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# RESTORATION, NOT JUST CONSERVATION, OF BAT CAVES — NEED, METHODS, AND CASE STUDY OF A *MYOTIS SODALIS* HIBERNACULUM

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## ABSTRACT

*The Indiana bat (*Myotis sodalis*) is a federally endangered species reliant on very cold Eastern caves. Many historic roosts are no longer suitable due to saltpeter mining, commercial development, and excessive disturbance. Disturbance can be controlled through well-designed gates and other protective measures. However, physical changes to the cave, such as enlarging passageways and modifying entrances, can alter the microclimate inside the cave so that it is no longer suitable for Indiana bats, even with gating. In 1998 Bat Conservation International and the U. S. Fish and Wildlife Service began a long-term project to monitor and better characterize the temperatures and microclimates of some of the most important current and former roosts. This led to the discovery that many of the sites traditionally considered important and protected, were in fact marginal roosts to which the bats retreated when their primary roosts were no longer available or suitable. Further microclimate research in one cave, Saltpetre (Carter County, Kentucky) led to a predictive model of changes in microclimate throughout the cave system and throughout the year. In the summer of 2003 the first modifications to restore former habitat conditions were completed. Potential impacts to public tours and cultural material were considered and accommodated. Continued microclimate monitoring and future bat counts will provide additional data necessary to adjust the initial modifications in order to achieve the desired 3°C drop in the overall cave temperature.*

## BACKGROUND

The Indiana bat ranges throughout the Appalachians and much of the Central Plateau. It was placed on the Federal Endangered Species list in 1967 due to its vulnerability and dramatic declines at its known roosts (32 FR 4001). It is a roost specialist, using a small number of particularly cold caves (3–6°C) as hibernacula. This behavior is possibly a strategy to avoid competition with other colonial hibernating species such as *M. lucifugus* and *M. grisescens*. However, it makes them more vulnerable to disturbance and roost loss. Indiana bats possibly numbered in the millions during pre-settlement times (Tuttle 1997), but the numbers have been plummeting in recent years, from 883,300 in the late 1960s–early 1970s to 353,185 by the 1995–1997 winter surveys (U. S. Fish and Wildlife Service 1999).

The 1983 Recovery Plan for the Indiana Bat (U. S. Fish and Wildlife Service 1983) divided the known hibernacula into three categories: Priority 1 (> 30,000 *M. sodalis*), Priority 2 (500-30,000), and Priority 3 (< 500). The limited roost availability and preferences of the species are well understood when we see that 51.8% of the population was found in 8 sites in only 3 states (Priority 1 caves). Another 44.7% were found in 69 sites in 11 states (Priority 2). The vast majority of known Indiana bat caves, 259, only held 3.6% of the population

(Priority 3). Clearly, even caves that are somewhat suitable for the species are not conducive to large colonies and population growth.

To further exacerbate the problem, the best caves for Indiana bats, i.e. the largest, deepest, and most complex, are often the caves most likely to be visited by recreational cavers or worse (for the bats), developed as a show cave. While disturbance is detrimental to the long-term success of the hibernating colony, the physical changes wrought upon the site through passage enlargement, entrance modification, and so on change the very airflow and temperatures which made the site so attractive to the bats in the first place (Tuttle and Stevenson 1978).

In 1998, with support from the U. S. Fish and Wildlife Service (USFWS) and many partners, Bat Conservation International (BCI) began a study of 12 of the most important Indiana bat hibernacula in 6 states. This program has received extensive cooperation from cavers, state and federal agencies, and others, and we now have temperature, humidity, and population data from over 40 sites in 10 states.

Our main goal was to categorize hibernacula as ideal (stable, cold temperatures), marginal (stable, high temperatures or sometimes cold but fluctuating temperatures) or risky (wildly fluctuating and sometimes too cold) (Tuttle and Kennedy 2002). But we were also able to note human-induced changes in the cave microclimate in several cases and work to restore those conditions to something more preferred by the bats in hopes that the populations would slowly increase. One of these sites was at Carter Caves State Resort Park (CCSRP) in eastern Kentucky.

## CASE STUDY—SALTPETRE CAVE

The CCSRP karst contains at least 28 caves, four of which are known to have hibernating Indiana bats. These are former Priority 1 **Bat Cave** (3681m of passage), the Priority 2 **Saltpetre Cave** and **Laurel Cave** (3005 and 1091m, respectively), and the Priority 3 **Cascade Cave System** (over 3200m, incompletely mapped). Historically, all have had public access year-round, with Bat and Laurel undeveloped (i.e. lights and walkways) and Saltpetre and Cascade developed. All were used for ranger-led tours except Laurel, which had unlimited permit access.

Bat Cave at one time held over 51,000 Indiana bats. Populations fluctuated erratically in the years since winter counts began, with little correlation to the known bat kills caused by flooding and vandalism. In addition, upper and lower entrances to the cave in an active stream valley cause warm air to flow up out of the cave in the winter, drawing colder air into the lower entrance, and reversing in the summer. This means that cave and roost temperatures are entirely dependent on the ambient (outside) temperature. Our 1998 visit confirmed our earlier conjecture: Bat Cave was a marginal roost. We had been protecting the wrong site for many years.

But what was the prehistoric site that was abandoned in favor of Bat Cave? And what caused the abandonment? An important clue came from the interpretive signs outside the Welcome Center. Visitors were told that the Bat Cave tour was 13–16°C (55-60°F), but that Saltpetre was 8–9°C (47–49°F), clearly closer to the ideal roosting temperatures than Bat Cave. A brief inspection discovered extensive roost staining throughout the cave (figure 1), most of which was obscured by soot and graffiti. None of this was noticed before, and indeed, the multi-entrance cave was unrecognized as an important bat roost. Despite

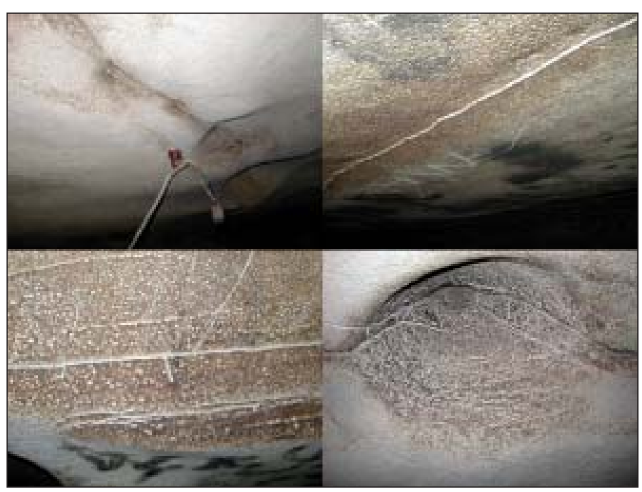

***Figure 1.*** *Obvious roost staining in Saltpetre Cave from hibernating Indiana bats. Note also the graffiti and remnants of old lighting.* Photos by Jim Kennedy, © 2000 BCI.

***Figure 2.*** *The author getting calibration temperatures at a datalogger in Saltpetre Cave. Inset is one of the Onset Computer Corporation HOBO Pro™ temperature/humidity dataloggers used in this study.* Photos by Elaine Acker and Jim Kennedy (inset), © 2000 BCI.

extensive modifications and visitation, it was still better on paper than nearby Bat Cave (Tuttle 1998; Tuttle and Kennedy 1999).

The years between 1998 and 2003 saw many extended visits to Saltpetre Cave to further study its historical changes and current microclimate. Dataloggers indicated that while the cave temperatures were still fairly stable, they were approximately 3°C (5.4°F) warmer than Indiana bats needed (figure 2). We also convinced CCSRP to suspend winter tours in the cave to lessen disturbance. This action alone brought the Indiana bat numbers in the cave from 13 in 1983 to 3100 by January 2003. This was a good indication that the cave was still attractive to Indiana bats, but we wanted to try to bring back the tens of thousands that must have once roosted there.

Part of our research was a collaboration with world-renowned cave microclimatologist, Australian Dr. Neville Michie (figure 3), who undertook a detailed investigation into the atmospheric conditions in the cave, developing a temporal (year-round) and spatial (throughout the cave) model of the cave's microclimate. We had hoped that such a model would be predictive, allowing us to predetermine the effects of any changes we made in our attempts to restore cave conditions to those of 200 years past. Traditional trial-and-error methods were too lengthy and uncertain for the type of restoration we envisioned.

## PROBLEMS WITH SALTPETRE CAVE

Saltpetre Cave (figure 4) was extensively mined for saltpeter for the manufacture of gunpowder, probably as early as the War of 1812. Extensive passage modifications were made to facilitate this industry. Sporadic rural tourism began at the cave after the war, with small parties being guided through the enlarged passages but likely few other changes being made to the cave. A full-blown commercial operation soon was in place, with electric lighting and other modifications being made to the cave to facilitate groups. Some buildings, roads, and other "improvements" were made to the area in and around the cave in the Civilian Conservation Corps style. In 1946 the property was purchased by Kentucky State Parks, which further modified the surface and the cave, and continued to offer tours.

Specific changes to the cave included the enlargement of the fissure at the Main Entrance and construction of a building over the entrance (figure 5). This not only altered the original airflow patterns but further diverted cold winter air from flowing downhill into the cave. The building was secured by a very bat-unfriendly gate. A concrete staircase immediately inside the Main Entrance added to the natural-collapse rubble and entrance-enlargement rubble to create a very effective air

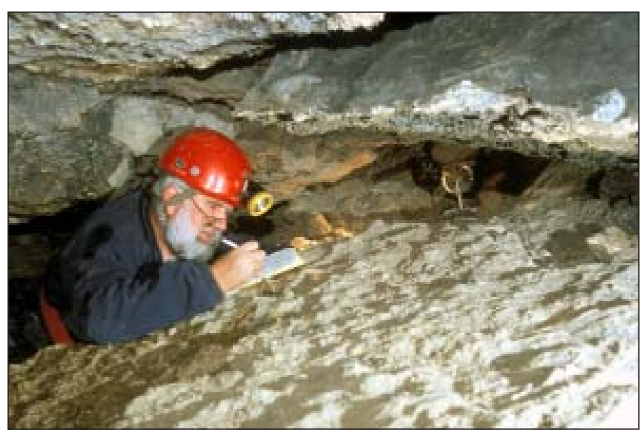

***Figure 3.*** *Dr. Neville Michie recording airflow with a custom-built micro-anemometer at the S&M Breakdown in Saltpetre Cave, the connection to the Moon Cave section of the system. Photo by Elaine Acker, © 2001 BCI.*

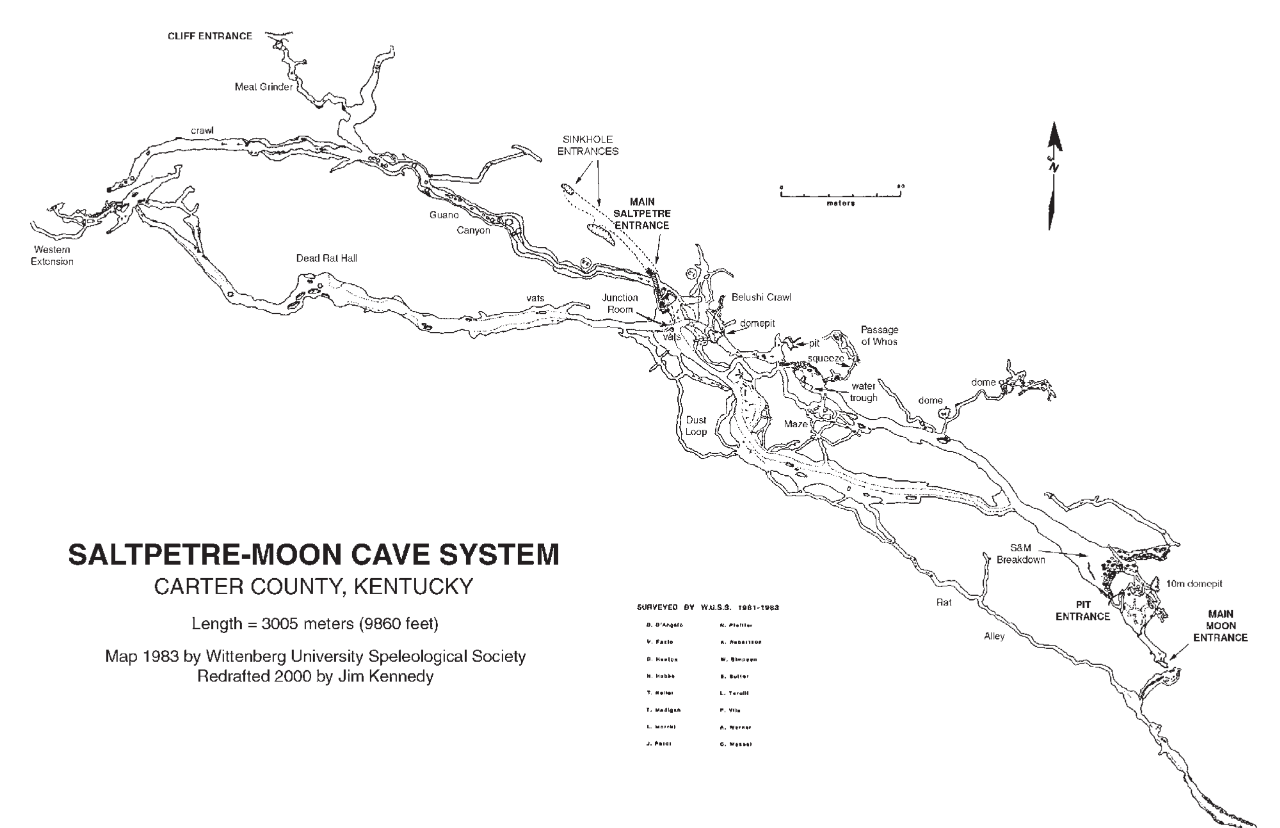


***Figure 4.*** *Map of Saltpetre Cave, Carter County, Kentucky. Courtesy Wittenberg University Speleological Society.*

dam, preventing cold air input from the lower Cliff Entrance during the winter (but allowing cold air leakage from the Cliff Entrance during summer). Two other fissure/sinkhole entrances (ungated) near the Main Entrance had been used as trash pits for generations (figure 6). CCSRP continued this practice, disposing logs, branches, and other landscaping waste into the sinks. This also reduced winter cold air input into the cave. Finally, within the cave, numerous passages were enlarged by saltpeter miners and tour route developers (figure 7), channelizing airflow through the cave and negatively reducing its transit time. Cold air flowing through the cave more quickly was not able to reduce the overall cave temperatures as much as air with slower transit times. The air also no longer flowed into many of the side passages and loops it once did, reducing the "cold storage" capacity of the cave, a concept akin to the loss of "bank storage" in stream channelization.

***Figure 5.*** *Building over Main Entrance to Saltpetre Cave before restoration work. The sinkhole entrances are just to the right, out of sight in this picture.* Photo by Jim Kennedy, © 2001 BCI.

## INITIAL RESTORATION ATTEMPTS

Through Michie's work and the additional data gathered from our network of dataloggers, we proposed several restoration efforts to take place in the summer of 2003. They included modifications to the Main Entrance building, specifically removal of the old vertical-bar entrance gate; construction of a modern angle-iron, bat-friendly gate incorporating a larger interior flight area; removal of the solid wooden sides of the building

***Figure 6.*** *Volunteer caver Nick Booth clearing logs and brush from one of the sinkhole entrances to Saltpetre Cave.* Photo by Cat Whitney, © 2003.

and securing it with bat-friendly gates (allowing for more winter airflow to enter the cave); and building up the hillside grade at the back of the building so that winter air would flow directly into the entrance rather than be diverted around it by the stonework. We also planned to clear the two sinkhole entrances by the Main Entrance and secure them with gates to allow for increased airflow. The low crawlway passage leading to the main cave from these entrances would be cleared of debris and slightly enlarged (to approximate prehistoric dimensions) in order to facilitate air flow. The last task on our agenda was the creation of a temporary wall in the cave to recreate a former passage restriction on a current tour trail, forcing the air out of its "channel" and through a longer, more complex path.

Many hurdles had to be overcome before the work could take place. A proposal was submitted for the work and approved, after a meeting and several modifications, by Kentucky State Parks (KSP) and Kentucky Department of Fish and Wildlife Resources (KDFWR). One of the more unusual and difficult problems we faced was getting approval from Kentucky Heritage Council (KHC), the state archeological and historical agency. Because Saltpetre Cave is on the National Register of Historic Places, the KHC was very nervous about anything that proposed "digging" and other changes. During a planning meeting we had a walk-through with a state archeologist and had to agree to pay another state archeologist to monitor our work during the three days we were actually working on the sinkhole entrances. Unlike KDFWR and KSP, KHC charged for time spent on the project. This unforseen expense was about 1/10 of our total project costs. We had to raise approximately $13,000 for the initial restoration work alone, not including Michie's research, 5 years of datalogger monitoring, planning meetings, and office time.

One of the biggest tasks in any project of this magnitude is always logistical planning. Scheduling between CCSRP, Roy Powers (master gate designer), and myself gave us relatively little time to order materials, recruit volunteers, and secure funding. We were very fortunate to have many talented cavers from a wide region come out to help. CCSRP donated lodging for our crew, KDFWR provided materials and additional

***Figure 7.*** *Heavily modified tourist trail in Saltpetre Cave. Original fossil stream passage is approximately 10m (33 feet) wide and up to 0.4m (1.3 feet) high. Current dimensions of the tourist trail are approximately 1.7m (5.5 feet) high by 1.2m (4 feet) wide, with excavation spoil piled to the sides of the tourist trail blocking access to the remaining original passage.* Photo by Jim Kennedy, © 2000.

*Figure 8. Building over Main Entrance to Saltpetre Cave after restoration work. Note bat-friendly horizontal bar gates.* Photo by Traci Wethington, © 2003.

*Figure 9. Caver volunteers Dale Lofland and Tanya McLaughlin constructing the temporary wooden wall for air flow diversion along a tourist route in Saltpetre Cave. Location is approximately same as in Figure 7.* Photo by Jim Kennedy, © 2003.

manpower, and several organizations and agencies assisted with additional funding. Seven days later, phase 1 of our restoration work was finished.

It all came together the week of 11-18 May 2003. The building at the Main Entrance was made more bat friendly and modified to allow additional winter airflow into the cave (figure 8), the sinkhole entrances were cleaned out and secured with welded grating to allow enhanced airflow, and a temporary wooden wall and door were erected in the main channelized tour path to force winter air through former routes in other passages (figure 9). All of our primary objectives were accomplished. We even took the volunteers on en extended tour through the cave one evening, downloading the dataloggers and pointing out some of the geology, biology, and microclimate of the cave.

## FUTURE WORK

More remains to be done. In summer 2004 we will download the dataloggers once again to determine how effective our initial efforts have been. During the upcoming year, we also want to finish grading the rear hillside to the top of the stonework at the Main Entrance building. We need to build up a "lip" at the downhill side of the sinkhole entrances to replicate the former configuration (long since leveled) in order to "funnel" more cold winter air into these entrances. And while not directly impacting airflow, we also should re-gate the Cliff entrance in order to make it more bat-friendly.

A bigger but potentially more important project is to perform radiolocation work on a former biological entrance (probably not human-sized) in Abe's Room. There is an obvious sinkhole/hillside collapse terminating the cave in this direction, and ample evidence from bats and woodrats, such as roost stains, droppings, and old woodrat food caches, indicate that there was a connection to the surface in this area. This has since been plugged by either natural causes or by construction of the park road. Reopening this surface connection would restore airflow in that whole branch of the cave and increase humidity to former levels, allowing the recolonization of that area by the thousands of bats that once must have overwintered there.

Finally, we hope to be able to remove the concrete stairs and associated rubble at the Main Entrance and replace then with a more "transparent" design, such as an open-grate metal staircase. This would facilitate winter air input from the Cliff Entrance and increase contributions from the sinkhole entrances. Of course, we will continue monitoring temperatures and humidities throughout the cave and census the bats every other winter to gauge results. Our work at this cave will be used as a model for microclimate restoration at other impacted, formerly important hibernacula, such as Coach Cave (KY), Mammoth

Cave (KY), and Wyandotte Cave (IN).

## CONCLUSION

This paper represents a new way of looking at bat cave protection. Too often, we think that if we just put up a gate or avoid the cave when the bats are present, then the population will be protected and therefore successful. However, recent studies are showing that many of the caves being protected are marginally suitable or no longer suitable for bats due to physical changes made by humans in the recent past. Other marginal "bat caves" are being protected when more ideal roosts nearby, abandoned because of human disturbance, are unrecognized. It is important to identify these sites and protect them, even if bats are not currently using them. If there have been negative changes to the cave's microclimate (and by extension, the entire ecosystem) from human alterations, it behooves us to fix those problems. Small changes, such as those described at Saltpetre Cave, Kentucky, can have huge positive impacts on the populations of all cave bats, and especially the endangered Indiana bat.

## ACKNOWLEDGEMENTS

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