

The Karst Fauna Region Concept and Implications for Endangered Karst Invertebrate Recovery in Bexar County, Texas

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Abstract

Nine Species of karst invertebrates known only from caves in Bexar County, Texas, are currently listed as endangered by the U.S. Fish and Wildlife Service. Although a recovery strategy has not been developed for the Bexar County species, accurately delineating the distribution and range of each species is a vital first step. A study contracted by the U.S. Fish and Wildlife Service indicated that the distribution of these rare species has been influenced largely by geologic controls on their habitat imposed primarily by faulting and the down-cutting of streams. Preliminary data based on local geology and the distribution of endemic fauna known at the time suggested that up to six areas, referred to here as karst fauna regions, might exist in Bexar County. They include the Culebra Anticline, Alamo Heights, Government Canyon, Helotes, University of Texas at San Antonio, and Stone Oak karst fauna regions. However, recently collected species distribution data indicate that the number of karst fauna regions in Bexar County may only be four or even as few as three. This presentation will explore the karst fauna region concept and the implications of new data for a Bexar County endangered karst invertebrate recovery strategy.

Introduction

Northern Bexar County, Texas, is underlain by multiple Cretaceous carbonate formations cropping out along the Balcones Escarpment. During the Miocene, as the ancestral Gulf of Mexico was subsiding to the southeast, the escarpment was created along a belt of weakness where episodic faulting produced more than 1,000 feet of displacement. The resultant Balcones Fault Zone consists of a series of northeast-trending, predominantly normal, nearly vertical, *en echelon* faults, which are down-thrown toward the coast (Shaw, 1978). In the roughly 20 million years since faulting ceased, river systems adjusted to this change in elevation by carving a series of steep canyons along the escarpment. The juxtaposition of older, harder limestones to the northwest with younger, softer sediments and sedimentary rock to the southeast has produced a landscape with a multitude of niches for biota including endemic cave-, aquifer-, and spring-adapted species found nowhere else on the planet.

Many of these species find their habitat within or above the karstic Edwards Aquifer system. The Edwards Aquifer Recharge Zone is composed primarily of exposures of the Edwards Group and overlying Georgetown Formation. The Edwards Group is divided into the Person and Kainer Formations which are further subdivided into seven members of relatively heterogeneous lithology (Stein and Ozuna, 1995). The Edwards Aquifer Contributing Zone, or the area from which surface runoff sheds to the recharge zone, is composed largely of the Glen Rose Formation and erosional remnants of the Kainer Formation. Caves in Bexar County occur primarily in the Glen Rose and Edwards Group Limestones as well as in the Austin Chalk formation, which lies stratigraphically above the upper confining units to the Edwards Aquifer (Veni, 1988).

On December 26, 2000, nine species of karst invertebrates known only from caves in Bexar County, were listed as endangered by the U.S. Fish and Wildlife Service under the authority of the federal Endangered Species Act. These spe-

cies are Madla's cave spider (*Cicurina madla*), Robber Baron Cave spider (*Cicurina baronia*), Vesper Cave spider (*Cicurina vespera*), *Cicurina venii* (no common name), Government Canyon Bat Cave spider (*Neoleptoneta microps*), Robber Barron Cave harvestman (*Texella cokendolpheri*), Helotes mold beetle (*Batrisodes venyivi*) and two ground beetles lacking common names (*Rhadine exilis* and *R. infernalis*) (USFWS, 2000).

That these unique species exist and that their habitat is threatened by the rapid urbanization of the City of San Antonio is enough information to justify their listing as endangered species. But much of what is known about the Bexar County karst invertebrate fauna has been derived from a relatively small number of specimens collected from an as yet unknown portion of each species' range. Despite diligent efforts of a small number of researchers, the logistical challenges in accessing karst habitat inherently limits the amount and type of information which can be directly gathered regarding the natural history of these often elusive fauna. Very little known of the species' behavior, population trends, and general ecology is not based on anecdotal observations or inferences based on other taxa in other ecosystems.

Conservation and recovery of these species depends upon the protection, in perpetuity, of a sufficient number of caves inhabited by each species, thus preserving genetic diversity and ensuring long-term survival. As the great majority of land in Bexar County likely to contain caves is privately owned, conservation and recovery of these species also depends to a large extent on cave preservation through consultations with the land-owning public. Urbanization has proceeded largely unchecked before and since the listing, and the number of potentially suitable cave preserve sites is dwindling.

The Karst Fauna Region Concept

The Karst Fauna Region concept was first published in 1994 in the recovery plan for endangered karst invertebrates in Travis and Williamson Counties, Texas (USFWS, 1994). It was based on "karst geologic areas" (karst areas) described in a report to the U.S. Fish and Wildlife Service and the Texas Parks and Wildlife Department (Veni, 1992). A companion study of similar form was conducted for the San Antonio area (Veni, 1994). The premise of these studies is that geologic and structural controls within the karst have resulted in the present distribution of troglobitic fauna by restricting their movement through the karst. These structural controls come in two basic

forms. One is a barrier caused by the absence of cavernous strata due to the down cutting of streams or fault juxtaposition of non-cavernous strata with cavernous strata. The other is a restriction that may be a temporal limitation to terrestrial troglobite movement such as saturation of voids beneath an intermittent stream, or a spatial limitation such as a narrow outcrop of cavernous strata between karst areas. This theory of "structural controls" was validated using an "endemism index" whereby a number of species thought to be restricted to a karst fauna region was compared to a number of species thought to occur across multiple karst fauna regions. The delineation of karst fauna boundaries was based on various observed geologic controls. The degree of endemism present within the boundaries was based on faunal distribution data available at the time. As a relatively small number of caves were surveyed in several of the karst fauna regions, refinements to the results of these studies were expected to occur as new data became available.

In the Travis and Williamson County recovery plan, karst fauna regions are further delineated into "karst fauna areas" which are defined as areas supporting one or more populations of listed invertebrates separated from other karst fauna areas within that karst fauna region by barriers to the movement of water, contaminants, and troglobitic fauna. These karst fauna areas are intended essentially as recovery units, which, if preserved in appropriate numbers, may lead to down listing of the species from endangered to threatened in a particular karst fauna region. Although a recovery strategy for the Bexar County invertebrates has not yet been formulated, it is likely to follow the model of the Travis and Williamson County recovery plan.

Six karst fauna regions are currently considered for Bexar County (USFWS, 2000). The Culebra Anticline and Alamo Heights karst fauna regions occur in outcrops of the Austin Chalk which are isolated from other cavernous strata. The other four karst fauna regions occur in the relatively contiguous outcrops of the Glen Rose and Edwards Group Limestones in an area roughly coincident with the Edwards Aquifer Recharge Zone. From west to east they include Government Canyon, Helotes, University of Texas at San Antonio, and Stone Oak. They are divided from one another by Los Reyes Creek, Helotes Creek, and Leon Creek, respectively. Each of these creeks has down cut through a significant portion of the karst and each frequently dries during arid weather.

The utility of the karst fauna region concept as a management tool is to further the recovery

goals of protecting isolated populations and preserving genetic diversity across each species range. In other words it functions as a predictor of the spatial distribution of genetic diversity among troglobites so that appropriate areas can be targeted for conservation and so that the minimum standard for down listing and recovery can be identified.

Complications to the Karst Fauna Region Concept

As with any model, the karst fauna region concept is based on a number of assumptions and uses inference to bridge gaps in the available data. Complications to the six karst fauna region model for Bexar County arise when new data are introduced to the original endemism index calculations and when alternatives to its assumptions are considered.

One significant complication stems from the fact that it is unknown whether boundaries between karst fauna regions are more significant to troglobite gene flow, and therefore genetic diversity, than barriers within karst fauna regions but between karst fauna areas. Little conclusive data are available about the extent of interstitial voids or mesocaverns in Bexar County as it pertains to their role in troglobite ecology and movement. No molecular data are currently available on the genetics or phylogenetic relationships between Bexar County karst fauna populations. Recently collected species distribution data seem to have conflicting implications.

As taxonomic work on specimens from Bexar County advances, new species are described and revisions and range extensions of previously identified species are made. Much of this work has been conducted on behalf of private landowners by various researchers while the most intensive study has been made on Camp Bullis (Veni, 1999). The number of new species discoveries in recent years, especially those within the same genus as listed taxa (Cokendolpher, pers. comm., 2001; Veni, 1999; Reddell, 2000; Reddell, 2001), suggests that the heterogeneity and complexity of local geology may provide many more barriers to troglobite gene flow than previously thought. Each cave, cave cluster, or fault block may represent its own isolated community of fauna. This possibility may have negative implications for the broader goal of cave conservation in Bexar County as the more restricted in range federally protected fauna are the smaller the geographic area is that may be afforded regulatory protection.

On the other hand, range extensions of at least two listed species may provide evidence

to the contrary. One of the most significant range extensions is that of *Cicurina madla*. Once thought to be restricted only to its type location, it has now been positively identified from eight caves. Its known range now includes caves formed in both the Edwards and Glen Rose Limestone Formations located in the Government Canyon, Helotes, University of Texas at San Antonio, and Stone Oak karst fauna regions (SWCA, 2001).

Another significant range extension is that of *Batrissodes venyivi*. Once thought to be restricted to two caves, two new locations have been documented on private lands (Chandler; Reddell pers. comm., 2000). The range of *B. venyivi* has now been shown to span the proposed Government Canyon and Helotes karst fauna regions. Incidentally, one of the original locations and one of the new locations have since been purchased as mitigation preserves, and a third is proposed to be included in a mitigation preserve.

These range extensions may indicate that geologic controls have no influence on the distribution of most listed troglobites across the contiguous Edwards and Glen Rose karst fauna regions. In fact, four of the six listed invertebrates known to occur in those karst fauna regions are now known to range across karst fauna region boundaries. These data, if integrated with the endemism index as originally calculated for these karst fauna regions, would significantly shift the results for the individual karst fauna regions toward non-endemism. This may indicate that, as was noted by the original investigator, the boundaries between the Government Canyon, Helotes, and University of Texas at San Antonio karst fauna regions "are only moderately effective and so the areas lend themselves for consideration as a single unit" (Veni, 1994, p 75). It may additionally indicate that the boundary formed by Leon Creek between the University of Texas at San Antonio karst fauna region and the Stone Oak karst fauna region is similarly only moderately effective. In this case the number of karst fauna regions in Bexar County could be four or even three. There is a precedent for this consideration as during the development of the Travis and Williamson County recovery plan two karst geologic areas were combined into one karst fauna region because of their similar faunal assemblages. However, it should be noted that new karst fauna data from Camp Bullis and its effect on the endemism of the Stone Oak karst fauna region is not considered here save one exception with regards to *C. madla*.

Such range extensions have been difficult to come by for a variety of reasons. Only adult

female *Cicurina* spiders are currently identifiable to species level. Although many caves in Bexar County are known to contain troglobitic *Cicurina* spiders, most of those populations remain unidentified as to species because only juvenile specimens have been collected. Adult females have rarely been collected. Adult males are currently required to identify *Neoleptoneta* spiders to species level. *Neoleptoneta microps* is known only from a single female specimen. They are also much smaller than *Cicurinas* and are thus more easily overlooked during biological surveys. *Batrissodes* mold beetles are also easily overlooked due to their size, which averages about two millimeters in length. Of the nine federally listed invertebrates, five are known from fewer than ten specimens that are identifiable to species level, and four of those five are known from three specimens or fewer. *Cicurina venii* and *C. vespera* are known only from one identifiable specimen each. The result is that, with the exception of the *Rhadine* beetles, the current state of knowledge as to the status and distribution of the listed Bexar County taxa is based on only a handful of data points.

Alternatives to the theories and assumptions on which the karst fauna region concept is based may also be viable. One assumption is that the troglobites reached their current distribution by dispersal through the sub-surface. This assumes that biologically open corridors exist (or existed on an evolutionary time scale) and are (or were) integrated between caves on a scale at least as spatially extensive as the smallest karst fauna region. In the case of the *Rhadine* beetles, biological corridors would have to have been integrated across the far ends of all four northern contiguous karst fauna regions. In the case of *Rhadine infernalis*, the Culebra Anticline would have to have been integrated as well. The karst fauna region concept also assumes that populations diverged genetically as their ranges become truncated or segmented by the imposition of geologic barriers to gene flow. Thus genetic diversity between populations may follow a relationship based on proximity to the origin of dispersal and the orientation of imposed barriers.

Not all troglobites known from Bexar County are assumed to have followed this evolutionary pathway, however. *Eidmanella rostrata*, for example, is a troglobitic spider which is known from caves in Bexar, Bandera, Burnet, Comal, Kendall, Kinney, Medina, Travis, Uvalde, and Williamson Counties (Cokendolpher and Reddell, 2001). This wide ranging distribution, across broad expanses of non-cavernous rock, is unlikely to have occurred

through sub-surface dispersal. Rather, *Eidmanella rostrata* is likely a recent troglobite whose various populations simply have not diverged enough from a surface ancestral species to be divided into separate species (Cokendolpher pers comm., 2001). Each isolated population functions ecologically as a separate species due to geographic isolation, but retains an anatomy lacking morphological differences sufficient to justify taxonomic re-classification. The spatial distribution of genetic diversity among populations of *E. rostrata* may then follow a more random pattern related more to the distribution of the surface ancestral species and independent of sub-surface structures.

Other troglobites including the harvestman *Hoplobunus madla* are thought to be older troglobites due to their degree of troglomorphic adaptation and apparent lack of closely related surface taxa. Like *E. rostrata*, they are known to range across many Texas counties in both the Edwards Plateau karst and the Balcones Fault Zone karst. Populations of these species have also not been divided into separate taxa because of an apparent lack of distinct anatomical characters. If their current distribution is a product of sub-surface dispersal, it would have occurred long before currently considered karst fauna region boundaries formed when the Edwards Plateau karst and Balcones Fault Zone karst were contiguous. This highlights another potentially faulty assumption implicit in the six karst fauna region concept which is that the Bexar County troglobites have rates of genetic mutation which are consistent with speciation occurring in the time since the impositions of karst fauna region barriers.

As Bexar county troglobites may have followed multiple evolutionary pathways and taxonomic conclusions have not been reached in the same manner for each taxa, it is difficult to know with absolute confidence whether taxa considered in the endemism index are being compared as "apples to apples."

Discussion

The purpose of this article is not to prove or disprove the validity of the karst fauna region concept, and it is certainly not intended to second guess the taxonomy. Both are works in progress and are herculean tasks. The purpose of this article is simply to illustrate that if applied inflexibly as a management or recovery tool, the karst fauna region concept has the potential to undermine steps toward cave conservation, and that sufficient uncertainties exist to warrant flexibility in its application.

With the exceptions of Government Canyon State Natural Area and Camp Bullis Military Reservation, almost all of the Bexar County karst is privately owned. Endangered Species Act enforcement on private lands is far more complicated than on federal or state lands. Funding does not currently, and will not likely in the foreseeable future, allow for significant purchase of karst invertebrate habitat by the U.S. Fish and Wildlife Service. Although the City of San Antonio has made significant progress in allocating taxpayer funds to purchase land for the sake of aquifer protection, those funds are limited and many caves containing endangered taxa are located outside of the aquifer recharge zone where purchase by the city is not allowable. Accordingly, recovery of the Bexar County karst invertebrates depends largely on private sector mitigation through purchase or donation of preserve lands as part of the Edwards Aquifer/HCP process or informal consultations with the U.S. Fish and Wildlife Service.

Such mitigation is only required by federal law where "take" is demonstrated. Take is a legal term used in the Endangered Species Act to describe harm to protected species and may result from permitted or non-permitted actions. In many cases irreparable damage to a cave ecosystem may already have been done by the time a non-compliant permit applicant engages in consultation with the U.S. Fish and Wildlife Service. In these cases on-site mitigation may not be a viable option and an opportunity for the purchase of off-site karst invertebrate habitat may exist. Given that a finite number of potentially suitable mitigation options remain in Bexar County, obstructions to taking advantage of those mitigation options should be avoided, where possible.

A recent case study in the University of Texas at San Antonio karst fauna region involved a development project for which a section 10(a) permit was issued for the incidental take of listed karst invertebrates. It was demonstrated to the satisfaction of the U.S. Fish and Wildlife Service that the long term survival of the species involved would not be jeopardized within the University of Texas karst fauna region by the issuance of the permit. The mitigation plan provided by the applicant as a condition of permit issuance included the establishment, in perpetuity, of two on-site and five off-site cave preserves containing a total of ten caves on 181 acres. The entrance of one on-site cave was filled and the resident population of troglobitic spiders may be extinguished. The two other on-site caves remain in approximately one-acre preserves and will provide monitoring sites to

study the effects of small preserves on troglobitic communities. The off-site mitigation preserves were distributed across the University of Texas, Helotes, and Government Canyon karst fauna regions. They will provide protection, in perpetuity, for other populations of the species impacted by the permitted development as well as dozens of populations of other rare and endangered karst invertebrates. Subsequent to the issuance of the permit, a legal challenge was brought against the U.S. Fish and Wildlife Service by an environmental group based, in part, on a claim that mitigation should not have been allowed across karst fauna region boundaries. Had a recovery plan been in place at the time of consideration of that permit, and had the service chosen to adhere strictly to a more narrow mitigation standard, then what was arguably the greatest private sector contribution to cave conservation in Bexar County may never have occurred. Furthermore, the development may well have occurred anyway.

As the City of San Antonio expands and property taxes rise, increasing development pressure is brought to bear on private land owners such as those who sold their lands for the above mentioned mitigation. Largely as a result of that plan, several San Antonio land owners have begun to speculate in budding private cave mitigation ventures. In essence, environmental features previously considered liabilities from a development perspective are beginning to be seen by some landowners as assets. It is likely in the interest of cave conservation to encourage this trend and to avoid creating obstacles to it that are not clearly warranted. Assigning economic value to caves by encouraging a market for mitigation preserves has been a more effective motivation for cave conservation on private lands than has been the threat of injunctive relief under the Endangered Species Act.

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