Temperature Data Logging in Missouri Bat Caves

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Abstract

We present our preliminary results of digitally logged temperatures in Missouri bat caves that are inhabited by the Indiana bat, *Myotis sodalis*, and the gray bat, *Myotis grisescens*. Both species are endangered. Eight Indiana bat hibernacula, including one mine, were monitored since the fall of 1998. Four of these included gray bats. The temperatures in some of the hibernacula declined quickly and deeply in reponse to cold fronts, while the more horizontal caves were more thermally stable. Relative humidities also dropped quickly during cold fronts. Some caves provide a variety of microclimates for different bat usages. This study is partially included in a national study of Priority I Indiana bat caves. Conclusions are only tentative at this time.

Introduction

The endangered Indiana bat, *Myotis sodalis*, and the endangered gray bat, *Myotis grisescens*, utilize particular caves in Missouri. Gray bats use various caves at different times of the year, while Indiana bats use caves for mating in the fall and for hibernation. Maternity roosts for gray bats typically are warm traps with high dome rooms. Hibernacula typically are caves or mines that have below-average temperatures. The mean annual temperature of the Missouri Ozarks (based on weather records we analyzed from Waynesville, Missouri) is about 13°C (55-56°F). Many Missouri caves reflect this mean annual temperature.

Since 1980 Richard Clawson used a digital thermometer to take spot measurements of ambient and rock temperatures during winter surveys of hibernating bats. A general idea of preferred hibernation temperatures developed, but we could not record the full range of temperatures until the advent of miniature data loggers.

In 1997 Missouri Department of Conservation's Mark McGimsey and Ken Lister installed Onset XT data loggers in three gray bat caves. Elliott joined that effort in 1998 and concluded it in 1999. Those data will be presented in a separate paper.

In Missouri regular censusing of Indiana bat caves began in 1975 and censusing of gray bat caves began in the late 1970s (LaVal and LaVal 1980, Missouri Department of Conservation 1992). Since 1980 Richard Clawson has led these surveys for the Missouri Department of Conservation. William R. Elliott joined the effort in 1998. Since 1979, Missouri's Indiana bats, as measured at five major hibernacula, have declined about 89%, from 210,000 to 23,000. Indiana bats have declined in most other states, except in Indiana, where recent surveys have shown a slight increase (Dunlap, 1999). Gray bats have declined less dramatically and now appear to be stable at their major maternity caves that are protected.

The drastic loss of so many Indiana bats calls for testing many hypotheses about their environment. In this study we are primarily concerned with two questions: Are Indiana bat hibernacula becoming too warm? Are they too variable in temperature? We shall focus on the 1998-1999 temperature data recorded in selected Missouri caves and a mine. This is part of a wider study of Indiana bat hibernacula by partners with Bat Conservation International. Preliminary results of Priority I caves will be released in a report by Merlin Tuttle of Bat Conservation International. These first results yielded some valuable information but no firm conclusions can be drawn at this time.

Materials and Methods

We used a new model of data logger sold by the Onset Computer Corporation, the Hobo® H8 Pro, with two channels for temperature and relative humidity (Figure 1). These data loggers are weatherproof, have an advertised accuracy of 0.2°C and 3% relative humidity, and a memory capacity of 64K (enough for more than a year of sampling).

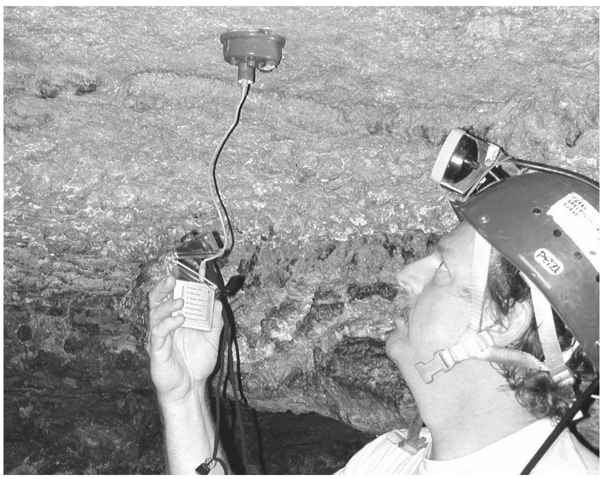

Figure 1. William R. Elliott uses an Onset Hobo® Data Shuttle to offload temperature and humidity data from the Hobo® H8 Pro data logger. The shuttle can hold data from up to seven data loggers.

The logger's 3.6-V lithium battery was rated for three years, but we had problems with resistance building up in some of the batteries, which caused some data loggers to stop early or not run at all. Onset notified its clients about this problem, and we replaced some of the faulty batteries after the first year, but we lost potential data from two out of 20 loggers because of the battery problem. The battery can be removed, briefly shorted with a paper clip or a pocketknife, then replaced. However, the problem can recur. Onset provided a different make of battery to remedy the problem, but one of our two failures was with the new battery. Some loggers would not relaunch with the one-year-old batteries, even after shorting them. The only other problem we noted was an anomalously high temperature spike on one occasion at one outdoor logger (81°C on February 21, 1999), which we ignored.

We deployed the loggers between July and October, 1998, and we retrieved data in August and September, 1999. At most sites we mounted an outdoor data logger on a tree near the cave entrance, and placed a plastic weather cover over the logger. Inside the cave, following Bat Conservation International guidelines, we usually mounted the data loggers on the ceiling at bat roosts with screw anchors installed with portable drills and hand tools. Each logger in the cave had a thin disc of clay between it and the ceiling, which kept the metal back of the logger in close contact with the rock. This arrangement allowed the logger to equilibrate more with the rock temperature instead of the air temperature. This was desirable since these bats are thought to select rock temperature over air temperature. The clay also allowed us to insert the probe of a digital thermometer behind the logger and take readings as a check. We also inserted a patch of clay into a hole or crack near the logger as a second check. On our return to retrieve data these check points were within a few tenths of a degree C of each other and what the logger registered. Ambient air readings were also taken.

Relative humidity often was at saturation in our study caves, and often exceeded the 95% limit that most electronic relative humidity sensors have. In our results the relative humidity often ranged up to a recorded value of 105% (which is impossible), but the overall pattern of humidity change throughout the year and in relation to weather events is still of interest. The relative humidity usually drops dramatically with strong cold fronts, then creeps up again.

Although deployed over a period of three months, the loggers were all set for a three-hour sampling interval on the same schedule, and their clocks were synchronized within one minute. Data were retrieved from the loggers using a small Hobo® Shuttle data transporter, which can store data from up to seven loggers. Data were then uploaded to a computer and analyzed using BoxCar® Pro 3.51 software from Onset. This program instantly graphs each data set. We merged data into approximately year-long data sets of several loggers, and we graphed the data using the Microsoft Excel 97® spreadsheet program.

We obtained weather data from 1975 through 1998 (as daily minimum and maximum temperatures) for several Missouri cities from the Department of Soil and Atmospheric Sciences, University of Missouri–Columbia. The data set from Waynesville, Pulaski County, Missouri, was the most complete and is geographically close to most of our study sites. We examined the secular trend of annual means, extreme lows, and extreme highs using Excel®.

Our study sites in Missouri were Great Scott Cave and Scotia Hollow Cave, Washington County; Bat Cave, Shannon County; Pilot Knob Mine, Iron County; Onyx Cave, Crawford County; and Brooks Cave, Great Spirit Cave, and Ryden Cave, Pulaski County.

Results

To save space we shall present graphs for three types of thermal situations that we see in our data: a site that appears too warm, a site that appears too variable, and a site that appears optimal for hibernation.

Figure 2 depicts the data from Great Scott Cave, Washington County, Missouri. This horizontal resurgence cave has two downstream entrances. We positioned one data logger on a tree and its temperature curve is shown as "outside." We placed four loggers on the cave ceiling at different points ranging from 30 meters to 150 meters inside. A fifth logger at 200 meters from the entrance did not run.

Station #1 in Great Scott is the usual winter roost for Indiana bats, but during colder periods they move farther into the cave to higher, warmer ceilings above the stream. #1 shows that temperature becomes less variable farther into the cave, as expected. However, the baseline temperature in the cave's interior is about 12°C, which may be too warm for a good Indiana bat hibernaculum. Station #1 experienced quite variable temperatures between 1 and 10°C from December, 1998, through March, 1999. During the winter the other roosts varied between 7 and 12°C.

Figure 3 depicts the temperature curve for Bat Cave, Shannon County. This cave has a large, funnel-shaped entrance on the side of a ridge above a river, and acts as a cold-trap. A data logger was placed on a low ceiling where the bats usually hibernate. Another logger was placed on a 12-meter-high ceiling where the bats sometimes move during cold periods; however, this logger did not run and had to be replaced. The graph shows that the lower ceiling temperatures, though in the desireable range much of the time, were quite variable, even dipping to -8°C (18°F) in early January, 1999. The response to cold fronts was nearly instantaneous (within the same three-hour sampling period).

Figure 4 is the temperature curve for Pilot Knob Mine, Iron County. This abandoned iron mine, excavated in rhyolite, is located near the top of a prominent hill and is well-ventilated by upper and lower entrances. The mine is a near-perfect cold-air trap. When approaching the

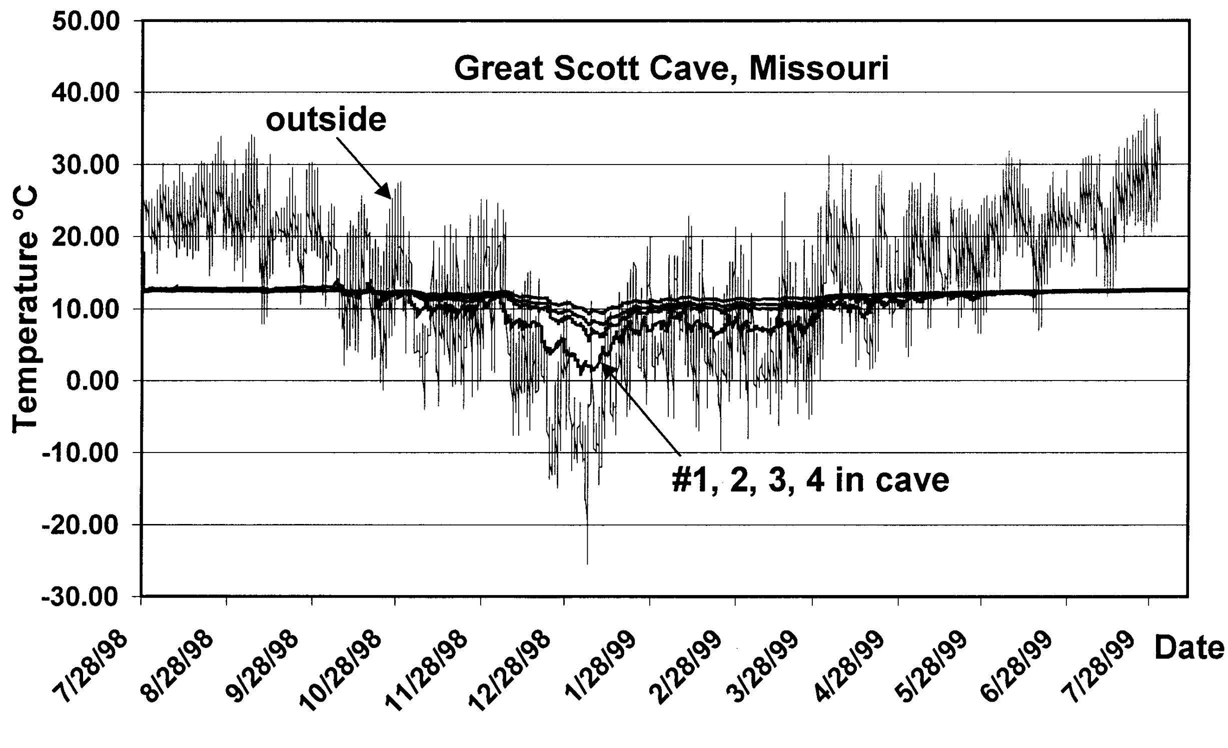

Figure 2. Temperature data from Great Scott Cave, Washington County, Missouri.

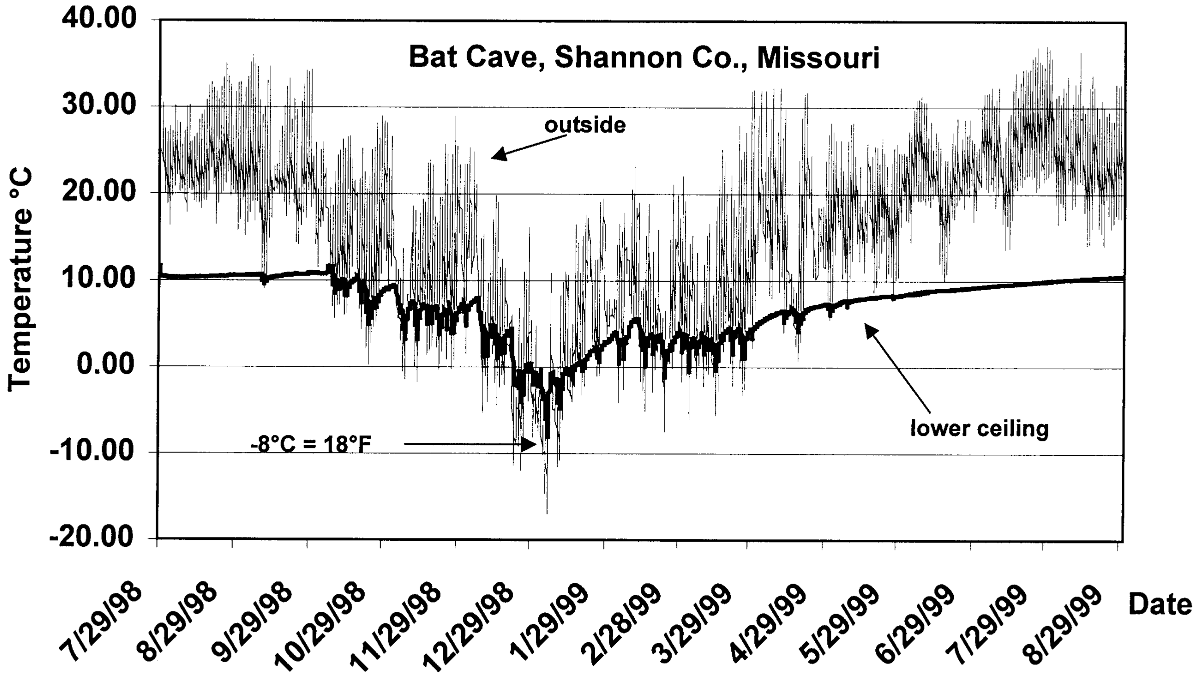

Figure 3. Temperature data from Bat Cave, Shannon County, Missouri.

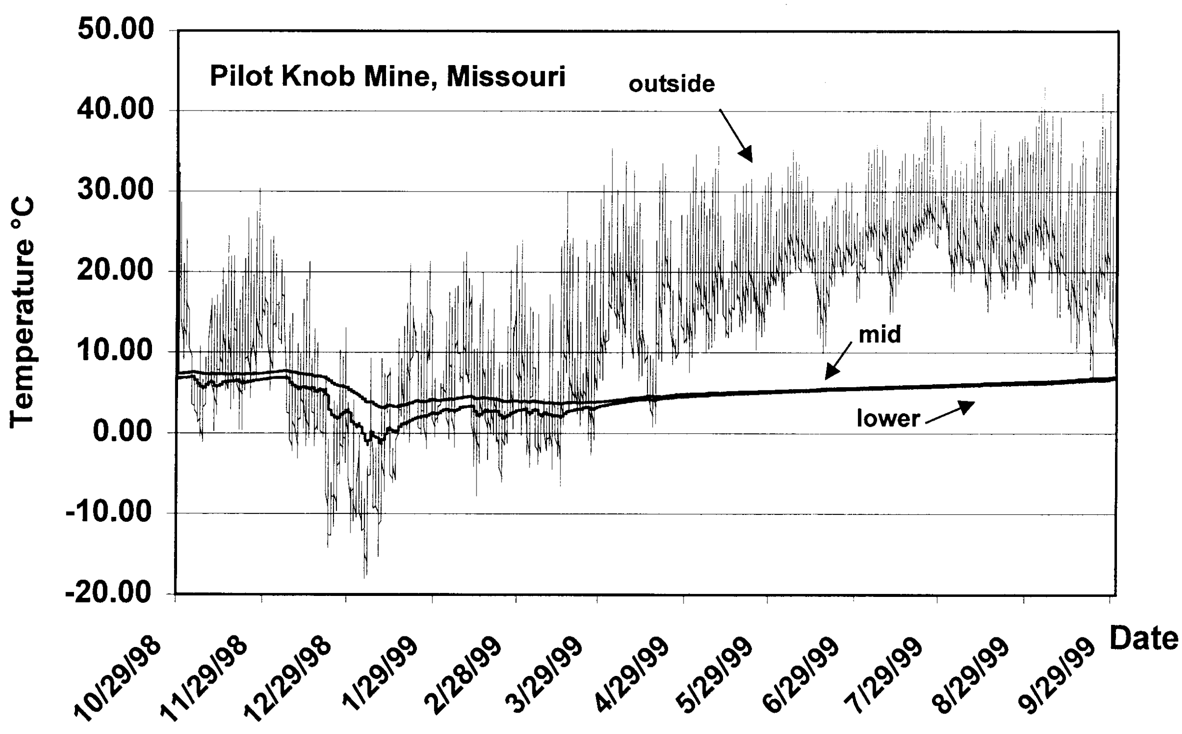

Figure 4. Temperature data from Pilot Knob Mine, Iron County, Missouri.

main, lower entrance of the mine, one usually meets an outflow of chilled air. The outdoor logger was located away from this effect. Two loggers were placed inside, one at about 100 meters inside and about 30 meters below the level of the entrance, and the other about 25 meters farther in and 10 meters lower, at the end of the accessible part of the mine. We did not attempt to enter the lowest levels of the mine, which are below dangerously steep, loose, rubble slopes. The loggers were placed on the floor below Indiana bat clusters because we had no portable drill at the time. Upon our return in October, 1999, we mounted the loggers on the ceiling about three meters above the floor. There should be some minor differences in temperatures from floor to ceiling, but not enough to change the overall thermal picture of the mine.

Figure 4 shows that Pilot Knob Mine is almost ideal for Indiana bat hibernation. Even in the summer the baseline temperature is about 8°C (46°F). During the winter the loggers registered -1 to 5°C. It seems likely that the lower, inaccessible areas of the mine may have slightly lower, but similar temperatures. The structure of the mine offers the bats many alternate roost sites at slightly different, but fairly stable temperatures.

Discussion

Great Scott Cave once housed up to 85,700 Indiana bats in 1983, but the census steadily declined to 9,100 in 1999. The main stream entrance is five meters wide and three meters high, and the secondary entrance, located two meters to the right of the main entrance, is about one meter in diameter. The tubular passage from the smaller entrance joins the main passage about 20 meters inside. A rebar bat gate was installed on the main entrance in 1978, at which time the smaller entrance was closed with a masonry wall. In 1991 the main gate was replaced with a more modern airflow, angle iron gate, but the wall remained in the smaller entrance. Observations of bats and temperatures over the years led us and Merlin Tuttle of Bat Conservation International to suspect that the masonry wall could be inhibiting air exchange, thus causing the front part of the cave to become warmer. In August 1999, Missouri Department of Conservation replaced the masonry wall with a bat gate. We will continue to monitor temperatures in the cave to see if the hibernaculum cools to a more optimal temperature. We cannot say at this time that warm temperatures caused the decline of Indiana bats in Great Scott Cave, but it is a concern.

Bat Cave held up to 76,700 Indiana bats in 1979, but they declined to 6,175 in 1993 and then to a few hundred in 1999. The cave also harbors gray bats. Clawson observed a die-off of about 35,000 Indiana bats in this cave in the winter of 1980. He observed many carcasses on the floor from the previous winter, presumably frozen to death by a severe cold front. We cannot be certain that a freeze caused the die-off, as the cave entrance was not fenced until 1986 and was vulnerable to an act of vandalism, but there was no evidence of such an act. Our 1998-1999 temperature graph varied from about 12° to -8°C, which could easily freeze bats. The shape of the temperature curve indicates much variation. We would classify Bat Cave, Shannon County, as a "risky cave" for bats because it is too responsive to cold fronts. However, it probably is a good hibernaculum most of the time. Since the severest cold fronts are unpredictable, it also would be risky to remedy the situation by trying to control cold air infiltration into the cave in some simple way.

It is not known when Indiana bats first occupied Pilot Knob Mine, but a colony of 80,000 was established by 1962 (Myers 1964). LaVal and LaVal (1980) estimated 139,000 Indiana bats by comparing the exit rate they observed with the exit rate of bats at Great Scott Cave. No reliable census has been made because much of the interior of the mine is not safely accessible. However, harp trapping at the entrance during the fall over the years indicates that this is still a healthy population. The mine temperature is optimal, and the site enjoys a high degree of protection from the U.S. Fish and Wildlife Service, so disturbance of the bats is almost nonexistent.

Most other caves showed temperature graphs intermediate between Pilot Knob Mine and Great Scott Cave. We observed the following variation: Brooks Cave 5 to 10°C, Scotia Hollow Cave 4 to 12°C, Onyx Cave 5 to 12°C, and Ryden Cave 7 to 12°C. Great Spirit Cave was the most variable at 0 to 21°C. All of these caves have had Indiana bat declines, so we cannot necessarily consider temperature as the one factor causing the decline.

From 1975 to 1999 the mean annual temperature (calculated from daily highs and lows) at Waynesville, Missouri, was 12.9°C (55.3°F). The standard deviation was 1.4°C and the range was 11.7 to 14.4°C (53 to 58°F). There appears to be no significant change in mean annual temperature since 1975. However, in examining extreme lows in January, we found that there may be a warming trend since 1975 from about -21 to -18°C (-7 to 0°F). We believe that extreme low temperatures from severe cold fronts are important in influencing hibernaculum temperatures, perhaps more important than mean annual temperatures. Severe cold fronts are usually associated with strong winds and barometric pressure drops, which cause more cold air invasion into caves than weaker fronts. However, we cannot predict how much influence such a slight increase in January lows would have on the hibernacula we have studied.

A number of factors are known or suspected to affect Indiana bat populations. Disturbance during hibernation was one of the first of these factors to be recognized and still is a threat at unprotected sites. Improperly designed cave gates have been implicated in some population declines, but all such gates have been removed or replaced. Loss or reduction of roosting or foraging habitat during the non-hibernation seasons has been postulated, but no instances of habitat-caused population loss have been documented to date.

In view of these other possible stresses on Indiana bats, we cannot conclude at this time that temperature shifts in hibernacula are primarily responsible for the loss of Indiana bats in Missouri. However, we plan to continue monitoring these sites for a few more years. Additional information may help us to resolve these questions.

Acknowledgments

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