Principles and Practice for Design of Cave Preserve Management and Monitoring Plans for Invertebrate Species of Concern, San Antonio, Texas

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Abstract

Karst areas around San Antonio, Texas contain over 300 known caves, some of which contain invertebrate animal species that are unique to the area. The U.S. Fish and Wildlife Service have proposed nine invertebrate species as Endangered Species. Concerned landowners and local agencies, hoping to obviate listing (which would be economically costly and an impediment to use of private property), have formed a coalition to protect, preserve, and manage caves known to have the species. Preserve Management and Monitoring Plans have been prepared for several caves based on guidelines promulgated by Fish and Wildlife Service and evaluation of conditions at each site. Important factors include protection of surface and sub-surface drainage areas, preservation of adequate foraging areas for trogloxenes, reduction of disruptive human access, control of non-native fire ants, and periodic monitoring to evaluate conditions and populations of species of concern. This paper will discuss the principles for design of Monitoring Plans and their practical application at one specific site.

Introduction

In 1991, nine species of invertebrates known only from caves in Bexar County, Texas, were petitioned for listing as Endangered Species under the Federal Endangered Species Act. The taxa include: four apparently different species of blind spider *Cicurina baronia*, *Cicurina madla*, *Cicurina venii*, and *Cicurina vespera*, each known from only one cave at the time the petition to list the species was submitted; *Neoleptoneta microps*, a spider known from one cave; *Texella cokendolpheri*, a harvestman known from one cave for certain and tentatively from another; *Batrisodes venyivi*, a beetle known only from one cave, *Rhadine exilis*, a beetle, known from four sites at the time of the petition; and *Rhadine infernalis*, another beetle, with two described subspecies: *R. infernalis infernalis*, known from two caves, and *R. infernalis ewersi*, known only from one cave, and specimens that could not be identified to subspecies, described as "hybrids," known from at least seven other caves.

The U.S. Fish and Wildlife Service published a proposed rule to list the species as Endangered on December 30, 1998. Threats considered to be potentially endangering these species are listed in the Proposed Rule as: destruction and/or deterioration of habitat by commercial, residential, and road construction; filling of caves; loss of permeable cover; potential contamination from such things as septic effluent, sewer leaks, runoff, and pesti-

cides; predation by and competition with nonnative fire ants; and vandalism.

Subsequent to the petition, additional research has found that some of the species are much more widely distributed and abundant than had been known previously. No new locations were found for *Cicurina baronia*, *Cicurina venii*, or *Texella cokendolpheri*. *Cicurina vespera* has been found in one new location, as have *Neoleptoneta microps*, and *Batrisodes venyivi*. *Texella cokendolpheri* has not been positively identified in its previously known habitat and may be extinct. No documented records of this species are known since 1985. *Cicurina madla* has been found in four new locations. Both of the *Rhadine* species were found to be more widespread than previously thought, with many newly discovered sites for each species. The number of caves from which each species is currently known is: *Rhadine exilis*: 31 caves; *Rhadine infernalis*: 22 caves, with three putative subspecies; *Batrisodes venyivi*: two caves; *Cicurina madla*: five caves; *Cicurina baronia*: one cave; *Cicurina venii*: one cave; *Cicurina vespera:* two caves, and *Neoleptoneta microps*: two caves. The species are currently known from a combined total of at least 56 caves.

Most of the land in the area is privately owned, and many landowners have plans for development of their properties. Cooperation of the landowners is essential for the protection of the species and the cave and karst environments in which they are found. In a series of meetings with landowners and local agencies, Fish and Wildlife Service agreed that if the long-term conservation of the nine species could be assured, then the listing proposal would be withdrawn. Specific criteria were issued by Fish and Wildlife Service for protection of caves and Invertebrate Conservation Areas. These were based on the Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas. This paper describes the criteria and suggests specific ways that they can be implemented to create Preserve Management and Monitoring Plans.

Fish and Wildlife Service Criteria

The karst areas of Bexar County have been divided into six regions, based on geology. At one time it was thought that these regions might be related to the distribution of the species, but this has not been consistently supported by new records of distribution. However, the Fish and Wildlife Service considers these regions to be valid and biologically important, and has laid down the requirement that they be considered in determining the adequacy of protection of the species. For purposes of determining adequacy of protection, the Fish and Wildlife Service requires that for all species that are known from at least three caves in one or more karst regions, protection of at least three Invertebrate Conservation Areas within each region is necessary. The Fish and Wildlife Service has not determined the appropriate course of action for those species known from fewer than three caves, except to require thorough surveys for additional locations.

An Invertebrate Conservation Area is defined by the Fish and Wildlife Service as: "an area known to support one or more locations of a 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."

This includes one or more caves and the surrounding areas that may provide surface and subsurface drainage, as well as surface foraging areas for trogloxenes.

To protect an Invertebrate Conservation Area, Fish and Wildlife Service specifies certain general considerations that must be taken into account. The first step is to define the area to be protected so that it provides for maintenance of adequate levels of all ecosystem components necessary for survival of the species of concern, and for adequate protection against definable threats. This is necessarily unique for each cave, and must be evaluated by examination of conditions above and below ground.

Important Factors

Fish and Wildlife Service defined the following as important factors for creating preserves: "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."

For each preserve designed, and for which a Management Plan is to be created, all of these factors must be examined, and provisions made for them.

Protection of Surface and Subsurface Drainage Areas

The first principle of cave preserve design is to protect the entrance and the surface area above the maximum footprint of the cave from all forms of disturbance and potential contamination by human-generated chemical or biological contaminants. Under conditions designed to eliminate all conceivable threats to the petitioned species, no matter how remote in probability of occurrence and regardless of cost or impact on human land use decisions, preserves would be large areas of undisturbed wilderness. With that level of protection as its implicit objective, the U.S. Fish and Wildlife Service has issued a guideline on karst species preserve size for the Travis and Williamson County species:

"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."

Applying that principle to the example of a cave that is 100 feet deep with its surface at 1,000 feet above sea level and its floor at 900 feet above sea level, ideally the preserve area should include all land surrounding the cave outward to the 900-foot elevation level. Although the Fish and Wildlife Service guideline may be practicable for caves that are shallow or in rugged topography, it becomes essentially unworkable and unnecessary for deep caves located in flatter landscapes. For example, applying the U.S. Fish and Wildlife Service guideline to one cave known to contain *Rhadine exilis* and to be approximately 115 feet deep, would result in a preserve area of over 125 square miles—that is, most of northwest Bexar County, including a large portion of the developed City of San Antonio. Clearly, the threat of contamination from areas miles away from the cave, even if higher in elevation, is remote. So, certain aspects of the ideal may be impractical and, perhaps, truly irrelevant to the effective protection of the species of concern.

For the karst invertebrates, by far the most important preserve objective will be protection of the surface above the entire cave footprint and the immediate surface and evident subsurface drainage areas directly affecting the cave of concern. This may be best determined by having a hydrogeologist examine the cave and surrounding area and make his or her best approximation on the parameters of the surface and subsurface drainage. Factors relevant to this determination may include but are not limited to regional dip, influences of fractures and faulting, and proximity to potentially related karst features. Often, some portion of these may extend beyond the property owned by or available to the conservation entity creating the preserve. In practice, with local land values exceeding seven dollars per square foot, economy calls for making the preserve size as small as possible, while still maintaining a functioning ecosystem and reducing the potential for contaminants entering the cave. This may call for acquiring additional property, developing cooperative agreements with neighbors, or limiting the area draining into the cave by creating berms around a suitable surface drainage area. In the San Antonio area, strict local regulations prohibit contamination of the aquifer, and greatly reduce the likelihood that any cave habitats would be contaminated.

Preservation of Trogloxene Foraging Areas

The proposed endangered species are very poorly understood by science. Very little is known about their trophic levels and dependencies, although it is presumed that they are predators and/or scavengers that feed either directly or indirectly on the eggs, bodies, or wastes of trogloxenes. Maintenance of a community of trogloxenes is deemed necessary to support populations of the dependent cavernicoles. For most caves in the area, the primary source of nutrient inflow appears to be crickets (*Ceuthophilus* spp.) and daddy-long-legs (*Leiobunum townsendii* Weed). Secondary, and probably much less important, is input from leaves and water falling or draining into the cave entrance or penetrating through seepage. In some caves, droppings of mammals such as bats and raccoons may be important sources of nutrient input, but this is not true of many of the caves from which the species of concern are known.

Specific management actions that can be included in preserve plans to protect and provide for continuing nutrient inflow to the caves are based on protecting sufficient foraging resources and access to provide for a population of trogloxenes typical of the cave. If possible, the preserve design should include an area of undisturbed native vegetation greater than would be necessary for trogloxene foraging, based on current understanding of foraging

range. Unfortunately, there are no data to support any notion of the size of trogloxene population necessary to support a viable population of any of the proposed endangered species or the abundance of foraging resources necessary to provide for healthy populations of trogloxenes. A radius of 30 meter (100 feet) from each cave entrance may be considered as the maximum likely foraging distance for crickets, based on data from Elliott. This is the furthest that Elliott found crickets wandering from the cave entrance. Alternatively, it may be possible to enhance the resources available to trogloxenes, thereby enabling smaller areas to provide for the same (or larger) populations. For example, planting persimmons (*Diospyros texana*), an important producer of food for crickets, may increase the resources for these trogloxenes, and indirectly benefit troglobites. Where bats or other mammals contribute to the cave ecosystem, every effort should be made to maintain accessibility of the cave to these animals. Appropriate gates can be designed and installed to permit easy access by trogloxenes while excluding unwanted human access.

Reduction of Disruptive Human Access

Although there has been no evidence that human intruders, other than speleobiologists, actually threaten any of the species of concern, the general concept that human intrusion is bad for the species is strongly held by advocates of preservation. For property owners, reduction of exposure to liability for injury is an important consideration. Limiting human access to the cave preserve is the appropriate answer, either by gates, fences, or both. The best method to do this has not yet been developed—all gates can be breached, and fences can be climbed or cut. Some proponents argue that the least obtrusive type of fence, such as barbed wire, is less likely to invite vandalism than more conspicuous fencing material. However, the Fish and Wildlife Service does not believe that barbed wire fencing is sufficient for cave preserves. It is not currently known what type of fencing would be acceptable to the Fish and Wildlife Service, reasonable in cost, resistant to trespassers, esthetically harmonious with the surroundings, and transparent to trogloxenes. As with any other cave gate, a gate for a preserve must be custom designed and built for that particular cave. It must be resistant to trespass but not disrupt access by trogloxenes, and be accessible to personnel carrying out the monitoring program. Also, provision should be made for access by rescue teams, in the event of an emergency.

Control of Invasive Exotic Species

Several species of exotic animals have invaded Texas caves. Effective Integrated Pest Management programs have not yet been developed and tested for species likely to occur in this situation. Of greatest current concern is the introduced fire ant (*Solenopsis invicta*), which is thought to be a predator on at least some of the species of concern. Although direct predation on any of the petitioned species has not been described, fire ants are known to prey on insects and also to forage inside caves. Fire ant control is considered necessary for the protection of karst ecosystems. Methods that have no impact on desirable insect species are not known to be especially effective for fire ant control. Current research is examining alternative ways of controlling fire ants, and may find more effective methods than those that are currently available. Any preserve plan should include recommendations currently being made by the Fish and Wildlife Service for fire ant control near caves known to have endangered species. All portions of the preserves should be accessible for fire ant control using the most appropriate approved technique. The current approved method calls for application of boiling water to active fire ant mounds within 35 feet of the cave entrances. Access to apply boiling water must be possible to all points within the preserve. Beyond the 35-foot radius, toxic baits can be placed in the morning and picked up before sunset, when the trogloxenes emerge. Fire ant control should be done quarterly, as part of the Preserve Management and Monitoring Plan. Preserve managers should be aware of exotic invasive species in the preserves, and should keep abreast of current techniques available for least toxic Integrated Pest Management in sensitive situations.

Periodic Monitoring and Maintenance

Because the primary reason for establishing and maintaining the cave preserves is protection of biota, some form of biological monitoring is necessary to evaluate the success of the preserves. Funding for the monitoring program could come from the landowner, land trust, or other management agency, or from a public agency such as the Fish and Wildlife Service that was concerned about the welfare of the species. Appropriate biological monitoring would, ideally, provide sufficient data to effectively evaluate conditions, estimate population parameters of species of concern, and detect incipient problems before they become detrimental to the ecosystem.

Biological monitoring over time should lead to accumulation of a body of useful data and information contributing to scientific understanding of the species and their ecosystems. Unfortunately, normal, healthy population parameters for any of the species known to occur in Texas caves are completely unknown. The handful of speleobiologists who have worked in the area have, at best, accumulated lists of species they found on only one or a few expeditions to any particular cave. There is no published knowledge of population size fluctuations in relation to any normal cycles or perturbations for any species of troglobite, trogloxene, or any cave in the area. Even anecdotal accounts are minimal. Therefore, systematic monitoring of populations of karst invertebrates over time and related to changing conditions would be breaking new scientific ground.

Crucial to the success of such an endeavor would be minimal disruption of the system by the monitoring process. Until very recently, the best speleobiology was based on the scorched earth policy of collecting at least one of everything in sight, and turning over rocks and debris in the quest for a complete list of species present. This "bugs in a bottle" science is not appropriate for protection of species of concern in a carefully managed preserve. Monitoring must be performed in the least disruptive manner consistent with acquiring useful data, and the impact of the monitoring process itself must be included as among the factors studied.

The team responsible for the monitoring process would ideally be the same year after year. It would include competent observers familiar with the species of concern and comfortable in the cave environment. The monitoring team should understand the objectives of the preserve and the long-term management goals, and be capable of performing all of the necessary tasks of monitoring and maintenance. Because of the interest of the Fish and Wildlife Service, the monitoring team should provide copies of their monitoring reports to the Fish and Wildlife Service, and should welcome Fish and Wildlife Service biologists' participation in the monitoring process. Because the greatest value of monitoring data would come only after a period of at least several years of study, a central repository of data with continuity of personnel would be ideal.

To establish a baseline, monitoring should be performed quarterly for several years at least. At each monitoring session, the following activities should be performed:

- Count all visible cave fauna in the cave, using minimally disruptive techniques, map the locations of all species observed, using a standard cave map prepared for that purpose.
- Examine the ground surface within and adjacent to the preserve for fire ant mounds and institute control measures as necessary.
- Measure temperature and humidity in at least three consistent locations within the cave. Use of HOBO data loggers permanently installed and downloaded at each monitoring session would give more data, and may be useful.
- Examine all gates and fences and repair or apply preventive maintenance as needed.
- Evaluate for other threats that may be impacting the karst ecosystem and the effects of management techniques employed to control or eliminate these threats.

Who Pays and Who is in Charge?

The most important unanswered question confronting the process of creating and managing preserves is that of responsibility for the costs and continued upkeep of the program. Initially, anticipating a cooperative relationship with the Fish and Wildlife Service, a coalition of land owners formed a non-profit organization for the protection and management of caves in the area, called the Bexar County Cave Protection Alliance. The Texas Parks and Wildlife Department was an active participant in the process. Unfortunately, the relationship between the coalition and the Fish and Wildlife Service has not been as cooperative as the coalition had hoped, and the future of the organization is in some doubt. The Fish and Wildlife Service asserts that only an organization with a history and track record of success in cave invertebrate conservation would be acceptable as a managing agency, and yet there is no such organization active in the area. Resolution of this dilemma is imperative for the successful development of a program of cave protection.

Many of the caves known to contain species of concern are on land owned by the Texas Parks and Wildlife Department and by Camp Bullis Military Reservation. These agencies may develop their own programs for creating and maintaining cave preserves. The remaining caves known to have the species are privately owned. Any expenses incurred in protecting and managing cave preserves accrues to the landowner. Many of the landowners are willing to assume these expenses, and incorporate cave preserves into open space plans for devel-

opment on their property. However, it is likely that more landowners would be cooperative and proactive if there were reasonable expectation of an agreement from the Fish and Wildlife Service that would ensure against exposure to prosecution under the ESA in the event that the species are listed as endangered.

Conclusions

If these principles are put into practice, the threats defined by the Fish and Wildlife Service as likely to harm karst invertebrates will be removed or reduced to insignificance in this area. These principles assure that:

- The cave is protected from destruction or deterioration.
- Permeable cover and natural vegetation within the cave drainage area is preserved.
- Sufficient drainage and forage area is protected to support a community of cave animals.
- Contamination by drainage of chemicals into the cave is prevented.
- A program of fire ant control is included.
- Vandalism is prevented.
- A monitoring program is established.

The major current impediment to the establishment of a network of preserves is the absence of acceptance by the Fish and Wildlife Service of a responsible management agency or organization that is also acceptable to the landowners in the area and agreement on the details of Preserve Management and Monitoring Plans for each cave of concern. If these obstacles can be overcome, and Preserve Management and Monitoring Plans put in place for at least some of the caves known to be inhabited by the species of concern, the long-term welfare of the species can be increased, and scientific understanding can progress from *speleobiology* toward *speleoecology*.