exists between Round Rock and Georgetown, where a large quarry exists and access to the property is limited. The Texas Speleological Society (TSS), a private, non-profit research group, recorded numerous caves in that area in 1963, but none have been investigated recently. Many of those caves may still exist.

In addition to continuing surveys for new endangered species localities, more intensive biospeleological studies of currently known karst features may also provide additional information on species distributions. More than 700 karst features have been located in Travis and Williamson counties (Elliott, pers. communication), of which about 100 are known or believed (through tentative identification of collected specimens) to contain endangered species (tables 1 and 2). Biospeleological surveys of many of the remaining karst features are either nonexistent, outdated (e.g. recent surveys have not been conducted), incomplete, or cursory. Detailed faunal surveys of those features that have not been adequately studied but which could support one or more of the listed species may lead to the discovery of additional endangered species localities. Although these surveys may increase the total number of known locations for the karst invertebrates, most new locations will occur within the currently defined range of each species. The overall range of each species is not expected to increase significantly beyond what is defined in this plan.

C. Habitat, Ecosystem, and Ecology

Little is known about the life history, ecology, and habitat requirements of the listed species and other karst fauna in central Texas. Although interest in **biospeleology** in Texas has increased in recent years, the research emphasis has been on taxonomy, biogeography, and a few behavioral studies (Barr 1974a,b; Barr and Steeves 1963; Bull and Mitchell 1972; Christiansen and Culver 1969; Elliott and Mitchell 1973; Elliott 1976, 1978a,b; Gertsch 1974; Goodnight and Goodnight 1967; Holsinger 1967; Maguire 1960; Mitchell 1968a,b,c, 1970; Mitchell and Reddell 1971; Muchmore 1969; Reddell 1965, 1966, 1967, 1970a-c), and more recently on geologic and hydrologic processes of karst (Veni & Associates 1988a,b, 1992). Elliott (1991a-f, 1992b-e) has begun a long-term, baseline ecology study of three caves as part of the LakeLine Mall Habitat Conservation Plan (see discussion in Section E).

Origin of Karst Features: "Karst" is 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 subterranean voids (caves, sinkholes, fractures, interconnections, etc.) so that the bedrock somewhat resembles a honeycomb. The formation of these features depends largely on the solubility of the bedrock and the rate and direction of groundwater movement. Water enters the subsurface through cracks, crevices, and other openings, dissolving away soluble beds of rock as it moves through the ground, until it discharges downhill at a spring outlet.

Many of the karst features occupied by the listed species were formed at or below the water table, and thus were once filled with water. As the groundwater table lowered through canyon downcutting and regional uplift, these features dried out and are now air-filled. These features are referred to as "dry" because they tend to have small catchment areas, take very little runoff, and contain little or no perennially flowing water. In some cases, cave and sinkhole entrances were formed as the groundwater table lowered, resulting in ceiling collapse of some cavities.

Some karst features may act as recharge structures to underground stream systems. For example, Buttercup Creek in the Cedar Park karst fauna region in Williamson County, overlies an important karst network composed of several caves such as Buttercup River Cave, Ilex Cave, Boulevard Cave, Whitewater Cave, and a large number of small sinkholes and caves that may contribute to an underground stream (Russell 1993). Testudo Tube is a more distant infeeder to the system. Available information indicates that the stream exits either at a spring in Bull Creek to the south, which contributes to Austin's water supply, or feeds into the northern pool of the Edwards Aquifer.

Evolution of Troglobites: Troglobites have been referred to as "relicts" of surface soil and leaf-litter faunas. A widely accepted explanation for the evolution of troglobites is that, during the course of climatic changes in the Pleistocene epoch (two million to ten thousand years ago), certain creatures retreated into the more stable cave environments, while their respective surface relatives either emigrated or became extinct (Barr 1968, Mitchell and Reddell 1971, Elliott and Reddell 1989). The troglobitic species survived and adapted to the cave environment and colonized the caves and other subterranean voids. Through faulting and canyon downcutting, the karst terrain along the Balcones Fault Zone became increasingly dissected, particularly around the Jollyville Plateau, creating "islands" of karst and barriers to dispersal. This led to increasing isolation of troglobitic populations from each other with subsequent speciation. Some groups speciate very readily, while others appear to speciate more slowly. Some species are more mobile than others and can achieve larger ranges. The restricted distribution of troglobitic species makes many of them highly susceptible to extinction (Elliott and Reddell 1989).

Habitat Requirements - Moisture and Temperature: Troglobites require high humidities (nearly 100%), and many are very susceptible to drying. Generally, areas within caves that have low humidities are almost entirely devoid of cave fauna (Elliott and Reddell 1989, Barr 1968). Caves that are encased with an inner shell of calcite, which can cut off water and nutrient infiltration, are also nearly biologically sterile (Elliott, pers. observation).

Water enters the karst ecosystem though groundwater and surface drainage. Well-developed pathways, such as cave openings, fractures, and solutionally enlarged bedding planes, rapidly transport water through karst with little or no purification. Caves are susceptible to pollution from contaminated water entering the ground because karst has little capacity for self-purification. The route that has the greatest potential to carry water-borne contaminants into the karst ecosystem is through the surface and subsurface drainage basin that supplies water to the ecosystem. Certain activities within this hydrologically sensitive area, such as application of pesticides and fertilizers, leakage from sewer lines, and urban runoff, could contaminate the karst ecosystem. The potential for contaminants to travel through karst systems may be increased in some areas relative to others due to local geologic features.

Most troglobites require stable temperatures. Cold, dry air entering a cave causes the fauna to retreat to more humid, warmer recesses (Reddell and Elliott 1991). During these times, some troglobites may be found in small ceiling pockets where the conditions are presumably warmer and damper, rather than on the floor where they are normally found (Elliott, pers. observation). During hot, dry periods, cave fauna may retreat into the cave soil or interstitial spaces where environmental conditions are more stable (Howarth 1983).

<u>Habitat Requirements - Importance of Surface Communities</u>: Due to the paucity of light and limited capability for photosynthesis, karst ecosystems are almost entirely dependent upon surface plant and animal communities for nutrient and energy input. Karst ecosystems receive nutrients from the surface in the form of leaf litter and other organic debris that have washed or fallen into the caves, from tree and other vascular plant roots, or through the feces, eggs, or dead bodies of **troglophiles** and **trogoxenes** (for example, cave crickets, raccoons).

Certain animal species, such as cave crickets, daddy longlegs, and raccoons appear to use most caves, provided there is sufficient area on the surface with habitat to support these species and the cave entrance is not blocked. A study to determine the foraging range and spatial/temporal distributions of cave crickets and daddy longlegs is currently underway as part of the LakeLine Mall Habitat Conservation Plan (see discussion in Section E). Recent research indicates cave crickets may forage more than 50 meters from cave entrances (W.R. Elliott, pers. comm., 1993).

Cave crickets (*Ceuthophilus* spp.) are an especially important component of the cave ecosystem, because many invertebrates are known to feed on their eggs, feces, nymphs, and dead body parts. Cave crickets typically roost and lay eggs in caves during the day, then emerge at night to feed. They are general predators and scavengers, but the exact food preferences of *Ceuthophilus* species in Texas are still unclear. Daddy longlegs harvestmen (*Leibunum townsendii*), which are abundant in many caves, may similarly introduce nutrients into the cave ecosystem. Raccoons are also ecologically important in many cave communities because their feces provide a rich medium for the growth of fungi and, subsequently, localized population blooms of several species of **collembolans**. Collembolans are tiny, hopping insects that reproduce rapidly on rich food sources and may become prey for some predatory troglobites.

Caves with large bat colonies usually harbor a community dominated by guano-feeders and related species. Some of the small caves of Travis and Williamson counties once harbored small bat colonies, usually cave bats (*Myotis velifer*). This species often abandons caves because of human disturbance or other factors (Elliott, *in press*). However, most of the caves inhabited by the listed species were not significant bat roosts in the past. The exceptions to this rule follow: 1) Tooth Cave apparently harbored a small bat colony at one time, but has not contained bats for many years (Reddell, pers. communication); 2) Steam Cave at Georgetown for many years has continued to harbor some *Myotis velifer* individuals, according to numerous cavers' reports; 3) On Campus Cave at Georgetown, apparently a major bat cave at one time, was sealed during land development, then reopened in 1992 (Mike Warton, geologist, pers. communication); 4) Beck Bat, Beck Horse, and Beck Ranch caves have had bat colonies at different times (Elliott, pers. observation). These data suggest that although the karst ecosystems containing the listed species may not depend on bats for nutrient input, some of the listed species can tolerate conditions around small bat colonies and may benefit from the increased nutrients.

Surface plant communities around karst features supporting the listed species range from pasture land to mature oak-juniper woodland. In general, exotic plants and animals (particularly fire ants) are believed to be detrimental and may result in competition with or predation upon native species and a decreased overall species diversity.

In addition to providing nutrients to the karst ecosystem, the surface plant community also serves to buffer the karst ecosystem against changes in the temperature and moisture regimes, pollutants entering from the surface (Biological Advisory Team 1990, Veni & Associates 1988a), and other factors such as sedimentation from soil erosion. Protecting native vegetation may also help control certain exotics (such as fire ants) that may compete with and/or prey upon the listed species and other karst fauna. Fire ants are particularly detrimental to karst ecosystems, although the full extent of their impact has not yet been determined. Soil disturbance, introduction of nursery plants and sod containing fire ants, garbage (potential food source), and electrical equipment are some of the factors contributing to fire ant infestations.

<u>Habitat Requirements - Use of Interstitial Spaces:</u> The extent to which the species use small humanly inaccessible voids, referred to as "interstitial spaces" (such as

fractures, fissures, cracks, etc.), between or around caves is not fully known. Use of interstitial spaces by troglobites has been observed in Japan, Hawaii, and Europe (Howarth 1983). At the LakeLine Mall site in Williamson County (see Section E), six **boreholes** (referred to as "coreholes" in certain documents) were drilled to determine the presence of interstitial fauna. The two caves on the site, LakeLine Cave and Underline Cave, both contain listed species (*Rhadine persephone* and *Texella reyesi*). Four to five *Rhadine persephone* beetles and one *Rhadine subterranea* beetle were found in one of the four boreholes that encountered a void (Well Trap #6, Table 2). This void was located about 600 feet northwest of LakeLine Cave in Williamson County. No troglobites were found in the other five boreholes (Horizon Environmental Services, Inc. 1991a).

Howarth (1983) refers to these interstitial communities as "crack fauna" and asserts that "caves are not isolated but connect with other subterranean habitats to constitute a single functioning system". He argues that troglobites primarily live in interstitial spaces, where environmental conditions are more stable, but will venture into larger voids and caves when conditions are suitable. Some troglobites have a lower metabolic rate and are able to use energy more efficiently than their surface relatives, and many have exhibited the ability to withstand long periods without consuming food. Thus, a steady food supply for these species may not be as limiting a factor as the need for high moisture levels and stable temperatures. This may explain the seasonal distribution of the cave fauna and the apparent paucity of troglobites during periods of dryness or temperature extremes (Howarth 1983).

Troglobites occupying interstitial spaces may receive nutrients through root systems of surface vegetation and through many small holes and fissures in karst areas where raccoons, cave crickets, and other surface fauna can enter the subsurface. Groundwater flow and surface infiltration are also vehicles for transporting nutrients through interstitial spaces. Certain strata in the Edwards Limestone are more prone to developing karstic solutional openings and thus may be more penetrable by nutrients than other strata. The extent of nutrient infiltration into the interstitium appears to be site-specific and is largely dependent on the nature of the limestone strata and the juxtaposition of subterranean voids. Thus, some strata may receive nutrient input over a large area, while others may receive input only through caves and sinkholes.

The distance that the listed species or other karst fauna retreat from cave openings is unknown but is probably dependent upon the presence of contiguous voids large enough for the fauna to occupy, proximity to nutrient supplies, and the ecological requirements of the species. For example, if the "epikarst" (the surface of the karst) is extremely honeycombed, as in the LakeLine Mall area, then troglobites may be found where there are continuous passages or open bedding planes. Furthermore, more mobile species, such as *Rhadine persephone*, may range farther from cave openings, while more sedentary species, such as *Neoleptoneta myopica*, may be physically restricted to nutrient-rich areas.

Habitat Requirements - Management Considerations: The karst features inhabited by these species and the ecosystems on which they depend have evolved slowly over millions of years and cannot be recreated once they have been destroyed. Protection of these ecosystems will require maintaining moist, humid conditions and stable temperatures in the air-filled voids; maintaining an adequate nutrient supply; preventing contamination of the water entering the ecosystem; preventing or controlling invasion of exotic species, such as fire ants; and other actions as deemed necessary. Additional research may help to develop or refine conservation and management practices necessary to achieve these goals.

In determining appropriate management techniques of surface communities, the ecological requirements of other species, such as the federally listed endangered black-capped vireo (*Vireo atricapillus*) and golden-cheeked warbler (*Dendroica chrysoparia*), whose ranges overlap with those of the listed invertebrates, will also need to be considered. Recovery plans for these species have been prepared (USFWS 1991, 1992).

<u>Ecology</u>: Most of the endangered karst invertebrates are believed to be predators of **microarthropods**, such as collembolans. Many troglobites also feed on well-decomposed organic matter. Others, such as the ground beetle, may consume cave cricket eggs or dead cave cricket parts. The limited data available suggest that most troglobites are food generalists (Barr 1968), although this does not preclude the development of food specialization in some species. Since several predator species coexist in most caves, one can expect some degree of prey specialization in these species.

Elliott and Reddell (1989) note that "there is no direct information on the life cycle of any of these species. Many surface relatives have a distinct seasonal life cycle, but collections throughout the year indicate that all of these species have lost this seasonality...".

The following list summarizes currently available on each species' biology.

Species 1 - *Neoleptoneta myopica*: This species preys on microarthropods and has been described as a "sedentary aerial spider that hangs from a small tangle or sheet web on long, thin legs" (Gertsch 1974). Mitchell and Reddell (1971) observed that "in Texas caves, generally, the spiders are the most important animals filling the 'small predator' niches." Since a cave can contain several different species of spiders, such as members of the genera *Neoleptoneta*, *Cicurina*, *Nesticus*, and *Eidmanella*, slightly different small predator niches apparently have developed in those communities. For example, in Tooth Cave, Travis County, there are 11 co-existing, troglobitic, small predators (6 spiders, a harvestman, 2 pseudoscorpions, and 2 *Rhadine* beetles) (Elliott and Reddell 1989).

Species 2 - *Tartarocreagris texana: Tartarocreagris texana* is usually found under rocks. Finding individuals of this species is so rare that little else is known of its habits (Elliott and Reddell 1989). All known pseudoscorpions are predators of microarthropods.

Species 3 - *Texella reddelli*: This species is usually found under rocks in darkness or in dim twilight. All phalangodids have large, raptorial pedipalps designed to seize and hold prey. Elliott (1978b) observed that *Banksula melones* and *Banksula grahami*, members of the same family from California, fed upon cave **psocids** (psocopterans) and collembolans placed in small containers, but preferred the collembolans, which were smaller. *Texella* and other small harvestmen tend to walk rather slowly and deliberately, unlike spiders, which tend to move faster. See further remarks on *Texella reyesi*.

Species 4 - *Texella reyesi*: This species is especially sensitive to drying and requires very moist, humid conditions (Elliott 1991a-f and unpublished data). Most individuals are found under large rocks, but are occasionally seen walking on moist floors. In Temples of Thor Cave, individuals are typically found about 30m from the entrance in total darkness, where humidity is high; they seldom occur farther in the cave where there is less water and food. In the hottest part of the summer when many of the small caves warm up and become drier, individuals may retreat into the interstitium or may be found only in the coolest, dampest spots in the caves. This species feeds on microarthropods. One individual in LakeLine Cave was observed feeding on fungi growing on a dead raccoon.

Species 5 - *Rhadine persephone*: *Rhadine persephone* is the largest, most visible, and most active of the species and is sometimes visible in strong light from a distance of 5 to 10 m. *Rhadine persephone* is usually found under rocks, although some individuals have been observed walking on damp rocks and silt. The beetle runs rapidly and patrols the floor area in search of prey, as does *R. subterranea*, a closely related and sympatric species.

While feeding behavior has not been observed in *R. persephone*, Mitchell (1968a, b) observed *R. subterranea* feeding on cave cricket eggs and dead cave cricket parts in Beck's Ranch Cave, Williamson County. James Reddell (pers. communication, in Mitchell 1968b) reported one observation of a *R. subterranea* beetle carrying a collembolan. *Rhadine subterranea* appears to be restricted to areas of deep, uncompacted silt, where it digs holes to remove and feed on eggs deposited into the silt by cave crickets. Mitchell also found *R. subterranea* larvae in the silt, but he felt the food supply was the limiting factor in the beetle's distribution. *Rhadine subterranea* is not believed to feed on organic material, fungi, raccoon feces, cricket droppings, or live cave cricket nymphs, as are some other invertebrates. Fungi may harbor parasites that result in beetle mortality. Predation on cave cricket eggs has apparently evolved in at least four different genera of troglobitic carabid beetles in North America (Howarth 1983).

In Tooth Cave, where numerous specimens were collected in 1965, *R. persephone* are more abundant than *R. subterranea*. The high population levels of *R. subterranea* in the Round Rock and Georgetown areas contrast sharply with its rarity at the southern margin of its range (for example, Tooth Cave), where population density and perhaps further range extension may be checked by interspecific competition. Competition due to broad niche overlap between *R. persephone* and *R. subterranea* may limit the latter in Tooth and Kretschmarr caves (Barr 1974a).

On one occasion Elliott (1992b) observed *Rhadine persephone* in LakeLine Cave to be more active at night. This may indicate a residual nocturnal behavior, similar to that seen in fully-eyed species of *Rhadine* beetles observed in caves on the Edwards Plateau (Elliott, pers. observations).

Species 6 - *Texamaurops reddelli:* *Texamaurops reddelli* is found in total darkness under and among rocks and buried in silt (Barr and Steeves 1963, Reddell 1966). All members of the family are believed to be predators. Both *Texamaurops reddelli* and *Batrisodes texanus* (below) have well-developed mouth parts and are also believed to be predators (Donald S. Chandler, Dept. of Entomology, University of New

Hampshire, in litt., 1993). Pselaphids are found in soil, moldy wood, moss, under stones and logs, in caves, or in termite nests. The term "mold beetle" refers to an old definition of "mold" as rotting plant material.

Species 7 - *Batrisodes texanus: Batrisodes texanus* is found in total darkness under rocks. In Off Campus Cave, it was found on the underside of a rock lightly buried in silty clay in total darkness (Chandler 1992). In Inner Space Cavern in August 1968, Elliott (unpublished data) collected a female as it ran from under a moldy match box in the Mud Room. It is believed to be a predator (see *Texamaurops reddelli*, above).

D. Reasons for Listing and Current Threats

One of the main threats to the listed species is loss of habitat due to urban development activities (53 FR 36029). The species occur in an area that is undergoing continued urban expansion at a rapid rate and few caves are adequately protected. Most of the species' localities occur adjacent to or near developed areas (residential subdivisions, schools, golf courses, roads, commercial and industrial facilities, etc.) or in areas that are proposed for development. Unless proper protective measures can be devised, urban development may lead to the filling in or collapse of caves, alteration of drainage patterns, alteration of surface plant and animal communities, as well as increased contamination and human visitation.

One cave cluster in the Jollyville Plateau karst fauna region occurs in an area that presently supports some residential and industrial development and where additional development has been proposed. Another cave to the north of this cave cluster occurs in an area that is undergoing expansion of a residential community. These two areas support six of the listed species and include the entire ranges of *Tartarocreagris texana* and *Texamaurops reddelli*.

Filling in and Collapsing of Caves: Some caves have been filled, collapsed, or otherwise altered during road construction and building site preparation (53 FR 36029). Various construction and development activities over caves or sinkholes may also result in the collapse of cave ceilings. There are limited data available on the number of caves that have been filled to date. Elliott and Reddell (1989) estimate that at least 10% of the caves in Travis County are destroyed every 10 years. This trend will only accelerate with increasing urban expansion. To date, two caves containing *Texella reyesi* are known to have been filled (Fossil and Sore-ped caves). Sore-ped Cave was filled in 1991 by the owner but was reopened after negotiations with the USFWS. Fossil Cave was filled around 1980 and has not been reopened. Underline Cave and Well Trap #6 will be destroyed as part of the LakeLine Mall Section 10(a)(1)(B) permit (see discussion in Section E). Other caves (such as Coffin Cave which contains *Batrisodes texanus*) may already have been filled due to recent development. Attempts to relocate Coffin Cave have been unsuccessful (53 FR 36029).

Ranching activities may also lead to the filling of cave entrances. The earliest published reference to local ranchers routinely filling cave entrances was by Vinther and Jackson (1948), who stated that entrances were closed in Williamson County "to eliminate hiding places for 'varmints'— predatory animals." Ranchers sometimes fill entrances or cover cave entrances by placing "cedar" (juniper) limbs across entrances to prevent cattle and goats from falling in (Elliott, pers. observations).

<u>Alteration of Drainage Patterns:</u> Because karst ecosystems depend on air-filled voids with some water infiltration, diverting water away from a cave could lead to drying and subsequent mortality of karst fauna, while increasing water infiltration could lead to flooding and loss of air-breathing species. Altering the quantity of water inflow could also result in changes in the nutrient regime.

Development activities that result in the alteration of natural drainage patterns include altering the topography, increasing impervious cover, installing water collecting devices, spray-irrigation systems, and other activities. Opening too many or too large entrances into a cave system during cave exploration may also result in drying. The extent to which these activities are impacting the listed species' localities needs to be determined.

Alteration of Surface Plant and Animal Communities: Land development and other human activities (such as agriculture) can lead to the loss of surface plant and animal communities on which karst ecosystems depend for nutrient supplies. With urbanization, native vegetation may be removed and replaced with impervious cover, nursery plants, and/or exotic plants. Subsequent changes in the animal community include the introduction of exotics, such as fire ants; loss or reduction of certain animals due to habitat loss, competition, predation, or other factors; and overall declines in species diversity. Many of these plants and animals (for example, cave crickets and daddy longlegs) may be critical to the nutrient regime of the karst ecosystem, and loss of these species could lead to nutrient reduction or depletion within the karst ecosystem. Removal of the native surface vegetation may lead to increases in temperature fluctuations, changes in the moisture regime, increased potential for contamination, and increases in sedimentation in the caves from soil erosion on the surface.

The impacts that altering surface plant and animal communities have on karst ecosystems are not fully understood and warrant further research. Important contributors to the karst ecosystem's nutrient regime need to be identified, as well as the surface area and other ecological requirements necessary to sustain these nutrient sources. Some of this information will be gathered as part of the LakeLine Mall Habitat Conservation Plan's studies (see discussion in Section E).

Contamination: Because karst is highly susceptible to groundwater contamination, urbanization (including industrial, residential, road, and commercial development) may result in the contamination of karst ecosystems. Types of contaminants associated with urbanization may include chemical, sewage, and oil pollution. These pollutants are derived from urban runoff; broadcasting, spraying, and fogging pesticides and fertilizers; hazardous materials spills; pipeline and storage tank leaks; power transformer and industrial accidents; leakage from septic systems, landfills, and sewer lines; and other sources.

Primary routes of contaminant entry into karst ecosystems include the surface and subsurface drainage basin of a karst ecosystem; air (for air-borne contaminants); and dumping of household garbage, construction debris, motor oil, alkaline batteries (which contain mercury), pesticides and other materials directly into cave entrances. Many caves are currently subject to disposal of refuse, urban runoff, and contamination from pesticides and fertilizers. Several chemical facilities are located along RM 2222 in the Jollyville Plateau karst fauna region near caves known to support six of the listed species. A cave containing *Texella reyesi* is directly under an oil pipeline. Provisions for protecting karst ecosystems from contamination need to be developed.

Human Visitation, Vandalism, and Dumping: Urban development near cave entrances is likely to increase human visitation to these caves. Possible impacts from human entry into a cave include habitat disturbance or loss due to soil compaction or changes in atmospheric conditions, abandonment of the cave by bats or other trogloxenes, and direct mortality (e.g., from stepping on karst fauna). These impacts may be reduced or avoided, depending on the caving skills and caution of the person(s) entering the cave. Vandalism may also result in the destruction or deterioration of the karst ecosystem. Dumping of toxic trash (such as alkaline batteries) can lead to contamination of the karst ecosystem. Disposal of household and other wastes may also attract fire ants.

Cave gates and fences are often installed to deter unauthorized human visitation and dumping; however, these devices may inadvertently alter the air flow, moisture, and nutrient regimes of the karst ecosystem. Installation of a cave gate may also destroy the aesthetics of the cave opening. Furthermore, the soil disturbance generated during the installation of cave gates and fences may encourage fire ant infestations in these areas. Nonetheless, carefully constructed and monitored cave gates and fences are appropriate in some situations and should be considered as an option at heavily visited or vandalized caves. Caves gates are further discussed in Tasks 4.3 and 7.3.

Fire ants: Fire ant activity in central Texas appears to have increased dramatically since 1989 (Elliott 1992a). The fire ant is an aggressive predator, and current evidence shows that it has a devastating and long-lasting impact on native ant populations and other arthropod communities (Vinson and Sorenson 1986; Porter and Savignano 1990). Fire ants have been observed building nests both within and near cave entrances as well as foraging in caves, especially during the summer.

The relative accessibility of the shallow caves inhabited by the listed invertebrates makes them especially vulnerable to invasion by fire ants and other exotic species. Fire ants can enter karst ecosystems through the cave entrance or through small holes from the surface and attack karst fauna in areas that humans cannot observe. Fire ants have been found in more than 50 percent of the caves that contain listed karst invertebrates and have been observed attacking and preying on several troglobitic species, as well as scorpions, cave crickets, and other karst dwellers (James Reddell, Texas Memorial Museum, in litt., 1993). Karst fauna that are most vulnerable to fire ant predation are the slower-moving adults, nymphs, and eggs. (Reddell, pers. communication). Even in the unlikely event that fire ants do not prey directly upon the listed invertebrates, their presence in and around karst areas could have a drastic detrimental effect on the karst ecosystem through loss of both surface and subsurface species that are critical links in the food chain.

Fire ant colonies occur in two forms: single-queen and multiple-queen colonies. Multiple-queen fire ant colonies occur in very dense concentrations (about 750-5000 mounds per acre) and successfully dominate areas previously occupied by the less dense (100-200 mounds/acre) single-queen form (Porter et al. 1991). The multiple-queen form is three times more abundant in Texas than in other parts of its range and recent surveys indicate it is spreading. This form invaded the Austin area sometime in the early 1980's (Porter et al. 1991).

Fire ant studies conducted by Porter et al. (1988) in Austin indicate that fire ants invade areas in two phases. In the first phase, fire ant queens invade an area through long-distance dispersal of winged queens or are introduced through imported products such as nursery stock or soil containing small fire ant colonies. Their invasion is aided by "any disturbance that clears a site of heavy vegetation and disrupts the native ant community." Several native ants are known to attack and kill founding fire ant queens. These native ants are especially important in eliminating founding fire ant queens and their colonies from non-infested areas. Once the fire ant becomes established, they enter the second phase during which the native ant communities are gradually eliminated and show little resurgence as the fire ant slowly expands and increases in number. This phase takes many years to complete (Porter et al. 1988). These factors should be considered when determining short and long-term methods of fire ant control.

Mining, quarrying, or blasting above/in caves: There are several limestone quarries in the Austin area that may contain suitable habitat for one or more of the listed species. Vinther and Jackson (1948) reported three caves south of Georgetown where a quarry is now located. Reddell and Finch (1963) reported two other caves in this area that were destroyed in 1960 and 1963 by quarry activities and at least 22 other caves and sinks on ranches that are now part of or adjacent to that quarry. Both *Batrisodes texanus* and *Texella reyesi* occur in caves to the north of this quarry. Other quarry properties in the area may still contain caves.

E. Conservation Measures

This section summarizes the regional karst and biospeleological surveys, research, and other conservation measures that have been conducted to date.

Regional karst and biospeleological surveys: Since the listing of the endangered species, numerous surveys have been conducted to better define the distribution and taxonomy of karst fauna in Travis and Williamson counties. Many of the studies are proprietary reconnaissance studies conducted by environmental consultants, geologists, engineers, cavers, and biospeleologists to locate caves and sinkholes on properties proposed for development. These studies have been funded primarily by private landowners, financial institutions, school districts, and governmental agencies and have resulted in the discovery of new endangered species localities.

In early 1989, the Texas Department of Transportation (formerly known as the Texas Department of Highways and Public Transportation) sponsored a karst feature survey and biospeleological study of karst features along the right-of-way of the proposed Austin Outer Parkway (State Highway 45) from Comanche Trail to U.S. 183 (Reddell 1989). That same year, Elliott and Reddell (1989) completed a major study of several caves in Travis and Williamson counties to further define the status and range of the listed species. Elliott and Reddell's surveys were funded by TPWD and TNC in preparation for a regional endangered species conservation effort involving local and state government and several conservation organizations. The report also discussed cave ecology, scientific and economic values of cave faunas, destruction rates of Central Texas caves, and threats to cave fauna. Acquisition, scientific, and management recommendations were also given, including long-term ecological studies, stewardship programs, cooperative agreements, and greenbelts. Through an Endangered Species Act Section 6 cooperative agreement with TPWD, USFWS funded continued karst and biospeleological studies by Reddell and his associates (1991). These studies helped further clarify the range of the listed species and determine areas that warranted additional study.

From 1990 to 1991, the City of Georgetown sponsored an extensive study of 21 caves and 19 other karst features in Georgetown's extraterritorial jurisdiction (Reddell and Elliott 1991). As a result of the study, Temples of Thor and Red Crevice caves were discovered and later sold to Melvin Simon & Associates, Inc. to become part of the LakeLine Mall Habitat Conservation Plan. Known cave locations from the Texas Speleological Society files were mapped onto the City of Georgetown's geographic information system.

Through an Endangered Species Act Section 6 cooperative agreement with TPWD, the USFWS funded a study (Veni & Associates 1992) of geologic controls on cave development and the distribution of karst fauna in the vicinity of Travis and Williamson counties. This study significantly improved the ability to predict where endangered species' localities might occur in Travis and Williamson counties. Veni divided Travis, Williamson, Hays, and Burnet counties into 11 areas (referred to as "karst fauna regions" in this recovery plan) based on geologic continuity, hydrology, and the distribution of 38 rare troglobites. By correlating distribution data for the 38 troglobites to the 11 karst fauna regions, Veni observed that the Jollyville Plateau, Central Austin, and Post Oak

Ridge regions have more endemic species than McNeil, Round Rock, and Cedar Park. For the purposes of this plan, the McNeil and Round Rock karst fauna regions have been combined, and areas where listed species do not occur have been omitted from Figure 2, with the exception of South Travis County (see discussion in Part I.B).

Veni and Associates (1992) mapped four zones in Travis and Williamson Counties indicating areas with different likelihoods of having extensive cave development and listed species. The boundaries are matched to known outcrops of cavernous limestone garnered from numerous geologic maps and studies and to hydrologic boundaries extrapolated from the elevations of cave passages compared to surface water divides. Zone 1 includes areas in the Edwards Group limestones that are known to contain listed species. Zone 2 comprises areas that may contain listed species or other endemic fauna. Zone 3 probably does not contain listed species or their habitat, and Zone 4 consists of noncavernous rock and thus does not contain caves or other karst features. Together, Zones 1 and 2 comprise about 55,000 acres in Travis County and about 100,000 acres in Williamson County (Figure 10).

Fire ant control study: In 1991, USFWS funded, through a Section 6 cooperative agreement with TPWD, a fire ant control study in and around 12 caves containing listed species in Travis and Williamson counties (Elliott 1992a). Three types of treatments were used including hot (nearly boiling) water, and the chemicals Amdro® and Logic®. Additional research is needed to determine the effectiveness of the treatments against fire ants and effects on the listed species.

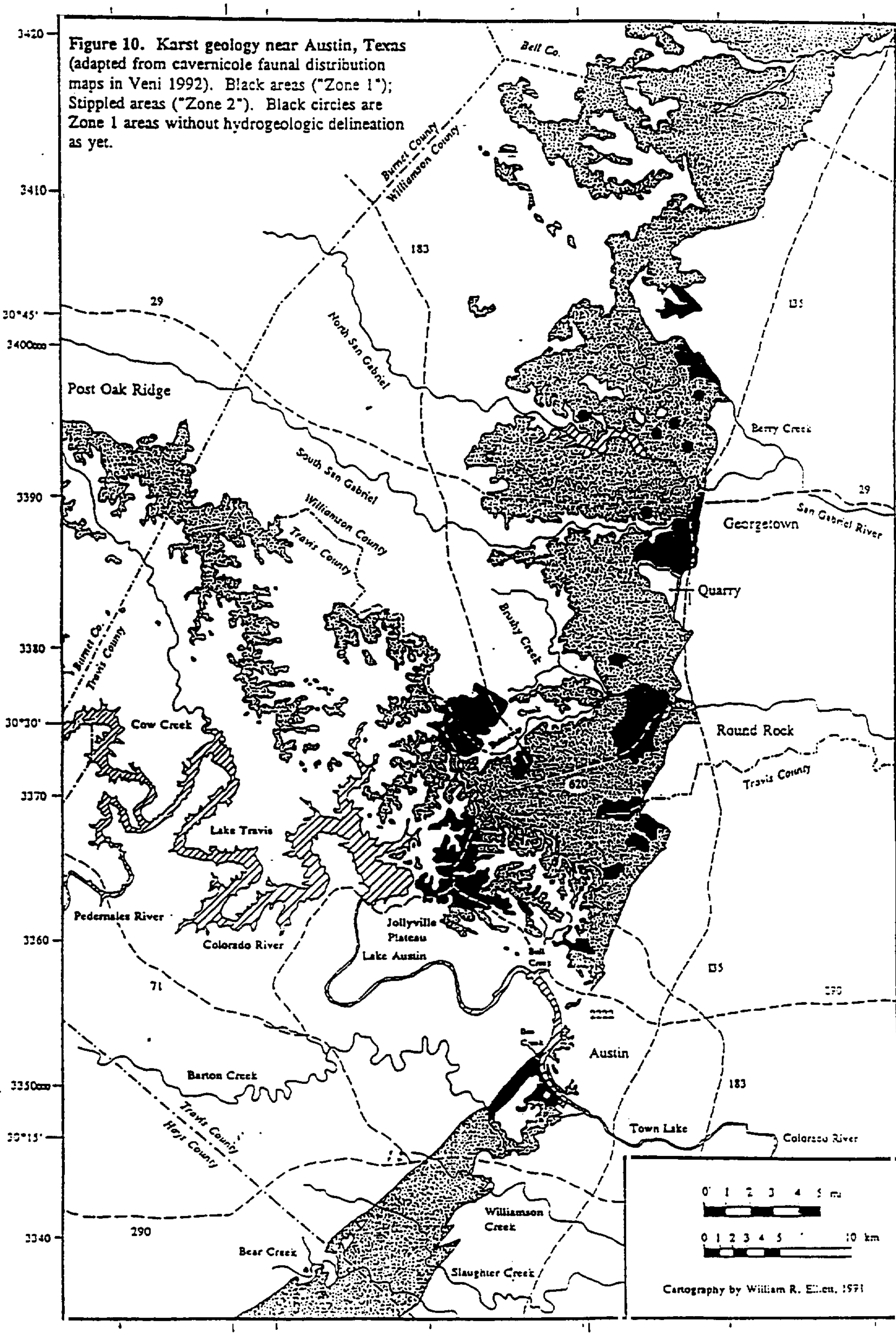


Figure 10. Karst geology near Austin, Texas (adapted from cavernicole faunal distribution maps in Veni 1992). Black areas ("Zone 1"); Stippled areas ("Zone 2"). Black circles are Zone 1 areas without hydrogeologic delineation as yet.

Both Logic® and Amdro® are harmful to arthropods. Use of Amdro or Logic may result in the mortality of the endangered species through consumption of the chemical(s) or contaminated prey which have ingested the bait. Adverse impacts to the species may be avoided through strict control of chemical applications. For example, applying chemical baits away from the cave entrance and outside of areas used by cave crickets may prevent introduction of the active ingredients into the food chain. By applying chemicals in the morning under dry, warm conditions, the ants may consume most or all of the chemicals before cave crickets exit the cave at sundown to forage.

Despite effective initial treatments, some areas may be rapidly re-infested with fire ants from surrounding areas, as happened at Kretschmarr Cave, and could require more than one treatment each year. The level and type of fire ant control necessary for each area will likely be site-specific, depending on adjacent land use and severity of the fire ant infestation.

<u>LakeLine Mall Habitat Conservation Plan (HCP)</u>: On February 13, 1992, the USFWS issued a Section 10(a)(1)(B) permit under the Endangered Species Act to Melvin Simon and Associates, Inc., to allow the "taking" of some *Rhadine persephone* and *Texella reyesi* individuals as a result of the proposed LakeLine Mall development. The Endangered Species Act authorizes the USFWS to permit the taking of federally listed species if such taking is "incidental to, and not the purpose of, the carrying out of an otherwise lawful activity" (16 U.S.C. Section 1539). Two caves (LakeLine and Underline) and one bore-hole (Well Trap #6) were found to contain listed species. Underline Cave contains *T. reyesi*, and Well Trap #6 contains *R. persephone*, while LakeLine Cave contains both species.

Both Underline Cave and Well Trap #6 will be destroyed during mall construction. The initial two to three-acre fenced preserve around LakeLine Cave will be reduced to less than 0.5 acre about two years after completion of the mall, which may result in loss or degradation of the cave ecosystem.

As part of mitigation for the taking as outlined in their Habitat Conservation Plan, Melvin Simon and Associates, Inc., acquired a total of 232 acres of preserve land in three separate areas known to support four caves containing *Rhadine persephone* (Rolling Rock and Testudo Tube caves) and *Texella reyesi* (Red Crevice and Temples of Thor caves). Three of the caves occur in Williamson County. Rolling Rock Cave is in Travis County. Texas Parks and Wildlife Department is the management authority for the LakeLine HCP.

Other mitigation measures in the LakeLine HCP include a 10-year monitoring program of certain environmental conditions (such as temperature, humidity, air movements, and rainfall) and karst fauna (including species, abundance, activity and location within the cave) for LakeLine Cave. This program will include monitoring for 5 years before and 5 years after mall completion, as well as during construction. The purpose is to determine the impacts of mall development on the cave ecosystem and the listed species. Commensurate five-year studies of environmental conditions and karst fauna will be done in Testudo Tube and Temples of Thor Caves to serve as control sites to the LakeLine Cave study. Studies will include food preferences, foraging range, and distribution of cave crickets and daddy longlegs harvestmen at the above three caves and fire ant control at all five sites. A karst ecosystem exhibit for public education will be displayed within the LakeLine Mall development project (Horizon Environmental Services, Inc., 1991b).

Elliott (1991a-f, 1992c-e) initiated the LakeLine Cave studies in May 1991 and began investigations of Testudo Tube and Temples of Thor caves in May 1992. Monthly ecological monitoring visits to these caves provide information on temperature, humidity, air movements, nutrient inputs, fire ants, and the distribution of numerous species in the cave, but may not provide much data on life histories and other aspects of the listed species' biology. The cave cricket/daddy longlegs study is providing data on the foraging behavior and spatial/temporal distributions of these species, which feed above ground at night. The cave cricket study will help determine the surface area around the caves needed to sustain these species. A major goal of this research is to determine whether the karst invertebrate community in LakeLine Cave is significantly affected by development of the shopping mall and to assist in making preserve recommendations for other caves.

In addition to the mitigation outlined above and prior to the development of the HCP, Melvin Simon and Associates, Inc. funded research designed to help determine the extent to which karst fauna occur in the interstitial spaces at the LakeLine Mall site. Six bore-holes were drilled into the bedrock near a cluster of surface karst features. Five-foot sections of 4-inch PVC pipe were installed in each borehole. To prevent surface material from entering the boreholes, approximately 2 feet of pipe protruded above the surface, and the edges around each pipe were sealed with rocks and dirt. Each pipe was then sealed to prevent moisture loss.

Pitfall traps containing a variety of baits, including moldy blue cheese, banana, peanut butter, and yeast were placed inside each borehole to attract karst fauna. This method was successful in trapping *Rhadine persephone* in one borehole. No troglobites were found in the other five. The baits do not attract many species, particularly more sedentary predatory species such as *Neoleptoneta myopica* and the *Texella* species. Baits may attract fire ants, as may the surface disturbance generated during the drilling process.

Regional Habitat Conservation Plan (HCP): The City of Austin is proceeding with development of a regional HCP, although specific preserve boundaries for the karst features have not been determined at this time. Individual applications for 10(a)(1)(b) permits and associated HCP's should contribute to achieving recovery plan goals, particularly in setting aside cave preserves.

Security measures: To control access to caves where unauthorized human visitation and vandalism present a serious threat to the karst ecosystems and possible injury to humans, cave gates have been installed at some cave entrances. Caves where gates have been installed to date include Tooth, Gallifer, Kretschmarr, Kretschmarr Salamander, LakeLine, and Sore-ped caves. Most of these cave gates consist of a locked door fashioned from an open steel grid to prevent unauthorized entry. Cave gates should be designed to permit normal air flow, water infiltration, and nutrient input. Since some cave gates have been known to filter out important nutrient sources, particularly larger animals such as raccoons, they should be closely monitored and rectified should such problems occur.

One alternative to gating that may pose less interference with the nutrient regime and other environmental factors (such as air and water movement) is the installation of a high fence around a cave preserve. Chain-link fences have been installed around Kretschmarr Cave and LakeLine Cave. Since both cave gates and fences are subject to vandalism, they may require frequent surveillance. The effectiveness of gating and fencing and their effects on the karst ecosystems should be closely monitored. Other alternatives to protecting caves from human visitation and vandalism, such as public education and routine site patrols, should also be explored.

Other conservation measures: In late 1988, the USFWS, in conjunction with two groups of developers, sponsored a **hydrogeologic** study of a cave cluster located to the northwest of the RM 2222 and RM 620 intersection to aid in determining measures to protect this cluster, which supports six of the listed species. The project, conducted by Veni & Associates (1988a), provided guidelines for protecting the caves based largely on hydrogeologic factors, but did not involve biological investigations. The study was used by a group of experts assembled by USFWS to prepare guidelines for the protection of the cave cluster. The group's guidelines were used in discussions between USFWS and the developers about protecting the caves and cave fauna.

Local caving organizations have been instrumental in locating and monitoring karst features and maintaining a database of their findings. Several of these organizations have published reports of their findings and made conservation and management recommendations that are useful to the USFWS. Other contributions made by local cavers include the removal of trash from cave openings and the detection of contaminant spills.

The entrances to Tooth Cave and Kretschmarr Cave have been under the stewardship of the Texas System of Natural Laboratories (TSNL) on behalf of the owners since about 1970. This resulted in the discovery of several more caves containing troglobites. A small area (about 0.6 acres) around Tooth Cave and a total of about six acres encompassing Kretschmarr Cave, Kretschmarr Double Pit, Gallifer Cave, Root Cave, and other sinkholes on the Jollyville Plateau were deeded by the owner to the TSNL in 1990. However, the preserves around these caves are not sufficient to counter nutrient depletion and prevent pollution should the surrounding areas be developed. The entire area is now infested with fire ants. Furthermore, some of these caves are under temporary deed to TSNL and may be sold at the owners' discretion.

F. Recovery Strategy

This recovery plan is designed to outline steps for long-term protection of the listed invertebrate species, including restoration and enhancement of the habitat where necessary. The recovery criteria state that each species will be considered for downlisting from endangered to threatened when three karst fauna areas (if at least three exist) within each karst fauna region in each species' range are protected in perpetuity (see Section II.A for a more detailed delineation of the criteria).

The "karst fauna regions" depicted in Figure 2 of this plan are adapted from the karst fauna areas delineated in Veni & Associates' 1992 report (see discussion in Section I.B). These regions are delineated based on geologic continuity, hydrology, and the distribution of 38 rare troglobitic species. Each karst fauna region can be further subdivided into karst fauna areas. For the purposes of this plan, a "karst fauna area" is an area known to support one or more locations of a listed species and is distinct in that it acts as a system that is separated from other karst fauna areas by geologic and hydrologic features and/or processes that create barriers to the movement of water, contaminants, and troglobitic fauna. Karst fauna areas should be far enough apart so that if a catastrophic event (for example, contamination of the water supply, flooding, disease) were to destroy one of the areas and/or the species in it, that event would not likely destroy any other area occupied by that species.

As troglobitic populations become increasingly isolated due to hyrdrogeologic processes, subsequent speciation among the isolated populations may occur. The recovery criteria are designed to allow these natural evolutionary processes to continue for each species. The recovery criteria aim at protecting populations and preserving genetic diversity across each species' range.

Full implementation of the recovery criteria should protect against catastrophic loss of the listed species. Because karst ecosystems can never be recreated once they are destroyed, an adequate number of karst fauna areas per karst fauna region should be protected in perpetuity to ensure the continued survival and conservation of each species. Ideally, at least three karst fauna areas per karst fauna region should be protected to provide a margin of safety against extinction if one or more protected areas are lost due to an unanticipated catastrophic event. This is particularly important for karst species since their habitat can not be recreated. If a given species only occurs in two karst fauna areas, that species would still be considered for downlisting provided both areas were adequately protected. Species whose entire range consists of only one karst fauna area (should one area be destroyed) will not be considered for downlisting. If a species occupies several karst fauna regions (such as *Texella reyesi*), but one or more of those karst fauna regions contains less than three karst fauna areas, then all karst fauna areas within that region must be protected in order to meet the recovery objective.

The first step in recovering these species is to identify the karst fauna areas targeted for recovery. According to the recovery criteria, all localities inhabited by four of the listed species (*Neoleptoneta myopica, Tartarocreagris texana, Texamaurops reddelli*, and *Batrisodes texanus*) should be provided long-term protection prior to consideration for downlisting. Three of the listed species, *Texella reddelli*, *Texella reyesi*, and

Rhadine persephone, occupy karst fauna regions that contain more than three karst fauna areas. Table 3 identifies the karst fauna regions in which each species occurs, the approximate number of karst fauna areas inhabited by each species, and the number of karst fauna areas that should be protected, based on the recovery criteria for downlisting and current knowledge of the species' distributions (figures 3-9). Continuing surveys for caves and karst invertebrates may result in an increase in the number of karst fauna areas occupied by some species.

In selecting karst fauna areas to be targeted for recovery, priority should be given to those areas that exhibit high species diversity and contain other rare or listed species. This ecosystem-based approach to choosing karst fauna areas for preservation should consider both the listed species and other endemic species and may prevent the need for listing additional species in the future. Numerous rare species inhabit the same karst terrains in Travis and Williamson counties. For example, Travis County contains at least 32 rare karst species, 25 of which are not federally-listed and some of which are undescribed (Elliott 1992a). Many of those rare species were taxonomically described in 1992 and some may become candidates for the endangered species list, especially those found in urbanizing areas. Therefore, judicious selection of karst areas for preservation will aid in the recovery of the listed species, help protect other important elements of the karst ecosystem in Travis and Williamson counties, and possibly prevent the need to list other species in the future.

Table 3. Approximate number of karst fauna areas to be protected for each species to be considered for downlisting. Information is based on currently available information on species' distributions (tables 1 and 2, figures 3-9) and recovery criteria for downlisting.

SPECIES	KARST FAUNA REGION	APPROX. # OF KARST FAUNA AREAS OCCUPIED	# OF AREAS TO PROTECT
Neoleptoneta myopica	Jollyville Plateau	3	ALL
Tartarocreagris texana	Jollyville Plateau	2	ALL
Texella reddelli	Jollyville Plateau	3	ALL
	Rollingwood	>3	AT LEAST 3
Texella reyesi	Jollyville Plateau	>3	AT LEAST 3
	Cedar Park	1	ALL
	Central Austin	1	ALL
	McNeil/Round Rock	>3	AT LEAST 3
	Georgetown	>3	AT LEAST 3
	N. Williamson Co.	>3	AT LEAST 3
Rhadine persephone	Jollyville Plateau	>3	AT LEAST 3
	Cedar Park	>3	AT LEAST 3
Texamaurops reddelli	Jollyville Plateau	2	ALL
Batrisodes texanus	N. Williamson Co.	2	ALL
	Georgetown	2	ALL

Within each karst fauna region, karst fauna areas that are targeted for recovery should be located as far apart as possible, to protect against catastrophic loss and to preserve genetic diversity within each species. Other factors to consider when selecting karst fauna areas include ability to ensure long-term protection, current level of habitat disturbance, past and present land use, presence of other rare or candidate species, ease of protection (landowner cooperation), and, where applicable, importance to the regional groundwater system.

Where the listed species' ranges overlap, particularly on the Jollyville Plateau, more than one of the species may occur in a given karst fauna area. For example, six of the seven species occur in the Jollyville Plateau karst fauna region, and three of the species' entire ranges are in the vicinity of the RM 2222/RM 620 intersection.

Two areas within the Jollyville Plateau karst fauna region that are already known to be very important to the survival and recovery of several of the listed species represent two distinct karst fauna areas and should be targeted for protection. One of these areas, the Tooth Cave karst fauna area, harbors six of the seven listed species and one of the most diverse cave biotas in the southwestern United States. The other area, the Stovepipe Cave karst fauna area, contains five of the listed species. Preservation of these two karst fauna areas would protect 100% of the range of two of the listed invertebrates (*Texamaurops reddelli* and *Tartarocreagris texana*) and 67% of the range of *Neoleptoneta myopica*. A suggested karst fauna area for the Stovepipe Cave cluster is presented in Figure 11.

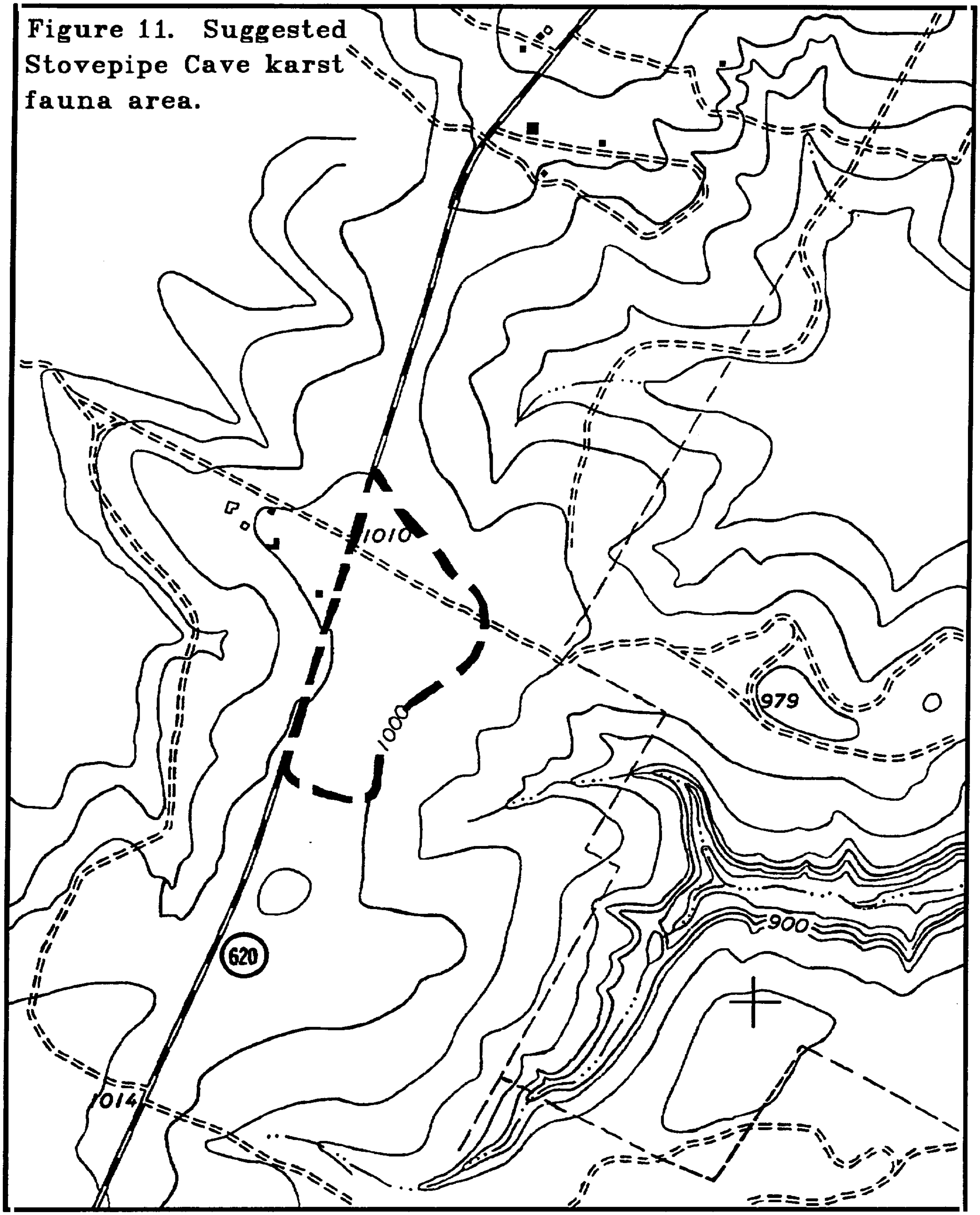


Figure 11. Suggested Stovepipe Cave karst fauna area.

The second major step in recovery is to determine the appropriate size and configuration of each of the karst fauna areas targeted for recovery. To be considered "protected", a karst fauna area should contain a large enough expanse of contiguous karst and surface area to maintain the integrity of the karst ecosystem on which each species depends. The size and configuration of each karst fauna area should be adequate to maintain moist, humid conditions, air flow, and stable temperatures in the air-filled voids; maintain an adequate nutrient supply; prevent contamination of surface and groundwater entering the ecosystem; prevent or control the invasion of exotic species, such as fire ants; and allow for movement of the karst fauna and nutrients through the interstitium between karst features.

Several factors should be considered in determining the size and configuration of karst fauna areas, including the pattern and direction of groundwater movement, direction and area of surface and subsurface drainage, preservation of the surface community above and surrounding the cave, and the presence of other caves or karst features. In general, land bounded by the contour interval at the cave floor is the area within which contaminants moving over the surface or through the karst could move toward the cave. Outside this contour, contaminants would move away from the cave. A hydrogeologic investigation may be useful in determining the surface and subsurface drainage basin of the karst ecosystem, local recharge areas, and direction of groundwater movement. This information would be used to determine the area necessary to protect the karst fauna area's water supply. The amount of surface area necessary to maintain the ecological processes of the karst ecosystem should also be considered and may be larger than the surface drainage area of the cave. Other nearby karst features, which may affect the moisture, air flow, temperature, and nutrient regimes and allow movement of karst fauna through the interstitium, should be included in each karst fauna area. Major sources of nutrient input and areas necessary to sustain these sources should be considered. Recent research as part of the LakeLine Mall HCP may provide some information on the importance of the surface area surrounding karst features in providing nutrients to the cave ecosystem. Wherever possible, karst fauna areas should connect to larger undeveloped lands that are not slated for future development, in order to ensure adequate nutrient flow into the karst ecosystem and to help combat the fire ant threat.

Setting aside large preserves may help to control fire ants. Porter et al. (1991) state that control of fire ants in large areas (>5 hectares) (12 acres) may be more effective than in smaller areas since multiple queen fire ant colonies reproduce primarily by "budding" (whereby queens and workers branch off from the main colony and form new sister colonies). Budding is a relatively slow process, and fire ants may not as quickly reinvade areas where they have been eliminated with this method. Native ant communities may also require large, undisturbed areas to help them combat the fire ant threat.

Research in some areas, including the fire ant's native range, indicates that fire ants are associated with open habitats disturbed as a result of human activity (such as old fields, lawns, roadsides, ponds, and other open, sunny habitats) but are absent or rare in late succession or climax communities such as mature forest (Tschinkel 1986). Although this association is not apparent in all areas, especially in central Texas (Porter et al. 1988, 1991), maintaining native vegetation communities may help sustain native ant populations and further deter fire ant infestations. Chemical control methods have some effectiveness in controlling fire ants, but the effect of these agents on non-target species (including the listed invertebrates) is unclear and, if used indiscriminately, may also eliminate native ant populations. Ideally, intensive fire ant control should be implemented along disturbed areas on the periphery of large preserves. This type of fire ant control, combined with safer but more labor intensive methods (such as hot water applied mound-by-mound) in the vicinity of cave entrances, should help sustain the native ant fauna and reduce the need to implement intensive control within the preserve.

Due to the multiplicity of factors to consider when determining the size and configuration of the karst fauna areas, the design of each karst fauna area will be site-specific. Although many factors (such as the species' ecological requirements, distribution in the interstitium, and the amount of surface area necessary to sustain nutrient flow) are unknown, the amount of time and financial expense to acquire this knowledge would preclude achieving the recovery objective if karst fauna area protection were delayed pending additional research in these areas. To compensate for this lack of knowledge, delineation of the karst fauna areas should be based on protecting the integrity of the karst terrain supporting the listed species and a conservative interpretation of the available biological and hydrogeological information.

Another step needed to accomplish recovery is to provide long-term protection for the targeted karst fauna areas. Methods could include land acquisition, conservation easements, and cooperative agreements with private landowners and public entities.

Implementation of appropriate conservation and management measures for each targeted karst fauna area is also needed for recovery. This may include control of fire ants and other threats; management of surface plant and animal communities; maintaining surface and groundwater quality and quantity; preventing vandalism, dumping, and unauthorized human visitation; and other actions deemed necessary. Additional studies will be necessary to monitor the effects of each management program, refine management techniques as appropriate, and determine any other steps necessary to fully recover the species.

Regardless of whether a listed species occurs in a karst ecosystem that is in or outside of a karst fauna area targeted for protection, the listed species are still protected under the Endangered Species Act (Act) unless authorization for incidental "take" has been obtained under Section 7 or Section 10 of the Act.

II. RECOVERY

A. OBJECTIVE AND CRITERIA

Objective: The prospects for complete recovery and delisting of these species are uncertain. Therefore, the objective of this recovery plan is downlisting of these invertebrate species to threatened status. Criteria for downlisting are given below.

Criteria: Each species will be considered for reclassification from endangered to threatened when:

(1) Three karst fauna areas (if at least three exist) within each karst fauna region in each species' range are protected in perpetuity. If fewer than three karst fauna areas exist within a given karst fauna region, then all karst fauna areas within that region should be protected. If the *entire range* of a given species contains less than three karst fauna areas, then all karst fauna areas where that species occurs should be protected and at least two karst fauna areas should exist and be protected for that species to be considered for downlisting.

There are seven karst fauna regions (adapted from the karst fauna areas in Figure 19 of Veni & Associates' 1992 report and reproduced in Figure 2 of this recovery plan) in Travis and Williamson counties that are known to contain listed species. These regions are delineated based on geologic continuity, hydrology, and the distribution of rare troglobites (see further discussion in Section I.B).

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

To be considered "protected", a karst fauna area must be sufficiently large to maintain the integrity of the karst ecosystem on which the species depend(s). In addition, these areas must also provide protection from threats such as fire ants, habitat destruction, and contaminants.

According to this criteria, all localities inhabited by four of the listed species (*Tartarocreagris texana*, *Texamaurops reddelli*, *Neoleptoneta myopica*, and *Batrisodes texanus*) should be provided long-term protection (refer to figures 3-9 and Table 3 in this plan). For those karst fauna regions inhabited by *Texella reyesi*, *Texella reddelli*, and *Rhadine persephone* that contain more than three karst fauna areas, identification of the karst fauna areas targeted for protection is included as a recovery task in this plan.

(2) Criteria (1) has been maintained for at least five consecutive years with assurances that these areas will remain protected in perpetuity.

This recovery plan is intended to outline steps necessary for the continued existence of these species and the karst ecosystems on which they depend. In some cases this will require continued human intervention to combat the fire ant threat. Without this intervention, the ability of the species to be self-sustaining within these karst ecosystems is uncertain.

These reclassification criteria are preliminary and may be revised based on new information (including research specified as recovery tasks in this plan). The estimated date for attaining the objective of this plan (downlisting to threatened) for all species is the year 2014, assuming full implementation of this plan. Since the time required to downlist each species may vary, each species may be downlisted separately. The feasibility of total recovery and delisting will be examined as part of this plan. The plan will be reviewed regularly and revised as necessary to incorporate new objectives and criteria as data become available.

B. RECOVERY OUTLINE

The following is an outline of the recovery tasks needed to attain the objective of this plan. Section C includes more detailed information on the tasks.

1. Identify karst fauna areas needed to meet recovery criteria

2. Determine appropriate size and configuration of karst fauna areas targeted for recovery

3. Provide long-term protection for karst fauna areas targeted for recovery

    3.1 Working cooperatively with private landowners
    3.2 Land acquisition, lease, and conservation easements
    3.3 Working with other agencies and organizations
    3.4 Regulatory

4. Implement conservation measures and manage karst fauna areas targeted for recovery

    4.1 Determine and implement appropriate methods to eliminate or manage fire ant threat

        4.11 Short-term fire ant control
        4.12 Long-term fire ant control

    4.2 Identify important sources of nutrient input into karst ecosystems and steps necessary to sustain nutrient flow

4.3 Determine and implement appropriate methods to prevent vandalism, dumping, and unauthorized human entry

4.4 Other actions deemed necessary

5. Additional research and information needs

5.1 Distribution information

5.11 Develop standards for conducting biospeleological surveys
5.12 Conduct additional karst and biospeleological surveys
5.13 Develop and maintain a central database of survey results

5.2 Hydrogeologic studies of karst fauna areas targeted for recovery

5.3 Additional studies on each species' ecology

6. Education

6.1 Develop educational programs on karst ecology to raise awareness of the general public and encourage protection of karst ecosystems
6.2 Develop educational programs for private landowners to encourage and demonstrate protection of karst fauna areas targeted for recovery
6.3 Develop educational programs on karst ecology and **hydrogeology** to help preserve managers, consultants, and other

professionals identify and protect karst ecosystems

7. Monitoring

    7.1 Develop monitoring program
    7.2 Monitor listed species and other karst fauna within karst fauna areas targeted for recovery
    7.3 Monitor threats in karst fauna areas targeted for recovery

C. NARRATIVE OUTLINE FOR RECOVERY ACTIONS

1. Identify karst fauna areas needed to meet recovery criteria. Priority should be given to those areas that exhibit high species diversity and presence of other rare or listed species. Other factors to consider when selecting karst fauna areas include ease of protection, past and present land use, current level of habitat disturbance, ability to ensure long-term protection, presence of other rare or candidate species, and, where applicable, importance to the regional groundwater system. Prior to targeting a karst fauna area for recovery, the species' presence should be verified (e.g., through taxonomic confirmation and/or recent surveys), which is part of Task 5.12.

   Two areas within the Jollyville Plateau karst fauna region that are already known to be very important to the survival and recovery of several of the listed species, represent two distinct karst fauna areas and should be targeted for protection. These areas are the Tooth Cave and Stovepipe Cave areas. A suggested karst fauna area boundary for the Stovepipe cave area is presented in Figure 11. Preservation of the Tooth Cave and Stovepipe Cave karst fauna areas would protect 100% of the range of *Texamaurops reddelli* and *Tartarocreagris texana* and about 67% of *Neoleptoneta myopica*'s range. Suitable habitat for two endangered songbirds, the golden-cheeked warbler (*Dendroica chrysoparia*) and black-capped vireo (*Vireo atricapillus*), also occurs in these areas.

2. Determine appropriate size and configuration of karst fauna areas targeted for recovery. The size and configuration of each karst fauna area should be adequate to protect the karst ecosystem's moisture, temperature, and nutrient regime; prevent contamination of the water entering the ecosystem; prevent or control the invasion of exotic species, such as fire ants; and allow for movement of the karst fauna and nutrients through the interstitium between karst features. The exact area necessary to allow for each of these factors is unknown and will be site-specific for each karst fauna area. Delineation of the karst fauna areas must be made on the best available information and be conservative to ensure the long-term survival of the species (see Section I.F for discussion on determining the size and configuration of karst fauna areas).

3. Provide long-term protection for karst fauna areas targeted for recovery

   3.1 Working cooperatively with private landowners. Many landowners have expressed interest and pride in their caves and should be encouraged and recognized for their efforts. Guidance and assistance (Task 6) on how to protect and manage karst ecosystems should be conveyed to landowners through various Federal and State programs and extension services such as those of the USFWS and TPWD. Since most caves and surrounding karst occur on private land, this task should be a major part of recovery.

3.2 Land acquisition, lease, and conservation easements. Land acquisition, lease, and conservation easements will likely be necessary to protect some karst fauna areas targeted for recovery. USFWS policy stipulates the agency will only acquire land from willing sellers.

3.3 Working with other agencies and organizations. A few caves containing listed species occur on public lands. The USFWS should work cooperatively with these various agencies and organizations to aid in the conservation and recovery of the listed species.

3.4 Regulatory. Section 9 of the Endangered Species Act prohibits the "take" of endangered animals without a permit. Enforcement of these provisions involves such things as USFWS law enforcement, Section 7 consultations with other Federal agencies, and issuance of Section 10 permits.

4. Implement conservation measures and manage karst fauna areas targeted for recovery. The following tasks should be monitored (Task 7) to determine their success in protecting populations of the listed species in the karst fauna areas targeted for recovery. Depending on the monitoring results, existing management techniques should be

revised as appropriate.

4.1 Determine and implement appropriate methods to eliminate or manage fire ant threat. Control of fire ant infestations will be necessary in the karst fauna areas where fire ants pose a threat. The intensity of fire ant infestations in each karst fauna area should be evaluated to determine the appropriate type and level of treatment, where warranted. Current research regarding fire ant biology and control methods should be reviewed and implemented as appropriate. Control efforts should be evaluated to determine their effectiveness and their direct impact on the listed species, if any.

4.11 Short-term fire ant control. Ideally, intensive short-term methods of fire ant control should be selectively employed along disturbed areas on the periphery of a large karst fauna area to reduce the need to implement intensive control near karst features inhabited by listed species. Caution should be taken to avoid treating non-target ant species. Any control method used indiscriminately may also eliminate native ant populations that help deter fire ant infestations.

Currently, the USFWS recommends hot water treatments as the most effective method of short-term fire ant control posing the least threat to karst ecosystems. However, this method is not always feasible, particularly in remote areas. The impacts of different types of low-toxicity chemical treatments on karst fauna will need to be evaluated. Strict controls on any chemicals applied to areas harboring the listed species will also need to be developed. Hot water pressure washers may also significantly reduce labor intensity required for hot water treatments and should be tested. Short-term control methods will probably need to be employed at least 1-2 times a year indefinitely for many areas.

4.12 Long-term fire ant control. While the short-term methods used in Task 4.11 may effectively reduce fire ant infestations temporarily, none of the methods currently employed provide long-term control. Long-term control may include biological and land management practices that do not require continued treatments, such as reestablishing native ant populations, preventing or minimizing soil and plant disturbance, and restoring or enhancing surface plant and animal communities. Setting aside large preserve areas (consistent with Task 2) to help combat the fire ant threat is recommended. See Section I.F for further discussion regarding long-term methods of fire ant control.

4.2 <u>Identify important sources of nutrient input into karst ecosystems and steps necessary to sustain nutrient flow</u>. While karst ecosystems are almost entirely dependent upon surface plant and animal communities for nutrient supplies, little is known about which nutrient sources are critical to the health of the ecosystem and what ecological requirements are necessary to sustain these sources. Nutrient sources are likely to be site-specific and may include plants, animals, decaying organic matter, fungi, and bacteria. An attempt should be made to determine what the primary nutrient sources are for each karst fauna area and what steps are necessary to sustain nutrient flow. For example, ongoing cave ecology studies at LakeLine Cave are providing some data on the foraging area required by cave crickets.

Types of management actions to sustain nutrient flow into a karst ecosystem may include providing a preserve area that is large enough to allow for plant and animal communities providing nutrient input to carry out all of their required activities (Task 2); protecting and, where necessary, restoring the water quality and quantity within a karst drainage basin; control or reintroduction of certain plant and animal species; protecting other karst features that may affect nutrient flow (Task 2); preventing vandalism, dumping, and unauthorized human entry (Task 4.3); and other measures necessary to maintain adequate infiltration of nutrients and prevent soil erosion and loss of productivity around caves. In managing surface communities, ecological requirements of other listed species that occur in the same area, such as the black-capped vireo and golden-cheeked warbler, should also be considered.

4.3 Determine and implement appropriate methods to prevent vandalism, dumping, and unauthorized human entry. Where human visitation and vandalism present a serious threat, cave gates and fences may be installed to protect the karst community. Cave gates and fences should be "transparent" in design so as not to alter or impede normal air flow or nutrient and moisture regimes. Soil disturbance should also be prevented to avoid introducing or increasing fire ant infestations. The impacts of cave gates and fences on the nutrient and moisture regimes of karst ecosystems need to be evaluated and rectified if they pose a threat. Cave gate and fencing designs that avoid disrupting the karst ecosystem should be explored. To avoid harm to the species, the Service recommends that cave gate and fence designs be submitted to the Service for approval prior to their installation on caves known to contain listed species.

Other means of protection, such as warning signs and public education, should be explored as possible alternatives to cave gating and fencing. Karst fauna areas should also be routinely patrolled in areas where human visitation poses a threat to help deter unauthorized visitations.

4.4 Other actions deemed necessary. Localized threats that pose serious impacts to a given karst community will need to be addressed on a case-by-case basis. Several karst fauna areas may lie adjacent to developed sites or other areas that have already posed some threat to the karst ecosystem, such as altering the natural drainage pattern, disrupting the native surface plant and/or animal communities, or introducing contaminants. The effects of these activities on the karst ecosystem(s) within the karst fauna area and possible remedies should be evaluated and implemented as appropriate.

5. Additional research and information needs

5.1 Distribution information.

Additional karst and biospeleological surveys are necessary to clearly establish the ranges of the listed species and to assist in completing Task 1 (Identify karst fauna areas needed to meet recovery criteria).

5.11 <u>Develop standards for conducting biospeleological surveys.</u> Standards for conducting these surveys will help ensure the quality and consistency of the work performed. Standards should include recording biotic and abiotic information that may be correlated to the presence or absence of listed species as well as indicate which caves provide suitable habitat for the listed species and other troglobitic fauna. This task should also include reporting requirements to be used in Task 5.13.

5.12 <u>Conduct additional karst and biospeleological surveys.</u> Standards developed in Task 5.11 should be followed. The primary purpose of this task is to locate additional karst fauna areas for those species that are currently believed to inhabit less than 3 areas in a given karst fauna region (refer to Figures 3-9 and Table 3). Ideally, as many locations inhabited by the listed species should be found and inventoried to determine which areas are most important for recovery.

Secondary purposes of this task are to confirm the identification of listed species in certain caves, survey for listed species in caves that have not been adequately surveyed or have not been surveyed in recent years, and determine whether listed species are present in caves that have not yet been surveyed. An attempt should be made to verify whether certain caves (such as Coffin Cave) still exist.

Due to limited resources currently available to detect karst features, many areas that may contain one or more of the listed species have not been adequately surveyed. Some karst fauna regions and portions thereof that have not been adequately surveyed include parts of South Travis County, a large area between Round Rock and Georgetown, and the northwest portions of North Williamson County and Cedar Park. Ongoing surveys in other regions may yield additional localities of one or more of the listed species. This may increase the number of karst fauna areas for some species from two to three or more in a given karst fauna region, and/or increase the number of karst fauna areas to select from when targeting areas for recovery.

5.13 Develop and maintain a central database of survey results. All karst survey results (including Task 5.11 reporting requirements, sightings and collections of endangered species and other karst fauna, and negative findings) should be reported for inclusion in a central database. The central database should compile and routinely update information on species' distributions and other relevant information that would assist in project reviews and recovery and regulatory activities.

5.2 Hydrogeologic studies of karst fauna areas targeted for recovery. A hydrogeologic investigation may be useful to determine the surface and subsurface drainage basin of caves and surrounding karst as well as the general direction of groundwater flow. The discovery of listed species in areas proposed for development has led to a number of hydrogeologic investigations of caves in the Austin area. Other factors, including the amount of surface area needed to maintain the nutrient, moisture, and temperature regimes of the karst ecosystem and to curtail or eliminate threats should be considered when delineating karst fauna areas as well. The results of these studies should be used to help determine the area needed to protect the water entering the karst ecosystem. Other factors discussed in Task 2 and in Section I.F will also need to be considered in determining the size and configuration of the karst fauna areas.

5.3 Additional studies on each species' ecology. Very little is known about the listed species' ecological requirements, including life history, habitat requirements, reproductive and foraging behavior, inter- and intraspecific relationships, and distribution in interstitial spaces. This information would be useful in determining what aspects of the karst ecosystem (in addition to nutrient input, high humidities, and stable temperatures) are critical to the survival of the listed species, and what measures are necessary to maintain the health of the ecosystem. Because this task would take many years to implement and complete, it will be used to assist in managing karst fauna areas targeted for recovery (Task 4) rather than determining their size and configuration (Task 2). The results of these ecological studies may also help identify the food base required by the listed species and other karst fauna and thus assist in determining important sources of nutrient inputs into the karst ecosystem (Task 4.2).

6. Education.

6.1 Develop educational programs on karst ecology to raise awareness of general public and encourage protection of karst ecosystems. This task may be accomplished through workshops and programs, brochures, videos, and other forms of public outreach. The material should be developed for all age levels and include information on karst hydrogeology and ecology, the biology of the listed species, and the importance of preserving karst ecosystems. Field projects designed to educate as well as help restore and enhance karst ecosystems should also be considered.

6.2 Develop educational programs for private landowners to encourage and demonstrate protection of karst fauna areas targeted for recovery. Establish demonstration areas where landowners can observe recovery efforts. Demonstration areas may be on private or public land. Management guidelines should also be developed for use by private landowners. These guidelines may be in the form of brochures, workshops, and/or other forms of public outreach. This task will be useful in accomplishing Task 3.1.

6.3 Develop educational programs on karst ecology and hydrogeology to help preserve managers, consultants, and other professionals identify and protect karst ecosystems. The purpose of this task is to provide training to promote professional expertise in identifying and studying karst ecosystems and hydrogeology. This task may be accomplished through integrating educational programs on karst ecology and hydrogeology into existing curricula at a local college or university, or other institution; through short courses; and/or through workshops and on-site demonstrations. The American Cave Conservation Association, a non-profit organization, organizes short courses on cave management training in various locations throughout the country. Courses include basic training in karst geology, hydrology, ecology, and management techniques, with an emphasis on local concerns and considerations. This organization and its program may be of assistance in accomplishing this task.

7. Monitoring. Monitoring should occur in all karst fauna areas targeted for protection to determine the success of conservation and/or management measures that are implemented (Task 4) and to guard against irreversible declines in the species' status.

7.1 Develop monitoring program. A program for monitoring both karst fauna and threats should be established using standards developed in Task 5.11. Criteria should be developed for gauging the ecological health of a karst ecosystem. For example, the presence of certain species associations under certain environmental conditions (such as temperature, moisture, and nutrients) could indicate the condition of an ecosystem. Methods should be designed to allow comparison of results from various data collection efforts and to reduce biases.

7.2 Monitor listed species and other karst fauna within karst fauna areas targeted for recovery. Conduct periodic surveys for the listed species and other karst fauna on which the species may depend (such as cave crickets and daddy longlegs), using techniques developed in Task 7.1. Surveys should be conducted in such a manner as to avoid disrupting the karst ecosystem.

7.3 Monitor threats in karst fauna areas targeted for recovery. The degree of fire ant infestations should be monitored to determine the level of threat and the benefit of control efforts. Effects of different types of fire ant control methods on the listed species and other karst fauna on which the listed species may depend (such as cave crickets and daddy longlegs) should also continue to be monitored. Routine inspections should be conducted to ensure adequate surface and groundwater quality and quantity and nutrient infiltration into the karst ecosystems. All gates and fences that are installed should be monitored and modified, if necessary, to ensure that nutrient input, moisture regime, and air flow remain unaltered. Other threats that may be impacting the karst ecosystem and the effects of management techniques employed to control or eliminate these threats should also be monitored.

D. REFERENCES CITED

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

Barr, T.C., Jr. 1974a. Revision of *Rhadine* LeConte (Coleoptera, Carabidae). I. The subterranean group. Amer. Mus. Novitates, No. 2539. 30 pp.

Barr, T.C., Jr. 1974b. The eyeless beetles of the genus *Arianops* Brendel (Coleoptera, Pselaphidae). Bull. Amer. Mus. Nat. Hist., 154: 1-52.

Barr, T.C., Jr. and H.R. Steeves, Jr. 1963. *Texamaurops*, a new genus of pselaphids from caves in Central Texas (Coleoptera: Pselaphidae). Coleopterist's Bull., 17: 117-120.

Biological Advisory Team (BAT) 1990. Comprehensive report of the Biological Advisory Team. Austin, Texas. 80 pp.

Brignoli, P.M. 1972. Some cavernicolous spiders from Mexico (Araneae). Accad. Naz. Lincei, Probl. Att. Sci. Cult., 171(1): 129-155.

Brignoli, P.M. 1977. Spiders from Mexico. III. A new leptonetid from Oaxaca (Araneae, Leptonetidae). Accad. Naz. Lincei, Probl. Att. Sci. Cult., 171(3): 213-218.

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

Chandler, D.S. 1992. The Pselaphidae of Texas caves (Coleoptera). Speleol. Monogr., 3. Texas Mem. Mus., Univ. Texas at Austin.

Christiansen, K., and D. Culver. 1969. Geographical variation and evolution in *Pseudosinella violenta* (Folsum). Evolution, 23(4): 602-621.

Curcic, B.P.M. 1984. A revision of some North American species of *Microcreagris* Balzan, 1982. (Arachnida: Pseudoscorpiones: Neobisiidae). Bull. British Arachnol. Soc. 6: 149-166.

Curcic, B.P.M. 1989. Further revision of some North American false scorpions originally assigned to *Microcreagris* Balzan (Pseudoscorpiones, Neobisiidae). J. Arachnol. 17: 351-362.

Elliott, W.R. 1976. Morphometrics and evolution of *Speodesmus* in Central Texas caves (Diplopoda, Polydesmida). Ph.D. dissertation, Texas Tech Univ. 155 pp.

Elliott, W.R. 1978a. The cave fauna of Texas. Pp. 59-63 *in* Fieseler, R.G., J. Jasek, and M. Jasek (eds.), An introduction to the caves of Texas. Natl. Speleol. Soc. Convention Guidebook, 19 pp.

Elliott, W.R. 1978b. The New Melones cave harvestman transplant. Report to U.S. Army Corps of Engineers, Sacramento, California. 62 pp.

Elliott, W.R. 1991a. Preliminary ecological monitoring at LakeLine Cave, 9 May, 1991. Report to Melvin Simon & Associates, Indianapolis. 4 pp.

Elliott, W.R. 1991b. Ecological monitoring at LakeLine Cave, 21 June, 1991. Report to Melvin Simon & Associates, Indianapolis. 5 pp.

Elliott, W.R. 1991c. Ecological monitoring at LakeLine Cave,
6 August, 1991. Report to Melvin Simon & Associates, Indianapolis. 9 pp.

Elliott, W.R. 1991d. Ecological monitoring at LakeLine Cave, 24 September, 1991. Report to Melvin Simon & Associates, Indianapolis. 6 pp.

Elliott, W.R. 1991e. Ecological monitoring at LakeLine Cave and Testudo Tube, 24 September, 1991. Report to Melvin Simon & Associates, Indianapolis. 6 pp.

Elliott, W.R. 1991f. Ecological monitoring at LakeLine Cave, 30 October & 29 November, 1991. Report to Melvin Simon & Associates, Indianapolis. 7 pp.

Elliott, W.R. 1992a. Fire ants and endangered cave invertebrates: A control and ecological study. Draft report to Texas Parks and Wildlife Dept. 30 pp.

Elliott, W.R. 1992b. Ecological studies of three caves in Williamson County, Texas: June, 1992. Report to Melvin Simon & Associates, U.S. Fish and Wildlife Service, and Texas Parks and Wildlife Department. 2 pp.

Elliott, W.R. 1992c. Ecological studies of three caves in Williamson County, Texas: July, 1992. Report to Melvin Simon & Associates, U.S. Fish and Wildlife Service, and Texas Parks and Wildlife Department. 3 pp.

Elliott, W.R. 1992d. Ecological studies of three caves in Williamson County, Texas: August, 1992. Report to Melvin Simon & Associates, U.S. Fish and Wildlife Service, and Texas Parks and Wildlife Department. 5 pp.

Elliott, W.R. 1992e. Ecological studies of three caves in Williamson County, Texas: September, 1992. Report to Melvin Simon & Associates, U.S. Fish and Wildlife Service, and Texas Parks and Wildlife Department. 3 pp.

Elliott, W.R. *In press*. Cave fauna conservation in Texas. Proc. Natl. Cave Mgm. Symp., Bowling Green, Kentucky. Amer. Cave Consv. Assoc.

Elliott, W.R., and R.W. Mitchell. 1973. Temperature preference responses of some aquatic, cave-adapted crustaceans from Central Texas and Northeastern Mexico. Intl. J. Speleol., 5: 171-189.

Elliott, W.R., and J.R. Reddell. 1989. The status and range of five endangered arthropods from caves in the Austin, Texas, region. A report on a study supported by the Texas Parks and Wildlife Department and the Texas Nature Conservancy for the Austin Regional Habitat Conservation Plan. 100 pp.

Gertsch, W.J. 1974. The spider family Leptonetidae in North America. J. Arachnol., 1: 145-203.

Goodnight, C.J., and M.L. Goodnight. 1942. New Phalangodidae (Phalangida) from the United States. Amer. Mus. Novitates, 1188: 1-18.

Goodnight, C.J., and M.L. Goodnight. 1967. Opilionida from Texas caves (Opiliones, Phalangodidae). Amer. Mus. Novitates, No. 2301. 8 pp.

Holsinger, J.R. 1967. Systematics, speciation, and distribution of the subterranean amphipod genus Stygonectes (Gammaridae). Bull. U.S. Natl. Mus., 259. 176 pp.

Horizon Environmental Services, Inc. 1991a. Karst invertebrate survey of the LakeLine Mall site, Williamson County, Texas. Prepared for Melvin Simon & Associates, Inc.

Horizon Environmental Services, Inc. 1991b. Habitat Conservation Plan for LakeLine Mall, Williamson County, Texas. Submitted to the U.S. Fish and Wildlife Service.

Howarth, F.G. 1983. Ecology of cave arthropods. Ann. Rev. Entomol., 28: 365-389.

Maguire, B., Jr. 1960. Monodella texana n.sp., an extension of the crustacean order Thermosbaenacea to the Western Hemisphere. Crustaceana, 9: 149-154.

May, R.M. 1992. How many species inhabit the Earth? Sci. American, 267: 42-48.

Mitchell, R.W. 1968a. Distribution and dispersion of the troglobitic carabid beetle Rhadine subterranea. Intl. J. Speleol., 3: 271-288.

Mitchell, R.W. 1968b. Food and feeding habits of the troglobitic carabid beetle Rhadine subterranea. Intl. J. Speleol., 3: 249-270.

Mitchell, R.W. 1968c. Preference responses and tolerances of the troglobitic carabid beetle, Rhadine subterranea. Intl. J. Speleol., 3: 289-304.

Mitchell, R.W., and J.R. Reddell. 1971. The invertebrate fauna of Texas caves. Pages 35-40 *in* E.L. Lundelius, Jr., and B.H. Slaughter, (eds.) Natural History of Texas Caves. Gulf Natural History Publishing. Dallas, Texas.

Muchmore, W.B. 1969. New species and records of cavernicolous pseudoscorpions of the genus *Microcreagris* (Arachnida, Chelonethida, Neobisiidae, Ideobisiinae). Amer. Mus. Novitates, No. 2932. 21 pp.

Muchmore, W.B. 1992. Cavernicolous pseudoscorpions from Texas and New Mexico (Arachnida: Pseudoscorpionida). Speleol. Monogr., 3. Texas Mem. Mus., Univ. Texas at Austin.

Park, O. 1960. Cavernicolous pselaphid beetles of the United States. Amer. Midl. Nat., 64(1): 66-104.

Platnick, N.I. 1986. On the tibial and patellar glands, relationships, and American genera of the spider family Leptonetidae (Arachnida, Araneae). Amer. Mus. Novit., 2855. 16 pp.

Porter, S.D., B. Van Eimeren, and L.E. Gilbert. 1988. Invasion of red imported fire ants (Hymenoptera: Formicidae): Microgeography of competitive replacement. Ann. Ent. Soc of America 81(6): 913-918.

Porter, S.D., A. Bhatkar, R. Mulder, S.B. Vinson, and D.J. Clair. 1991. Distribution and density of polygyne fire ants (Hymenoptera: Formicidae) in Texas. J. Econom. Entomol. (84)3: 866-874.

Porter, S.D. and D.A. Savignano. 1990. Invasion of polygyne fire ants decimates native ants and disrupts arthropod community. Ecology 71(6): 2095-2106.

Reddell, J.R. 1965. A checklist of the cave fauna of Texas. I. The invertebrata (exclusive of Insecta). Texas J. Sci., 17: 143-187.

Reddell, J.R. 1966. A checklist of the cave fauna of Texas. II. Insecta. Texas J. Sci., 18: 25-56.

Reddell, J.R. 1967. A checklist of the cave fauna of Texas. III. Vertebrata. Texas J. Sci., 19: 184-226.

Reddell, J.R. 1970a. A checklist of the cave fauna of Texas. IV. Additional records of Invertebrata (exclusive of Insecta). Texas J. Sci., 21: 389-415.

Reddell, J.R. 1970b. A checklist of the cave fauna of Texas. V. Additional records of Insecta. Texas J. Sci., 22: 47-65.

Reddell, J.R. 1970c. A checklist of the cave fauna of Texas. VI. Additional records of Vertebrata. Texas J. Sci., 21: 139-158.

Reddell, J.R. 1989. Austin Outer Parkway, State Highway 45, Segments 3 and 4, Environmental Impact on Cave Fauna. Report prepared for Texas Department of Highways and Public Transportation.

Reddell, J.R. 1991. Further study of the status and range of endangered arthropods from caves in the Austin, Texas, region. Draft Section 6 report on a study for Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service. iv + 178 pp.

Reddell, J.R., and W.R. Elliott. 1991. Distribution of endangered karst invertebrates in the Georgetown Area, Williamson County, Texas. A report on a study for the City of Georgetown. 64 pp.

Reddell, J.R., and R. Finch. 1963. The caves of Williamson County. Texas Speleol. Survey, 2(1): 1-61.

Ubick, D., and T.S. Briggs. 1992. The harvestman family Phalangodidae. 3. Revision of *Texella* Goodnight and Goodnight (Opiliones Laniatores). Speleol. Monogr., 3. Texas Mem. Mus., Univ. Texas at Austin.

U.S. Fish and Wildlife Service. 1991. Black-capped Vireo (*Vireo atricapillus*) Recovery Plan. Austin, Texas. pp. vi + 74.

U.S. Fish and Wildlife Service. 1992. Golden-cheeked Warbler (*Dendroica chrysoparia*) Recovery Plan. Albuquerque, New Mexico. 88 pp.

U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants: Coffin Cave mold beetle (*Batrisodes texanus*) and the Bone Cave harvestman (*Texella reyesi*) determined to be endangered. FR 58 43818-43820.

U.S. Fish and Wildlife Service. 1994. Endangered and threatened wildlife and plants; 90-day finding on a petition to delist seven Texas karst invertebrates.

Veni & Associates. 1988a. Hydrogeologic investigation of the Jollyville Plateau karst, Travis County, Texas. Report prepared for Parke Investors Ltd., 620 Investors Ltd., and U.S. Fish and Wildlife Service.

Veni & Associates. 1988b. Hydrogeologic and biologic investigation of McDonald Cave, Travis County, Texas. Report prepared for Murfee Engineering Co., Austin, Texas.

Veni & Associates. 1992. Geologic controls on cave development and the distribution of cave fauna in the Austin, Texas, region. Prepared for U.S. Fish and Wildlife Service. v + 77 pp.

Vinther, E.C., and A.T. Jackson. 1948. Williamson County. pp. 62-64 in *The Caves of Texas*. Natl. Speleol. Soc., Bull. 10.

Vinson, S.B. and A.A. Sorensen. 1986. Imported fire ants: Life history and impact. Texas Department of Agriculture and Texas A&M University. 28pp.

III. RECOVERY PLAN IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated costs for the Travis/Williamson counties karst invertebrates recovery program. It is a guide for meeting the objective discussed in Part II of this plan. This schedule indicates task priorities, task numbers, task descriptions, duration of tasks, responsible agencies, and estimated costs. These actions, when complete, should accomplish the objectives of this plan. It should be noted that the estimated monetary needs for all parties involved in recovery are identified for the first three years only; therefore, Part III does not reflect the total estimated financial requirements for the recovery of this species. The total estimated cost of recovery, according to each priority, is provided in the Executive Summary. The USFWS has identified agencies and other "responsible parties" to help implement the recovery of these species. This plan does not commit any "responsible party" to actually carry out a particular recovery task or expend the estimated funds. Likewise, this schedule does not preclude or limit other agencies or parties from participating in the recovery program.

Priorities in column one of the following implementation schedule are assigned using the following guidelines:

Priority 1 - An action that <u>must</u> be taken to prevent extinction or to prevent the species from declining irreversibly in the <u>foreseeable</u> future.

Priority 1 ● - An action that by itself will not prevent extinction, but which is needed to carry out a priority 1 task.

Priority 2 - An action that must be taken 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.

<u>Key to Acronyms used in Implementation Schedule</u>

COA	- City of Austin
CORR	- City of Round Rock
EPA	- Environmental Protection Agency
FWS	- U.S. Fish and Wildlife Service
	ES - Ecological Services
	LE - Law Enforcement
LLMHCP	- LakeLine Mall Habitat Conservation Plan
NBS	- National Biological Survey
NPS	- National Park Service
TCMA	- Texas Cave Management Association
TNC	- The Texas Nature Conservancy
TPWD	- Texas Parks and Wildlife Department
TRCO	- Travis County
TSA	- Texas Speleological Association
TSNL	- Texas System of Natural Laboratories
TSS	- Texas Speleological Society
TXDOT	- Texas Department of Transportation
USDA	- U.S. Department of Agriculture
USS	- University [of Texas] Speleological Society
WICO	- Williamson County

KARST INVERTEBRATES (TRAVIS & WILLIAMSON COUNTIES, TX) RECOVERY PLAN IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY: FWS REGION	RESPONSIBLE PARTY: FWS PROGRAM	RESPONSIBLE PARTY: OTHER	COST ESTIMATES ($000): YEAR 1	COST ESTIMATES ($000): YEAR 2	COST ESTIMATES ($000): YEAR 3	COMMENTS
1	3.1	Work cooperatively with private land owners	ongoing	2	ES 	 TPWD	15 15	15 15	15 15	
1	3.2	Land acquisition, lease, and conservation agreements	15	2	ES Realty	LLMHCP *various		30 70	30 70	
1	3.3	Work with other agencies and organizations	ongoing	2	ES		20	20	20	
1	3.4	Regulatory	ongoing	2	ES LE		10 10	10 10	10 10	
1	4.11	Determine and implement short-term fire ant control in areas targeted for recovery	ongoing	2	ES	*various	30 50	30 50	30 50	
1	4.3	Determine and implement methods to prevent vandalism, dumping, and unauthorized entry	ongoing	2	ES	*various	5 5	5 5	5 5	
1•	1	Identify karst fauna areas needed to meet recovery criteria	2	2	ES		5	5		
1•	2	Determine appropriate size and configuration of karst fauna areas targeted for recovery	2	2	ES		10	10		

* Various includes EPA, TPWD, TxDOT, TrCo, WiCo, COA, CORR, TCMA, TSNL, TSA, TSS, USS, TNC, and others

KARST INVERTEBRATES (TRAVIS & WILLIAMSON COUNTIES, TX) RECOVERY PLAN IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY: FWS REGION	RESPONSIBLE PARTY: FWS PROGRAM	RESPONSIBLE PARTY: OTHER	COST ESTIMATES ($000): YEAR 1	COST ESTIMATES ($000): YEAR 2	COST ESTIMATES ($000): YEAR 3	COMMENTS
1•	5.2	Conduct hydrogeologic studies of karst fauna areas targeted for recovery	3	2	ES	 *various		10 30	10 30	
1•	6.2	Develop and implement educational programs for private landowners	ongoing	2	ES	 *various	10 30	4 6	2 3	
1•	7.3	Monitor threats in karst fauna areas targeted for recovery	ongoing	2	ES	 *various		7 8	7 8	
2	4.2	Identify sources of nutrient input into karst ecosystems and steps to sustain nutrient flow	3	2	ES	 LLMHCP TPWD	10 20 15	5 5 5	5 5 5	
2	4.4	Implement other conservation measures necessary in areas targeted for recovery	ongoing	2	ES	 *various				This task will depend on actions deemed necessary for conservation, and costs are unknown at this time.
2	6.1	Develop and implement educational programs for the general public	ongoing	2	ES	 *various			10 20	
2	6.3	Develop and implement educational programs for preserve managers, consultants, and other professionals	ongoing	2	ES	 NPS *various		50 10 40	5 5	

* Various includes EPA, TPWD, TxDOT, TrCo, WiCo, COA, CORR, TCMA, TSNL, TSA, TSS, USS, TNC, and others

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				FWS						
				REGION	PROGRAM	OTHER	YEAR 1	YEAR 2	YEAR 3	
2	7.1	Develop monitoring program	1	2	ES NBS				10 10	
2	7.2	Monitor listed species and other karst fauna within karst fauna areas targeted for recovery	ongoing	2	ES	LLMCHP *various			15 5 15	
3	4.12	Determine and implement long-term methods of fire ant control	15	2	ES NBS	*various				This task will depend on control methods used and costs are unknown at this time
3	5.11	Develop standards for conducting biolspeleological surveys	1	2	ES		5			
3	5.12	Conduct additional karst and biospeleological surveys	2	2	ES	*various	5 25	5 25		
3	5.13	Develop and maintain a central database of survey results	ongoing	2	ES	TPWD		10 10	10 10	
3	5.3	Conduct additional studies on each species' ecology	5	2	ES	*various	25 25	15 15	15 15	

* Various includes EPA, TPWD, TxDOT, TrCo, WiCo, COA, CORR, TCMA, TSNL, TSA, TSS, USS, TNC, and others

Appendix A. Glossary

Aedeagus – In male insects, the mating organ which is everted from the posterior.

Apical – At the tip of a structure (see proximal).

Apophysis - In arthropods, a chitinous ingrowth of the exoskeleton for muscle insertion.

Attenuated – Elongated, especially appendages, antennae, etc.

Biospeleology – The study of cave life and its relations to the surface and subsurface environment.

Book lungs – Primitive breathing organs found in lower arachnids such as scorpions and some spiders.

Borehole - In this work, a vertical hole drilled in bedrock for sampling karst fauna. Referred to as "corehole" in certain documents.

Carabid - Ground beetle, including Rhadine Persephone.

Carapace – The upper exoskeleton of the thorax of an arachnid.

Carinate – Having a carina, or keel, running lengthwise along an appendage.

Cavernicole – A species occurring only in caves, not necessarily eyeless and depigmented.

Chelae – The pincerlike claw of a scorpion's or pseudoscorpion's pedipalp.

Chelicerae – The first pair of appendages in an arachnid in front of the mouth, adapted for grasping and cutting up food; usually claw-like.

Collembolans (springtails) - Minute insects that have a forked structure on the abdomen that enables them to jump. Usually common and abundant. Feed on plant material, fungi, bacteria, arthropod feces, pollen, algae, and/or other food sources.

Dark zone – The permanently dark zone of the deep cave environment where no light penetrates, as opposed to twilight zone.

DNA (Deoxyribonucleic acid) - the substance that carries the cell's genetic code in the nucleus.

Elytra – In beetles, the hardened front wings which serve as covers to protect the delicate hind wings when the insect is not flying.

Endemism, endemic – Indigenous or native to a restricted area.

Epigean – Living on the surface, as opposed to living below the surface (hypogean).

Eye mound – In harvestmen, the conical projection on the dorsum (upper side) of the body bearing the two eyes.

Facet – An individual visual organ in the compound eye of an insect.

Feebly arcuate - slightly arched.

Femur – The third joint of an arachnid appendage.

Foveae - Small pits on the surface of the arthropod body.

Genital operculum - In harvestmen, a flap covering the genital opening.

Holotype – The primary type specimen selected as representative of a species by a taxonomist who describes the species. A holotype must be housed in a scientific collection that is available for study by qualified scientists.

Hydrogeology – The study of water dynamics in relation to geology, especially groundwater.

Infragroup - A collection of species within a subgroup (see below) that share similar physical and/or genetic traits. The smallest division in a hierarchical system of grouping species based on degrees of relatedness.

Karst – A terrain characterized by landforms and subsurface features, such as sinkholes and caves, that are produced by solution of bedrock (usually limestone or gypsum). Karst areas commonly have few surface streams; most water moves through cavernous openings underground.

Metathoracic wings – The hind wings of an insect.

Metatibial pencil of setae – A small brush of setae (hairs) found on the tibia of the third leg.

Microarthropod – A tiny arthropod, such as a springtail, mite, etc.

Monophyletic assemblage – A group of species that has descended from a common ancestor.

Niche - The role a species plays within its community or ecosystem.

Obsolescent eyes – Eyes that are nearly absent; only a small remnant may remain.

Ocular knobs - Eye remnants (bumps) that would normally bear a compound eye.

Ovipositor cuticle – The surface of the female ovipositor (an organ for laying eggs in the soil).

Palpal – Pertaining to the pedipalps.

Parastylar - On either side of the stylus, part of the harvestman's penis.

Paratopotype – A type specimen selected by a taxonomist as a representative example of a species and which comes from the original type locality which he/she designates.

Paratype – A secondary type specimen selected by a taxonomist to represent a species being described; not necessarily of the same sex as the holotype or from the type locality.

Pedipalps – The second pair of appendages in arachnids, the bases of which provide a jaw-like function; the pedipalps provide a grasping or pinching function for handling food.

Phalangodid - Daddy longlegs harvestman, including Texella reddelli and Texella reyesi.

Polymorphic – Exhibiting much physical variation among individuals.

Postopercular process – In some harvestmen, a projection posterior to the genital operculum.

Pronotum – In insects, the dorsal (upper) side of the anterior (front) part of the thorax. In *Rhadine* beetles, the pronotum is elongated like a neck.

Protuberance - A knob or prominence.

Proximal – At the base of a structure (see apical).

Pselaphid - Short winged mold beetle, including Texamaurops reddelli and Batrisodes texanus.

Psocid - Small, soft-bodied insect, usually less than 6 mm long.

Punctulate - Pitted.

Retrolateral – On the backside of an appendage.

Robust - Relatively thick-bodied, compared to others in the same group (opposite of *slender*, below).

Rugosity – A rough or scaly quality to the exoskeleton.

Scute – An exoskeletal plate on the dorsal (upper) side of a harvestman's body.

Setae - Hairs.

Slender - Relatively thin-bodied, compared to others in the same group (opposite of *robust*, above).

Spatulate – Flattened like a spatula.

Species group - A collection of species that share similar physical and/or genetic traits. The highest division in a hierarchical system of grouping species based on degrees of relatedness.

Spermathecae – Sacs used for the storage of sperm in female pseudoscorpions and other invertebrates.

Stylus – The long, thin part of a harvestman's penis.

Subcontiguous – Not quite touching.

Subgroup - A collection of species within a *species group* (see above) that share similar physical and/or genetic traits. An intermediate division in a hierarchical system of grouping species based on degrees of relatedness.

Speleology – The scientific study and exploration of caves.

Sympatric – Two species within the same genus occurring in the same place.

Tarsomeres - The segments at the end of an arthropod leg.

Taxonomy – The classification and nomenclature of living things, also referred to as "systematics". A taxonomist publishes species descriptions and/or revisions in scientific journals, based on studies of the anatomy, biology, or genetics of a certain taxon (group).

Tergal chaetotaxy – The pattern of setae (hair-like structures) on the dorsal (upper) plates of an arthropod.

Tergite – The dorsal (upper) plate of an arthropod's abdominal segment.

Tibia – The fourth joint of an arthropod leg.

Transverse impression - A crease that runs from side to side.

Trochanter - In arthropods, the second joint of the leg.

Troglobite – An animal that completes its lifecycle and spends its entire life in openings underground (such as caves) usually with small or absent eyes, attenuated appendages, and other adaptations to the subsurface environment.

Troglomorphy, troglomorphism, troglomophic – The physical characteristics of a troglobite, typified by eyelessness, attenuated appendages, depigmentation, delicate integument or exoskeleton, and greater development of some sensory organs.

Troglophile – An animal that spends most of its life in openings underground, but may also be found above ground; not usually eyeless or depigmented.

Trogloxene – A cave-dwelling animal that leaves the cave on a regular basis to feed, such as bats and cave crickets.

Tubercle - A small, rounded nodule or mound.

Twilight zone – The cave zone in which light from the entrance is still visible.

Vestigial – Having only a vestige, or a remnant, of a structure left.

Appendix B. Individuals and Agencies Providing Comments on the Draft Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas.

Almquist, Albert. Private citizen

Chandler, Donald S. Department of Entomology, University of New Hampshire

Gaines, Jimmy. Private landowner

Heitz, Michael J. Director, Parks and Recreation Department, City of Austin

Howarth, Frank. Entomologist, Bishop Museum

Jost, Lou. Representative, Sierra Club Austin Regional Group

Krause, Albert A. Chairman, National Speleological Society

McFarlane, Donald A. Assistant Professor, Chairman of National Speleological Society Fauna Protection Committee

McKinney, Larry. Director, Resource Protection Division, Texas Parks and Wildlife Department

Minton, Mark. President, The University Speleological Society

Peck, Marie and Gerald. Private citizens

Robinson Ranch

Rose, Mark. General Manager, Lower Colorado River Authority

Russell, William. Austin Project Manager, Texas Cave Management Association

Ruhl, J.B. Attorney, Fulbright & Jaworski

Steed, David L. Principal, DLS Associates

Texas Crushed Stone Company

Veni, George. George Veni & Associates

von Rosenburg, Clyde. Chief Planner, Long Range Planning, City of Georgetown

Warton, Mike. Director, Texas Cave Management Association

Appendix C. Summary of Comments Received on the Draft Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas.

This recovery plan was available for public review and comment on June 7, 1993. The United States Fish and Wildlife Service (Service) requested comments by September 7, 1993. The Service distributed 207 copies of the draft plan to various agencies and individuals and sent 21 letters notifying county judges and local and national organizations that the plan was available for public review and comment. Comments were received from 21 individuals, agencies, or organizations.

All comments were considered when developing the final plan. The Service appreciates the time that each of the commenters took to review the draft and to submit their comments.

The comments discussed below represent a composite of those received. Comments of a similar nature are grouped together. Substantive comments that question approach, methodology, or financial needs called for in the draft plan as well as suggested changes to the plan, are addressed here. Comments received that related to listing decisions and general comments about the Endangered Species Act that did not relate to the recovery planning process are not discussed here. Comments regarding simple editorial changes or providing additional biological information were incorporated as appropriate without discussion here. Favorable, supportive comments were also received, but are not summarized.

Several agencies, organizations, and individuals expressed interest in cooperating with the Service in implementing the recovery program. Many have also made valuable contributions toward the conservation of these species, including research and education. The Service wishes to thank these entities for their interest and achievements and looks forward to a cooperative and successful effort to achieve the recovery objective.

All comments received are retained in the Austin, Texas, Ecological Services office as part of the Administrative Record of recovery plan development.

Comment: The choice of three karst fauna areas per karst fauna region is apparently arbitrary and not supported by quantitative theory or observation. Are three karst fauna areas per region too few?

> **Service Response:** A more detailed discussion of how the recovery criteria were derived is provided in Section I.F (Recovery Strategy). The number of karst fauna areas protected for each species is directly related to the risk that the species faces should one karst fauna area be lost; the more karst fauna areas that are protected, the smaller the risk that the species will go extinct. The plan calls for protection of **at least** three karst fauna areas for each species in each region where three or more areas exist. Although the choice of three karst fauna areas per region is not based on statistical procedures, discussions among Service biologists and independent cave and conservation biologists indicate that three karst fauna areas per region should provide minimum adequate protection against catastrophic threats.

Comment: The McNeil and Round Rock karst fauna regions are biologically indistinguishable and have no significant geologic barriers to karst invertebrate faunal migration. Hence, they should be considered as a single karst fauna region.

Service Response: These two karst fauna regions have been combined in the final plan, which is discussed in Section I.B (Distribution).

Comment: To minimize the cost of buying or leasing karst fauna areas targeted for protection, a minimum number of karst fauna areas should be protected, and the physical size of the karst fauna areas should be kept to a minimum. The USFWS should provide more specific guidelines to determine the size and configuration of karst fauna areas. An interim standard minimum setback, or possibly a range of setbacks that could reasonably be expected under assumed sets of circumstances should be established. Several comments requested a sample delineation of karst fauna areas.

Service Response: The Service believes the recovery criteria present the minimum number of karst fauna areas necessary to ensure the continued survival of each species (see Section I.F for discussion of the recovery criteria). The size and configuration of each karst fauna area will necessarily be site-specific due to the multiplicity of factors that must be considered to ensure adequate protection. The size and configuration of each karst fauna area must be large enough to maintain the integrity of the karst ecosystems on which these species depend. The final plan discusses factors to consider in determining the size and configuration of karst fauna areas (see discussion in Section I.F) and gives an example of the size and configuration the Service recommends for one of the most important karst fauna areas (Figure 11).

Comment: Several comments were received regarding the distribution and abundance of interstitial space and use of interstitial space by the karst invertebrates. Some supported research to determine the extent to which the karst invertebrates use interstitial spaces while others felt such research would be too costly and not productive. Some believed the distribution of the interstitial populations is unknown and essentially undeterminable and that so little is known of the distribution of interstitial space (and whatever fauna may inhabit this space) that attempting to modify preserve boundaries to benefit the interstitial fauna does not seem justified.

Service Response: Research indicates that karst fauna occur in the interstitium in the vicinity of caves opening to the surface. The interstitium in the vicinity of caves may provide a more stable environment than the larger cave environment, particularly during periods of dryness and temperature extremes. Thus, the Service believes the interstitium is an important component of the karst ecosystem and can have an effect on subsurface drainage patterns that define the moisture regime of the cave. We believe the interstitium should be considered as a component of the karst ecosystem, along with surface and subsurface drainage patterns, surface vegetation communities, species diversity, and other factors discussed in the plan, that should be considered when delineating the area necessary to preserve karst invertebrate habitat in a specific cave. Including consideration of the above factors and factors discussed in the plan will result in protection of important segments of the karst ecosystem including caves where listed species occur. Considering species diversity in deciding which caves to include in a karst fauna area may preclude the need to list additional karst invertebrates in the future.

The Service agrees that cost and amount of time necessary to determine the full extent to which the karst invertebrates use the interstitium are probably too prohibitive to be practical. We have modified the plan and removed that task and are instead recommending a "conservative" approach to delineating karst fauna areas that need to be protected. Although the precise extent of the species' use of the interstitium may never be known, delineation of the karst fauna areas should be based on the assumption that the species do inhabit these areas but are limited by nutrient, moisture, and other physiological requirements. The Service believes that the guidelines for determining the size and configuration of the karst fauna areas (see Section I.F) should provide adequate protection of the karst ecosystems, including individuals in the interstitium.

Comment: The assumption that *Rhadine persephone* eats cricket eggs may be in error and no efforts should be made to determine preserve areas until the biology of the species is understood.

Service Response: Karst invertebrates are difficult to study because of their subterranean nature. Several ecological studies have been done on *Rhadine subterranea* indicating that this species feeds on cricket eggs. Since no studies on the feeding habits of *Rhadine persephone* are available, we look to comparative studies on closely related species. This information is considered preliminary as applied to *Rhadine persephone* and the recovery strategy will be modified as new information becomes available if it proves necessary. As written, the recovery plan calls for protection of at least three karst fauna areas containing *Rhadine persephone* in each karst fauna region in which the species occurs. If the karst ecosystem for each of these areas is protected as a whole, then *Rhadine persephone*'s specific needs should be protected as well.

Comment: The recovery plan area should be limited only to those karst fauna regions where the species are known to occur.

Service Response: The recovery criteria are based on the known localities of the listed species. Figure 2 has been revised to eliminate karst fauna regions where the listed species do not occur, with the exception of the Southern Travis County karst fauna region (see discussion in Section I.B). A survey effort of the South Travis County karst fauna region has been identified as part of a priority 2 task (5.12) in the recovery plan. Should additional survey efforts indicate that the South Travis County karst fauna region is not likely to support any of the listed species, the recovery plan would be revised accordingly.

Comment: The recovery plan should extend the area of protection to other Texas counties outside of the known ranges of the listed species where similar limestone formations occur, since these species' ranges may extend beyond the areas where they have been found in Travis and Williamson counties, Texas.

Service Response: The recovery plan is based on the known ranges of the listed species, which are limited to areas within Travis and/or Williamson counties. Due to the numerous surveys that have been conducted to date, the species' ranges are believed to be fairly well defined, particularly those that are endemic to the Jollyville Plateau, and are not believed to extend far beyond the current known distributions. For example, none of the listed species have been found in caves located in Coryell or Bexar counties despite extensive surveys. Since these species cannot travel above ground, discontinuous limestone strata, formed by hydrogeologic features and/or processes (such as canyon downcutting by rivers and creeks) present barriers to their migration. Since some areas on the periphery of some of the species ranges have not been adequately surveyed, Task 5.12 identifies the need to conduct additional surveys in these areas. Should any of the listed species ranges be found to extend substantially beyond the currently known range, the status of that species and the recovery plan would be revised accordingly, if appropriate.

Comment: Even if the plan protects the listed species it will not adequately protect the groundwater system and the "potentially-endangered Buttercup Creek Salamander."

Service response: The ecosystem approach to protecting karst features that is outlined in the plan should provide some incidental protection for groundwater. Maintaining undeveloped, natural areas around karst features containing the listed species will maintain the quality of water passing through the karst feature and subsequently into the groundwater supply. However, aquatic organisms have different habitat requirements than the terrestrial species for which this plan was developed. The groundwater inhabited by subterranean aquatic organisms originates from many sources and a single karst fauna area delineated to protect habitat for terrestrial karst invertebrates may not be sufficient to protect groundwater quality for aquatic organisms. Several aquatic salamanders in the Buttercup Creek area are listed as Category 2 candidate species and their status is monitored by the Service.

Comment: The plan should maximize the number of non-listed species receiving incidental protection.

Service response: The ecosystem approach to preserving karst fauna areas should provide protection for some non-listed karst invertebrates within the protected karst fauna areas. Species diversity and the presence of other rare or endemic karst fauna will be considered when selecting karst fauna areas for preservation and the text has been changed to reflect this.

Comment: Positive impacts of human visitation on karst ecosystems are not addressed in the plan. Most adverse impacts discussed in the Background are associated with unorganized groups and not with caving organizations. The knowledge gained from experienced cavers should outweigh any negative impacts to the karst ecosystem, should any be incurred. Organized cavers provide a valuable service in locating, monitoring, and conserving (eg., through detecting contaminant spills and removing trash from cave entrances) karst features.

Service Response: The Service recognizes and greatly appreciates the valuable contribution caving organizations have made toward the conservation of karst ecosystems. A discussion of the contributions toward the conservation of karst ecosystems has been added to Section I.E (Conservation Measures). The discussion in Section I.D (Threats) has been reworded to state that impacts from human visitation may be reduced or avoided, depending on the caving skills and precautions taken by the person(s) entering the cave.

Comment: Collecting by scientists in the course of biospeleological surveys is a cause of mortality to the karst invertebrates and is clearly disruptive to the habitat and microhabitat of the karst invertebrates. Collecting and surveying should not be considered a conservation measure.

Service Response: Collecting karst invertebrates for ecological studies does result in mortality of individuals of the karst invertebrate species and minor disruption of karst invertebrate habitat. However, any person wishing to collect endangered karst invertebrates must have the necessary federal and state permits and the number of specimens that can be taken is limited by the terms of the permit. Studies and collections of the endangered karst invertebrates help to gather information on how best to protect and recover the species. Few individuals are permitted by the USFWS to collect invertebrates in caves already known to contain endangered species.

Comment: The Service has not given enough attention to the hazards that cave gating may pose to karst invertebrates. More explicit guidelines are needed for gate and fence design, and enforcement of these guidelines is also necessary. A cave should only be considered "protected" from unauthorized human visitation if it is safely left ungated, or if the gate is "transparent" to the flow of nutrients, water, and air into the system.

Service Response: Potential hazards of gating and fencing are discussed more thoroughly in the final plan, with the recommendation that fence and gate designs meet Service approval prior to implementation. A specific design has not been included in the recovery plan in order to take into consideration site specific features and take advantage of any new technology that becomes available. Task 4.3, which discusses the installation of cave gates and fences, and Task 7.3 (monitoring of threats) have been reworded to state that all gates and fences that are installed should be monitored to ensure that nutrient input, moisture regime, and air flow are not altered. Any gates and fences that impede the normal flow of nutrients, water, and air into the ecosystem should be removed and, if necessary, replaced using a "transparent" design.

Comment: The recovery plan lacks a concrete timetable. The Service should publish a resource work plan, with discrete implementing objectives, projects, and milestones.

Service Response: Full implementation of the recovery tasks depends on the cooperation and involvement of several agencies, organizations, and private landowners. Implementation will require flexibility to accommodate the schedules and funding availability of all recovery plan participants. The Implementation Schedule estimates the number of years necessary to complete the tasks identified in the plan and the year each task should be initiated (Year 1, 2, or 3). Estimated dates for attaining the recovery objective (downlisting) are provided in Section II.A.

Comment: The plan should be formally briefed to key agencies, organizations, and private landowners in Travis and Williamson counties to promote their cooperation and avoid unintended harm while studies proceed.

Service Response: Successful implementation of the recovery program is dependent upon working cooperatively with private landowners (Task 3.1) and other agencies and organizations (Task 3.3), both of which are priority 1 tasks. Task 6 (Education) calls for an initiative to develop public awareness through a variety of means.

Comment: It is not clear what the monitoring tasks are intended to determine. Monitoring should determine the failures or successes of the recovery program, and the plan should be designed to accommodate needed changes in response to monitoring results.

Service Response: The Service concurs, and has reworded tasks 4 and 7 to clarify this issue. Another purpose of monitoring is to detect population declines and to prevent an irreversible decline in the species' status.

Comment: The "conservation measures" proposed in the plan are based on conjecture. There is no evidence that they have direct benefit to the species. Assignment of priorities to the recovery tasks is based on unsupported assumptions. Data relating to threats to the species are not definitive and there is no proof that threats to the species exist.

Service Response: Most conservation efforts undertaken for the karst invertebrates to date have focused on refining information on the taxonomy, distribution, and biogeography of the species. These efforts have enhanced our understanding of the past and present geology of the areas where the endangered karst invertebrates are located and the potential boundaries to their distribution. Additional efforts underway as part of the LakeLine Mall HCP should add to our understanding of the more specific habitat requirements of the endangered karst invertebrates. The plan also calls for other research to assist in determining certain conservation measures needed.

The conservation measures proposed in the plan and the prioritization of recovery tasks are based on basic principles of conservation biology and ecology as they relate to the karst invertebrates. Applying these principles to the karst invertebrates necessarily incorporates an element of "best professional judgement" since the karst invertebrates are small and subterranean and the details of their individual life histories are not known. When information on a listed species is limited, we look to comparative information on similar species to assist in assessing threats to the karst invertebrates, to determine measures that can be taken to ensure their safety, and to set recovery priorities. Recovery plans are reviewed periodically and as information becomes available that suggests changes in the threats to the species, the proposed conservation measures, or the recovery priorities, the plan can be revised accordingly.

Comment: The data are insufficient on these bugs to even consider them endangered, let alone develop a recovery plan.

> **Service response:** The listing of these invertebrates is discussed in the Federal Register at 50 FR 29238, 51 FR 29672, 53 FR 12787, 53 FR 36029, 58 FR 43818, and 59 FR 11755. These documents discuss the taxonomy, biology, ecology, and threats to the species. Comparative information on similar species is discussed where information is not available on the individual karst invertebrates. The Service believes that information contained in these documents justifies the species endangered status and that recovery planning is appropriate.

Comment: The Service should include a table or an appendix that documents when each species was confirmed present in each of the caves. Some collections may have been made years ago and it would be useful to verify if the subject populations persist at these locations. A suggested format for a new table identifying locations discovered since 1988 was included with the comment.

> **Service Response:** Task 1 states that where taxonomy of collected specimens is in question or where recent surveys are not available, the presence of listed species should be confirmed prior to targeting a karst fauna area for recovery. Confirmation of the presence of listed species in caves that have not been adequately surveyed or have not been surveyed in recent years is identified in Task 5.12. The Service believes the tables are understandable and informative as presented and only minor changes have been made for the final report.

Comment: The draft points out a "knowledge gap" in sites, but does not indicate the number of surveys that have been done that have found apparently suitable habitat, that were adequately surveyed for listed species, and that were unable to find those species. The Service undoubtedly has this information, since permittees are required to furnish it anually as a condition of their permits.

> **Service response**: Until March of 1992, the Service required permittees to provide information only on where listed species were found and not on sites that were surveyed and no listed species were found. Since there are relatively few individuals requesting permits for karst surveys, little new information has been obtained as a result of the new permit requirements. Even when permittees report negative karst survey results, they rarely provide enough information on the physical and biological characterstics of the karst features to determine relative habitat quality. Consequently and unfortunately, the Service does not have complete information on the number and location of surveys that did not find suitable karst invertebrate habitat. The new permit requirements were aimed, in part, at obtaining that information.

Comment: Once the recovery plan is finalized, the proposed National Biological Survey may be in place. Assignment of priorities to research efforts should incorporate the input from this agency.

> **Service Response**: The National Biological Survey (NBS) is in place and they have been indicated as a responsible party in the implementation schedule to

this plan. In the draft plan, the Service identified priorities for the tasks in this plan. As a part of the public review of this plan, we invited comments from all federal agencies and the public on the recovery strategy, funding, and priorities. The role the NBS plays in implementing the karst invertebrate recovery plan will be determined by their funding and priorities.

Comment: The draft plan allows for only one "widely accepted explanation...of troglobites, ignoring alternative explanations. This is most important when the draft plan advances the 'island' theory which is disputable on several points. The draft plan does not document any extinction or cite any data to back up the statement that troglobites are vulnerable to extinction.

Service response: The 'island' theory and the Service's use of the term 'islands' is discussed in the 90-day finding on the petition to delist the karst invertebrates (59 FR 11755). The use of the term 'islands' refers to areas of karst that are isolated from other areas of karst by downcutting stream channels or other features.

The original petition to list the karst invertebrtes requested listing the Tooth Cave blind rove beetle (*Cylindropsis sp.*) as an endangered species. On July 1, 1987, the Service published a notice that the petitioned action was warranted but precluded for all of the species except the Tooth Cave blind rove beetle. The notice announced that listing was not warranted for this species on the grounds that the single known specimen was in such poor condition that it could not provide adequate material for taxonomic evaluation and that the best scientific information indicated that the taxon was extinct (53 FR 12787).

Comment: There is new information provided in the plan regarding taxonomic revision to several of the species for which complete references are not provided. It may be useful to disclose which taxa are still subject to expected revisions and if these may result in further subdivision of the karst fauna areas targeted for protection in accord with the recovery criteria.

Service Response: Pertinent taxonomic references are cited and discussed in section I.A. Complete references are provided in Section II.D (References Cited). In addition, a notice discussing recent taxonomic changes and the status of the newly described species was published in the Federal Register on August 18, 1993.

We are not aware of any taxonomic revisions in progress at this time, but, future taxonomic research could result in redescriptions, as happened with the harvestmen and the mold beetles. Of the seven endangered karst invertebrates, *Texella reddelli* and *Texella reyesi* are most likely to contain populations that may eventually be redescribed as distinct species. Taxonomic revisions are not based on the number of sites at which a species is found, but on morphological and/or genetic characteristics and variation that exists among individuals. The recovery criteria aim at preserving genetic diversity across each species' range (see Section I.F).

Comment: The plan is mistaken that mature adult male specimens are required for positive identification of the mold beetles and the harvestmen. The published descriptions suggest that the invertebrates are distinguished using easy keys and clear differences presented in the descriptions and require no particular expertise beyond the ability to count to 5. The identifications of the karst invertebrates are based on obvious (although microscopic) morphological characteristics that can be determined by anyone with a minimal degree of interest but no advanced degrees.

Service response: The comment is correct in that no genitalia characteristics were used in Chandler's (1992) redescription of the pselaphid beetles in Texas caves. The text has been changed to reflect this.

Ubick and Briggs (1992) use male genitalia characteristics extensively in their redescription of the genus *Texella*. Their analysis is based on 29 characters: 20 male genitalia characters; 2 female genitalia characters; 3 secondary sexual characters; and 4 somatic characters. Ubick and Briggs explain that phalangodid harvestmen exhibit "pronounced interspecific variation of both somatic and genitalic characters as well as in the patterns of relationship which emerge upon their analysis." They also make extensive use of scanning electron microscopy and associated, technical, specimen preparation techniques for viewing the characters on which their analysis is based.

Ubick and Briggs present keys for both male and female specimens. The key for the males is based on all 29 characters while the key for the females is based only on female genitalia characters, somatic characters, and secondary sexual characters (nine characters).

The key for females is useful when an individual is sufficiently distinct to allow identification on this small number of characters alone. Given the small number of characters available for identifying females and the degree of intraspecific variation present, positive identification of individuals from new localities may not be reliable based on female specimens alone.

Ubick and Briggs (1992) publication does say that *Texella reddelli* and *Texella reyesi* "are clearly very closely related and, using the standards of genitalic distinctness applied to other *Texella* species, may even be considered conspecific." They rely on somatic characters to distinguish *Texella reddelli* and *Texella reyesi* since the somatic differences are present in spite of a geographical overlap in the range of the species.

In his description of cavernicolous pseudoscorpions from Texas and New Mexico, Muchmore (1992) discusses the genital characteristics of *Tartarocreagris texana* and other species but notes that "little has yet been recorded about the genitalia of neobisioid pseudoscorpions." The text has been changed to reflect this.

The Service acknowledges that several of the karst invertebrates (such as the ground beetle and the mold beetles) could be properly identified by knowledgeable amateurs based on the published taxonomic keys. However, given that intraspecific variation exists in any species, all of the specimens require microscopic examination (and some require use of an electron microscope), and that there are relatively few expert or amateur entomologists familiar with troglobitic species, it is advisable to have all specimens examined by a qualified systematist.

Comment: In the description of *Tartarocreagris texana*, the concept of "tergal chaetotaxy" is mispresented and contrary to the definition presented in the glossary.

Service response: The definition of tergal chaetotaxy presented in the glossary is the correct definition while the explanation in the text was in error. The text has been corrected to reflect properly the concept of tergal chaetotaxy.

Comment: The current ranges of the karst invertebrates are far in excess of the ranges at the time of listing and the Service should not proceed with finalizing the recovery plan until a conclusion is reached regarding the petition to delist the karst invertebrates. Government spending should not be used for expensive plans to save species that may not even be endangered.

Service Response: On March 14, 1994 a "not warranted" finding on the petition to delist the endangered karst invertebrates was published in the Federal Register (FR 59 11755). A "not warranted" finding indicates that the Service believes the petition did not present substantial information indicating that the karst invertebrates may warrant delisting at this time. This finding includes an evaluation of issues raised by the petition, including the range expansion, and discusses ongoing threats to the karst invertebrates. The finding determined that, in spite of the increase in known locations for some of the invertebrates, the species and their habitats are subject to current and potential threats through destruction and/or deterioration of habitat by construction, filling of caves, and loss of permeable cover; contamination from such things as septic effluent, sewer leaks, run-off, and pesticides; predation by and competition with fire ants; and vandalism. The finding also determined that these threats are present throughout all or a significant portion of the range of each species in spite of an increase in number of known locations.

Comment: If the fire ant threat can be relieved only through continued human intervention, the species should remain listed as endangered. Downlisting from endangered to threatened implies that protection of these species is less important than it was before.

Service response: The goal of recovery is to restore listed species to a point where they are viable, self-sustaining components of their ecosystem, to allow delisting. The Act requires the Service to develop and implement recovery plans to accomplish this goal. However, removal from the list may not be possible for all endangered and threatened species. In the case of the seven endangered karst invertebrate species, the possibility of delisting is uncertain since they may depend on continued human intervention to control the fire ant threat and may never be self-sustaining without this intervention. The criteria for downlisting (Section II.A) includes protection of karst fauna areas from fire ants. This will likely involve management of the fire ant threat through human intervention and this must be taking place and be assured of continuing before downlisting would be considered.

Although threatened species face less immediate threat than endangered species, they still receive protection under the Act. If the provisions in the downlisting criteria are met, the Service believes "threatened" will reflect the true status of the species.

Comment: The Service should consider the "protein bait" method of fire ant control near caves that has been developed by the City of Austin.

Service Response: Fire ants represent a major threat to the karst invertebrates and the Service is willing to explore new methods of fire ant control as they are developed.

Comment: The Service needs to provide more information to the public to allow identification of the species. The specific characteristics that define and distinguish the listed invertebrates need to be detailed and publicized so that when these species are encountered by the public they can be protected.

Service Response: The listed species are restricted solely to caves and other karst features. For safety purposes, the Service advises that only experienced cavers or individuals accompanied by experienced cavers should enter such features. In addition, a scientific permit under Section 10(a)(1)(A) of the Act is required to collect listed species. Positive identification of the karst invertebrate species must be confirmed by an invertebrate specialist, which often requires microscopic examination (including electron microscopy) of preserved specimens.

Comment: The Service should institute a program of "spot checks" to check the reliability of information provided by developer-hired biological consultants.

Service Response: The party hiring a biological consultant is responsible for investigating the qualifications and credentials of the consultant. Service biologists review information provided to the Service by biological consultants, and may or may not agree with the results and opinions consultants present. In addition, any individual conducting studies on endangered species is required to have all necessary state and federal permits and is responsible for complying with the terms of such permits and with all other aspects of the Endangered Species Act.

Comment: Most of the karst fauna areas where the species occur fall on private property. Funds should be budgeted in the plan to monetarily compensate private landowners for assisting in the recovery of these species.

Service Response: Working cooperatively with private landowners who wish to assist in the recovery of the endangered invertebrate species is a major part of this recovery program and is identified as a priority 1 task (3.1). Participation by landowners in recovery efforts is voluntary. Cooperatively funded projects (through the Service's Partners for Wildlife program or other programs) may be possible. Task 3.2 states that land acquisition, lease, and easements will likely be necessary as well to protect the karst fauna areas targeted for recovery and has also been identified as a priority 1 task. Task 3.2 also states that the Service will only acquire land from willing sellers. Cost estimates to carry out these tasks are provided in the Implementation Schedule.

Comment: The cost to achieve the recovery objective should be prioritized and minimized as much as possible. Efficacy can be gained by eliminating tasks that involve formidable technical challenges and unrealistic goals and tying conservation efforts for these species into other ongoing conservation efforts in the Austin region. In addition, conservation easements are a cost effective option for conservation in rural areas less threatened by urban development and should be encouraged.

Service Response: In an effort to cut costs and provide a recovery plan with an achievable objective within the foreseeable future, the Service has eliminated several tasks from the draft plan that were time and/or cost-prohibitive, such as determining the extent to which the species use interstitial spaces and developing methods of detecting subsurface voids. Other tasks were combined to provide a more succinct plan. To further reduce recovery costs, the Service has considered other ongoing conservation efforts as identified in the Implementation Schedule. Working with other agencies and organizations, many of which are listed in the Implementation Schedule, is a priority 1 task in this plan (Task 3.3). One possible method identified for providing long-term protection for karst areas is easements (Task 3.2). This task has also been identified as a priority 1 task.

Comment: Many monitoring and survey tasks are ideally suited for skilled volunteers, and caver organizations should be integrated into the draft plan and invited to send representatives to planning sessions.

Service Response: The Service recognizes the valuable contribution that skilled volunteers and experienced cavers can make toward the recovery of the karst invertebrates and appreciates the knowledge and assistance received from such individuals to date. Several local caving organizations are listed as "responsible parties" in the Implementation Schedule. To fully implement the recovery program, the Service will need to work with these and other parties. The Service has identified working with agencies and organizations as a priority 1 task in the plan (Task 3.3).