

# Protecting Caves and Cave Life

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## Abstract

Some human activities threaten caves and cave life, causing disrespect for caves, habitat loss, declines in populations, or even extinction. The protection of these resources involves management of the landscape above the cave as well as the details of cave gates and security systems. Cave restoration can improve conditions for cave life but may also cause problems if not properly done. The spread of White-nose Syndrome in North American bats has changed our approach to accessing caves for all activities. "Clean caving" and decontamination are precautions against the accidental spread of wildlife diseases. Public education about cave and karst conservation is essential because many are not aware of the gradual degradation of cave resources and threats against cave life.

Key words: cave protection, gating, conservation, restoration, bats, White-nose Syndrome, Amphibian chytrid fungus

## I. Protecting Cave Life

### Threats to Cave Life

Caves are often thought of as unchanging environments, but with modern instruments 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 truly cave-adapted species, called troglobites or troglobionts, but may have troglophiles (cave-loving species) and troglonexes (animals, like 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 have deep or large entrances. Such entrances allow cold air to flow inward during strong cold fronts. In contrast, in summer gray bats and 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 for young bats in the summer, >30°C in grays and >40°C for free-tails .

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 caused severe declines in numerous bat species (Elliott, 2000), but since 2006 White-nose Syndrome (WNS) has killed more than 1 million bats in the eastern US. Bats will be discussed in more detail below.

Amphibian chytrid fungus, *Batrachochytrium dendrobatidis* (Bd), was found in southern Missouri caves by Rimer and Briggler (2010). This disease has killed many amphibians worldwide, but this was the first

report from caves. Eight of 12 caves sampled were positive in all five counties visited. Five of the seven species of salamanders and frogs sampled were positive, with an individual infection of rate of 31%. Chytrid was confirmed in the grotto salamander, *Eurycea spelaea*, the first report in a troglobite. It is not known if humans spread the chytrid spores into caves, but once in an area it can spread via groundwater, humans, or pickerel frogs, which use caves seasonally. Chytrid and WNS in caves point to the need to practice "clean caving" and decontamination as a precaution against the spread of wildlife diseases.

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 with wastes, such as ammonia and other nitrogen-based compounds, in infiltrating waters, can bring 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 wells can lower karst 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 salamander, amphipod 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 example of Shelta Cave, below).

### **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. Since some troglobitic species are endemic to a single cave or a small cluster of caves, and 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, which consume night-flying insects, some of which are agricultural, forest, or public health pests (Cleveland et al. 2006). In Missouri, about 800,000 gray bats, which roost in caves year-round, consume 490 metric tons of insects per year (Missouri Department of Conservation 2010). 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 important.

Declines in North American cave bats became noticeable in the 1950s. Six of the 47 continental U.S. bats are currently on the U.S. endangered species list and additional species have been petitioned for listing. 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, *Myotis sodalis*, lost significant numbers through

disturbance of their hibernacula and improper gating decades ago. If such bats cannot hibernate deeply, they use up their body fat too fast, 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 Valdina Farms Sinkhole, a large cave near San Antonio, Texas. 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 ghost-faced bats, *Moormoops megalophylla*. A salamander, *Eurycea troglodytes*, which lived only in that cave, probably is 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 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, 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, causing 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 from the loss of gray bats apparently caused a domino effect in Shelta Cave, in Huntsville, Alabama. Shelta had the most diverse cave community known in the southeastern U.S., but land development encroached on the cave in the 1960s and the townspeople were concerned about youths entering the cave. The cave 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 affected the colony too. 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). The gate was replaced with a high fence around the area in the early 2000s, and some bats returned.

WNS is the most severe threat to cave and mine-hibernating bats to date, killing more than 1 million bats of nine species from 2006 to 2010 in the eastern US and Canada. As the fungal infection, probably originating from Europe, spread from the northeastern US into Canada and south and west as far as Oklahoma, many agencies and landowners prepared for the worst and wrote response plans. Thousands of caves were closed or restricted to human access to avoid possible spread of the infectious, microscopic spores of *Pseudogymnoascus* [formerly *Geomyces*] *destructans*, the apparent causative agent. Bats spread the spores, but it is not clear how much was spread on unwashed caving gear and clothing. Strict decontamination rules are required for anyone to enter many caves now, and an effective treatment is not yet in sight. It is clear that more and better cave gates and alarm systems will be needed for important bat caves, but also more research, bat monitoring, and disease surveillance. It is impossible and undesirable to gate all caves containing bats, which might number 90,000 of perhaps 100,000 caves in the US. Even noncolonial bats are affected, such as *Perimyotis subflavans*, the tri-colored or eastern pipistrelle bat, and sites remain infectious for long periods after bats have died off. Captive holding of bats for study, treatment, or even propagation, may be the last resort for some species that are rapidly declining, such as *Myotis lucifugus*, the little brown bat. It is likely that WNS will spread to the western US and even into the highland tropics, wherever bats hibernate in chilly caves and mines.

Many cave bats produce small amounts of guano during migration and hibernation. If WNS causes a decline in gray bat maternity caves in summer, there could be a decline in nutrient input to some cave systems in the southeastern US. Some conservationists have proposed replacing lost gray bat guano in caves, but there are problems in that strategy:

1. Many caves with high biodiversity lack gray bats (Elliott 2008), so loss of gray bat guano is not a general threat to all cave biodiversity.
2. Large-scale guano transfer is an untested idea. My search of 25,000 references in the American cave biology literature found 32 reports on guano, but none was an experimental transfer of bat guano from one cave to another.
3. Large-scale guano transfer from one cave to another might introduce infectious *Pseudogymnoascus destructans* spores, whereas many are trying to practice contamination control within caves, as well as decontamination before and after entering caves.
4. Large-scale guano transfer from a gray bat cave would disrupt the source cave. Other types, such as freetail guano, contain different fauna and flora, and it might be biochemically harmful to the recipient community of guanophiles.
5. The total energy contribution of gray bat guano to a cave ecosystem has not been measured well. Many nutrients come from rotting detritus, organics in infiltrating groundwater, bacteria, fungi, dead pickerel frogs and salamanders, cave crickets, etc. Most of the carbon flux in two Missouri cave streams that were studied is from allochthonous sources (Lerch et al. 2000, 2002).
6. Wildlife agencies and researchers do not have the manpower for large-scale guano transfer in a scientifically controlled fashion.

Further discussion of bats may be found below in Cave Gating Criteria and Cave Restoration.

## II. Cave Preserve Design

Cave conservation encompasses many aspects, which can be applied to developed show caves as well as to “wild” (unmodified) caves. Show caves, however, have special problems, such as growth of cyanobacteria and plants near trail lights, accumulation of “cave lint” and trash, and general disruption of the cave’s ecology. Some show caves avoid the use of trail lights but still have good trails; the 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 rules of access to the cave. Many publicly owned caves can be left “open” to the public as long as they do not vandalize or disturb cave life.

Besides WNS considerations, some caves require a permit system for entry, based on flooding hazards or other considerations of safety or sensitivity. Usually a “permit” or “restricted access” cave would be gated to control access, but appropriate signs are needed to inform people of the availability of permits (fig. 1). 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. Heretofore, a few eastern American caves harboring gray bats in the summer and Indiana bats in the winter, were accessible between bat seasons in May and September, but now few are managed that way.

Cave preserves have been set aside for the protection of endangered, nonbat species. Too often, however, such preserves surround only the entrance area and do not include the entire extent of the cave, much less the recharge area to the cave (often called the "watershed" in American usage). It is essential to have good scientific information about the cave: an accurate map, a description, inventories of the cave's resources and a hydrogeologic assessment. The latter 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 cave's water sources, which makes it possible to more scientifically manage the landscape.

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 entrances 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 in Texas lacking streams have been as small as one hectare just for the protection of terrestrial invertebrates. 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. Krejca et al. (2002) recommended a minimum preserve size of 28-40 ha (69 to 99 acres) around a small cave or cave cluster, as well as maintenance and adaptive management against other threats, such as red, imported fire ants (*Solenopsis invicta*). 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 it 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 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 2,331 ha. The cave was under two private properties for many years with extensive forest cover, losing streams, light farming, and cattle production. Even though the cave was managed by the Ozark Underground Laboratory, gray bats gradually declined for several reasons. In the 1990s 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 contributed to the decline too. Today, more of the cave's recharge area is under careful land use, but it remains to be seen if the cavesnail will increase again (USFWS 2001, Elliott and Aley 2006, Elliott et al. 2008).

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 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, and could be considered as stream buffers removed at a distance, and 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 (Elliott, 1994).

Some states publish “Karst BMP” sheets, providing the “best management practices” for construction and other ground-disturbing projects on karst. These BMPs should be applied to prescribed burns and other conservation projects. Different types of karst may require different BMPs. The essentials of a karst BMP are summarized below:

1. A karst BMP should generally describe karst geology, hydrology, and biology, and emphasize that karst resources are easily damaged by sediments, spills, dumping, and construction activities.
2. Identification of sinkholes, recharge areas, sinking streams, gaining streams, caves, and springs is needed to avoid problems. Consult geological, speleological, and state natural heritage surveys. Cave maps are useful for determining the extent of a cave. Dye-tracing studies can delineate the recharge area for a cave, sinkhole, or spring. Some karst features are hidden under certain soils.
3. Staging and storage areas with fuel and oil should be located away from karst features, and must have erosion controls. Concrete and wash water is disposed off-site. Temporary roads should not be steep, and should have runoff controls.
4. Buffer zones of at least 30 m (100 ft.) should be maintained around caves, sinkholes, and springs. Sediment controls are installed upslope of buffer zones. Pesticides and prescribed burning are generally banned within buffer zones.
5. Disturbed areas should be re-vegetated or allowed to regrow after a project. Annual nonnative grasses such as rye or wheat may be planted in conjunction with native species to provide short-term erosion control. Areas subject to erosion may be planted with nonnative mixtures for rapid establishment and erosion control. Follow-up inspections are required and continued controls may be necessary.
6. Avoid altering drainage patterns, and properly dispose of debris and trash away from karst features. Temporary erosion controls should be removed after serving their purpose, but some permanent controls may be needed.

### **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. Poor cave gates can harm wildlife and cave resources, but good ones can improve conditions for bats and other wildlife. 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 needed to gate a cave; for example, it cannot be done properly by a general welding contractor without providing specifications, a design and on-site supervision by an experienced cave gater. Knowledge of cave ecology, especially bats, is necessary before a gate is considered. Similar techniques are used for gating abandoned mines, which often harbor bats of great value. Some governmental agencies and cave conservation groups assist cave owners in cave gating, but first a decision guide must be followed (below).

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”; it is much too weak. Chain link fences are easily breached, but can be used around sinkholes if necessary; stronger “vertical bar fences” are

now preferred. 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 and other resources in the cave. A cave gate is not a substitute for good land management, but it 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), Missouri Department of Conservation, and the National Speleological Society (NSS) are available on the World Wide Web and in publications.

### **Cave Gate Styles**

Depending on the needs of the cave, the type of entrance, bats and other wildlife, the design could specify a full gate (fig. 2), half gate or fly-over gate (fig. 3), window or chute gate (particularly for maternal gray bats), cupola or cage gate (fig. 4), bay window gate, enclosure, fence, or no gate at all. For example, some bat caves that may need a gate for protection are not feasible to gate for certain physical reasons. Many caves that are feasible to gate ought not 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, U.S. Forest Service, U.S. Fish and Wildlife Service, the Missouri Department of Conservation, NSS, and others. ACCA's designs were adopted by BCI and many government agencies, and have become the industry standard.

The above organizations teach annual, regional cave-gating workshops to demonstrate the proper decision-making process, design, and construction techniques for ecologically sound cave gates (fig. 2). These gates have resulted in significant protection and increases of colonies of endangered bats, such as grays, Indianas, and others. Protection of other irreplaceable cave resources is another benefit of properly built gates. Such workshops may also lead to the formation of regional cave-gating groups from different organizations. The workshop comprises lectures supplemented by building a real cave gate under the direct supervision of cave gating experts. Each gate is somewhat different, and various problems in funding, logistics, design, safety, teamwork, and construction must be solved.

Gates are now made stronger than in the past, but it is important to check and repair them 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 or modified steel "angle iron," although stainless and manganal steels may be used in corrosive environments. The latter are more expensive and are unnecessary in most applications. The service life of most steel gates may be 30 years.

## **Cave Gating Decision Guide**

### **1. 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.

### **2. Are there poor reasons for gating the cave? For example,**

- For fear of liability, which probably is 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.

### **3. 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.
- Technical reasons: The entrance is too small for a proper gate (e.g., half gate for gray bat maternity colony), or the environment or budget will not allow a good design.

Score one point each **against** gating if any good reasons against gating hold true.

### **4. Are there good reasons to gate the cave?**

- 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 needed.
- The cave has high value, is threatened, and it can best be studied and appreciated with a good permit system combined with a gate.

Score one point each **for** gating if any good reasons hold 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**

Electronic technology now allows cave conservationists to deploy alarms and surveillance equipment in lieu of cave gates, or to supplement gates that are frequently attacked. Light, vibration, and magnetic sensors are becoming available that can distinguish human intruders from bats and other small animals.

An 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 vandalism of the equipment. A silent alarm would alert an authority, who could apprehend or warn the intruders. The key question to consider in designing a silent cave alarm system is, "Who will respond, and how quickly?" If law officers or managers cannot respond within one hour to apprehend the intruders, then the alarm system probably will not be a deterrent.

There are many options for these security systems, a few of which are outlined below. Sensors for detecting humans could include attractive objects, pressure mats, light detectors, infrared light beams, motion detectors, vibration detectors, magnetic detectors, and infrared trail cameras with invisible flash.

The cheapest intrusion detector is an attractive, inexpensive object, like a coin placed in a known place in the cave. If it disappears since the previous visit, then the manager knows that an unauthorized person or a packrat has been there.

Pressure mats were designed for indoor use. Such mats are switches using no electrical power until they are triggered by someone stepping on them. They are not reliable sensors unless they are placed on a flat, hard surface, then covered with soil. They can be linked together to create a security zone. It may help to place something just beyond the mats that will attract an intruder and lead him to step on the mat unknowingly. A simpler method might be a sign with a momentary switch to the system labeled "Do not touch this."

Light detectors are available in custom alarms or 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.

Custom light sensor alarms can alert a manager or law officer via radio, telephone, or satellite communication to the internet. However, it is usually necessary to install such sensors in the dark zone, leaving the entrance and twilight zone unprotected. They require continuous electrical power, as do motion detectors, which can be accomplished with solar panels and batteries or other power sources and cables, which must be concealed.

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. Arrays of infrared beams or "beam breakers" are now used to monitor elevated bat activity during WNS-related activity.

Vibration detectors can be concealed and tuned to respond only to the seismic shaking caused by a human walking, or by earthquakes. They are more effective when attached to a cave gate, but like all cave electronics, they must be hardened against the harsh, damp, mineral-rich cave atmosphere and flooding.

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 telephone call, radio call, or satellite signal 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. The image must be clear enough to identify the suspect. They are somewhat labor-intensive, and vulnerable to attack if the culprit notices the equipment, but they are easily deployed to new sites as needed.

### **III. Management and Education**

#### **Cave Management**

A general goal of land management over a cave is to not alter the landscape 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. Installing septic systems may relegate the cave to a sewer.

In prescribed burns one should insure that smoke does not enter caves, especially those occupied by endangered bats. For example, if one burns a hillside under certain meteorological conditions, a cold front may carry the smoke down the slope and into a cave, especially if it is a cold-air trap. This could be harmful for hibernating bats. Conversely, smoke could rise up a hill and into a cave that serves as a summer roost, because it may be 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 assume that it is all right to do so, and they will continue. Inaction is considered condoning the bad behavior. Vandalism sometimes extends to harrassment or killing of bats and other wildlife. Trashy caves become training grounds for ignorant behavior, places to act up, and this behavior spreads to other caves.

The same behavior is seen in illegal dumpgrounds, where a few leave some household trash on vacant land. If no one objects, others then opportunistically dump there and the problem accelerates. Signage does not seem to help at that point.

We can involve volunteers in photographing, documenting, then carefully removing graffiti. Such a conservation project helps to restore public respect for a cave, especially if we publicize the work and explain the effort. An important educational need is filled in this way. We can also take the opportunity to educate volunteers about wildlife during the project, which they appreciate.

Most graffiti that this author has seen is not historically significant, but important signatures and markings usually are left in place or else documented in a photographic file or database before removal. Certainly aboriginal and other valuable markings and art must be protected. 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 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 and gross graffiti, breakage, spray painting two bats to death, hundreds of beer cans from underground parties, and candles from occult ceremonies. Cavers repeatedly tried to clean up the mess and notified MDC. Finally, MDC gated the cave in April 2000 to stop the cycle. MDC simultaneously instituted a easy procedure for getting access to the cave by telephone interview. MDC awarded grants to two grottos (caving clubs) to clean up the cave using 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, one should 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: cyanobacteria near electric lights, exotic species in cave lint along trails, or epigeal (surface) wildlife that is attracted to artificial food sources in the cave. The following questions should be asked before planning projects:

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

The historic period is an important question in ecological restoration for bats, many of which have declined drastically within the last few decades. Some species of bat can be protected by bat-friendly gates. Some roosts may return to the "maximum past population" as measured by ceiling stains. Most colonies do not fully recover. Very large bat colonies (e.g., free-tails) may not tolerate a full gate at all because of the bottle neck, traffic jam, and acoustical confusion it may cause.

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 (Elliott 2006).

No cave is ever completely restored to its former aesthetic or ecological state. Proper biological inventory and project planning will improve the success of restoration efforts.

### **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 deserve protection before they become degraded.

Caves can be very different, and comparing and ranking them seems difficult. In some states adequate records exist to 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 can then be derived for the whole cave, and used for ranking and prioritizing caves or karst regions. A cave could be scored for its length, depth, hydrology, biodiversity, value as a bat cave, geology, paleontology, archaeology, history, speleothems, aesthetics, recreational value, and the threats against it. There are various ways to score each aspect; for instance, for biodiversity one can consider the total number of

species present, how rare or endemic the cave's troglobitic species are, the cave's importance to endangered species, and its overall biodiversity. Small numerical differences between caves are not important, and the rankings are 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 carefully shared among organizations for the purpose of protecting significant caves from road and land development and other threats. The locations of caves, especially those on private lands, are protected in each system so as not to draw the attention of potential intruders. Coordinates can be truncated to coarse values for mapping over large areas without revealing cave names or precise locations.

## Public Education

Cave conservation includes publications, videos and educational programs for the public. MDC and other organizations offer workshops on cave ecology for biologists and teachers.

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 connected to 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. 2) Our caves have already lost so much—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 advocate for the cave and the bats to those who have authority over it. Even for those who do not enjoy caves, it is important to know that bats provide ecosystem services to us in the form of insect control, and that valuable karst groundwater resources and caves are highly related.

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Fig. 1 A 2010 version of a cave sign with information on White-nose Syndrome.



Fig. 2 The National Cave Gating Workshop, 2009, built a bat-friendly, full cave gate at Cliff Cave, Missouri, to protect multiple resources, including endangered Indiana bats.



Fig. 3 A large half gate or fly-over at Great Spirit Cave, Missouri, completed 2002. The gate weighs 18 metric tons and measures 31 m wide by 5 m high. It protects gray bats, *Myotis grisescens*, in summer, Indiana bats, *Myotis sodalis*, in winter, and multiple resources in this Natural Area cave.



Fig. 4 A cupola or cage gate over a sinkhole entrance, which allows bats to gain altitude and exit laterally, easier than flying up through a horizontal grate.

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