**Part 2 Section A—Identifying and Protecting Cave Resources**

# Biological Dos and Don’ts for Cave Restoration and Conservation

**William R. Elliott**

Coexisting harmoniously with a cave’s ecology is extremely important for planning cave restoration projects, protecting cave life, and creating low-impact guidelines for cavers. This chapter targets the conservation of cave macrobiology—cave life that you can see with the unaided eye. Conservation of microscopic cave-dwelling organisms is discussed in the chapter by Boston, Northup, and Lavoie. (See microbial habitats, page XX.)

This chapter targets the conservation of cave macrobiology—cave life that you can see with the unaided eye.

Before restoring a cave to a more natural state, 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 we might ask if *nuisance* species are present—perhaps cyanobacteria thrive near electric lights; perhaps *exotic* (nonnative) species live in cave lint along trails; or perhaps surface wildlife is attracted to artificial food sources in the cave. No cave is ever completely restored to its former aesthetic or ecological state. Proper biological inventory and project planning will increase the success of restoration efforts.

For both show caves and wild caves, ask questions 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 time period or prior natural condition should we restore this cave—10 years ago, 100 years, pre-European?

## Restoration Dos

Follow a few simple principles to keep restoration goals in sight.

- Plan the project’s scope and ask basic questions about the desired outcome.
- Enlist the help of a cave biologist to compile a species list for the cave. (If no species list is available, use lists for similar caves in the area as a guide.)
- Ask the cave biologist to lead a bioinventory trip into the cave, update the species list, and make notes on cave microhabitats and sensitive areas before the restoration commences.
- Ask the biologist to examine cave lint and manmade woodpiles that you may want to remove. These areas can be *biological magnets* for native cave species because of the shelter, food, and higher moisture content in the lint or woodpile (Elliott 1992, 1997).
- Schedule the cleaning of special habitat areas over an extended time—cleanup in stages will allow fauna to migrate to other areas

**Best Management Practices**
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For cavers and cave managers, best management practices (BMPs) are guidelines for protecting cave or karst resources. BMPs originated as a method to help land managers comply with environmental regulations.

Future BMP revisions will be based on scientific research, monitoring results, and technological improvements. The following are examples of current BMPs associated with caves and karst.

Sometimes we walk a thin line between diverting water away from sinkholes and maintaining recharge.

It may be good to divert polluted runoff from streets and parking lots away from sinkholes and caves, but it may be detrimental to divert all runoff and diminish sources of water. Elliot (2004) provides a karst BMP that applies to many areas.

Another BMP advocates the use of

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and biofilms to recover. (A *biofilm* is a thin layer of sediment, organic matter, and bacteria or fungi, on which small arthropods, like millipedes, feed. See biofilms, page XX.)

- Remove glass, metal, wiring, and other trash if it has been checked for small cave dwellers. Gently brush or blow small creatures from the trash onto the floor, or have a cave biologist examine them. Some old trash is historical—contact a historical archaeologist to look things over. Historical items from early tourism have been lost to the good intentions of cleanup crews. (See historical preservation, page XXX.)
- In show caves, various methods have been used to control photosynthetic organisms that grow near electric lights. Sodium hypochlorite (household bleach), formaldehyde, hydrogen peroxide, and steam generators have been used to temporarily reduce algae and other lamp flora. However, these methods have no lasting effect and tend to indiscriminately kill other cave-dwelling biota. (See algae control, page XXX.) Growth can be better controlled through selection of light wavelength, reduction in wattage, or light-shielding and redirection. Current best practice is moving toward solutions provided by new lighting technologies. (See lamp flora control, page XXX.)

## Restoration Don'ts

- Don't disturb bats or other wildlife while restoring the cave.
- Don't disturb or remove anything from a biological study site.
- Don't indiscriminately use chemicals. In rare cases, if manufactured chemicals are deemed appropriate, then completely remove residue and byproducts from the cave. (See anthropogenic, page XX.)
- Don't contaminate adjacent areas with water containing sediments, chemicals, wastes, or nutrients.
- Don't remove cave lint or manmade woodpiles in one step, unless a qualified cave biologist has determined that the area has few or no inhabitants. Drastic removal may *trap out* the small creatures that have migrated into the area and reproduced there over many decades. Consider leaving a small residue of lint or wood in hidden areas at the site if small numbers of creatures are using it (Elliott 1992, 1997).
- Don't remove natural food sources for cave life, such as sticks and leaves, or corpses and droppings of wood rats, mice, raccoons, ringtails, bats, crickets, frogs, and others. Such food sources may present opportunities for cave biologists to study species rarely seen or not previously known in the cave. Removal of naturally occurring organics may be justified for scientific sampling or for restoration of the natural nutrient balance in the cave.
- Don't install cave gates, modify the entrance, or move anything within the cave if it could significantly alter air or water flow, or hinder the movements of bats and other wildlife (Elliott 1997). Digging into an entranceless cave would be an exception, but conscientious gating decisions should be made in favor of conservation. (See virgin digs, page XXX.) Consult the latest gating designs of the American Cave Conservation Association, Bat Conservation International, and the National Speleological Society (Vories and others 2004), and use experienced cave gate designers and welders. (See cave gating, page XXX.)

## Conservation Dos

Cavers need a few guidelines to coexist harmoniously with cave life during caving trips.

- Learn more about cave life, especially sensitive species and *species of concern* (rare, threatened, or endangered species). Entering some caves or areas during the wrong season or ignoring posted warnings may be a violation of state or federal law, even on private land. The NSS website <http://www.caves.org> or members of the NSS Biology Section and the Biospeleology website <http://www.utexas.edu/depts/tnhc/biospeleology> are good sources of information.
- Report sightings or provide photos of cave wildlife to the cave owner or manager and, if possible, to scientists who may be documenting species records in the area. Scientists at state or federal agencies, universities, or museums often handle the reporting.
- Be careful in cave entrances in the spring, when eastern phoebes, vultures, swallows, and other birds may be nesting and rearing young. Inform others so they can avoid accidentally disturbing wildlife anywhere in the cave.
- Mark narrow paths through cave passages to avoid trampling habitats for cave-dwelling species, speleothems, or other features. Consider placing small, well-positioned signs in the cave to warn others of bat roosts, crayfish, or cavefish habitat, and other sensitive areas. (See trails and signs in caves, page XXX.)
- Go equipped to carry out all personal waste products—urine, solid waste, vomit, spit, and trash. Cave communities are often adapted to low levels of nutrients, and we should not add to the mix. (See human waste, page XX and page XXX; also see packaging human waste, page XXX.)
- Work with others to determine the maximum number of people per cave entry and the maximum number of trips per year (or other time interval). This limitation would be the carrying capacity for human visitation to a cave. The term *carrying capacity*, borrowed from ecological science, means the population size of a species that an area can continuously support. In some caves, carrying capacities for humans should be established and monitored. It is not easy to calculate the number of cavers or trips that can be tolerated by a cave. Some cave stewards set reasonable limits and carefully observe the results over long periods of time. Cave registers and permit systems are effective monitoring tools when coupled with good bioinventories (Elliott 1997). (See cave inventories, page XX.)
- Become more aware of current best management practices (BMPs) for caves and karst. (See BMP sidebar, page 42; also see current best practice, page XX and strategies, page XXX.)

## Conservation Don’ts

- Don’t allow people to take pets, horses, or vehicles into cave entrances.
- Don’t make loud noises. Shrill or loud voices and sounds will disturb nesting birds, roosting bats, and other wildlife.
- Don’t build fires near cave entrances or inside caves. Fires and smoke can kill bats, birds, insects, and other animals.
- Don’t smoke in caves.
- Don’t use toxic chemicals in caves. If manufactured chemicals are

retention/filtration basins to clean up routine runoff and to retain spills before they go underground (Olson and Schaefer 2002).

Forested buffer zones are necessary for the health of some cave systems. For example, in the midwestern U.S., forested riparian corridors should be maintained and human visitation should be monitored to help protect gray bat populations in caves.

Karst management guidelines have been published in various government and consulting reports (Elliott 2000). Cave management guidelines are usually based on inventory information and are specifically designed for the protection needs of each cave. (See cave

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deemed appropriate, then completely remove residue and byproducts from the cave. (See anthropogenic chemicals, page XX.)

- Don't disturb bats while caving. Various bat species use caves for nurseries, hibernation, and bachelor colonies. Two especially sensitive times in the United States are May through July, when many bats give birth and rear young, and November through April, during hibernation. These times vary depending on the latitude and the species. (See hibernating bats, page XX.)
- Don't heavily disturb streams, especially those with *stygobites* (cave-adapted fish, crayfish, salamanders, or other aquatic species). Cavers should go single-file or stay out of the water if travel excessively disturbs the bottom.
- Don't drastically change water flow patterns, drain pools, or make alterations that could affect stream scouring or sedimentation, especially in areas inhabited by *stygobites* (aquatic troglobites). For instance, blowing out or draining a rimstone dam could strand or kill cave life. (See hydrologic problems, page XXX-XXX.)
- Don't collect cave life unless you possess the proper permit for scientific studies, and have the owner's or managing agency's written permission. For example, in Missouri, regardless of other federal, state, local, or private permitting requirements, you must obtain a Wildlife Collector's Permit from the Missouri Department of Conservation to collect any cave life. Other states have similar laws.

## Examples of Ecological Disturbance in Show Caves

A show cave sometimes accumulates unwanted nutrients and materials that gradually disturb the cave's ecological balance. Except for bat caves with large amounts of guano, caves are typically nutrient-poor environments and the cave-adapted species living there are adapted to a slow way of life.

Some show caves eventually lose their native wildlife as a result of human disturbance. Structures and development modifications influence changes in temperature, airflow, and humidity. Cyanobacteria and mosses often grow around show cave lights. Accumulations of cave lint, trash, wood, and even human waste can influence habitat changes. In a few extreme cases, show caves have been contaminated by leaking septic systems and sewer lines, causing overgrowths of bacteria and fungi, and resulting in invasions of exotic species that replaced the native cave species.

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### Electric Lights

Algal growth in show caves is stimulated by electric lights and restoration is often difficult and time-consuming (Aley 1972). In Carlsbad Caverns National Park, Aley and others (1985) conducted studies on exotic flora and microflora and identified 26 species of algae, plus moss protonema and two ferns.

Hundreds of species of algae were found growing in the cave. Approximately 70% of the organisms identified were cyanobacteria, 20% were green algae, and 10% were moss protonema. Many of the algal genera and three of the algal species in Carlsbad Cavern have also been found growing in total darkness in other caves. (See algae, page XXX.) Algal growth, once abundantly established due to artificial lighting, will not quickly disappear when it is deprived of light. Light intensities were measured at a number of the sites in Carlsbad Caverns.

In alcoves, the minimum light intensity threshold for algal growth had a mean value of 17.2 lux (1.6 footcandles) with a standard deviation of 7.5 lux. In nonalcove sites (most situations) the mean threshold was 47.4 lux (SD =

20.5 lux). At Frozen Niagara in Mammoth Cave, algae and moss protonema were steam-cleaned from ceiling formations (Aley 1997) but the growth returned.

Show caves have used either sodium hypochlorite (household bleach such as Clorox®) diluted to a 10% solution, or a 3% to10% solution of hydrogen peroxide, or steam generators for controlling photosynthetic flora. (See algae control, page XXX.)

However, bleaching, cleaning, or steaming the algae are inadequate solutions for several important reasons.

- The growth of algae and other lamp flora is only temporarily mitigated.
- Other cave organisms are compromised in the process.
- Even depriving the algae of light is inadequate for controlling growth.

Bleaching and cleaning treatments may make the cave look better in the short term, but they are almost certainly not ecologically sustainable—other cave organisms are easily harmed during these procedures. (See bleach, page XXX.)

Several new lighting technologies are providing improved methods for avoiding inappropriate over-stimulation of photosynthetic species in show caves. (See lamp flora control, page XX.)

*Exotic* (introduced) invertebrate communities may also be encouraged by the presence of electric lights. Signature Pool, located near the trail in Carlsbad Cavern, is a microcosm of moss, algae, eyed copepods, and eyed flatworms (*Phagocata* sp.), that were probably introduced. The small community is driven by a light bulb hanging over the pool (Elliott 1997, 2000).

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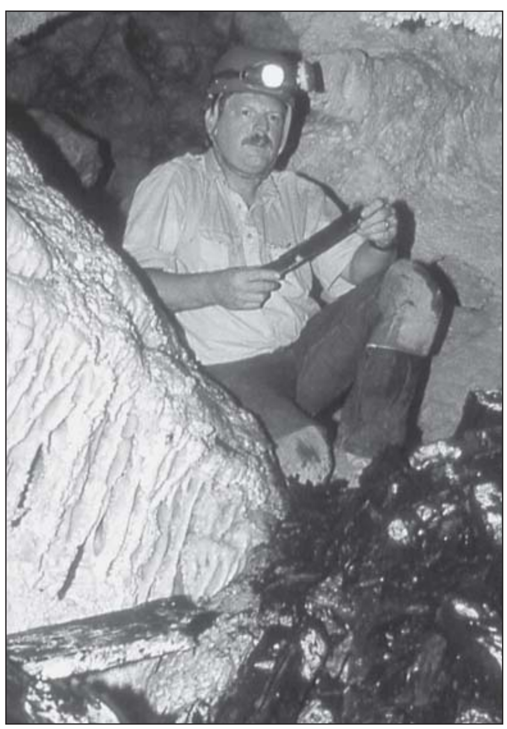
## Woodpiles

In Carlsbad Cavern Elliott (1997) studied old woodpiles that probably were remnants of structures installed in the 1920s. Most of the wood was depleted of nutrients and no longer supported visible fungal or bacterial growth. However, some wood was up to 80% water by weight, and served as a moist substrate. Some piles contained almost no invertebrates, while others were a haven for several species. Elliott recommended removing most of the piles over an extended time and leaving a small residue for fauna to utilize.

## Cave Lint

Lint studies have yielded interesting results in Carlsbad Caverns. In connection with annual lint camp cleanups, Jablonsky and others



W.R. Elliott

**Figure 1**. William R. Elliott examined an old woodpile off the trail in Carlsbad Cavern, 1996. The wood was depleted of nutrients, contained no inhabitants, and was scheduled for removal. Woodpiles in other areas contained arthropods and were retained. Some remnant wood contained up to 80% water and served as moist substrate material for certain invertebrate species.

(1995) placed tagged lint (treated to be clearly visible under ultraviolet) on the visitor trail, and found that it moved up to 100 meters down the trail. Testing also showed that much lint moved to the edge or completely off the trail. Under a microscope, samples of cave lint contained synthetic and natural fibers, dirt, wood, insect parts, human hair, animal fur, fungi, processed tobacco, paper, and other debris. Unidentified mites were also seen in some of the samples (PL Jablonsky, personal communication). (See lint and dust, page XX.)

### Food Service

The National Park Service instituted tighter housekeeping controls on the food service operators inside Carlsbad Cavern. They now remove the contents of all trash barrels by the end of the day to combat the large number of raccoons that invaded the cave at night (DL Pate, personal communication). Crickets are unnaturally distributed in the cave because they are attracted to food in the area called the Lunch Room, 750 feet below the surface (Elliott 2000). The National Park Service management plan advocates removing the in-cave food facilities (NPS 1996).

### Sewage Leaks

Sewage leaking from pipes or septic tanks may cause ecological imbalance in caves. In Carlsbad Cavern, a sewage leak infiltrated to the cave passages, causing localized fungal growths fed upon by swarms of fungus gnats—the gnats, in turn, supported a local community of spiders (Elliott 1997). (See infrastructure and infiltration, page XX.)

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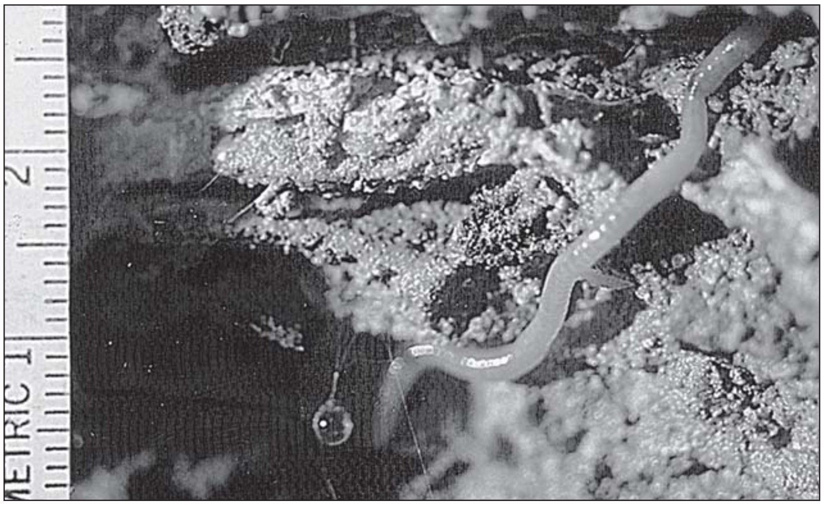
**Figure 2**. This fungal overgrowth was caused by a sewage leak into Carlsbad Cavern. Broken tile sewer lines caused the problem, even though this location was hundreds of feet below the surface.

In a bizarre 1993 case in the midwestern U.S., earthworms came out of the cave walls and rocks fell out of the ceiling of a show cave over an extended time period. The cave management thought that the earthworms were causing the problems and should be exterminated.

Systematic observation and sampling revealed that the earthworms were following infiltrating sewage into the cave from broken sewer lines and forgotten, leaking, septic tanks built on top of the cave (Elliott 2000).

The epikarst in that area, though mantled with good soil, was highly transmissive. Dye traces proved that the cave was cross-connected to many input points on the surface, including septic systems. Bacteriological sampling showed the presence of sewage-associated bacteria (including *E. coli*, *Salmonella*, and *Shigella*) in many air and water samples from the cave. Two European exotic species of earthworm, *Eiseniella tetraedra* and

*Dendrobaena rubida*, were found crawling on wet surfaces in the cave, and were actually eating softer, marly beds of rock, which probably were laden with bacteria.




W.R. Elliott

**Figure 3**. The manure earthworm, *Eisenia foetida*, was identified in a polluted, midwestern show cave. Sewage infiltration brought large numbers of two earthworm species into the cave. (See page 1 of color section.)

There was little or no odor in the cave, but airborne bacteria levels were high enough to cause concern about prolonged exposure. Clay banks in some areas were festooned with rich and colorful fungal gardens, which were inhabited by invading hothouse millipedes and sow bugs. No troglobites could be found in the cave.


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**Figure 4**. Green and gray mold colonies on shelf, probably *Penicillium*, were found on a shelf in a sewage-polluted, midwestern show cave. (See page 1 of color section.)

W.R. Elliott

**Figure 5**. Hothouse millipedes *Oxidus gracilis*, on a ledge in a polluted midwestern show cave. Large numbers of this species in a cave indicate nutrient enrichment.

After these initial findings, the owners initiated intensive maintenance and repair of the septic system. They also took steps to prevent infiltration of nutrients from the theme park above the cave. The earthworms were not killed, and were considered friends because they consumed much of the contamination. After about two years of work, the management reported that the cave was returning to normal biologically, and that rockfall (which probably was related to both high water infiltration rates and earthworm activity) had decreased to a low level.

## Examples of Ecological Disturbance in Wild Caves

### Trampling Species and Compacting Habitats

Overuse by visitors may cause disturbance even of tolerant species and compaction of substrates with loss of microhabitats for small, cryptic species. Many troglobites are *thigmotactic*, that is they like to hide under rocks. Though the effect of trampling on such species has not been studied extensively, cavers should constantly be aware of what's under their feet. It stands to reason that confining impacts to marked routes will compact less area and will result in healthier habitat for invertebrates (Elliott 2000).

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### Bats Are Sensitive

Some bats are sensitive to human disturbance as slight as traveling past their hibernation or nursery roosts. Disturbance can cause bats to abandon their young and the cave. Summer or winter disturbance is critical since only a few caves have suitable microclimates for colonial bats (Mohr 1972; Poulson 1976). (See bat disturbance, page XX.)

Disturbance and arousal of hibernating bats can cause 10 to 30 days of fat to be used (Brady 1982). Several such disturbances can cause bats to starve before their springtime exit. The gray bat, *Myotis grisescens*, and the Indiana bat, *Myotis sodalis*, are especially sensitive to disturbance; both are endangered species. (See endangered bat species, page XX.)

A critical question concerns the appropriate historical period to target in ecological restoration for bats. Define the most appropriate natural condition for restoration of a cave that serves (or served) as a bat roosting site. Many bat colonies have declined drastically within the last few decades.

With proper management, some roosts may return to the maximum past population as measured by ceiling stains, but most colonies do not fully recover (Toomey and others 2002). Some species of bats can be protected by bat-friendly structures. For example, fly-over gates or fences are necessary for some bat species, while properly designed bat-compatible gates are appropriate for species that will fly through (Vories and others 2004).

In one study, the population of aquatic invertebrates and eastern pipistrelle bats, *Pipistrellus subflavus*, increased greatly in Mushroom Cave, Missouri, after a bat-friendly gate was installed to limit human traffic. (D Ashley and D Drees, unpublished results). Plan carefully because some bat species (for example, Mexican free-tails) will not return if a gate is installed. (See cave gating, page XX.)

### Toxic Fumes

Fumes can be harmful to cave life and humans. For example, welding fumes can be very dangerous, especially if the metal being welded contains zinc or other elements. Welding in caves should be preceded by a study of air movements to see if contaminants will naturally blow out of the cave entrance, or if a temporary exhaust system should be used (Elliott 1995).

Elliott (1997) improvised an exhaust system for welding fumes during the construction of a bat gate in Gorman Cave, Texas. However, the system was overwhelmed by cigarette-smoking workers who created a cloud of particulates and harmful vapors (nicotine is not only harmful to humans, it also works as a contact insecticide as well as a vapor insecticide). Always consider the potential effects of fumes and chemical vapors.

## Summary

To avoid damaging the cave’s ecology, a few dos and don’ts can be followed during restoration projects and other trips to caves. Some of the rules come from common sense and fit easily into the general caving ethic, but some concepts require increased knowledge about cave life. Experienced cave biologists are available and willing to help. Most of them started out as cavers, and they enjoy working with cavers. For the address of the NSS Biology Section, see the current National Speleological Society Members Manual or visit the NSS website at <http://www.caves.org>.

For information and photos, visit the Biospeleology website (Elliott 2002) at <http://www.utexas.edu/depts/tnhc/biospeleology>. For further information on the many threats to cave life as well as cave and karst management issues, see Elliott (2000) posted on that website.

Remember that cave life is part of the cave itself, not something that came along after cavers discovered the passages. Some cave-adapted species have lived underground for millions of years. Some species have probably lived underground longer than the age of the caves that they currently inhabit.

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Many bat species have been using caves for hundreds of thousands, if not millions, of years. Many cave-dwellers have long life spans, slow reproductive rates, and adaptations to low-food situations. They are very vulnerable to disturbance and sensitive to alterations in their environment.

Another significant fact is that caves serve as important refuges for common surface species during drought and winter. A few examples are pickerel frogs, salamanders, overwintering moths, raccoons, and sometimes bears. Without undisturbed cave habitat, even these common species can decline.

Most cavers would never knowingly harm a cave animal. To be responsible cavers, we must consider the possible future consequences of our actions and remember that we are only temporary visitors to someone else’s home.

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