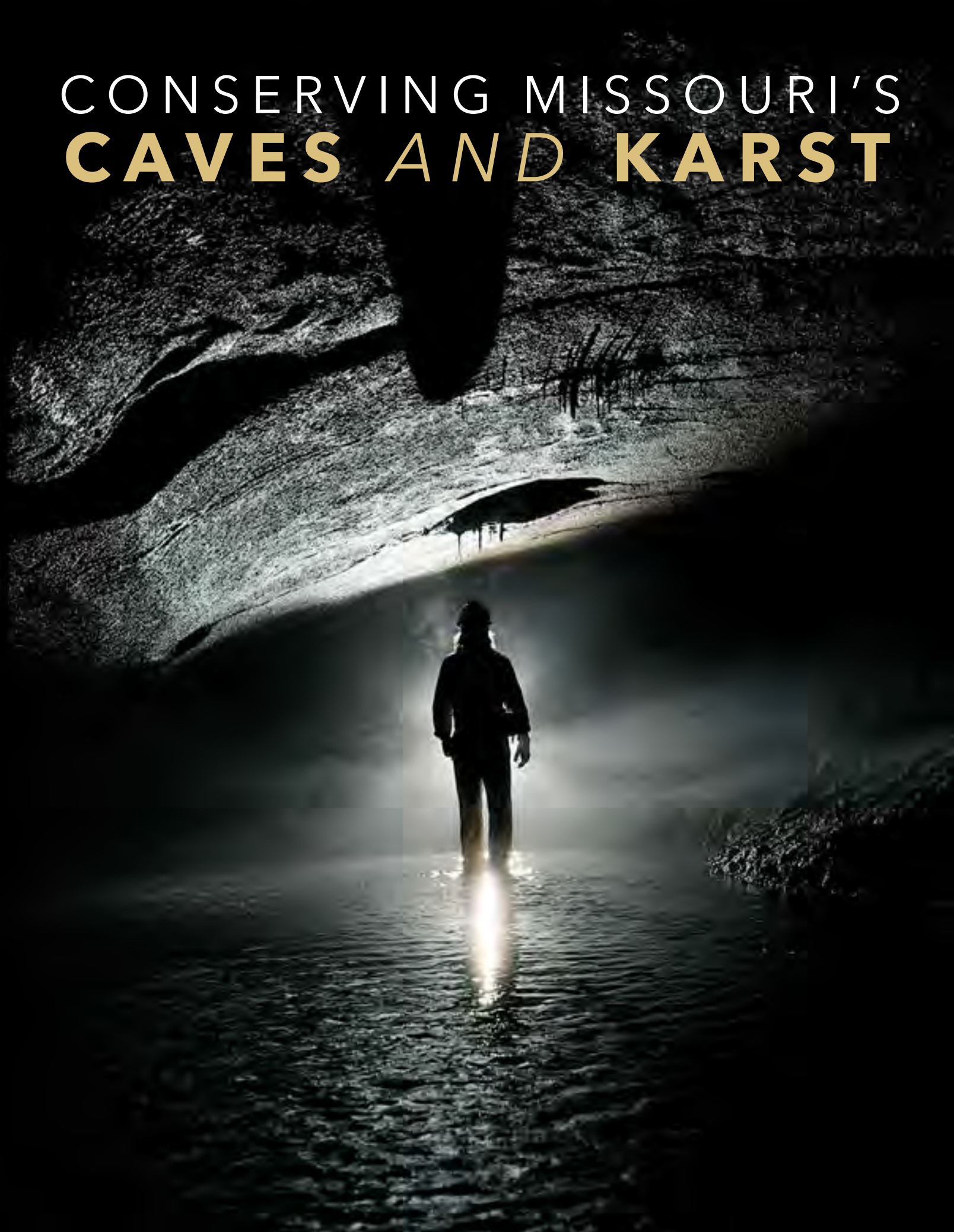
CONSERVING MISSOURI'S **CAVES** *AND* **KARST**



SPELEOTHEMS

by William R. Elliott

A speleothem is a secondary mineral deposit in a cave, derived by a chemical reaction from bedrock or other materials. The term comes from the Greek word *spelaion* for cave and *thema* for deposit. In Missouri and many states, it is illegal to remove, mark on, or damage these fragile speleothems or other cave resources without the cave owner's written permission. Cave owners are encouraged to help protect these irreplaceable cave formations.

Rickard Walk

Here are the more common speleothems in Missouri.

ANTHODITE A cluster of needles or quill-like crystals.

ARAGONITE A crystalline form of calcium carbonate, which usually crystallizes in clusters. It is the second most common cave mineral after calcite.

BOXWORK Intersecting mineral blades projecting from the walls or ceiling of a cave; can be calcite, gypsum, limonite, silica, or other minerals.

CALCITE The most common cave mineral and the usual constituent of most speleothems; the trigonal polymorph of calcium carbonate.

CAVE CORAL A coral-like deposit with branching stems and nodular tips, formed by dripping or splashing water.

CAVE ICE Floating calcite crystals that look like ice forming on a pool. May cover an entire pool.

CAVE PEARL A carbonate concretion, often spherical, that forms in shallow cave pools.

COLUMN Formed by the junction of a stalactite with the stalagmite below it.

DRAPERY, CURTAIN, BACON A folded or furled speleothem that hangs down from inclined walls or ceilings.

FLOWSTONE A smooth, sheet-like deposit formed by films of flowing water on walls and slopes.

GYPSUM FLOWER A deposit, usually calcium sulfate, that grows from the base with petals that curve radially outward from the center.

HELICTITE A twisted speleothem, which grows via a small capillary canal. Varies from straight to antler-like and other forms.

RIMSTONE, GOUR A dam or rim that forms at the edges of pools, where calcite crystals collect. They can range from a fraction of an inch to several feet high.

SPATHITE An aragonite, tubular stalactite consisting of a vertical succession of small, petal-shaped, thin-walled cones that resemble a bell-bottomed soda straw. Common in the Ozarks.

STALACTIFLAT A shelf of flowstone attached to a stalactite; deposited on a former clay or gravel fill, that is now gone. Canopies, false floors, and hanging bathtubs are related forms that grew over now missing banks. Such forms, common in the Ozarks, indicate a long cave history.

STALACTITE, SODA STRAW A vertically hanging speleothem formed by dripping water and generally having a tube or its remnant at the center. *See photo above*.

STALAGMITE A vertically oriented convex floor or ledge deposit formed by dripping water.

CONSERVING MISSOURI'S
CAVES *AND* KARST

CONTENTS

Rickard Walk

William R. Elliott

Reprinted from* Missouri Conservationist *articles in the March 2000 and October 2000 issues. Revised March 2007 and January 2026.

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BELOW MISSOURI KARST

Eons in the making, Missouri's geology naturally gives rise to caves.

BY WILLIAM R. ELLIOT

Imagine a landscape marked by limestone and dolomite ridges, dry hollows, sinkholes, big springs, natural bridges, underground streams, and caves. That's Missouri karst! The word "karst" comes from the German for the limestone region of Krš, Slovenia. It's the most common kind of geology found in Missouri.

Missouri is known as *The Cave State* because of its large number of caves. At least 7,900 caves are recorded in the Missouri Speleological Survey's files in Rolla. Tennessee exceeds our count with more than 10,000 caves, but people discover about 100 new caves each year in Missouri, so our number will continue to rise. Certainly our caves are among the largest and most spectacular in the nation. There are caves in 78 of our 114 counties, mostly in the Ozarks, but some as far north as Hannibal.

Many of our ancient caves have passed through several lifetimes of development. They began with the dissolving action of slightly acidic groundwater on fractured bedrock. This natural plumbing enlarged because of collapse, canyon cutting by internal streams, accumulation of clays and gravels, and re-excavation by streams. The continual dripping of flowing water laden with dissolved rock gradually deposited calcite in these openings, creating a variety of formations collectively called speleothems. Eventually, the fate of a cave is to erode away, as illustrated by natural bridges.

These events in our karst landscape ranged over huge spans of time. The sea deposited Missouri's oldest cavernous rocks around 500 million years ago during the Cambrian Period.

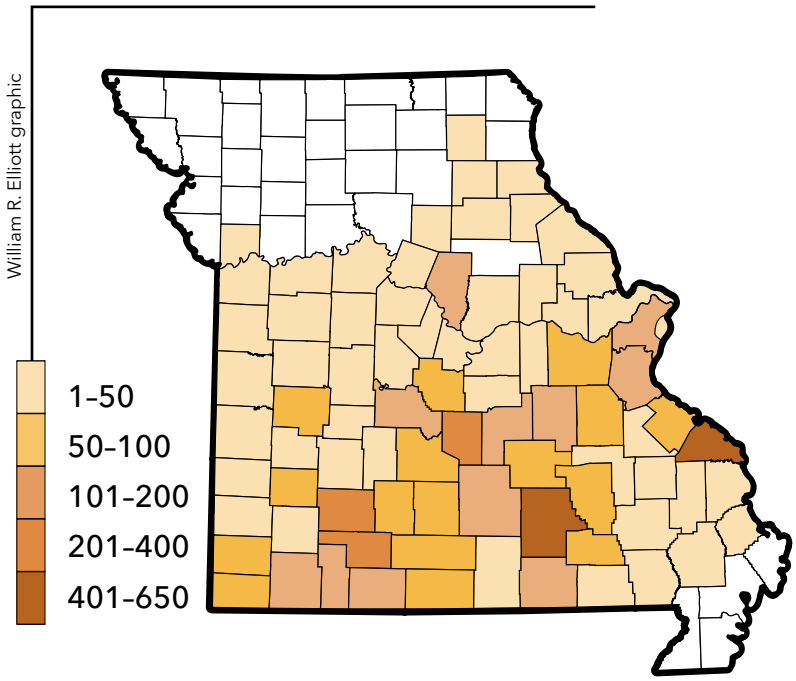
The Gasconade dolomite of the Ordovician Period (around 450 million years old) is the most cavernous rock formation in Missouri.

In the Mississippian Period (about 350 million years ago), marine organisms created the Burlington/Keokuk limestones that today are highly cavernous around Springfield, Columbia, and northeastern Missouri. By the time the Cenozoic Era began 66 million years ago, Missouri had dolomite and limestone up to 1,500 feet thick. At present, our karst is

Over eons, the movement of groundwater has dissolved a labryinth of underground passages — both beautiful and awe inspiring. Missouri is rich in caves and has become known as The Cave State.

Jim Huckins

Caves per County



developing rapidly, as evidenced by the large, deep springs and numerous losing streams (streams with sections that flow underground or that "lose" water because it seeps into the karst groundwater system).

With 754 caves as of 2025, Shannon County has the most caves of any county in the state. Perry County ranks second, with 693 caves running through a region known as the Perryville karst. Caves in this area are large, complex, flood-prone systems, which have made groundwater contamination a growing problem. Crevice Cave is the longest in the state at 31 miles. Berome-Moore Cave is an extensive system in which ancient cat tracks have been found.

The Springfield Plateau contains hundreds of relatively younger caves. Expanding urban areas threaten groundwater and the endangered Ozark cavefish. Some caves have beautiful speleothems despite all the mud, and cave structures tend to be fairly simple.

The largest continuous karst terrain is in south-central Missouri. The Salem Plateau is considered a cave factory, with the oldest and most spectacular caves in the Gasconade and Eminence dolomites. Some caves may have components dating back many millions of years. The caves are wet and muddy with lots of unctuous red clay (a sticky, slimy clay with no grit). This stuff completely stains cavers' coveralls and gear.

The Mark Twain karst around Hannibal is formed in Louisiana limestone and Burlington limestone. Mark Twain Cave, which is open to the public, is an astonishing maze with few speleothems.

Jim Huckins Photos

Speleothems found in caves include (above) flowstone and (left, top to bottom) aragonite bush, helictite tipped with crystalline needles, and cave popcorn.

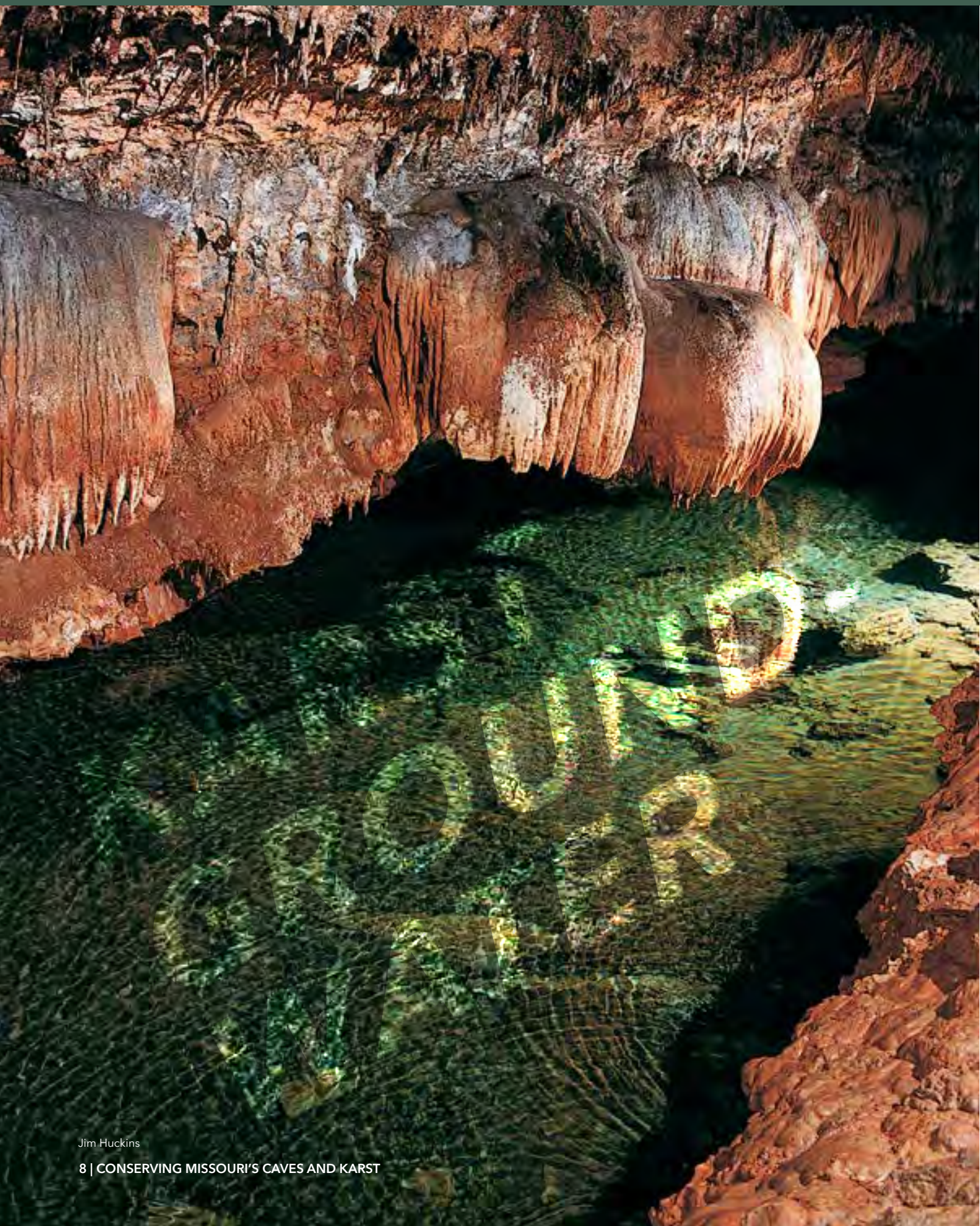
The St. Louis karst has been all but obliterated by urban development. German brewers used the caves for aging and storing beer in the 19th century. Cherokee Cave, used by the Lemp brewery, was partially destroyed by highway building, but still contains fossils of the extinct flat-headed peccary that were studied by the famous paleontologist George Gaylord Simpson. When one considers what happened to the numerous caves under St. Louis, one wonders if this will be the fate of caves near Springfield, Branson, Lake of the Ozarks, and other developed areas.

Most people know that speleothems, such as stalactites and stalagmites, take hundreds or thousands of years to grow. These cave resources are protected by state or federal law. But caves contain many other fragile resources, such as bats, groundwater, and diverse phenomena that can benefit us educationally, scientifically, and recreationally.

Since 1979, MDC has been building its program of cave conservation, research, and education. We manage more than 250 caves on state lands, and we extend a helping hand to private and federal landowners in studying and protecting their cave resources.

MDC has purposely acquired some caves that needed protection for endangered species, such as gray bats and Indiana bats. A few caves are protected for posterity, because they are pristine examples of Missouri karst. Through several programs and cooperative agreements, many of our caves are available for educational programming, mapping, and biological and geological inventory, as are some caves on other public lands.

Even if one does not care much for caves, one can appreciate that the groundwater issuing from our caves and springs is an important resource for Missourians. The porous rock of karst is where much of our drinking water collects, gets filtered, and flows, while huge springs in the Ozarks feed important trout fisheries and provide rich habitat for wildlife. ▲



Jim Huckins

Jim Huckins

KARST GROUNDWATER

Missouri's hidden but vital resource needs our protection.

Karst groundwater is an incredible natural resource. It provides drinking water for many Missourians, sustains iconic springs and streams, and supports unique underground ecosystems. The quality of the groundwater, however, depends on us humans — how we use the land and how well we protect the recharge areas.

You've likely heard the phrase that whatever goes up comes down. In karst landscapes, the saying is whatever goes down comes back up — often through a cave, a spring, or a well.

HOW GROUNDWATER MOVES IN KARST

About three-quarters of the water that reaches Missouri's major rivers in karst regions has passed through underground systems at some point. Karst is a landscape where water from the surface follows dissolved channels in the rock, creating features such as sinkholes, springs, and caves. When surface water enters these systems, it becomes groundwater recharge, replenishing wells, cave streams, and springs.

Two types of recharge occur:

- Diffuse recharge, when water seeps slowly through soil and rock, receiving some natural filtration.
- Discrete recharge, when water plunges rapidly through sinkholes, losing streams, or fractures, often carrying contaminants.

The U.S. Forest Service conducted a watershed study (1966–1973) on Hurricane Creek, which has both surface flow and underground flow. They found that only 25 percent of the recharge was diffuse, while 75 percent of the recharge in that basin was discrete, meaning that much of the water passed underground with little to no cleansing.

KARST GROUNDWATER BASICS

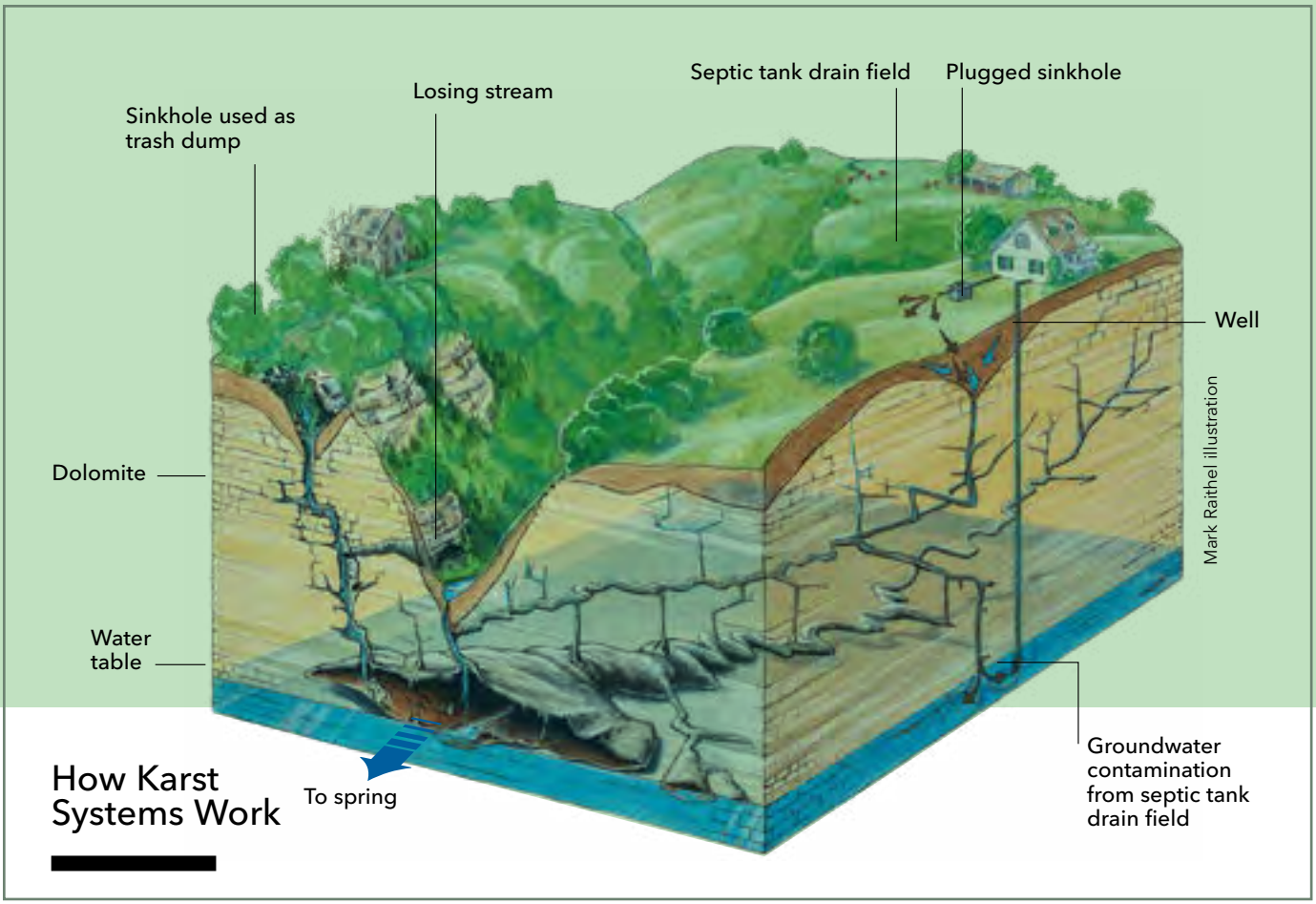
» Groundwater plays a key role in karst landscapes, dissolving soluble rocks to create caves, sinkholes, springs, and underground streams.

» About 50 percent of Missouri has karst features, with most in the Ozarks and Springfield Plateau.

» Sinkholes, caves, and losing streams directly link the surface and groundwater.

» Karst groundwater can travel more than one mile per day, compared to only feet per year in nonkarst aquifers.

» Karst groundwater is vulnerable to contamination; runoff, septic wastewater, and spills can quickly contaminate springs and wells in karst areas.



How Karst Systems Work

William R. Elliott

When thinking about natural cleansing, note that in many cases the underground openings are too big to filter out bacteria and parasites. Some discrete recharge zones can't even filter out large materials such as acorns, walnuts, cans, and pieces of Styrofoam.

SINKHOLES AND SURFACE CONNECTIONS

Sinkholes are depressions that funnel surface water into underground streams. Their shapes range from shallow bowls to steep-sided funnels. All act as fast, direct pipelines between surface water and groundwater.

In a study in southern St. Louis County, researchers simulated intense rainfall by using fire hydrants and hoses to introduce a 30-minute pulse of water and a harmless dye into six sinkholes. They then measured the response in the cave stream.

For each sinkhole, water levels at the sampling stations rose in 45 minutes or less, even though the underground travel distances were as much as a quarter mile. Intense thunderstorms in the area would add water to all sinkholes at once, and the travel rates would be substantially faster than what was observed in this study.

The typical Missouri cave emits water from the base of a bluff. Cave water originates from many sources. Karst groundwater flows as if through conduits and is not filtered like water in sand aquifers.

The experiment shows how storms can drive runoff into caves and springs within minutes. Intense rainstorms can cause rapid and lethal flash floods on cave streams, completely filling passages with water, so be sure to carefully consider the weather before entering certain caves.

OTHER DISCRETE RECHARGE HAZARDS

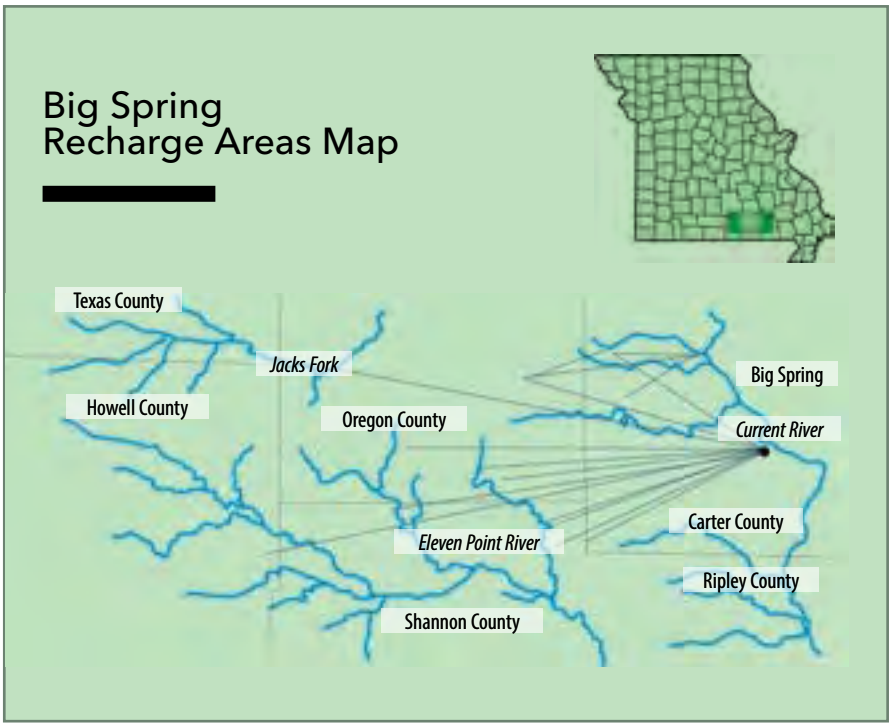
Not all recharge points are obvious. Some discrete recharge zones show little evidence on the surface but still channel pollution underground. Septic systems built in karst areas can sometimes intersect these pathways, sending untreated sewage directly into groundwater.

Losing streams are another common recharge pathway. A losing stream is a surface stream where water sinks into the underground system. In the Ozarks, nearly every intermittent stream has losing segments, which carry water quickly underground, often with little natural cleansing.

THE IMPORTANCE OF LOSING STREAMS

Losing stream valleys are important groundwater recharge zones in the Ozarks. Although they represent about 10 percent of the land area, they are responsible for about 40 percent of the groundwater recharge. Protecting these streams from pollution is critical for maintaining water quality in the surrounding wells and springs.

The typical losing stream in the Ozarks is a dry gravel bed, except for a few days or weeks after major rainfall. Many of these segments began as sinkholes that were later filled with coarse gravel carried in by floods. Despite appearing dry most of the time, they can move anywhere from a few gallons to hundreds of gallons of water per minute from the surface stream into the groundwater system. In one documented case, a losing stream carried more than a million gallons of poorly treated industrial sewage each day, contaminating wells and springs across 60 square miles.



Janet Cuthbertson graphic

Runoff from pasturelands also can degrade water quality via losing streams. Strips of ungrazed vegetation along channels, especially along the normally dry losing-stream segments, will help filter stormwater and trap contaminants. Even narrow vegetative strips about 50 feet wide along each bank provide valuable protection.

STORMWATER, URBANIZATION, AND RECHARGE QUALITY

Urban and suburban development increases the volume of storm runoff as well as the amount of pollution it carries. Most contaminants are concentrated in the *first flush* of stormwater. This runoff, often as polluted as raw sewage, can enter the groundwater directly through sinkholes or losing streams.

Detention basins built to hold stormwater and reduce flooding rarely improve water quality. Some are even located on losing stream segments and consequently deliver polluted water into groundwater systems.

To protect water quality, improved approaches to stormwater management are needed, especially in Missouri's karst areas. Green infrastructure, such as vegetated swales, rain gardens, and permeable pavement, can help reduce both the volume and the pollutant load of runoff before it reaches recharge zones.

RECENT HIGHLIGHTS IN MISSOURI KARST RESEARCH

- **Grotto Sculpin Studies:** The endangered grotto sculpin is found only in the caves and streams of Perry County, Missouri.
- **University Studies:**

  Missouri State University: Nitrate in pastures

  University of Missouri: Groundwater near concentrated animal feeding operations

  Truman State University and **Southeast Missouri State University**: Cave biology and water quality
- **Emerging Contaminants:** Pharmaceuticals, personal care products, and microplastics are appearing in karst aquifers.
- **New Tools:** Dye tracing remains the standard; eDNA is emerging for detecting species and pollutants.

Karst-created sinkholes collect runoff water that is often heavily laden with organic and chemical pollutants.

CLIMATE AND RECHARGE IN KARST

Recent decades have brought more frequent and intense rainfall to Missouri, increasing the risk of rapid contamination and flash flooding in caves and springs. At the same time, extended dry spells reduce spring flow and stress aquatic ecosystems.

Karst systems, with their sensitivity to these weather extremes, highlight the need for careful land management and forward-looking water policies.

GROUNDWATER AND CAVE LIFE

Karst groundwater systems provide habitat for a diversity of cave animals. Most of the food that sustains cave-adapted species is washed in through discrete recharge features, concentrating cave life around these points.

New tools like environmental DNA (eDNA) have expanded our ability to detect and monitor rare species through water sampling. In caves, eDNA found in water can alert researchers to the presence of animals such as cavefish and cave crayfish. Conservation efforts also now often include mapping recharge zones to better protect the quality of the water that supports these ecosystems.

David Stonner

An aerial view of Big Sink Natural Area and Sunklands Conservation Area near the Current River and Ozarkian hills.

FAST AND FAR: HOW KARST GROUNDWATER MOVES

Groundwater in karst moves with remarkable speed, often a mile per day, while in nonkarst areas it generally travels just a few feet per year.

The longest distance that groundwater has been traced in the United States was in Missouri. Dye introduced into a losing stream segment of the Eleven Point River resurfaced 16 days later in Big Spring in the Current River basin, having traveled nearly 40 miles.

Because groundwater can move at different rates along different paths, contaminants may reach one spring or well within hours while taking weeks to appear in others. Cleanup efforts are typically slow, costly, and rarely successful. With karst as with most natural systems, damage is easy, fixing is difficult, and prevention is best.

Jim Rathert

Bristly cave crayfish

ONE SOURCE, MANY OUTLETS

Water that enters karst systems at one point will often flow out into multiple springs and wells, sometimes several miles apart and across different watersheds. Such complex flow systems help explain the relatively wide distribution of some cave-dwelling species, such as the Ozark cavefish, which ranges from southern Missouri into Arkansas and Oklahoma. ▲

ACKNOWLEDGMENT

This article was adapted from one written in 2000 by Tom Aley for the *Missouri Conservationist*. Tom Aley (1938–2025), a renowned hydrologist and founder of the Ozark Underground Laboratory, advanced the use of dye tracing and expanded understanding of karst groundwater systems. His work continues to guide groundwater protection in Missouri and beyond.

MISSOURI CAVE LIFE

A dark, bleak habitat gives rise to some peculiar inhabitants.

BY DAVID C. ASHLEY AND WILLIAM R. ELLIOTT

People visit Missouri caves for a variety of reasons. Some seek opportunities for exploration, photography, or geology; others study the organisms associated with cave habitats, a discipline called biospeleology. If you are intrigued by the underground, take a trip with us to a typical Missouri cave.

The first thing we notice is cool air drifting out of the entrance. If we made our trip during the winter months, the cave air would feel warm instead. It's all relative. Cave temperatures stay fairly constant. Missouri caves typically range from 55 to 58 degrees Fahrenheit throughout the year.

In the entrance zone of the cave, we occasionally see birds. The eastern phoebe often builds nests here. Vultures often raise their chicks here, too. Most birds, however, do not normally enter a cave; they just use its mouth for protection from the weather.

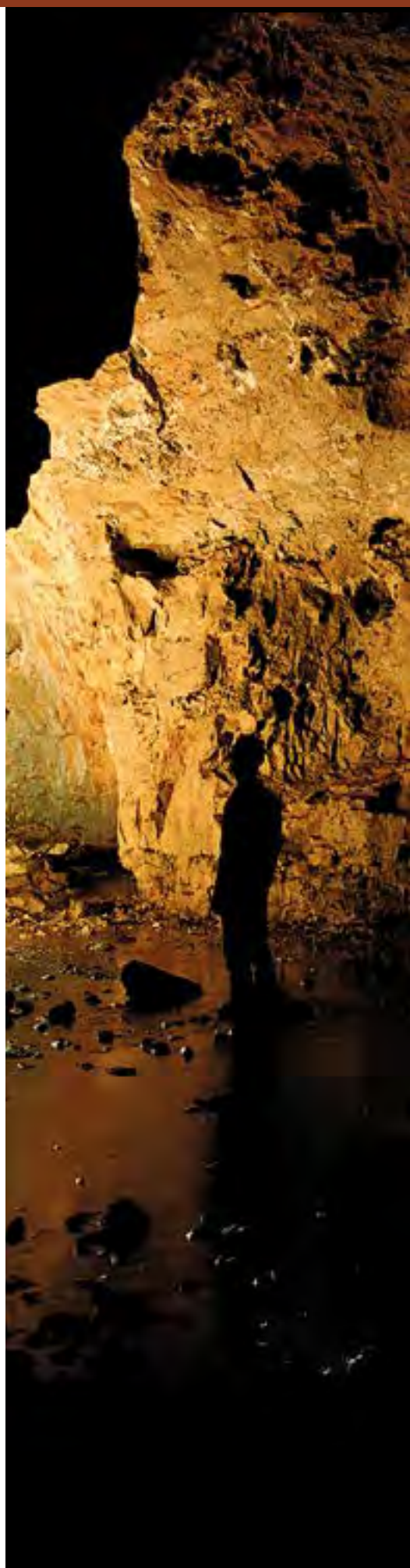
Snakes also use entrance areas. On hot summer days, the cooler air exiting the cave can help cool down a snake's body temperature. Snakes usually do not travel too far in, for there is little food deep in the cave.

Woodland plants may live near the mouth of the cave. Mosses and walking ferns may grow in the cooler air and in the low light of the cave entrance.

Entrance areas usually accumulate leaf litter and organic debris. Small logs, sticks, and bark fragments blow in or float in with rainwater. If we sift through this debris, we could find a surprising diversity of small invertebrates from the decomposer community that are here to break it down. These creatures are often so small that they are overlooked by most cave visitors (human, that is).

Occasionally we find salamanders in this entrance area, but they also live outside. Perhaps they are taking advantage of the cave's constant temperature, high humidity, or prey found in the leaf litter or cave stream. The beautiful cave salamander is orange with black spots distributed over its body. It commonly lives outside of caves, under logs and leaf litter in the forest.

Other salamanders that are fond of caves, but not restricted to them, include the slimy salamander and the dark-sided salamander. None of these



Herald moths (left) hibernate in caves. The troglophilic spider *Meta ovalis* (below) tends its egg case in its cave nursery. Walking fern (right) prefers shade and often grows in cave entrances.


Jim Huckins


William R. Elliott


William R. Elliott


Gordon T. Maupin


William R. Elliott


William R. Elliott

The cave webworm (above) is the larva of a fungus gnat. The grotto salamander (left) grows skin over its eyes. Bear claw marks (far left) testify to animal use of caves.

Jim Huckins

animals poses any threat to humans. They feed on small invertebrates they find in the leaf litter or streams. The leaf litter community may contain small millipedes, centipedes, terrestrial isopods (often called pill bugs or roly-polies), terrestrial snails, earthworms, and a variety of insects. We might see fungus gnats, flies, and midges resting on the cave walls. These flying insects are not restricted to the entrance zone of the cave, and they might move deeper into the cave, particularly in winter months.

As we head deeper into the cave, the light diminishes quickly. We have reached what biospeleologists call the twilight zone. Few photosynthetic plants can exist in this dark zone, and certainly none live deeper in the cave. Often the same animals we see at the cave entrance venture into this zone, but most stop here. The twilight zone tends to be short. Turns in the cave passage generally block light from penetrating any further.

Bedrock fossils, such as fossil coral, crinoids (sea lilies), and brachiopods (shelled creatures), can be seen in the walls of our caves. These creatures were once inhabitants of the oceans that extended through what we now call

Missouri. In fact, crinoids are Missouri's official state fossil.

As these animals died and fell to the ocean floor, they were covered by accumulated skeletons and shells of smaller organisms and eventually became part of the limestone or dolomite bedrock that is so common in Missouri. The fossils were more resistant to dissolving than the limestone, and we are now able to enjoy viewing them in many caves.

We often see evidence — bones, skulls, or tracks — of organisms that used caves in the past.

William R. Elliott

Fungus-coated scat documents recent use of the cave habitat by a raccoon. Numerous wildlife species enter caves for shelter, food, and water.

Jim Rathert

Cave salamanders display a variety of adaptations to cave life.

Explorers have found skulls of extinct saber-toothed tigers or giant lions in Missouri caves. We might see claw marks or the bed of a bear that hibernated in the cave some time ago. As black bear numbers increase in Missouri, we might start seeing evidence of new cave use by bears.

If we look in out-of-the-way places that haven't been trampled, we might find tiny bat bones. Each species of bat has a distinctive skull, mandibles, and teeth. We can identify and carbon-date these microfossils. Such studies can help us understand the severity of past glaciations, the habitat requirements of endangered gray and Indiana bats, and the range of climate changes Missouri could expect in the future.

In most large caves, the bulk of the area receives no light whatsoever. Some cave ecologists break this dark area into two separate zones — dark zone with fluctuating temperature and dark zone with constant temperature. Some organisms seem more likely to live in one region than the other.

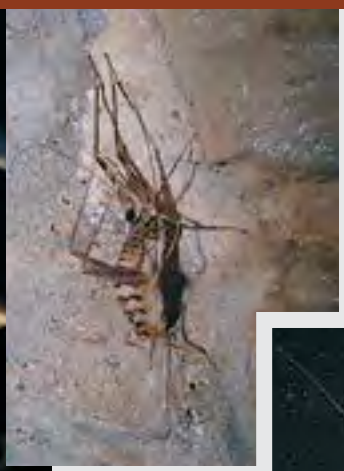
Probably everyone knows bats love caves. Many bats also roost in forests, barns, homes, and church belfries, but some bat species are almost always associated with cave habitats, roosting either singly or in incredibly dense clusters with several hundred bats per square foot. Some species live in caves only during the summer, some are found in caves only during winter hibernation, and some live in caves all year.

Bats often roost in the same spots, and their guano accumulates below them. Guano piles of gray bat colonies are sometimes several feet high and several yards in circumference. Regardless of the size of the pile, the guano provides a nutrient source for bacteria and fungi and for the small animals that feed on those decomposers.

A student once said ". . . in Missouri, a cave is a hole in the ground filled with mud." Many Missouri caves also contain streams and pools. Salamanders move from the water to the cave floor and cave walls. Another amphibian — the pickerel frog — overwinters in caves.

Other organisms are restricted to the water. These include salamander juveniles, crayfish, aquatic snails, fish, several species of aquatic isopods, small flatworms called planaria, and small shrimp-like invertebrates called amphipods.

Because food is so limited in most cave systems, the cave community must take advantage of all sources of nutrition. In fact, caves with large bat populations tend to have larger numbers of other animals because the bat guano provides important nutrients. Caves where



William R. Elliott Photos

Evolution has claimed the eyes and pigment of the Ozark cavefish (above). Other wildlife, including (right, clockwise) cave crickets, pseudoscorpions, and isopods, display a variety of adaptations to cave life.

leaf litter and twigs often blow in through entrances or flush in through ceiling cracks also will have higher populations of cave organisms.

The occasional log, guano pile, or raccoon scat can be a nutrient magnet for cave organisms such as beetles, millipedes, terrestrial isopods, and cave salamanders.

Some of the animals we see deeper in the cave look different from those we saw earlier. They are often white or pink and blind. These cave-adapted species have been isolated from the surface environment for many thousands of years. They have lost the ability to produce pigments in their skin or outer layers of the body, as well as the ability to produce eyes.

Cave-adapted species often have other intriguing differences in their biology. Sensory structures, other than eyes, often are more developed than in similar species that have never colonized cave habitats. Often their antennae and legs are much longer than their aboveground counterparts, and their metabolism seems more adapted to living in a nutrient-poor environment.

Biospeleologists categorize cave organisms based on their use of the cave habitat. Those that would not survive long outside of a cave are called *troglobites*.

CAVE ETHICS

Caves are protected by many statutes, including the Missouri Cave Resources Act — §578.200–578.225. This act protects cave owners against trespassers, vandals, and water pollution through caves, sinkholes, and subsurface waters. Locks, gates, and doors on caves are protected.

- Other statutes governing cave use can be found in the *Wildlife Code of Missouri*, the Missouri Clean Water Law, the Missouri Dead Animal Disposal Law, the Federal Cave Resources Protection Act, and the Federal Endangered Species Act.

- To promote respect for the natural contents, archaeological artifacts, life forms, and water of caves, the National Speleological Society created the following caver's motto: *Take nothing but pictures, leave nothing but footprints, kill nothing but time*.

- Another popular saying is: *Walk softly and leave no trace*.

- For information on cave laws and codes of conduct, go to **caves.org/conservation**.

William R. Elliott Photos

A NEW SPECIES OF CAVE CRAYFISH

In 1999, MDC biologists William R. Elliott, Ken Lister, Melissa Shiver, and Rhonda Rimer collected a species new to science, *Orconectes stygocaneyi*, the Caney Mountain cave crayfish. Their work was part of a study funded by the U.S. Fish and Wildlife Service.

They found an eyeless crayfish in a muddy stream passage in one of the caves at Caney Mountain Conservation Area in Ozark County. Lister collected one adult male and one adult female for identification by an expert taxonomist. Tissue from the female was deep frozen for DNA work by a geneticist, and both specimens were preserved for study.

Elliott was thrilled when he examined his photos of the male's gonopods (mating appendages) and realized that this was a species of the genus *Orconectes*, instead of one of two known cave crayfishes in Missouri.

Five species of blind *Orconectes* inhabit caves from Indiana to Alabama, but this was the first blind *Orconectes* found in a cave west of the Mississippi River.

Finding a new species of cave crayfish is a rare event. The last one discovered in Missouri had been in 1952. Some cave species are older than the caves they live in, which may be millions of years. Some species of cave crayfish have an extremely slow growth rate, low reproductive rate, and long lifespan; so, it is important to carefully study and conserve these cave populations.

To date, the Caney Mountain cave crayfish has been found only in this one location. To protect this rare species, access to the cave is restricted to scientific studies. Fortunately, the cave is inside a protected natural area far from development and known pollution sources.

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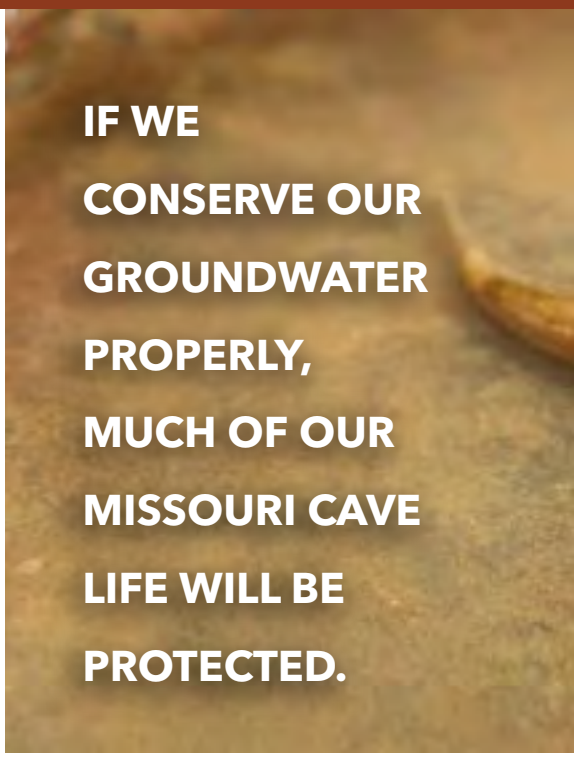
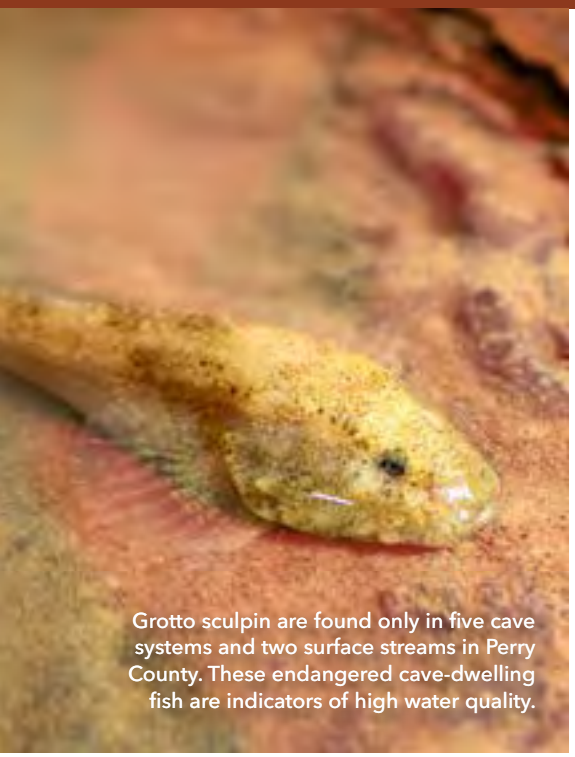


Missouri's rich troglobitic fauna include white and blind cavefish, millipedes, crustaceans (crayfish, isopods, and amphipods), and planaria.

Organisms living in caves, but not restricted to them, are called *troglophiles*. These organisms also live in forests, basements, and other habitats. We consider most species of salamanders, except the grotto salamander, in Missouri to be troglophiles. Other troglophiles include pigmented amphipods, isopods living in cave streams and cave pools, fish that move up streams into caves, and many insects.

Organisms that spend considerable time in caves but cannot complete their entire life cycle in a cave habitat are called *trogloxenes*. They might use a cave to hibernate, as do bears, pickerel frogs, and certain moths; or they might roost in caves during the day and exit the cave at night to feed, as do bats and cave crickets.

The category *accidental* refers to organisms that find their way into caves but are unlikely to survive there. If they do not find their way out of the nutrient-poor environment, they will probably perish. Animals that fall down sinkholes, as evidenced by some of the skulls and bones



Grotto sculpin are found only in five cave systems and two surface streams in Perry County. These endangered cave-dwelling fish are indicators of high water quality.

of prehistoric animals, often do not make their way back to the surface.

Cave life is vulnerable to many kinds of problems, such as disturbance or trampling, vandalism, overcollection, enrichment by sewage and runoff, chemical pollution, water projects, invading exotic species, and urbanization. In the United States, seven species of troglobites (that we know of) have become extinct, six of them in the last 50 years; and 30 species are recognized as endangered or threatened.

Missouri's Tumbling Creek cavesnail, *Antrobia culveri*, is found only in that one cave. Its decline, caused by water quality degradation, led to its listing as endangered in 2002. All seven species of endangered bats in the continental United States depend on caves at least seasonally.

If we conserve our groundwater properly, much of our Missouri cave life will be protected. We are making progress in conservation by setting aside and protecting bat caves of strategic importance. MDC is doing its part by protecting caves known to harbor endangered species on its lands and cooperatively monitoring bats and cavefishes in other caves held by private, state, and federal owners. ▲

DISEASES FOUND IN CAVES

Some diseases are associated with caves and the wildlife that live in caves. When exploring caves, people can be exposed to some of these. Here are a few common ones.

Histoplasmosis is a fungal disease that can cause respiratory issues. It can be found in bird and bat droppings (guano). Normally it does not affect people, but people with weakened immune systems may be at risk. In Missouri, only gray bats leave massive guano piles in caves. You should avoid going into these caves not only due to potential diseases, but because you may cause disturbance to the bats (which are federally endangered). Researchers take precautions by wearing a mask when around large amounts of guano.

White-nose syndrome is an invasive fungal disease that only affects hibernating bats. Originally from Eurasia, it was first found in the U.S. in the winter of 2006–2007. It spread quickly across the eastern and midwestern states, leading to massive declines in bat populations. Appearing as a white powder on the nose and wings, this fungal disease causes the bats to awaken more frequently during hibernation than they would naturally. This extra rousing burns more of the fat that bats need to survive winter, and they end up starving to death. Bats that do survive a winter with white-nose syndrome will put on more fat the following fall, to prepare for hibernation. Some species are now listed as endangered, or have been proposed to be listed as endangered, because of the toll this disease has taken on their populations. For more information on white-nose syndrome, please visit **www.whitenosesyndrome.org**.

Amphibian chytrid fungus is a fungal disease that affects amphibians (frogs, toads, and salamanders) by affecting their skin membranes, which leads to other issues, including death. It has led to the decline of amphibian populations around the world. This fungus can thrive in the moist environments of caves. More details about chytrid fungus can be found at the Cornell Wildlife Health Lab's website at **short.mdc.mo.gov/oZD**.

To avoid spreading these and other pathogens, always decontaminate your clothes and gear after coming out of a cave and before entering another cave site.

MISSOURI BATS

We have nothing to fear from these creatures of the night.

BY MARK MCGIMSEY

Missouri is home to 16 species of bats. Although they are sometimes referred to as flying mice, bats are not rodents. They belong to a group of mammals called the Chiroptera, meaning "hand-wing," and are the only mammals that can fly.

Bats are clean, shy, and intelligent creatures. They occupy almost every habitat worldwide and are the primary predator of many insect pests that cause millions of dollars of damage to farms and forests annually. Worldwide, there are more than 1,400 different species of bats; they comprise nearly one-quarter of all mammal species. Bats vary in size, weighing from only slightly more than 2 grams to more than 2 pounds. The largest bats are called flying foxes and have a wingspan up to 6 feet. Flying foxes live in southern Africa, India, islands of the South Pacific and northern Australia. Missouri bats range in size from 2 grams (1/10 ounce) to 42 grams (1 ounce). The largest bat in Missouri, the hoary bat, has a wingspan up to 16 inches.

HOW BATS EAT

Bats in other parts of the world feed on a variety of food items, but all Missouri bats feed exclusively on invertebrates, mainly flying insects.

In addition to detecting prey visually, bats also rely on echolocation, a form of sonar. Bats emit pulses of high frequency sounds at a rate of a few to 200 per second. By listening to the echoes reflected back to them, they are able to "see" prey with their ears. Echolocation enables bats to capture small flying insects and to avoid obstacles in their path.

Bats drink water and can do so while in flight. As a bat skims over the surface of the water, it simply lowers its head and takes occasional gulps of water.

HIBERNATION

Because insects are not available as food during winter, bats in Missouri survive cold months either by migrating to warmer places or hibernating. Hibernation is a state of rest in which heart and breathing rates are drastically reduced to help conserve energy. Bats reduce their body temperature from over 100 degrees F to the temperature of their hibernation site, usually 40–60 degrees F. The heart rate is slowed from over 1,000 beats per minute (bat in flight) to only one beat every four or five seconds.

A hibernating bat can survive on only a few grams of stored fat during its five- to six-month hibernation period. weight during hibernation. Each time a bat is awakened, it may lose up to two months of stored fat reserves. Bats that are repeatedly disturbed are forced to emerge early from their roosts. If this emergence occurs before the insects have returned, the bats starve.

REPRODUCTION

Bats in Missouri breed in autumn, and the females store the male's sperm until the following spring, when fertilization takes place. The gestation period lasts only a few weeks, and baby bats are born in May or June. Most female bats produce only one offspring (pup) per year, although some species give birth to three or four babies at a time. The young are fed milk until they are capable of foraging on their own. Baby bats grow rapidly, and most young can fly within four weeks.

BATS IN CAVES

Of the 16 species of bats that can be found in Missouri, seven regularly use caves. Occasionally other species, such as the silver-haired bat and eastern red bat, will roost in caves, but normally hibernate outside of caves.

SPECIES FOUND IN CAVES AND MINES:

- **Big brown bat** (statewide)
- **Indiana bat** (mostly statewide, but not currently in southwestern or western MO, or the Kansas City area)
- **Northern long-eared bat** (statewide)
- **Gray bat** (statewide except Kansas City area, northwest MO, and extreme southeast MO)
- **Eastern small-footed bat** (Ozark and southwest MO in regions with glades)
- **Little brown bat** (statewide)
- **Tricolored bat** (statewide)

Northern long-eared bat

Stan Tekiela

Big brown bat

Eastern small-footed bat

Indiana bat

Gray bat

© Merlin D. Tuttle, Bat Conservation International: *big brown, indiana, gray, and eastern small-footed bats*

Little brown bat

Jim Rathert

Tricolored bat

William R. Elliott

© Merlin D. Tuttle, Bat Conservation International

Northern long-eared bats

BENEFITS OF BATS

Bats are a vital part of the natural world. Bat species in other parts of the world play an important role in pollination, pollinating up to 400 products that humans eat (agave, bananas, avocados, etc.)

Missouri bats help control nocturnal insects, including mosquitos and agricultural pests. Many forms of cave life depend on the nutrients that bats provide through their guano.

ENDANGERED BATS

Worldwide, many bat populations are declining at an alarming rate. Special methods of protection have been established to help safeguard these dwindling populations. Three Missouri cave bat species, the gray bat, the northern long-eared bat, and the Indiana bat, are listed as federally endangered by the U.S. Fish and Wildlife Service and state endangered in Missouri. The northern long-eared bat was once very common in Missouri and throughout its range. However, the species drastically declined from white-nose syndrome and is now one of the rarest species in the state. The tricolored bat, a once common species seen in caves, also drastically declined from white-nose syndrome and has been proposed for listing as federally endangered.

Ozark big-eared bats (*Corynorhinus townsendii ozarkensis*) have not been observed in Missouri since 1971. This species, listed as state and federally endangered, used to live in caves in the southwestern part of the state, but today lives only in a few caves in northwestern Arkansas and northeastern Oklahoma; however, efforts to find the species in Missouri in recent years have been limited. The Ozark big-eared bat was listed as endangered because of its small population, reduced distribution, and vulnerability to human disturbance. Habitat loss and disturbance at maternity caves and hibernation sites are likely causes of its decline.

Conservationists are taking proactive management measures to assist in the protection of these species. These include gating or fencing important bat caves and placing warning or interpretive signs at other caves to minimize human disturbance. ▲

BATS AND RABIES

Bats are commonly feared because they can carry rabies. But rabies in bats is rare. Only a small percentage of bats — **less than half of 1 percent** — carry the rabies virus. As with any wild animal, if a bat allows you to approach it, the animal may be sick and should be avoided. Do not handle bats or any other wild mammal without training. If you come into physical contact with a bat (or other wild mammal), please seek immediate medical attention, as rabies is fatal once symptoms appear.

BAT BIOLOGISTS GO UNDERGROUND

Jim Rathert

To avoid disturbing bats unnecessarily, MDC, partner agencies, and nonprofit organizations conduct hibernation surveys for gray and Indiana bats on a two-year cycle. When conducting these surveys, biologists record all bat species found as well as all cave life. During years with no Indiana and gray bat hibernation counts, they conduct biosurveys statewide at other hibernacula (caves and underground mines) to look for other bat populations as well as other cave life.

In summer, gray bats occupy many maternity caves, where larger rooms and warm conditions are suitable for bearing young. Because human presence in a maternity colony is harmful to the bats, these colonies are monitored with thermal infrared video that records bats as they leave the cave at night, or the amount of guano the colony produces is measured during winter hibernacula visits.

MILESTONES OF MISSOURI'S HIDDEN HOLLOWS

Chronicling Missouri Caves from the Ice Age to the 21st Century.

BY H. DWIGHT WEAVER


Jim Huckins

Historians have long held that during his expedition into the United States, De Soto, the famous 16th-century explorer, died in Arkansas in 1542 and did not reach what is now known as Missouri.

But in 1993, a commission of prominent De Soto scholars released newly translated, highly controversial, 400-year-old Spanish accounts that challenge this view. According to Donald E. Sheppard, a researcher who traced De Soto's Missouri route for the group, the expedition found saltpeter near what is now Pilot Knob in Iron County and also near the White River in the Branson neighborhood.

The discovery of saltpeter, or potassium nitrate, was of great importance because it was used to make gunpowder. Bat guano found in caves was a common source. The Missouri sites were the only places, according to Sheppard, where De Soto's people found saltpeter in North America. Later, after leaving Missouri, the conquistadors fought the Indians on their push into the vast wilderness of the United States. When they eventually ran out of gunpowder, the men used their firearms as clubs or made horseshoes with them.

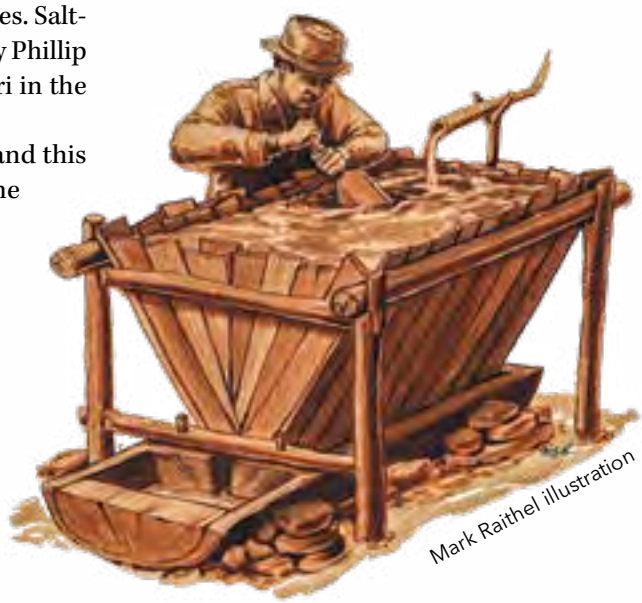
Because of the need for gunpowder, saltpeter miners were the first Europeans to place an indelible stamp upon the history of Missouri caves. Saltpeter mining, which may have begun with De Soto, was resumed by Phillip Renault in the 1720s and carried to its greatest heights in Missouri in the early 1800s by Gen. William H. Ashley.

But 19th-century Missourians had many other uses for caves, and this lineage of utilitarian values, spanning more than 200 years, is the fabric that weaves together the early milestones of Missouri cave history.

People used Missouri caves as taverns, barns, spring houses, beer and wine cellars, as well as sites for social gatherings, political events, and religious services. This was because the caves were available and conveniently warm in winter and cool in summer. Settlers harnessed spring-fed cave streams to provide power for paper mills, woolen mills, sawmills, and gristmills.

By the 1840s, caves in the St. Louis area were attracting German brewers from the old country. A new industry was thus born, transforming St. Louis into a Midwest brewing center.

Early settlers used cave spring water to leach saltpeter — used in gunpowder, preservatives, and fertilizers — from guano deposits found in Missouri caves.


Mark Raithel illustration

The Weston McCormick Distilling Company tower could be seen from Boone County's Rockbridge Cave entrance in this 1933 photo. The constant cool temperatures of caves also aided brewers.

Historical Society of Missouri, Columbia ▲

Without the caves, which have a natural temperature range of 52 to 60 degrees 365 days a year, this brewing industry might not have been possible in St. Louis in the days before electricity was available.

The Civil War period represents a dark interlude in this march through time. Caves often served as rendezvous points for troop movements, hideouts for guerrilla forces and slaves, and, during the Reconstruction years, safe havens for outlaws.

By the 1880s, a new era had arrived. Mark Twain popularized Missouri caves in the fictional adventures of Tom Sawyer. People came from all over the world to see the cave Mark Twain wrote about, and public demand for other caves to visit brought about the opening of Missouri's first real show caves. Another new industry sprang up in Missouri — underground tourism.

During these years and well into the 20th century, most people generally thought of caves as little more than landscape curiosities without significant value, unless they could be used commercially. Landowners often considered caves a nuisance and a liability. Until the late 1950s, there was no scientific imperative or widely held conservation ethic to protect caves and their contents. But the caves did interest scientists.

The first report on Missouri caves published by a Missouri geologist appeared in 1868 and was written by Garland C. Broadhead. In the 1880s, Ruth Hoppin, an amateur biologist, captivated American zoologists with her discovery of blind albino fish and crayfish in caves around Sarcoxie. During the same period, Missouri's pioneer female geologist, Luella Agnes Owen, dared the conventions of her gender and time by exploring the caves of the Ozarks to determine their geologic origin. Her book, *Cave Regions of the Ozarks and Black Hills of South Dakota*, published in 1898, became a classic.

Courtesy St. Joseph Museum

Luella Owen

As the 19th century turned, archaeology got a toehold in Missouri caves through the work of Gerard Fowke. Prominent in his day but somewhat eccentric, Fowke carried out the first large-scale excavations of central Missouri caves in search of Indian burial sites and artifacts. Toward the middle of the 20th century, Dr. Carl Chapman, founder of the Missouri Archaeological Society, introduced the concept of the prehistoric utilization of Missouri caves.

Hundreds of Missouri caves were used by prehistoric Native American cultures for shelter, burial, and ceremonies, and as a source for water, clay, flint, and minerals. Human burials, artifacts, and rock art still bear silent witness to the way the Indians used Missouri caves over a period of some 10,000 years.

Perceptions of caves were changing, and two notable events in the 1930s helped push this change along. William Morris Davis, a geologist, published a major paper on the origin of limestone caverns. J. Harlen Bretz, a distinguished geologist at the University of Chicago, tested the Davis hypothesis by doing fieldwork in the caves of the Ozark Uplift of southern Missouri. His research, supported by Missouri State Geologist Edward L. Clark and subsequently Thomas R. Beveridge, resulted in the publication of the book, *Caves of Missouri*, in 1956.

The Bretz study and book were more than just academic achievements and a scientific milestone; they were endeavors that captivated Missouri cave enthusiasts, laymen, and scientists alike. Thomas R. Beveridge, who was instrumental in seeing that the Bretz book got published, and Henry Douglas of the Virginia Cave Survey, who gave the early Missouri cavers much advice, provided inspiration for the birth of the Missouri Speleological Survey, or MSS, in 1956. Dr. Oscar Hawksley, a biologist from Warrensburg; Jerry Vineyard, a geologist from Dixon; and Frank Dahlgren, a machinist from St. Louis, founded the organization.

The founders designed the nonprofit consortium to unite the cave-oriented ambitions, skills, knowledge, enthusiasm, and dedication of both amateurs and professionals. Its membership was (and is) open to anyone who demonstrated responsibility in cave conservation and gave evidence of reciprocating efforts towards the organization's goals.

To facilitate its work and provide a permanent repository for material gathered by its many affiliate caving groups, MSS entered into a cooperative agreement with the Missouri Geological Survey and Water Resources, which is now the Missouri Department of Natural Resources' Division of Geology and Land Survey. State Geologist Thomas Beveridge extended a hand of friendship to the cavers. It was a handshake that would bear fruit and foster a partnership that would last for generations.

TUMBLING CREEK CAVE — A NATIONAL NATURAL LANDMARK

Tumbling Creek Cave in Taney County, Missouri, is the most biologically diverse cave west of the Mississippi River. It's also the most studied cave in Missouri. With at least 128 documented species, it is home to four federally listed species including a maternity colony of gray bats and the Tumbling Creek cavesnail, a species found nowhere else on earth.

The excellent condition of this cave didn't happen by accident. It stems from decades of dedicated work by its owners, Tom and Cathy Aley, and a slew of volunteers and partners. Tom bought the cave in 1966 to establish the Ozark Underground Laboratory (OUL), using the cave as a research station for studying karst systems and figuring out how to trace the water flow within them. His wife, Cathy, also a scientist, joined this endeavor in 1974. Through the OUL, they provide groundwater and karst consulting services, and at the cave they practice conservation management while also offering educational opportunities for students and professional groups.

When the Tumbling Creek cavesnail was discovered in 1968, an estimated 15,000 resided in the cave. But over time, the numbers began declining. By 2000, the population had fallen to 150, and in 2002, the U.S. Fish and Wildlife Service put the cavesnail on the endangered species list.

The cavesnails' decline pointed to sedimentation from overgrazed land that covered the cave's recharge system. So, the Aleys began buying nearby land (more than 3,500 acres) to restore it. They have stabilized streambanks, cleaned up dumps, repaired eroded gullies, sowed native plants, and planted 75,000 trees.

Today 1300 acres of this land is grazed on a rotational basis, where cattle forage on small areas for a limited time, so the pastures can recover. This benefits a local rancher and also helps maintain the natural communities found on the landscape. These efforts have improved the water quality below the surface, which is helping the cavesnails. Surveys conducted between 2015 and 2025 have estimated cavesnail populations from 500 to1200 individuals.

Thanks to the Aleys and others, Tumbling Creek Cave is an example of an ecosystem that is working well both above and below ground, showcasing the intricacies of karst ecology. The Tumbling Creek Cave Foundation was established in 2004 to maintain this legacy throughout the future.

Tumbling Creek cavesnail
Noppadol Paothong

The accomplishments of MSS since 1956 toward a better understanding of and appreciation for our Missouri cave resources are legion. The organization's volunteers have recorded, mapped, and reported on thousands of caves in the state. In 1985, the efforts of Missouri cavers received attention when MSS received a national Volunteer Action Award for its members' service and community spirit.

But state involvement in caves began before the creation of MSS and its partnership with a branch of state government. The State of Missouri officially acquired its first caves in the period 1923 to 1928 with the creation of several state parks containing caves and springs, including Meramec State Park. Two of the more than 30 caves in Meramec State Park were used as show caves and operated as concessions.

In 1933, Missouri passed legislation enabling the U.S. Forest Service to start defining areas for a national forest. By 1945, the service created Mark Twain National Forest. Its 1.25 million acres contain hundreds of caves, but decades would pass before true cave resource management would begin in the forest.

Jerry Gott, a retired cave management specialist at Mark Twain, said that when he started with the U.S. Forest Service, "there was little emphasis or resource attention given to the management of caves. Thanks to some laws related to endangered species, caves as an environment for these species have gotten the public's attention. With the passage of the 1988 U.S. Cave Resource Protection Act, the Forest Service is now much more involved in cave management than in the past."

In the 1960s, Congress established the Ozark National Scenic Riverways in Dent, Shannon, and Carter counties, and the Eleven Point National Scenic River in Oregon County. The National Park Service soon discovered there were hundreds of caves on these properties in need of special attention.

ILLEGAL OR BAD CAVING HABITS

- Trespassing
- Making graffiti
- Smoking (tobacco smoke is poisonous to cave life) and vaping
- Tampering with cave gates
- Building fires
- Removing artifacts
- Breaking speleothems (cave formations) or removing already broken ones

Also in the 1960s, a long-standing tradition of fierce competition between the many show caves of Missouri ended when they joined together to form the Missouri Caves Association. Since no two caves are alike, cave operators decided it was better to work together to reach their mutual audience than to compete.

In the 1970s, influenced by endangered species laws, MDC began acquiring numerous tracts of land to preserve forest and wildlife resources and protect threatened and endangered species. Some cave resources were specifically targeted because they are used by the Ozark cavefish and endangered species of bats. With government agencies acquiring significant karst areas of the state, an imperative was born to protect and manage cave resources with conservation and preservation in mind.

Conservationists discovered that Missouri caves were home to rare and delicate life forms; contained invaluable prehistoric human and extinct ice age animal materials; were ornamented with beautiful, unique, and fragile cave formations; contained vast reservoirs of water; and were sensitive components of the major spring systems and groundwater aquifers of the Ozarks.

In the late 1970s, the Department of Natural Resources began adding parks to its system where karst and caves were a focus of interpretation and visitation. Today the Division of State Parks manages more than a dozen parks containing wild caves, as well as several parks with major show caves.

The Missouri Cave Resources Act was passed in 1980. It protects caves by prohibiting vandalism of any type and recognizes the value of caves. It also maintains the right of private cave owners to manage or use their caves as they see fit. The law also helps protect the quality of Missouri's groundwater by prohibiting the use of a cave or spring for sewage disposal or other pollution-causing activities.

By the early 1980s, under contractual agreements, the Missouri Speleological Survey and Cave Research Foundation teamed up to inventory cave resources on government lands in Missouri so the agencies could make wise decisions in the development of their cave management plans.

In 1992, cavers organized the Missouri Caves and Karst Conservancy with the help of the Ozark Regional Land Trust. It was a first step toward creating partnerships that would buy caves to protect them. Today, cavers, nonprofit organizations, and state and federal agencies work together to purchase caves to protect the endemic and endangered species.

These are but a few of the significant milestones of Missouri's cave history. They take us from the days when Europeans first set eyes upon the American heartland to the beginning of the 21st century. Missouri caves, once largely ignored unless they could be used or mined, have finally gained a measure of respect and protection for their inherent values. We now have the mechanisms in place to save the very best of these remarkable, nonrenewable, irreplaceable natural resources and their precious wildlife. ▲

CAVING SAFETY

In Missouri, a common caving hazard is hypothermia caused by exposure to 55-degree water. Some have drowned in cave flash floods, so keep an eye on the weather.

Newcomers to caving should visit a grotto (caving club) and go through training. A list of grottos is available from the National Speleological Society at **caves.org/state/Missouri**.

Cavers should always observe the following precautions:

» **Wear a caving/climbing helmet with a sturdy chinstrap.**

» **Wear a battery-powered headlamp** on the helmet and carry at least three extra sources of light in a caving pack or backpack, along with other needed supplies.

» **Wear sturdy clothes** or coveralls, long underwear, waterproof or sturdy gloves, and good hiking boots or rubber boots with a good sole. If it's a wet cave, a wetsuit would be beneficial.

» **Never go caving alone or without the owner's permission.** Go with at least two other experienced cavers. Always tell someone responsible where you will be and what time you will return.

» **Stay within your limits.** Do not use ropes or cable ladders until you have been adequately trained by experienced vertical cavers. Do not climb down shafts that you cannot climb up again. Do not go underwater in a cave without being totally trained and certified as a cave diver.

CAVE RESTORATION

Cave teams go underground to mop up after vandals.

BY WILLIAM R. ELLIOTT AND JONATHAN B. BEARD

Visitors to Missouri caves often are spellbound by the natural beauty they find, but caves aren't always as lovely as they could be. Many times they are missing delicate formations (speleothems) that have been destroyed or removed by previous visitors. Or, the caves may be marred by fires, digging, marking on walls, littering, or the killing of cave wildlife — all actions which are illegal.

Just as conservationists restore prairies, forests, glades, and wetlands, a few dedicated cavers and conservation biologists are working to restore abused caves. In Missouri, much of this work is carried out by caving groups (called "grottos"), the Missouri Caves and Karst Conservancy, as well as the Missouri Department of Conservation, and other public agencies.

No one can completely repair all the damage to a cave. A broken stalactite or stalagmite that took millennia to form from dripping or flowing water may never regrow. The path the mineral-laden water took through the bedrock may now be naturally cemented, or conditions may be different than in the past. When the porous rock of caves has been contaminated by skin oils and mud, it may darken, or the growth of formations may stop. These conditions are hard to impossible to reverse.

Cave restorers accept the fact that damage often occurs much more quickly than it can be fixed and that their efforts will never restore a cave to pristine condition. Even after they have labored to clean spray-painted graffiti from a cave wall, the results are often unsatisfactory.

During restoration, care must be taken to not accidentally further damage cave resources. Harsh chemicals that can poison cave life are never used and stiff wire brushes that might scratch the rock are avoided. Restorers start with gentle methods, like nylon scrub brushes and cave water, and see how successful they can be with muscle power.

Cave Biologist William R. Elliott, top, uses a flexible wheel sander to erase graffiti at Lone Hill Onyx Cave on Meramec Conservation Area in Franklin County. Members of the Ozark Highlands Grotto, above, rinse soot from the flowstone floor of Jolly Cave in Newton County.

Jim Rathert

Cave restorers have developed a technique to fix broken stalactites like the one shown above.

Graffiti in caves goes back to prehistoric times and may be as important as a cave's geologic features. In 1992, an enthusiastic and overzealous group of young restorers armed with wire brushes severely damaged 15,000-year-old bison paintings in a French cave.

Before restoration begins, cave restorers carefully explore the cave and document what they find with photographs. They then decide what graffiti should be removed and what should remain. They don't remove old pictographs, petroglyphs, signatures, or anything else that might carry special historical significance.

If graffiti becomes cemented under a coating of calcite, they may leave it alone and let the calcite continue to cover it, or they may carefully grind it off. Another option, especially when bedrock is defaced, is to conceal it with color-matched mud.

Members of multiple grottos learned many of their restoration techniques in the 1980s when they began work on Breakdown Cave, a privately owned, severely abused cave. The cave served as a proving ground for methods of removing muddy handprints and graffiti, and it was the site where a new technique for repairing broken speleothems was developed. These techniques have since has been taught and used at other sites across Missouri.

One method of repairing stalactites involves drilling matching holes that are angled to each side of the break and filling the holes with epoxy. A stainless steel bolt with its head removed is threaded into one hole, and the other end of the bolt is inserted into the matching hole on the other side of the break. Often the angled bolt can be threaded so snugly into the speleothem that it is unnecessary to prop up the stalactite with a brace while the epoxy cures.

Other cave conservation tools include photo monitoring and mapping. Many cavers document caves by mapping them in detail with compass and tape surveys. Cave photography — a challenging art requiring the use of multiple flash units — can record the conditions in a cave for posterity.

Building gates on caves is a tool of last resort. However, often gates are needed to protect endangered or fragile species or beauty that otherwise would be lost to rampant vandalism.

In 2000, MDC gated Little Scott Cave, which is located at Pea Ridge Conservation Area in Washington County. Cavers from three St. Louis grottoes repeatedly cleaned the cave, but the cave was abused for so many years that only a gate could prevent vandals from continuing to trash it.

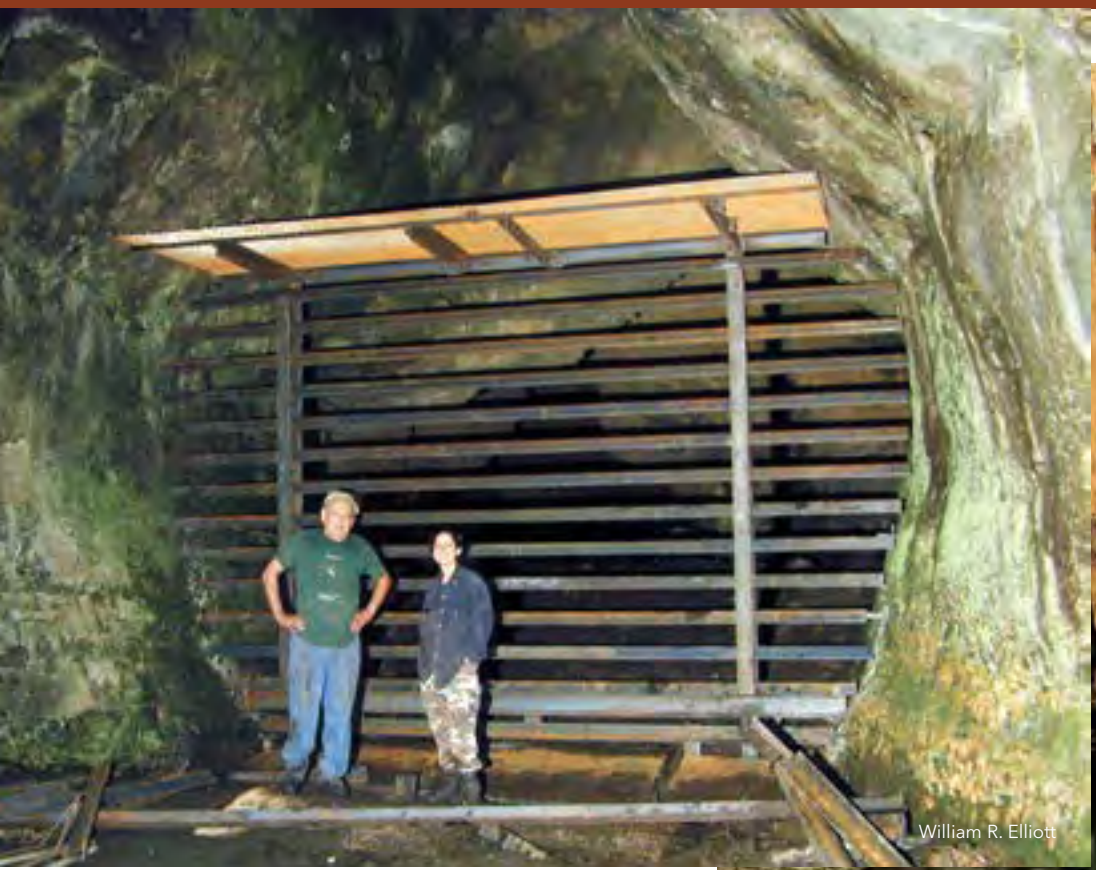
Cave gates are built to be as environmentally friendly and as strong as possible, using designs specified by the American Cave Conservation Association and Bat Conservation International.

The gates are typically made of heavy-duty angle iron with spacing that will not hinder the flow of air and water. The bars are spaced about 5¾ inches apart, and the vertical posts are placed as far apart as engineering allows to give bats a wide flyway.

The gate is pinned into the bedrock with one-inch hardened steel rods, and reinforced concrete is sometimes used to prevent vandals from digging under the gate. The bars are reinforced with angle iron stiffeners welded inside. The lock is protected in an enclosed steel box on the inside of the gate to prevent vandals from easily attacking it with tools.

It is illegal in Missouri to tamper with any cave gate or lock. Public agencies pursue and prosecute those who illegally enter protected caves. One must obtain permission to enter private caves, and also public caves. Nearly all state and federal caves in Missouri are closed to the public to prevent the spread of white-nose syndrome.

Different styles of cave gates are used in different types of entrances. Maternity colonies of gray bats will not tolerate a full gate across the cave entrance. In maternity caves with a large entrance, we sometimes build a "half gate" that has an open flyway above it. A large overhang is built at the top to prevent intruders from climbing over the gate.



William R. Elliott

The half gate at Blackwell Cave was built in 2001 by Roy Powers and Kristen Bobo (pictured) with help from cavers, MDC, and the U.S. Army Corps of Engineers. Since its construction, maternal gray bats have returned to the cave in large numbers; they usually will not use full gates, even with ample bar spacing.

The Lily Pad Room in Onondaga Cave

Eugene Vale

When managing caves for endangered bat species, such as the Indiana and the gray bat, we must consider the seasonal bat use of particular caves. Gray bats use certain caves in the winter and different caves in the summer, while Indiana bats use certain chilly caves only in the fall and winter. They stay in forests during the summer.

Some bat caves don't need gating, and some cave entrances can't be gated because of their size and shape.

Good cave management also considers the cave's place in the natural setting. Food, air, and water inputs are not altered. During cave cleanups, we remove old woodpiles slowly over time — even if they have been placed there recently — because they may be providing food and shelter for secretive cave creatures. However, hard trash, such as cans, bottles, and plastics, are removed quickly.

Pristine caves are sometimes protected by secrecy, agreements, or gating. Different agencies in Missouri have different regulations for visiting caves. For information about visiting caves, please contact the appropriate agency. Caves are not renewable resources, and restoring caves after they have been damaged is not a good solution. The only recourse to vandalism and damaging overuse of caves is conservation through education and protection before damage is done. ▲

RESOURCES FOR CAVE RESTORATION

The Missouri Caves and Karst Conservancy and other organizations assist cave owners in conserving and protecting their caves. MDC provides help to private landowners to protect and restore caves. Financial assistance may be available. Contact the cave biologist at (573) 522-4115, ext. 3282.

RESOURCES FOR LEARNING ABOUT CAVES

MDC'S BAT BIOLOGIST is available for public lectures on caves and cave life. Contact the bat biologist at (573) 522-4115, ext. 3282.

MDC CAVE EDUCATIONAL AND MONITORING PLAN: MDC has a cooperative agreement with the Cave Research Foundation to map, monitor, and inventory all MDC caves. MDC also has a few select caves statewide open for educational programs guided by MDC staff.

To search for cave events, visit **mdc.mo.gov/events**.

MISSOURI STATE PARKS offers cave tours to the public at some of the caves that it manages. Learn more at **mostateparks.com/activity/cave-tours**.

CAVE RESEARCH FOUNDATION (CRF)
CRF is a nonprofit that facilitates the research, management, and interpretation of caves and karst and promotes their conservation.

Website: **cave-research.org**

MISSOURI CAVES AND KARST CONSERVANCY (MCKC)
MCKC is a land trust that is dedicated to protecting cave and karst resources through management, education, and research. It also works to ensure the caving community has access to caves for exploration, surveying, mapping, and other activities.

Website: **mocavesandkarst.org**

MISSOURI SPELEOLOGICAL SOCIETY (MSS)
MSS is a nonprofit made up of individuals and organizations that are engaged in the study and research of speleology (the exploration of caves) in Missouri.

Website: **mospeleo.org**

FRONT COVER BY **RICKARD WALK**
BACK COVER BY **WILLIAM R. ELLIOTT**