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PRE- AND POST-GATE MICROCLIMATE MONITORING

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Abstract

Changes in the physical configuration of a cave or mine, such as entrance size or number, can have profound effects on the interior microclimate. Good gates can protect the fauna and other resources of the site. Poorly-designed and located gates can be horribly detrimental to the very things they are supposed to protect. When problems are identified, these poor gates are usually removed immediately and replaced with better designs. In the interim, the resource has been compromised, and bats (if present) may have abandoned the site altogether. While common sense during the design process will help one avoid many potential problems, a good set of baseline environmental data to compare with the post-gating data will clearly show if unacceptable alterations have been made. The wonders of modern technology now offer us lightweight, durable, and (relatively) inexpensive data loggers and other tools to record necessary data. We will cover a variety of monitoring devices and focus on the tools and methods used by the four-year Indiana Bat Hibernacula Temperature Monitoring Project. Examples of altered and restored cave microclimates will be given along with the broad findings of this project.

Existing Microclimate Data

The data we have on the microclimate conditions for roost sites is only representative of a point in time when the measurements were taken. We do not have good studies that would document microclimate conditions as they change over time. The data we do have is typically from a researcher who enters a cave to do a population count taking a thermometer with him and taking the temperature of ambient cave temperatures. We do not know the make of the temperature equipment (or calibration) or where in the cave the temperature was taken or at what height or distance from the walls. At best, you have a rough idea of possible microclimate conditions at the time of the measurement. This is not enough data for good management decisions.

The study of cave microclimates in the United States is in its infancy, and has mostly been limited to the observation of airflow at cave entrances. More in-depth studies have been performed in some European and Australian caves, but rarely to the point of developing a predictive model. How can we quantify the effect change *X* will have on the temperature of the cave? Is this a cave that is suitable for such things as endangered bats? Aren't all caves in a particular area the same temperature? This are the questions cave meteorology hopes to answer.

There have been a few good microclimate studies that have utilized thermocouple probes where data is recorded continuously and feed into computers. But more recently, the availability of small, sturdy, and relatively inexpensive data loggers has allowed us to place these at many locations and at multiple caves. Although not a product endorsement, our experience with the inexpensive HOBO Pro datalogger ($147 for quantities if 10-99 at Onset Computer Corp, http://www.onsetcomp.com) has proven to be fairly reliable in cave conditions and has given us information with good resolution. These dataloggers have a large memory capacity (32,645 high resolution measurements) and have an accuracy of ±0.2°C. One of the best features of these dataloggers is that they may downloaded and relaunched (at the same parameters as the original launching) while still in the hibernaculum by an Onset device called a Shuttle that stores data from 7 full HOBO Pros, or more from partially-full dataloggers. The data is then uploaded to a computer later.

Microclimatic Factors

In order to understand the importance of having good microclimate data prior to making management decisions about cave gating, we need to understand a few basic principles about cave microclimate. Cold air is comparatively dense and will sink while warm air is comparatively light and will rise. If you know: (1) the configuration of the cave; (2) the temperature of the outside air compared to the inside air; and (3) where the cave entrances are located, you can begin to predict how and when air will move in the cave system and where warm or cold air traps may exist. Normally the microclimate of a cave will be the mean annual surface temperature of the surrounding area, but in reality it is much more complex. In order to begin understanding the basics of microclimate, one should first read Tuttle and Stevenson (1978), followed by as many of the other papers listed in the Reference section below as are available.

Large complex cave systems with multiple entrances, multiple levels, lots of vertical differences, and varying passages tend to be the most stable in terms of microclimate, but also contain the most microclimate diversity. These complex systems allow use by multiple species that are able to find their peculiar microclimate needs met in some area of the system. By contrast, the simplest caves that consist of a single entrance with a fairly limited void (on the order of tens or hundreds of meters) tend to have little thermal buffering and provide little to no microclimate diversity. The unfortunate thing for bats and other cave dwelling species is that the large complex caves that provide the best habitat for the most species are also the caves that are most likely to attract the most human activity. High levels of human activity encourage commercialization that usually results in cave modification such as: (1) increasing the size of entrances and passages; and (2) adding doors, steps, and walls which negatively affect the airflow and microclimate, resulting in increased adverse impacts on cave-dwelling species.

We can also use this knowledge at a cave site not currently occupied by bats to determine whether or not it is worth protecting, based on its potential usefulness as bat habitat. In other words, there are many caves that should be protected for bats because the habitat is still suitable, but which are not currently considered bat caves. This information also allows us to determine what changes to a cave environment, such as entrance enlargement or plugging of secondary entrances, may have led to its degradation as bat habitat. Note that this only addresses changes in physical parameters of the roost itself, not behavioral impacts like disturbance or exterior impacts like logging. In some cases, we may be able to determine the precise changes that caused the cave to be no longer suitable for bats and undo them.

NABCP Indiana Bat Habitat Study

The rest of this paper will focus on studies done by the North American Bat Conservation Partnership (NABCP) at Indiana bat hibernacula across the range of that species in the United States. This study has been coordinated by the author and Bat Conservation International. It cam about with the release of the Revised Agency Draft of the Indiana Bat Recovery Plan in October 1996 (USFWS 1999). Although the conventional wisdom assumed that since the most important hibernation caves were gated, they were protected, and therefore decline of the species was attributable to some other cause. In actuality, this is not always the case, and in some instances installing bat gates may have the opposite result from that intended (Tuttle and Kennedy 2002). Many caves once utilized by Indiana bats have been modified by commercialization, saltpeter mining, or through recreational cave exploration where cavers have plugged an old entrance, created a new entrance, or enlarged a passage.

In 1998, BCI began a study of Indiana bat hibernacula at 15 sites in 7 states in order to see if we could obtain enough microclimate data (temperature and humidity) to characterize roosts, correlating roost temperatures with population fluctuations. We hoped to determine why the bats have stopped using some sites while continuing to use others, and why some populations declined while others remained stable or even increased. The study grew by 2002 to include more than 30 sites in 10 states. We have been able to clearly group hibernacula into 3 categories – stable and ideal (temperature ranges between 3 and 6°C year-round); stable and marginal (temperatures 7-10°C year-round); and unstable, with wildly fluctuating temperatures largely dependent on the ambient temperature.

Almost all sites were protected by some form of gate, but after several years it became clear that several of the gates were contributing to the decline of the populations at those sites instead of the intended protection. This gave us the opportunity to begin small-scale restoration efforts to re-establish the prior conditions that once attracted bats.

One site we investigated was Great Scott Cave, Missouri, where the Indiana bat population declined by 80 percent in the mid 1980s due to a temperature increase in the cave. The timing of the decline in bat population seemed to coincide with the installation of a bat friendly gate. After we discussed this with Rick Clawson of the Missouri Department of Conservation (MDC), we learned that there was also an upper entrance to the cave. When MDC installed the bat gate in the main entrance they also cemented in the upper entrance to secure it from human entry. From our year-round temperature monitoring data we determined that the upper entrance was essential for the airflow in the cave, allowing warm air to flow out. MDC quickly removed the blocked upper entrance and installed a bat-friendly gate. Resulting air temperatures in the cave immediately dropped approximately 3°C, now well within the range useful for the bats. Bat counts are scheduled for this winter, so it will be interesting to see if the anticipated population increase begins to show.

Saltpetre Cave at Carter Caves State Resort Park in northeastern Kentucky is another example. When we originally visited the park to place dataloggers in nearby Bat Cave, a Priority 1 Indiana bat hibernaculum, we noticed the interpretive sign that mentioned the cave's cold temperatures. We did not have much time, but our initial investigation of Saltpetre Cave showed extensive roost stains, mostly obscured by soot and graffiti. The cave has undergone extensive modifications as far back as the early 1800s from saltpeter mining and subsequent tourist development. We were able to place a few dataloggers in the cave, which showed an unusually stable but slightly elevated temperature regime. But the extensive staining indicated a formerly large population that had abandoned the roost due to passage and entrance modifications. We contracted with Dr. Neville Michie, one of the world's leading cave microclimatologists, to study the cave climate in greater detail and make specific recommendations for mitigation. We spent an intense week each in the middle of winter (January) and in the middle of summer (July) measuring almost every conceivable aspect of the cave's meteorology in order to develop a geographic and temporal model of the air flow and temperatures in the cave. We also added seven more dataloggers in other locations to the three we already had. Part of our work involved tracing air currents with chemical "smoke" and measuring air speed with custom-built microanemometers, which were configured to also calculate air volume. From this data Michie was able to identify several actions that will correct the inadvertent changes to Saltpetre Cave's microclimate, without impacting the tourism or historic artifacts there. Actual work was delayed until a variety of state approval was gained, and is scheduled for spring 2003. Combined with the winter closures, Saltpetre Cave will likely regain a large percentage of its former population, returning from a stable-marginal roost to a stable-ideal roost. Nearby Bat Cave, on the other hand, is a unstable-fluctuating roost, and is probably used by the bats only as a last refuge after being driven from Saltpetre. If our hypotheses are correct, we have been protecting the wrong cave all along.

We have been actively trying to restore other sites as well. At Coach Cave in central Kentucky, the Kentucky Department of Fish and Wildlife Resources built a rock-and-concrete "air dam" and the main entrance to re-create the original entrance sinkhole contour and slow the flow of cold air from the cave. While temperatures have already begun to drop in this 3.4 mile cave system, high humidity is still a problem. Condensation is seen directly on the roost stains and gypsum flowers, a type of speleothem. This is not normal, as Indiana bats do not use damp roosts, nor does gypsum form in a high-moisture environment (it is water-soluble). During the summer of 2002 an artificial upper entrance to the cave was sealed, hopefully preventing more of the warm moist air from entering the cave and condensing on the cool walls. Perhaps this will finally restore the cave to it's natural, historic conditions. If not, we'll try something else. Coach Cave is the former home to over 100,000 Indiana bats, which totally abandoned the site as a result of the changes from the short-lived commercialization.

A similar project is being planned for Wyandotte Cave in Indiana, where excavation of the main entrance area for tourists has resulted in a slight increase in the otherwise stable and suitable cave temperatures.

Mammoth Cave, Kentucky, has a problem similar to Saltpetre Cave, but on a much larger scale (346.01 miles of passage and over 30 entrances, compared to 1.86 miles of passage and 6 entrances). Multiple changes from early saltpeter mining and development from tourism, including the excavation on several new entrances, has increased the temperature and humidity in this cave system. The National Park Service has already retrofitted the artificial entrances with airlocks, and experimented with various remedies for the natural entrances. However, the sheer size of the cave makes it more difficult to judge the effect of individual changes. New evidence discovered in the past few years (Toomey et. al 2002) give us hope that the cave may once again be home for the millions of bats that once roosted there every winter (Tuttle 1997).

Conclusion

In order to restore altered microclimates to hibernacula, one needs to know about the prior conditions. However, we rarely have this luxury, and must rely on circumstantial evidence, particularly at sites presently abandoned by bats. The key to intelligent tinkering, to paraphrase Aldo Leopold, is to not do anything drastic that you can't undo. Microclimate modeling is an important tool for roost characterization, which should lead to prioritization for protection or restoration. Remember that sites with bats are not necessarily the best sites for bats.

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