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Protecting Caves and Cave Life

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Human activities and disrespect for caves threaten many caves and cave life, leading to habitat loss, declines in populations, or even extinction. Protection of these resources involves management of the landscape above the cave as well as the minute details of providing proper security systems for caves. Cave restoration can improve conditions for cave life but can also cause problems if not properly done. Public education about cave and karst conservation is essential because many people are not aware of the gradual degradation of cave resources.

PROTECTING CAVE LIFE

Threats to Cave Life

Caves are often thought of as unchanging environments, but even in the farthest reaches of large caves there are detectable, annual changes in air and water. Some caves are naturally perturbed by flooding or temperature shifts, and these events influence the types of communities found there.

Caves that flood violently usually lack troglobites, the truly cave-adapted species, but may have troglophiles (cave-loving species) and trogloxenes (animals, such as bats, that roost in caves but exit to feed or migrate). Indiana bats (*Myotis sodalis*) and gray bats (*Myotis grisescens*) hibernate in the near-freezing zone of certain cold-air-trap caves, which are caves with deep or large entrances. Such entrances allow cold air to flow inward during strong cold fronts. In contrast, Mexican free-tailed bats (*Tadarida brasiliensis mexicana*) prefer warm caves with high ceiling domes, which, combined with bat body heat, help to create an incubator effect (over 40°C) for young bats in the summer.

Different animals are adapted to the natural extremes of caves and other habitats. Human-caused threats, however, can severely tax the ability of wildlife to adjust. Some of the most destructive changes to caves were brought about by quarrying and water projects that completely destroyed, or flooded caves. Human disturbance of bat roosts has caused severe declines in numerous bat species (Elliott, 2000). Bats will be discussed in more detail below.

Other pressures on cave life act over long time spans and are more difficult to measure. They include hydrological changes caused by land development, which can alter the normal hydrological cycle and increase sedimentation. For example, residential developments may cause an increase in nitrogenous wastes and sediments washed into caves. Sediments can be harmful to aquatic creatures with gills and/or soft body tissues, such as cavefishes, salamanders and cavesnails (eyeless, subterranean snails).

The enrichment of caves by wastes, such as ammonia and other nitrogen-based compounds, in infiltrating waters can lead to an increase in bacterial growth. Bacteria in groundwater are not killed by sunlight, and they can be transmitted for many miles. Residential developments may also bring exotic species, such as the aggressive red imported fire ant, which has caused many problems in caves in Texas (Elliott, 2000).

Regional overpumping of karst groundwater can lower groundwater to the point where important springs and wells run dry, endangering species that live there and threatening water sources. In Texas, endangered species of salamanders, amphipods, and wild rice have been affected by such trends.

Dramatic chemical spills can harm caves if the contaminants seep into streams or other routes into the cave. Once chemicals are in the groundwater, they are difficult to remove. Nutrient loss seems to happen less frequently than nutrient enrichment but can cause severe problems (see later example of Shelta Cave).

Extinct and Endangered Species

Although about six North American troglobitic species are thought to be extinct, it is likely that others became extinct before they could be discovered or described. Local populations of invertebrates, fishes, salamanders, and bats have been extirpated. Because some troglobitic species are endemic to a single cave or a small cluster of caves, and because many caves have been disturbed, filled, quarried, mined, or polluted, it is possible that some species have disappeared recently without our knowledge.

Bats

Bats are important contributors to the world's ecological health. Caves harbor numerous bat species that consume night-flying insects, some of which are pests (McCracken *et al.*, 2002). In the tropics, bats that eat fruit and pollinate plants often roost in caves. So, even though some bats do not use caves, the bat–cave connection is still important.

Declines in North American cave bats became noticeable in the 1950s. Six of the 42 continental U.S. bats are currently on the U.S. endangered species list. The six are dependent on caves for part of their life cycle, and human disturbance has been the major factor in their decline. For example, Indiana bats (*M. sodalis*) have lost significant numbers through disturbance of their hibernacula and improper gating, but also perhaps through warming of their roosts caused by global warming. If such bats cannot hibernate deeply, they use up their body fat too quickly, which results in starvation or death before spring.

Large water projects can drown caves under reservoirs or use them as recharge wells. A recharge project caused violent flooding of the Valdina Farms Sinkhole, a large cave near San Antonio, TX. In 1987, a large flood pulse cleaned out the cave. The cave lost a colony of four million Mexican free-tailed bats (*Tadarida brasiliensis mexicana*) and a rare colony of the leaf-chinned bat (*Moormoops megalophylla*). A salamander (*Eurycea troglodytes*) that lived only in that cave is probably extinct as a result.

The mining of caves for saltpeter, bat guano, or other minerals can have a drastic effect on bat colonies and other fauna. Mexican free-tailed bats have been disturbed by some guano mining in Texas, while some miners may have aided the colonies by mining out rooms that otherwise would have filled with guano. The better operations mine only in the winter when the bats are gone. The opening of large second entrances can severely alter the meteorology of a cave, causing bats to vacate. Marshall Bat Cave in Texas lost its free-tail colony after 1945, when a large, 40-m-deep shaft was dug into the rear of the cave to hoist out guano. The shaft caused too much ventilation and cooling of the cave.

Mammoth Cave once harbored Indiana bats before the entrance was modified to block incursions of cold winter air. The National Park Service is currently trying to reinstate the natural temperature profile of the cave.

Nutrient loss resulting from the loss of gray bats apparently caused a domino effect in Shelta Cave, in Huntsville, AL. Shelta had the most diverse cave community known in the southeastern United States, but land development encroached on the cave in the 1960s, and local residents were concerned about youths entering the cave, which harbored a large colony of gray bats. The National Speleological Society purchased the cave in 1967, and they moved their headquarters to a building nearby. They gated the cave in 1968 with a strong, cross-barred gate that had been taken from an old jail. This gate, in hindsight, was inappropriate for bats, which abandoned the cave within two years. Urbanization of the area probably also affected the colony. In 1981, a horizontal-bar, bat-friendly door was put on the gate, but no bats returned to the cave. The loss of bat guano to the lake in the cave probably contributed to the decline of cave crayfishes there (Elliott, 2000).

Cave Preserve Design

Cave conservation encompasses many techniques that can be applied to developed show caves as well as to wild, or unmodified, caves. Show caves, however, have special problems, such as the growth of cyanobacteria and plants near trail lights, accumulation of cave lint and trash, and general disruption of the ecology of the cave. Trail lights are not used at some show caves; instead, visitors are provided with electric hand lanterns, and viewing native wildlife along the trail is a goal of the tour. Such show caves usually provide a more educational experience for the public.

Good cave management includes developing rules for access to the cave. Many publicly owned caves can be left open to the public as long as visitors do not vandalize or disturb cave life. Educational signs at cave entrances are used to inform the public of etiquette and safety rules (Fig. 1). Some caves may require a permit system for entry, based on bat seasons, flooding hazards, or other considerations of safety or sensitivity. Usually, such a cave would be gated to control access, but appropriate signs are needed to inform people of the availability of permits. Certain caves may be considered closed for recreation but not for monitoring and research. Examples include a few caves that are especially pristine and rich in multiple resources or which have overlapping seasons for endangered bats. For example, a few eastern American caves harbor gray bats in the summer and Indiana bats in the winter, and must be closed to entry except perhaps between seasons in May and September.

Cave preserves have been set aside for the protection of endangered species. Too often, however, such preserves surround only the entrance area and do not take in the entire extent of the cave, much less the recharge area to the cave (often referred to as the *watershed*). It is essential to have good scientific information about the cave, including an accurate map, a detailed description, inventories of resources of the cave, and a hydrogeologic assessment. The last item may require a dye-tracing study, in which tracer dyes are put into streams, sinkholes, and other input points. The dyes are recaptured with charcoal traps placed in cave streams, springs, or wells. Maps can then be drawn that delineate the water sources of the cave, which makes it possible to manage the land around the cave intelligently.

FIGURE 1 An informative cave sign.

Lack of detailed information should not stall conservation planning, however. For example, foresters in Missouri try to maintain water quality to ensure a pesticide-free food supply for gray bats. They maintain a continuous forest canopy 60 m wide along streams, in the 8 ha around and above gray bat cave openings, and as travel corridors 60 m wide from gray bat caves to riparian foraging areas. This canopy provides protection from predators and a substrate for insect production.

Buffer zones around small caves that lack streams may include one or more hectares for the protection of terrestrial invertebrates in the cave. It is important to maintain native vegetation and drainage patterns on the epigeum (surface). Even intermittent cave streams may have sources beyond a few hectares, so the preserve would necessarily be larger in such cases. If the cave preserve is adjacent to undeveloped lands, then occasional visits to the cave by raccoons and other nonresident species may continue to provide necessary nutrient inputs in the form of droppings. If the preserve is isolated by developed lands, then the preserve area probably should be larger to maintain native flora and fauna. Camel crickets and harvestmen may exit the cave at dusk and forage for carrion and feces in the surrounding area, but these arthropods may not travel more than 50 to 100 m from the cave entrance. Pesticide use is banned or limited in cave preserves to avoid poisoning the cave fauna directly or indirectly. Even a small cave may have to be protected with a strong cave gate to prevent heavy visitation and vandalism, which can alter the cave habitat. Such cave gates should be designed to freely allow bats and small animals to pass back and forth. Preserve designs are discussed in various species recovery plans and in guidelines issued by the U.S. Fish and Wildlife Service and other agencies.

Buffer zones around large caves may be more difficult to achieve. For example, Tumbling Creek Cave in Missouri has high biodiversity and a recharge area of 9 mi^2 (2331 ha). Since 1967, the cave was protected under two private properties with extensive forest cover, losing streams, and light farming and cattle production. Even though the cave was protected by the Ozark Underground Laboratory, gray bats gradually declined for unknown reasons. Recently, sedimentation from poor land usage by a neighbor contributed to the decline of a cavesnail unique to the cave. A drought of several years probably also contributed to the decline. Today, more of the recharge area of the cave is under careful land use, but it remains to be seen if the cavesnail will increase again.

In Southeast Alaska's Tongass National Forest, studies found that some old-growth forest areas had to be protected on intensely karsted terrain. The limestone was so pure that little mineral soil had developed, and trees grew out of a thin moss blanket. When the area was clear-cut, the thin soils washed off into the numerous sinkholes, which fed cave streams, which fed salmon streams. In a sense, the karst served as three-dimensional stream banks feeding the local streams; they could also be considered as stream buffers removed at a distance, and were protected under existing laws and forestry standards. Some cave entrances and sinkholes received slash and runoff from logging and roads, in violation of the Federal Cave Resources Protection Act. Many of these areas are now protected from road building and timber harvest.

Some states have published karst best management practice (BMP) sheets for construction projects on karst. Different types of karst may require different BMPs. Missouri's 2000 karst BMP is reproduced below, with some modifications, by permission of the Missouri Department of Conservation.

MANAGEMENT RECOMMENDATIONS FOR CONSTRUCTION PROJECTS AFFECTING KARST HABITAT

Introduction

Karst features range from sinkholes, vertical shafts, losing streams, and springs to complex underground drainage systems and caves. These features are the result of the dissolving action of water on carbonate bedrock. Underground drainage systems can be extensive; as a result, specific karst features can be impacted by disturbances occurring miles from the affected area.

Associated with karst features are unique plants and animals that have at least part, if not all, of their life cycle dependent upon the unique environment of these systems. Even slight alterations or disturbances can have significant impacts upon these plants and animals. It is of utmost importance that construction projects in known karst topography be extremely sensitive to the potential impacts that may occur and that all possible precautions be taken to prevent or reduce those impacts.

Karst Identification

It is often difficult to clearly delineate the type and extent of karst features present due to the complex and varied processes involved in their formation; however, it is important to correctly identify and delineate karst features so that these areas are managed properly for the resident species (e.g., a bat hibernaculum or a bat maternity cave).

- Initial investigation should include the use of state, federal, and private geotechnical data. Observation by speleologists or geotechnical consultants should be considered if existing data indicate the presence of karst features in the vicinity. Initial geological investigation of the immediate and surrounding area of the proposed project site should be conducted to determine the presence and type of karst features.
- The identification and delineation of karst features should include the following: location, distribution, and dimensions of rock cavities; location, distribution, and dimensions of soil voids; depth and configuration of the rock surface; variation in the physical characteristics of the subsurface soils and rock; groundwater quality and flow patterns.

Access and Staging Area Management Recommendations

Staging areas are those short- or long-term sites within a construction or development area where most equipment and materials are stored. These areas are often accessed frequently, and when fuel and oil are stored here the potential for run-off and erosion in these areas may be high.

- Erosion and sediment controls should be installed and maintained to prevent discharge from the site.
- Staging areas for crew, equipment, and materials should be established well away from karst features such as caves, sinkholes, springs, and highly erodible soils when practical.
- Stationary fuel and oil storage containers should remain within a staging area or another confined area to avoid accidental introduction into the groundwater.

- Excess concrete and washwater from trucks and other concrete mixing equipment should be disposed of in an area well away from karst features, streams, and wetlands.
- If temporary roadways must be built, ensure that roadways are of low gradient with sufficient roadbed and stormwater runoff drains and outlets. Appropriate containment basins, silt fences, filter strips, etc. should be included for retention of storm water run-off as a means for reducing sedimentation introduction into karst features and groundwater.

Buffer Zone Management Recommendations

The buffer zone is the vegetated area immediately surrounding the karst feature, which helps slow runoff and filter out pollutants that might enter karst systems. A buffer zone of at least a 100-foot radius should be maintained on all sides around caves, sinkholes, and springs.

- Buffer zones located down slope of construction areas should be physically screened with sediment controls, such as silt fences or filter strips. Sediment controls should be monitored after rain and maintained for the duration of the project.
- General application of pesticides, herbicides, or fertilizers within the buffer zone should be prohibited to avoid contamination due to overspray or runoff. Fertilizer use or spot-application of pesticides and herbicides may be acceptable if appropriate nonrestricted chemicals are used.
- All buffer zones disturbed by the project should be revegetated immediately following or concurrent with project implementation. Native trees, shrubs, and grasses should be planted to ensure long-term stability in areas where the soil erosion threat is not critical. Annual non-native grasses such as rye or wheat may be planted in conjunction with native species to provide short-term erosion control. Areas judged to be subject to immediate soil loss due to steep slopes or other factors causing critical erosion conditions may be planted with non-native mixtures to ensure rapid establishment and erosion control.
- Post-construction evaluation of vegetation establishment should be conducted at 1-month intervals for at least 3 months after completion of the project. Any recommended sediment controls should be inspected at these times. If determined beneficial to soil stability and not adversely impacting site function and/or aesthetics, recommended sediment controls should remain permanent.

Karst Area Management Recommendations

Karst areas provide habitat for a diversity of highly specialized and sensitive vertebrate and invertebrate animals. These areas also provide an important filtration system for the underground water humans use and drink. For this reason, it is important to avoid rerouting waterways and drainage patterns in karst areas.

- All construction debris, refuse, discarded containers, and any other waste materials should be stored away from karst areas. Take care to contain this material to prevent its accidental introduction into caves, sinkholes, or springs as a result of cleanup activities, runoff, flooding, wind, or other natural forces.
- Sedimentation and erosion controls appropriate to soil type, water flows, exposure, and other site-specific factors should be implemented during all phases of construction.
- Sediment and erosion controls should be monitored periodically. Clean, repair, and replace controls as necessary.
- Final revegetation of disturbed areas should use native plant species. Grasses, such as rye or wheat, may be used with non-native mixtures initially to maintain soil stability until establishment of native vegetation can be completed. A monitoring program should be included in the project proposal to ensure successful revegetation efforts.
- All temporary erosion and sediment controls should be removed (unless removal would cause further disturbance) and disposed of within 30 days after final site stabilization is achieved or after temporary practices are no longer needed.
- All debris and excess materials should be removed and properly disposed of upon completion of project.

Cave Gating Criteria

Cave gates are steel structures built to protect cave resources by keeping out human intruders while allowing air, water, and wildlife to pass freely in and out. Cave gates have locking doors or removable bars so that authorized persons can gain access during appropriate seasons for necessary work. Poorly designed cave gates can harm wildlife and cave resources. Cave gating is not an automatic solution to cave conservation problems, and there are many reasons for not gating a cave. Technical knowledge and experience are required to gate a cave; for example, installing a gate cannot be done properly by a general welding contractor without the proper specifications, design, and on-site supervision by an experienced cave gater. Knowledge of cave ecology, especially bats, is necessary before a gate can be considered. Similar techniques are used for gating abandoned mines, which often harbor bats of great value. Some governmental agencies assist cave owners in cave gating, but first a decision guide must be followed, as discussed later.

A few rules of thumb can be followed for cave gates. Natural entrances should not be sealed, but opening a long-sealed cave also can cause problems for the cave unless some means of protection is devised. Gates should not be made of reinforcing bar (or *rebar*), as it is much too weak. Chain-link fences are easily breached but can be used around sinkholes if necessary. Do not construct any raised footings, stone work, or concrete walls on the floor or around a gate because they can hinder air exchange and change the temperature at the bats' favorite roosts. Gates should be tailored for the wildlife inhabiting the cave. A cave gate is not a substitute for good land management but is a last resort.

Limited space does not allow a full discussion here of the many construction techniques that have been developed for cave gating. Cave gate designs and specifications by the American Cave Conservation Association (ACCA), Bat Conservation International (BCI), and National Speleological Society (NSS) are available on the World Wide Web and in publications.

Cave Gate Styles

Depending on the requirements of the cave, the type of entrance, and the presence of bats and other wildlife, the design could specify a full gate, a half gate or fly-over gate (Fig. 2), a chute gate (particularly for maternal gray bats), a cupola or cage gate (Fig. 3), an enclosure, a fence, or no gate at all. For example, due to certain physical restraints, it may not be feasible to gate some bat caves that require the protection of a gate. Also, many caves that could be gated do not have to be gated because other modes of protection may work better.

It is important to rely on an experienced cave-gating expert. Leading organizations are ACCA, BCI, NSS, U.S. Forest Service, U.S. Fish and Wildlife Service, and the Missouri Department of Conservation, among others. ACCA's designs were adopted by BCI and many government agencies and have become the industry standard. These organizations conduct regional cave-gating workshops to demonstrate the proper decision-making process, design, and construction techniques for ecologically sound cave gates (Fig. 4). Construction of such gates has provided significant protection of colonies of endangered bats, such as grays, Indianas, and others, which has resulted in increases in their populations. Protection of other irreplaceable cave resources is another benefit of properly built gates. These cave-gating workshops may also lead to the formation of regional cave-gating groups made up of representatives from local organizations. The workshops include lectures supplemented by construction of actual cave gates under the direct supervision of cave-gating experts. Each gate is somewhat different, and various problems in funding, logistics, design, teamwork, safety, and construction must be solved.

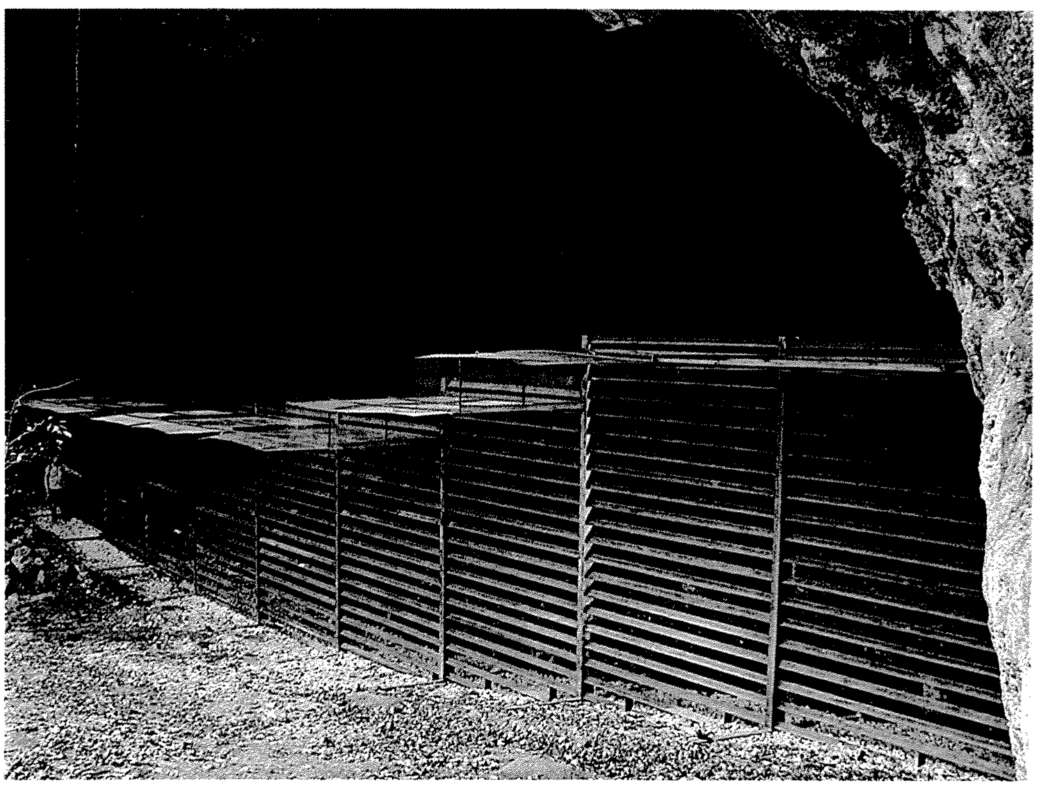

FIGURE 2 The half gate at Great Spirit Cave, Missouri, is 31 m wide and weighs 16 metric tons. It protects gray bats (*Myotis grisescens*) in the summer, Indian bats (*M. sodalis*) in the winter, and many other resources.

FIGURE 3 A cupola or cage style of cave gate allows bats to gain altitude and exit laterally, which is easier than flying up through a horizontal grate.

FIGURE 4 A cave-gating class builds a bat-friendly cave gate at McDowell Cave in Missouri. Note the T-bar stiffeners inside the end of the top horizontal bar which provide greater strength and an airfoil design for lower wind resistance. Proper spacing of the bars is essential.

Gates are now made stronger than in the past, but it is important to check and repair them regularly because any cave gate can be breached by determined vandals. Designs have evolved to foil attempts to tunnel under a gate or to destroy the door or lock. Specifications vary for different gate styles. Gates are usually made of mild steel angle iron. Stainless and Manganal steels may be used in corrosive environments, but they are more expensive, more difficult to cut and weld, and unnecessary in most applications. The design life of most mild steel gates may be 30 years.

Cave Gating Decision Guide

ARE THERE POOR REASONS NOT TO GATE THE CAVE? For example,

- Purely aesthetic objections to a gate while the cave's resources are being degraded anyway.
- It may "start a trend" towards too much gating.
- Because a few people consider themselves above the rules and may threaten the gate.

Score no points for any poor reasons not to gate.

ARE THERE POOR REASONS FOR GATING THE CAVE? For example,

- For fear of liability, which may be nonexistent; cave owners are protected by law in some states.
- For administrative convenience (instead of having a comprehensive conservation program).
- To keep wild animals or competing explorers out.

Score no points for any poor reasons to gate.

ARE THERE GOOD REASONS NOT TO GATE THE CAVE? For example,

- The gate, as designed, will not comply with current ACCA and BCI standards.
- A vigilant owner or manager lives nearby.
- Other controls can be used—road gates, signs, surveillance.
- Visitors probably will comply with a good permit system.
- Cave management experts are opposed to the gate.
- The cave gaters are inexperienced and overconfident.
- No one will commit to checking and maintaining the gate.
- The entrance is too small for a proper gate (e.g., a half-gate for gray bat maternity colony), or the environment or budget will not allow a good design.

Score one point each *against* gating for any good reason against gating that holds true.

ARE THERE GOOD REASONS TO GATE THE CAVE? For example,

- The cave is hazardous to casual visitors, and no other controls (permits and signs) are adequate.
- Endangered species inhabit the cave and can be bolstered by protection.
- The cave is a target for vandals, looters, and trespassers; a better clientele is desired.
- The cave has high value, is threatened, and can best be studied and appreciated with a good permit system combined with a gate.

Score one point each *for* gating for any good reason to gate that holds true.

FINAL RESULTS Add up the points for and against gating, and determine which seems more important. Other criteria may have to be considered.

Security Systems

In the near future, technology will allow cave conservationists to deploy electronic alarms and surveillance equipment in lieu of cave gates or to supplement gates that are frequently attacked. New sensors are becoming available that can distinguish human-sized intruders from bats and other small animals. The major option for a cave manager would be an audible alarm versus a silent alarm. The former may frighten off intruders or anger them, possibly leading to an attack on the equipment. A silent alarm would alert an authority, who could apprehend or warn the intruders. In the latter case, the key question would be "Who will respond, and how quickly?"

A few of the many options for these security systems are outlined below:

- Sensors for detecting humans could include light detectors, infrared light beams, motion detectors, pressure mats, and seismic detectors.
- Light detectors are available as data loggers, which record the time and date that a light illuminated the detector in the dark zone of the cave. Such data loggers may be used to measure the amount of traffic in well-traveled caves or to detect if anyone has trespassed into a closed cave, but the data are downloaded later and cannot determine anyone's identity. Similar light sensors can be linked to an alarm system that would alert a manager or law officer; however, it is usually necessary to install such sensors in the dark zone, which would leave the entrance and twilight zones unprotected.
- Invisible infrared light beams can be positioned at a certain height so that bats and wildlife are unlikely to trip them, and they can be deployed in the entrance, but false alarms may occur. They require continuous electrical power, as do motion detectors. The latter might be tuned to ignore small animals, and they can be placed in the entrance.
- Pressure mats can be buried just below the surface and can be linked together to create a security zone. Such a mat uses no electrical power until it is triggered by someone stepping on it.
- Seismic detectors can be concealed and tuned to respond only to the seismic shaking caused by a human walking or by earthquakes.

All of the above sensors must be linked to a system that conveys information out of the cave, either via a cable that must be concealed or by wireless relays. The system can then trigger an automated message or radio call to an authority.

Concealed video and still cameras are routinely used by law officers to obtain evidence leading to the arrest and conviction of law breakers. They are somewhat labor intensive and vulnerable to attack if noticed by culprits, but they are easily deployed to new sites as needed.

MANAGEMENT AND EDUCATION

Cave Management

A general goal of land management over a cave is not to alter the landscape very much or build infrastructure such as sewer lines, pipelines, roads, and the like, especially if the cave contains streams and species of concern. Paving over the top of a cave cuts off much of its water supply. Emplacing septic systems may relegate the cave to a sewer. For prescribed burns, smoke must not be allowed to enter caves, especially those occupied by endangered species such as bats. For example, if a hillside is burned under certain meteorological conditions, a cold front could carry the smoke down the slope and into a cave, especially if it is a cold-air trap. This smoke could be harmful for hibernating bats. Conversely, smoke could rise up a hill and into a cave that serves as a summer roost and is a warm-air trap.

Cave Restoration

Many cavers and cave managers favor cave cleanup and restoration projects for multiple reasons. Graffiti removal may seem to be only an aesthetic pursuit, and it usually does not directly help restore wildlife in the cave unless toxic materials are removed. However, one has to consider how some caves become targets for vandalism. If a government agency or cave owner allows people to vandalize and litter a cave, then many visitors may assume that it is all right and will continue to do so. Inaction could be considered as condoning the bad behavior. Vandalism sometimes extends to harassment or killing of bats and other wildlife. Trashy caves give rise to ignorant behavior and serve as places to misbehave; this behavior then spreads to other caves. The same behavior is seen in illegal dumping grounds, where a few leave some household trash on public or vacant land. If no one objects, others then opportunistically dump there, and the problem escalates. Signage does not seem to help at that point.

Volunteers can be enlisted to photograph, document, and then carefully remove graffiti. Such a conservation project helps to restore public respect for a cave, especially when the work is publicized and the effort explained. An important public education need is filled in this way and it is an important opportunity to educate volunteers about cave wildlife.

Significant signatures and markings usually are left in place or documented in a file or database before removal. Various rules and laws define the type and age of markings that must be preserved in place, so it is best to check with the appropriate state historical program office about such requirements. More stringent requirements may be practiced by conservationists on their own initiative.

An example of effective restoration is Little Scott Cave in Missouri, managed by the Missouri Department of Conservation (MDC). This cave is near a highway, and it became a target for repeated vandalism, including extensive graffiti, breakage, the death of two bats by spray painting, the littering of hundreds of beer cans from underground parties, and occult ceremonies. Cavers repeatedly tried to clean up the mess and notified the MDC. Finally, the MDC gated the cave in April 2000 and simultaneously instituted a easy procedure for getting access to the cave. Those interested in entering the cave can call or e-mail the agency to get the combination to the lock on the cave gate, as long as they can answer some basic questions about caving etiquette, gear, and safety. MDC awarded grants to two grottos (caving clubs) to clean up the cave with low-impact techniques in which no chemicals were used. This work was noted in local newspapers and in Elliott and Beard (2000).

Before restoring a cave to a more natural state, it is important to consider how altered the cave is and define realistic goals for the restoration project. Is it a show cave with many years of accumulated change and little hope of complete restoration, or is it a wild cave that is not so ecologically disturbed? In a show cave, nuisance species may be present, such as cyanobacteria near electric lights, exotic species in cave lint along trails, or epigean (surface) wildlife that is attracted to artificial food sources in the cave. The following questions should be asked before planning projects:

- Do we know what native species should be in the cave?
- How can we restore the cave to a more normal aesthetic and ecological state without harming the native species?
- To what historic period should we restore the cave?

The historic period is an important aspect of ecological restoration for the benefit of bats, the populations of which have declined drastically within the last few decades. Some species of bat can be protected by bat-friendly structures (e.g., a fly-over gate or fence for some species or a properly designed gate for species that will fly through). Some roosts may return to the maximum past population, as measured by ceiling stains, but most colonies do not fully recover. Some bat species (e.g., Mexican free-tails) will not tolerate a gate at all. No cave is ever completely restored to its former aesthetic or ecological state, but a proper biological inventory and careful project planning will increase the success of restoration efforts.

It is important not to remove decayed wood and organic matter from a cave without first checking it for cave life, which may have colonized it over many years. An NSS handbook now exists to aid in proper cave restoration and conservation.

Prioritizing Caves

Cave protection usually involves crisis management: Caves and cave life that are under the greatest threat receive the most attention. Rarely do we look at caves over a large region and consider which ones are most deserving of protection before they become degraded. Caves can vary greatly, and comparing and ranking them would seem to be a daunting task. In some states, adequate records exist that would allow cavers, managers, and scientists to evaluate and prioritize caves for protection. Ideally, a cave would receive a numerical score for each of its resources. A composite score could then be derived for the entire cave and could be used for ranking and prioritizing caves or karst regions. A cave could be scored for its length, depth, hydrology, biology, geology, paleontology, archaeology, history, speleothems, aesthetics, recreational value, and threats against it. Each aspect could be scored in various ways; for instance, for biology, we could consider the total number of species present, how rare or endemic the troglobitic species of the cave are, the importance of the cave to endangered species, and its overall biodiversity. Small numerical differences between caves would not be important, as the rankings would be used as a general guide.

Most states have a natural heritage database, usually within a state agency, and many states have a state cave database, usually managed by a nonprofit cave survey organization. Increasingly, these databases are being voluntarily shared by the two types of organizations for the purpose of protecting significant caves from road and land development and other threats. The precise locations of caves, especially those on private lands, are protected in each system so as not to draw the attention of potential intruders.

Public Education

Cave conservation includes publications, videos, and educational programs for the public. The Missouri Department of Conservation and other organizations offer workshops on cave ecology for biologists and teachers (Elliott, 2002). It is not necessary for the public to become experienced cavers to achieve conservation goals, but it is helpful to inform the public about all the resources offered by caves. Two concepts are important to convey to the public: (1) caves operate on a much longer time scale than surface landscapes and are essentially nonrenewable resources, and (2) our caves have already lost so much that when we visit a cave we should give something back to it. For example, we can pick up trash, teach others about cave conservation, or be advocates of the cave in regard to those who have authority over it.

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Links and references with an asterisk are available at the Biospeleology web site: http://www.utexas.edu/depts/tnhc/.www/biospeleology

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