PHOLEOS

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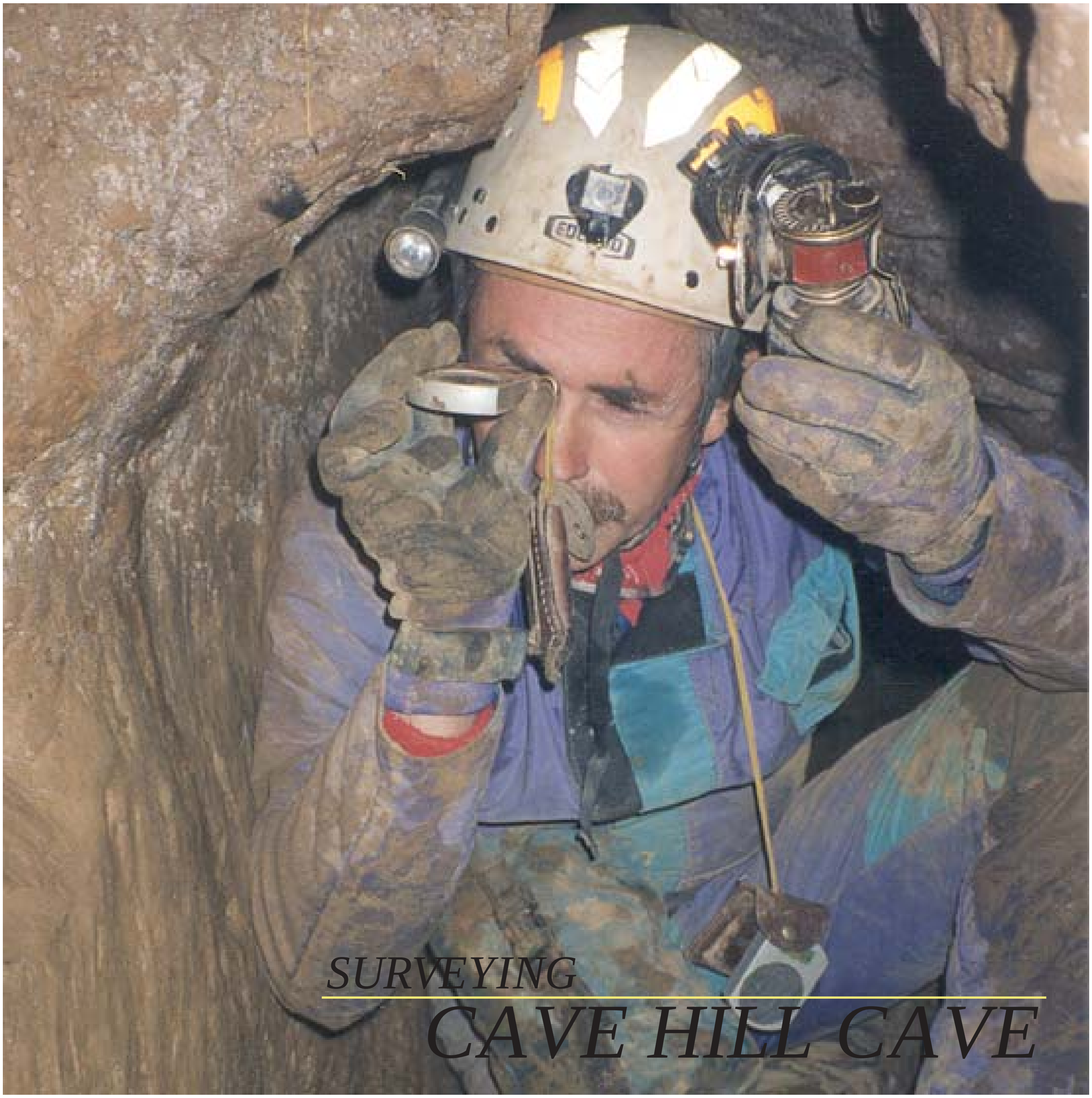

SURVEYING CAVE HILL CAVE

PHOLEOS

VOL. 21 (1, 2)
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CONTENTS

Research

Reviews

PHOLEOS

Pholeos is a biannual journal of the Wittenberg University Speleological Society (WUSS), an internal organization of the National Speleological Society (NSS).

Purpose
The Wittenberg University Speleological Society is a chartered internal organization of the National Speleological Society, Inc. The Grotto received its charter in May 1980 and is dedicated to the advancement of speleology, to cave conservation and preservation, and to the safety of all persons entering the spelean domain.

WUSS Web page
http://www4.wittenberg.edu/student_organizations /wuss/

Subscription rates are $7 a year for two issues of *Pholeos*. Back issues are available at $3.50 an issue.

Exchanges with other grottoes and caving groups are encouraged. Send all correspondence, subscriptions and exchanges to the grotto address.

Membership
The Wittenberg University Speleological Society is open to all persons with an interest in caving. Membership is $16 a year and comes with a subscription to *Pholeos*. Life membership is $150.

Meetings
Meetings are held every Wednesday at 7:00 p.m. when Wittenberg University classes are in session. Regular meetings are in Room 319 in the Barbara Deer Kuss Science Hall (corner of Plum St. and Bill Edwards Dr. - parking available in the adjacent lot).

Submissions
Members are encouraged to submit articles, trip reports, artwork, photographs, and other material to the Editor. Submissions may be given to the Editor in person or sent to the Editor at the Grotto address. Guidelines for submitting research papers can be found on the inside back cover of this issue.

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CO-EDITORS' NOTE

Greetings from the co-editors of Pholeos! We've had a busy past year with trips to Carter Caves for fun, survey and research work. We're continuing our comprehensive survey of the Cascade Cave system and we are working on our latest research project, recording the population of cave crickets in Carter caves. Crawl-a-thon was another great success this year with 18 of our members attending and participating in events. We've also been visiting other caves throughout Indiana, Ohio, and Kentucky as well as doing our part to help out with cave conservation. Hopefully this issue of *Pholoes* will bring to light all of the things that we have been working on this year and in previous years. Our sincere apologies for publishing this issue late - we have been busy here. Happy reading!

Bryan Welch

FRONT COVER: Bill Stitzel taking compass bearing during survey of Cave Hill Cave, Adams County, Ohio (photo by H. Hobbs).

BACK COVER: *Plethodon glutinosus* (Green) from Coon-in-the-Crack Cave I, Carter County, Kentucky (photo by H. Hobbs).

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PRESIDENT'S MESSAGE

I can't help feeling a bit nostalgic as I write this. This edition of *Pholeos* will be the last I will have a chance to work on as a Wittenberg student. In a few short weeks, I and the other WUSS seniors will take our place as alumni of both Wittenberg University and WUSS. Since I joined the caving club as a freshman, I have been fascinated by the experiences I have enjoyed as a member. As you will no doubt notice as you read this issue of *Pholeos*, this year has been no exception. WUSS members are continuing the rich legacy of exploration, conservation, research, and friendship that we have been given by those before us. Here is a glimpse of what we've been up to.

Members are currently working hard to map Cascade Cave in Carter County, Kentucky and are proud to announce that the end is in sight. There is still plenty left to keep us busy, but due to several trips and plenty of volunteers this summer we are well on our way to completing this important project. As well as surveying, several members spent time this summer conducting research in Kentucky, West Virginia, and Ohio.

Fall semester was as busy as ever with trips to OTR, introductory trips for new members, helping out with Dr. Hobb's Cave Ecology class, vertical clinics, speakers, and surveying trips to Cascade Cave. Some members also volunteered time to talk to local Boy Scout troops about cave conservation and safe caving techniques. Trips were taken to Horse Cave, Kentucky for the ACCA clean up, Sloan's Cave, and Carter Caves State Park. Not to mention the first ever Caving Club/Outdoor Club capture the flag game.

We kept busy spring semester with trips to Crawl-a-Thon, Indiana, and of course more surveying trips to Cascade. A successful trip to TAG was a favorite for members who had been working had to perfect vertical techniques. Many of us also had the opportunity to conduct and assist with research in Kentucky and Ohio. We will end the year with a trip to Hocking Hills to hike and practice vertical work, a great party, and our first ever WUSS banquet. Needless to say, members are fired up for a summer of fun and mud!

Caving at Wittenberg is and always has been an invaluable opportunity for WUSS members. The other seniors and I are proud to graduate as WUSSes and "pass the light" to a new group of eager, cave-hungry Wittenberg Students. Let us hope that WUSS will always be there for those that want to spend their time as an undergraduate doing something truly worthwhile, meaningful, and unforgettable. Thanks to all of those who's continuing interest in the club makes everything possible.

Best Regards,

Lindsay McCullough, President
WUSS # 0469
NSS # 48931

Pickeral frog in Kohm's Cave, Ste. Genevieve County, Missouri (photo by H. Hobbs).

RESEARCH

The Ecological Impacts of Saltpeter Mining in Caves

by Kristen Baughman, NSS# 48494, WUSS # 0464

Abstract

The mining of saltpeter from caves was an important American industry in the first half of the nineteenth century. The processes involved in extracting the soil from caves and refining it had irreparable effects on the cave environment. Such effects include: altering airflow patterns within the cave, soil compaction, disturbance and destruction of fauna and their habitats, the introduction of water into previously dry areas of caves, and the introduction of foreign organic matter into the cave system. Saltpeter mining is more than just an interesting historical phenomenon; it is still a significant ecological factor in many cave systems today.

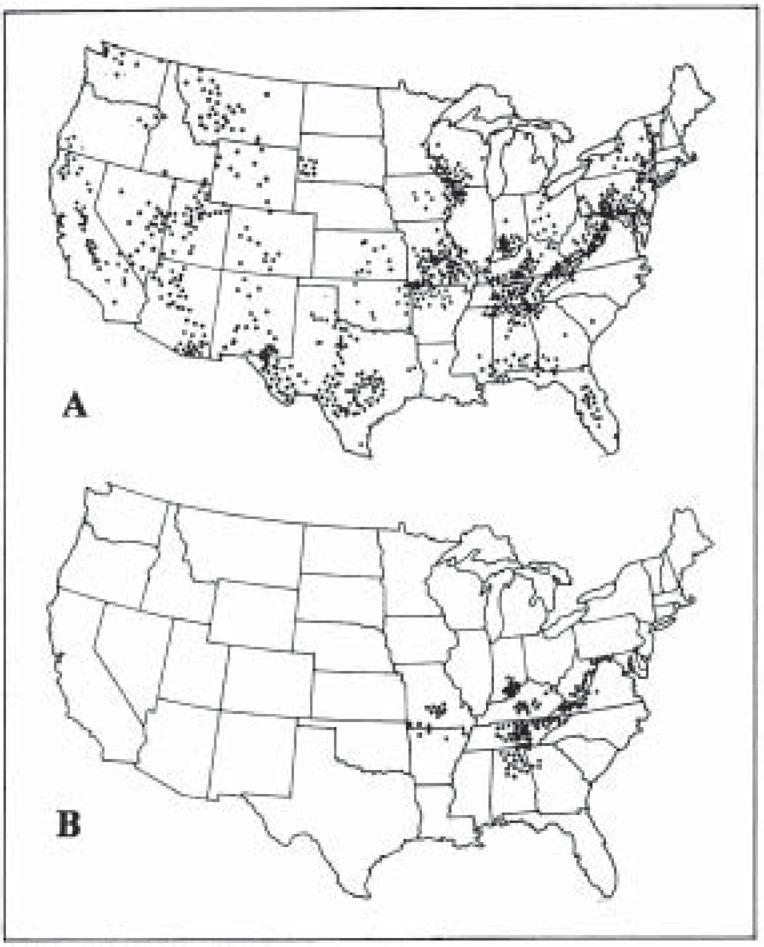

Figure 1. A.) Distribution of limestone caves in the United States. B.)Distribution of limestone caves containing saltpeter. From: NSS Bulletin,

Many people do not realize the important role that caves have played in shaping American history. The rocks and soils of many limestone caves contain potassium nitrate, also known as saltpeter, an essential ingredient in gunpowder as well as an important agent in preserving meat in the days before refrigeration. The process of mining these cave soils and extracting the saltpeter from them was a booming industry commencing prior to the American Revolution and continuing up through the Civil War. A letter written by President Thomas Jefferson to Pierre Samuel du Pont de Nemours in 1806 shows the importance of saltpeter to our national security, stating that there is "a single [saltpeter] cave which would supply us for the whole term of a war" (George 2001: iv). This was in reference to Great Saltpeter Cave, Rockcastle County, Kentucky, but there are hundreds of caves across the United States and the world that were used for saltpeter mining operations. The greatest concentration of saltpeter caves in the United States occurs in the mid-western and southern areas including Kentucky, Tennessee, and Alabama, states that contained some of the most productive caves (see Figure 1). Many histories have been written on this subject, detailing the mining operations undergone at various caves, including the famous Mammoth Cave, Edmonson County, Kentucky, which is now a national park. Many additional articles have been published on the mineralogical properties of saltpeter and the chemical process by which it is created. The goal of this paper, however, is to examine the ecological impacts that saltpeter mining causes within the cave environment.

To determine if the soil in a cave was nitrous, simple tests were performed by these early entrepreneurs; tests that, amazingly, were reported to be fairly accurate, considering the lack of scientific knowledge necessary to perform them. They would look for areas of loose, dry earth and make a small furrow in it, and if upon re-examination a short time later the furrow appeared to be smooth again, it was believed to contain saltpeter. Also, miners would often look for soil containing whitish, needle-like crystals. Sprinkling the crystals onto hot coals and having them burn quietly with no sparking or cracking, determined that soil contained saltpeter (Powers

1981). Once a cave was determined to contain sufficient amounts of saltpeter, mining operations were begun. Depending on the size of the cave and the saltpeter demand, operations could range from one-man jobs to sizable productions employing as many as fifty men.

Once a site was determined to contain saltpeter earth, then began one of the most obvious cave-altering processes involved in the business of saltpeter mining—the extraction of cave soils. Records show that one bushel (0.04 m^3) of earth produced three pounds (1.36 kg) of saltpeter (Smith 1981). This number was tested through an "Action History Experiment" performed at Mammoth Cave National Park, Kentucky in 1975, using historically accurate tools and techniques for saltpeter extraction. This experiment came up with a yield much lower than the common historically recorded figures, but could have been a result of the experimenters' lack of expertise in this process (Eller 1981). However, it is still clear that astounding amounts of soil had to be removed in order to gain worthwhile amounts of saltpeter. Records from Sauta Cave, Jackson County, Alabama state that the mine there could turn out an average of 700lbs. (317.52 kg) of saltpeter per day; other records place that number as high as 1000lbs (453.60 kg) (Smith 1981 and Powers 1981). Based on historical data that it takes approximately one bushel (0.04 m^3) of earth to net three pounds (1.36 kg) of saltpeter, this means that on average, 233 to 333 bushels (8.25 m^3 to 9.44 m^3) of soil were being extracted from this particular cave per day. An 1862 report of saltpeter production from four caves mining saltpeter in Alabama at that period of time, stated that a total of 16,135lbs. (7,318.84 kg) of saltpeter was produced in a four-and-a-half month time span (Smith 1981). To yield such a quantity of saltpeter approximately 5,378 bushels (190.36m^3) of earth would have been extracted from those four Alabama caves alone. Angelo I. George has done careful calculations of the average annual saltpeter output for Mammoth Cave, Edmonson County, Kentucky and Great Saltpeter Cave, Rockcastle County, Kentucky, two of the largest saltpeter operations in the nation, and came up with the figures 53,238lbs. (24,148.76 kg) annual production at Mammoth and 103,519lbs. (46,956.22 kg) at Great Saltpeter at peak period of operation (George 2001). Using even a very conservative estimate of one pound (0.45 kg) yield of saltpeter per bushel (0.04 m^3) of soil, means that the yearly average amount of soil removed from these two caves was approximately 156,757 bushels (5,548.56 m^3) per year.

Of course the amount of soil and rock extracted from caves would have varied greatly over the course of time depending upon the market demand—the figures cited above from Alabama caves were obtained from the midst of the Civil War, a time when saltpeter was very high in demand in the United States. However, when one looks at such figures and imagines the huge quantities of soil that would have been removed from caves over the course of a hundred years of operation, it is astounding. This alters the cave incredibly, enlarging passages, and removing silt that may have taken centuries or millennia to fill. Enlarging cave passages would most likely alter the airflow of caves, greatly affecting the established atmosphere in various sections of the cave. Changing the conditions to which cave organisms have become adapted, this would most likely have a negative outcome for the organisms living in the disturbed areas. For example, Saltpetre Cave, Carter County, Kentucky, a cave whose passages were greatly enlarged through soil removal by saltpeter miners, was historically home to a large colony of the endangered species of Indiana bat (*Myotis sodalis*), based on ceiling stains. These bats seem to prefer caves at a slightly colder temperature and research is currently being conducted to determine exactly how the airflow through this cave operates and the controlling factors behind it. It seems nearly impossible to determine what the pattern of airflow through this cave would have been prior to the time that the mining alterations were made and, in turn, what effect the change would have had on the bat population therein. Many caves contain endemic species and in the soil excavation processes miners also may have removed organisms living therein. Enlarging cave passages also would allow human access into parts of the cave that may previously have been inaccessible. This opens the door for a gamut of human-introduced problems that are inevitable when they step into the cave—broken speleothems, graffiti, trash left behind, and tromping on organisms—just to touch the tip of the iceberg.

Another detrimental aspect of mining soil from caves is the process of expanding passages so that mine workers and equipment can readily enter and exit the cave. Breakdown, which is rock that has fallen from the ceiling and walls of the cave, often had to be removed in order that the soil underneath could be obtained and so that equipment could be transported. Rows of carefully sorted blocks can still be seen lining cave walls or placed in giant heaps in rooms where miners put them to get them out of the way. A good example of this can be seen in Dixon Cave, Edmonson County, Kentucky where it has been observed that "the miners left the rocky fragments within the cavern piled in what might be described as transverse stony billows, of which we counted eighteen; each wave being forty feet through the base, and rising thirty or forty feet above the true floor" (DePaepe 1981: 103). These piles, although not natural to the cave environment, could serve to provide a new habitat for organisms. Further study would be interesting in order to discover what types of organisms have adapted to life in these relatively new breakdown piles (as compared to the naturally occurring breakdown piles that might have been there thousands of years, since the time when the cave went from a phreatic to vadose state). In Mammoth Cave, Edmonson County, Kentucky, today a national park and possibly one of the most famous and most studied saltpeter operations in the country, a continuous rock wall once existed from the entrance along the Narrows Passage to the Rotunda (Hill and DePaepe 1979). This wall is said nearly to have blocked the entrance, which would greatly alter the natural opening and exit used by organisms and perhaps changing the input of allochthonous materials into the cave.

Another key modification made in some caves by miners in an attempt to increase cave passage size was literally to blow away parts of the cave walls and speleothems. Reports of blasting in saltpeter caves note things such as drill holes for black powder, blast marks on the edges of adjacent slabs, and smoky residue left from explosions, as evidence of the miners destructive presence (Finch 1967). Not only did they blast away sections of the limestone cave walls, but in some caves they also created new entrances to provide quicker access to the deeper recesses of the cave. This would undoubtedly change airflow patterns within the cave, probably even more drastically than the aforementioned soil removal, again being extremely disruptive and harmful to certain cave fauna. In some cases there is evidence of the blasting away of cave formations. For example, Hauer (1967: 2-55) reports that in Perry's Saltpeter Cave, Botetourt County, Virginia in the miners' attempt to reach desired niter-rich soil located beneath eight inches (0.20 m) of calcite deposition, the calcite was blown away, creating "hundreds of translucent calcite fragments in the debris." Obviously, the destruction of portions of the cave, including speleothems, and amassing such huge piles of breakdown constitute an amazing effort that irreparably changed the natural design of the cave.

Another part of this process of mining cave soils that affects the cave environment are the methods by which the soil is transported. Even in the smallest mining operations, miners followed set paths over which they routinely carried the soil out of the cave. Many mining operations were large enough to require the use of mules or oxen to haul carts to and fro and at several caves, rail systems for the carts to travel upon were installed. In Mammoth Cave an ox cart road was built, referred to as the "carriage" or "turnpike" cart road. At the end of this road slaves would carry the "petre dirt" and dump it into the carts. Then, oxen would carry it to the leeching vats. This road "became as hard and smooth as pavement from wear" (Hill and DePaepe 1979: 253). The soil upon which they traveled would become highly compacted, destroying the habitat of organisms that use loose cave soils in which to burrow. For example, cave crickets are known to lay their eggs in the soil of caves; compaction makes this very difficult, thereby decreasing their capability to reproduce.

The oxen used in Mammoth Cave were actually stabled within the cave itself, just beyond Booth's Amphitheater. They were fed corn and corn blades and "for many years corn cobs littered the floor of the cave" (Hill and DePaupe 1979: 253). Bringing these pack animals into and out of the saltpeter caves introduces foreign sources of organic matter that can be used as potential sources of food by opportunistic cave organisms—both from the feed scattered on the cave floor and the animal feces that were undoubtedly left behind, even if removal efforts were made. This is a potential alteration of the food web within the cave.

Once the earth was gathered from the cave, then began the process of leeching it in order to extract from it the precious saltpeter. A quick summary of how this process was historically carried out is as follows:

> The soil and rock fragments were excavated and placed in large rectangular or V-shaped wooden hoppers; water was poured through to dissolve the nitrate minerals. The liquid leachate was collected and piped to evaporation furnaces on the surface outside the cave. Here the solution was concentrated by boiling and then percolated through a vat of wood ashes (potash). Calcium was replaced by potassium from the wood ashes to form potassium nitrate, or saltpeter, in the only chemical conversion required in the production sequence. The saltpeter solution was again concentrated and impurities removed in evaporation furnaces. Additional cycles further increased the purity of saltpeter. Cooling the remaining liquid

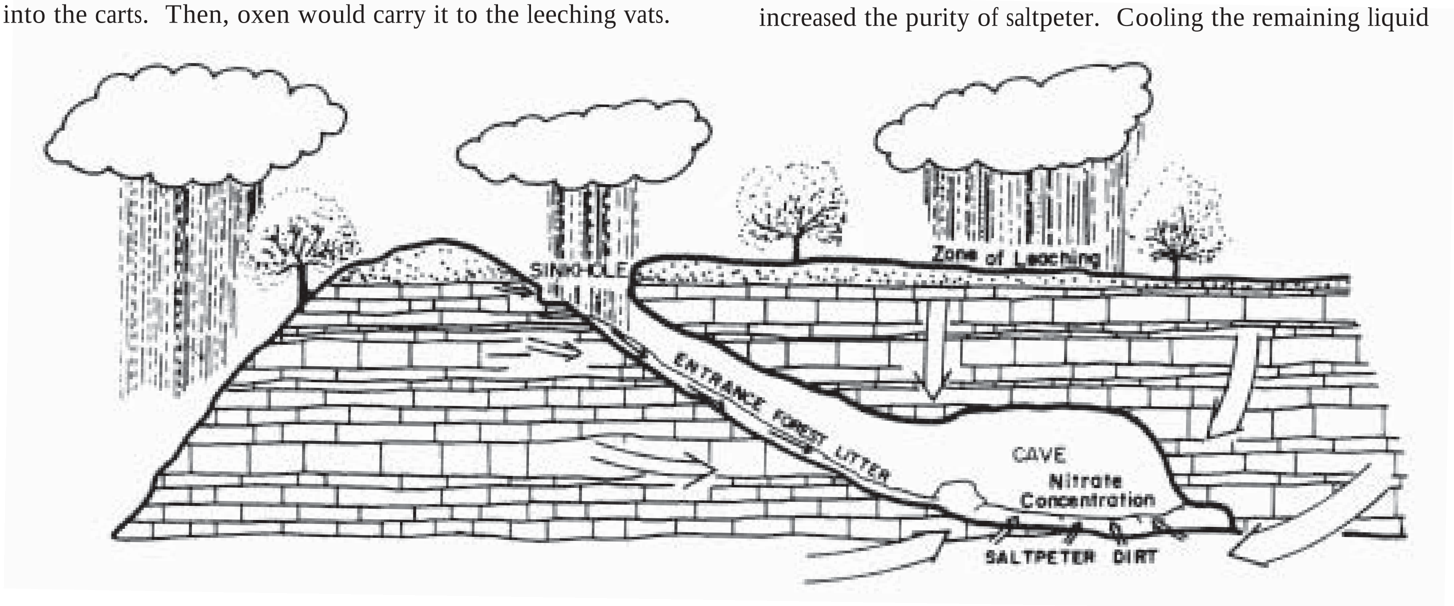

Figure 2. Idealized model of cave nitrate origin: the ammonium (NH4+) ion is transported by seeping groundwater (arrows) to the dry cave where it is oxidized to nitrate by the nitrifying bacteria, Nitrosomonas *and* Nitrobacter. *From: Hill, 1981*

promoted the growth of saltpeter crystals (George and O'Dell 1992: 6).

The extent of the equipment used, of course, varied depending on the size of the cave and the size of the operation. In many caves, such as at Mammoth Cave, leaching of the cave soil actually took place within the cave itself (mainly to reduce the distance the soil had to be carted) and, therefore, required that water be pumped into the cave. Hill (1981), respected expert in the field of saltpeter origin research, has shown that saltpeter most often occurs as a result of seeping groundwater transporting the ammonium (NH_4^+) ion to the dry cave, where it is oxidized by *Nitrosomonas* and *Nitrobacter*, the nitrifying bacteria (See Figure 2). Hence, saltpeter-rich soil is often found in areas of caves containing damp soil, but not flooded areas since it has been shown that where water drips into cave sediments, nitrate is leached away. Therefore, by pumping water into the cave for leaching purposes, water was introduced into areas of caves lacking much active water flow or drip. Bringing water into an area that was previously dry creates the potential for producing more biological activity in that area. Aquatic organisms now have a source of possible habitation, thereby potentially altering the food web in those portions of the cave.

Another side effect associated with pumping water for leaching saltpeter soil, stems from the source of the water being used. Obviously, for the sake of convenience, water would be pumped from a nearby location. Pumping water from a karst aquifer is often very complex, since the underground network of "pipes" is intertwined. Obtaining water from a stream in a nearby cave or spring alters the balance of the entire system; by removing water from one point, it ultimately will have an effect on the water supply available further down the line. For example, the water used at Mammoth Cave was mostly obtained from water diverted from the entrance waterfall, then gravity fed into the vats in the cave below (Hill and DePaepe 1979). This water falling into the cave entrance would have been an important input of allochthonous materials available to the cavernicoles inhabiting the cave. Trapping the water in a pipe would certainly prevent this from occurring and, therefore, deprive an ecosystem with an inherently limited food supply, of important nutrients.

Once the soil was leached and the saltpeter extracted there is the question of what was done with the soil that had been leeched of its nitrates, also referred to as lixivated soil. Researches have proven that the soil can essentially be "recycled;" soils known to have been leached previously of their nitrate are shown to have regenerated, rebuilding relatively high nitrate concentrations (Hill and DePaepe 1979). Apparently though, saltpeter miners did not always take advantage of this property, because as George and O'Dell (1992:8) report of the saltpeter works at Mammoth Cave, "once leaching was complete, the chemically exhausted soils were discarded and spread outward from the rectangular hoppers. The gradual build-up of lixivated soil formed a saltpeter apron. When the hoppers became unmanageable, the hoppers were disassembled and rebuilt at a higher elevation." Hill and DePaepe (1979:252) also note that at Mammoth, "the ox cart wheels made both rut and hub-mark impressions in the wet lixivated saltpeter dirt that had been discarded along the cave passageways. Also, many hoof prints were impressed in the wet dirt by the oxen." Basically, it seems that the used soil was rather carelessly redeposited within the cave, and surely organisms and their habitats were damaged or destroyed in the process.

Clearly the height of saltpeter mining occurred in the first half of the nineteenth century, with peaks during the War of 1812 and the Civil War. After the Civil War, nitrates and gunpowder were imported freely again and the process of extracting saltpeter from cave earth became virtually extinct. The invention of the Haber process for fixing atmospheric nitrogen in 1913 completely ended reliance on natural nitrate deposits, and completely sealed the fate of this industry (Eller 1981). Therefore, in many saltpeter caves, mining operations simply ceased and equipment was abandoned. Left behind were the physical records of the miners' activities within the caves, many of which are still visible today, over a century later. Objects foreign to the cave environment, such as wooden water pipes and wooden vats and carts, rather abruptly discarded and deserted, now provide new habitats and food sources for cave organisms.

Reflecting upon the important role that saltpeter mining played in American history, Horace C. Hovey, an early speleologist from the late nineteenth century, stated, "It is strange that these interesting materials of American history seem to have completely escaped the attention of our best historians" (Hill and DePaupe 1979: 262). Over a century later, many historians have since examined when, where, how, and why saltpeter mining took place. However, little attention seems yet to have been paid to what exactly saltpeter mining did to the ecological balance of the cave environment. For example, many historians have considered and calculated the total saltpeter output from various caves, but it does not seem that too many have looked at the reverse side of that question—just how much soil was required to be disturbed, therefore, to provide the nation with such large quantities of saltpeter. Without a lot of specific scientific data recorded from these caves prior to the start of mining operations, conclusions as to the full extent of impact may be hard to obtain, but some obvious effects still remain to be seen within caves even today. Hopefully, this paper has raised some questions that can be further studied regarding the ecological impacts of the saltpeter mining industry.

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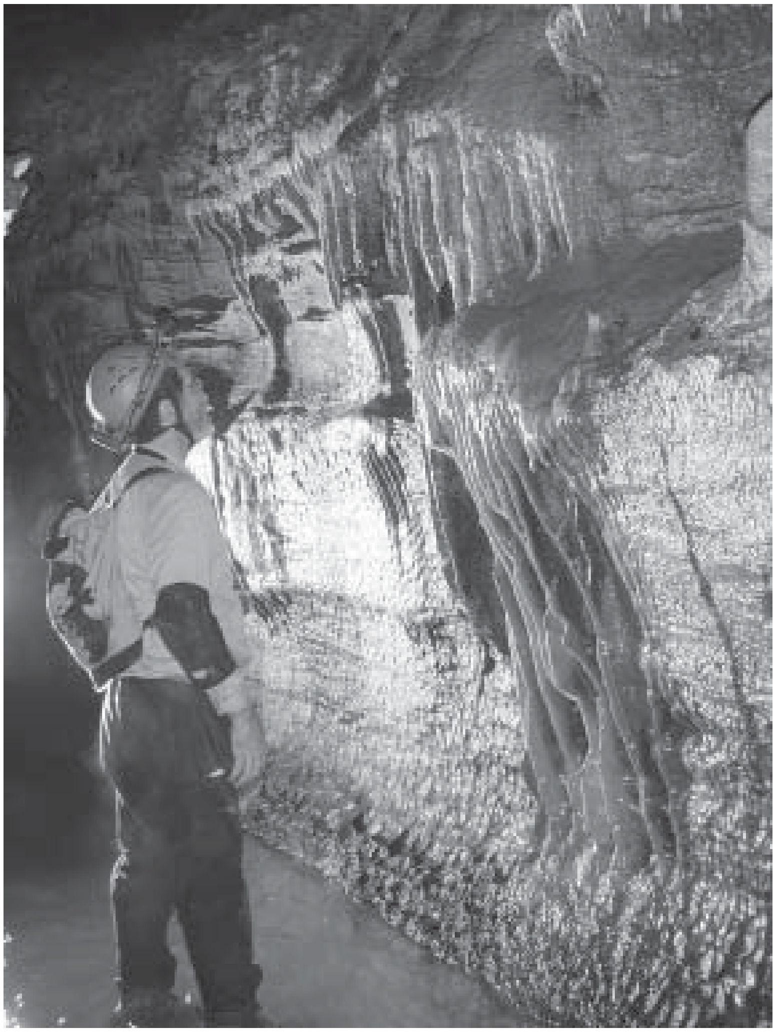

Flowstone in Kohm's Cave, Ste. Genevieve County, Missouri (photo by H. Hobbs).

Climatic effects on the population density of the salamander, *Plethodon glutinosus* (Green), in Coon-in-the-Crack Cave I, Carter County, Kentucky

by Matthew C. Hazelton, NSS# 47187, WUSS# 449 and Horton H. Hobbs III, NSS# 12386 HM, CM, FE, WUSS # 0001

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Abstract

The purpose of the study was to correlate changes in surface climate with those in population densities of a species of salamander, *Plethodon glutinosus*, in Coon-in-the-Crack Cave I, Carter County, KY. *P. glutinosus* is a lungless salamander and needs high humidity to respire through its skin. They are nocturnal and are active only during times of high humidity and mild temperatures. Once a month, from March 2000 to February 2001, Coon-in-the-Crack Cave I was searched systematically for salamanders. For each accessible salamander, location within the cave, snout to vent length, weight, and sex were recorded. HOBO® Data Loggers were placed throughout the cave to record temperature and humidity. Data loggers also collected surface temperature and humidity data to facilitate the comparison of surface and subsurface climatic conditions to the distribution and abundances of each species in the cave. This study explains the seasonal distribution and climatic preferences of cave-exploiting *P. glutinosus* within the cave environment. The salamanders were absent from the cave until surface temperatures reached 27°C during the day and dropping to 15°C at night with surface humidity fluctuating from saturation level to 12% relative humidity in a single day. *P. glutinosus* use Coon-in-the-Crack Cave I as a refugium from high temperatures and low humidity. *P. glutinosus* predominately inhabit the cave environment when the surface climate is not conducive to their survival, too dry or hot, and female *P. glutinosus* use the cave as a breeding ground.

Introduction

For almost half a century temperature and water have been known as paramount factors in the survival of salamanders. Brattstrom (1963) showed that behavioral adjustments are the only temperature control available to salamanders and Thorson and Svihla (1943) found that amphibians lose water even when they are in saturated environments and at normal temperatures. This study was completed to build upon these earlier studies and to determine the effects of temperature and humidity on the usage of caves by the Slimy Salamander, *Plethodon glutinosus* (Green) (Figure 1).

Plethodontid salamanders cannot tolerate extreme temperatures; their acceptable range is 9-27°C but the preferred temperature is 17.4°C (Spotila 1972). *P. glutinosus* requires high humidity to survive because it is a lungless species of salamander that respires through its damp skin (Cowley 1998).

Figure 1. Plethodon glutinosus.

The rate of dehydration is dependent upon body size, temperature, and heavily upon humidity (Spotila 1972). Because low humidity can kill these salamanders in a matter of hours, slimy salamanders are found in epigean habitats that are moist and relatively cool. On dry nights they must stay in places that they select as a suitable microclimate. Their success in such a widespread area and variety of climates, especially considering their sensitivity to temperature and humidity, is due to their ability to choose optimal microclimates. One such microclimate is characteristic of the hypogean environment of the cave. Slimy salamanders living above ground are active predominantly at night because relative humidity is high. But when occupying a cave, they are not restricted by fluctuating humidity and temperature.

Figure 2. Eurycea longicauda *(Green).*

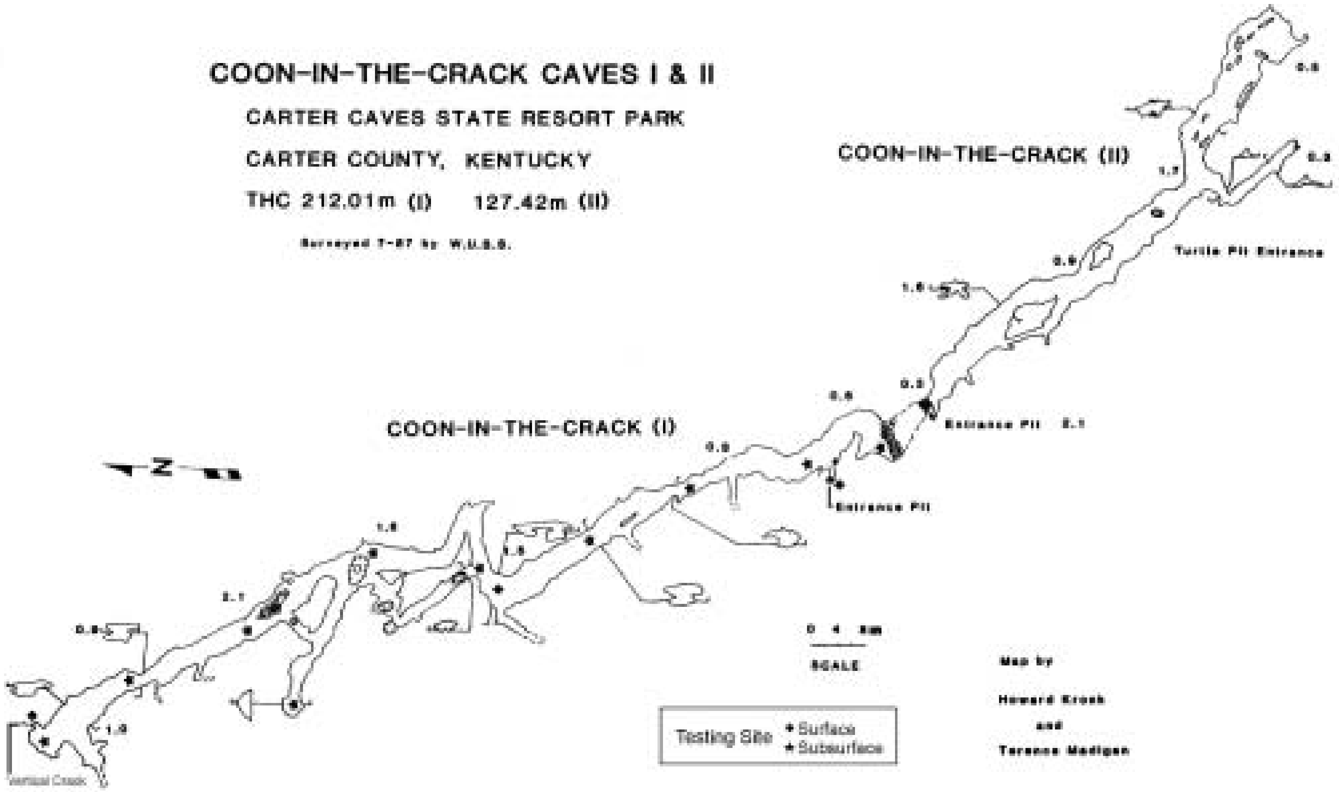

Figure 3. Plan map of Coon-in-the-Crack Caves I & II (modified from Kronk and Madigan 1988) showing study sites.

All salamanders are carnivorous and consume a wide variety of food. Their diet includes spiders and various insects such as flies and crickets. Although primarily carnivorous, they eat plants occasionally; moss and limestone fragments also have been found in salamander stomachs (Neumann 1998, Peck 1974). Yung (2000) found that the diet of epigean *P. glutinosus* consisted of 42% ants, 26% beetles, as well as sow- bugs and earthworms. Hypogean *P. glutinosus* likely consume organisms available to them in the cave. Heleomyzid flies, the crickets *Hadenoecus cumberlandicus* Hubbell and Norton and *Ceuthophilus stygius* (Scudder), and the spider *Meta ovalis* inhabit Coon-in-the-Crack Cave I and provide a source of food for *P. glutinosus* as well as *E. longicauda*, a second salamander that dwells in the cave occasionally (Figure 2). Plethodontids will eat any organism within a reasonable size range. Therefore, habitat selection is not restricted by food type, but by the availability of food (Hairston 1949). Even if food is plentiful, favorable temperatures and humidities, such as those in caves, must occur frequently enough during the year for surface dwelling salamanders to forage effectively and satisfy energy requirements (Spotila 1972). The slimy salamander is in an intermediate position in the epigean food web (i.e., it preys upon smaller herbivores and carnivores but is preyed upon by other carnivores) but is one of the climax species in the hypogean food web. Almost any carnivorous species that can catch the salamanders will eat them if they are not deterred by a slimy, bad tasting film that the salamanders secrete when threatened (Hairston 1949).

After breeding in early April, deposition of the eggs occurs during late spring in the north and late summer in the south (Yung 2000). The high humidities and nearly constant temperatures of caves create ideal conditions for the survival of the hatchlings year round. Because of this, hypogean salamanders do not always limit themselves to laying eggs during the normal surface periods (Highton 1956). Eggs always are deposited in moist areas such as under logs, bark, or, when possible, in caves. Clutch size for these plethodontids is four to twelve eggs. The hatchlings are completely black and do not emerge until approximately three months after the eggs are deposited (Yung 2000). Because of the absence of a juvenile aquatic stage in the life of *P. glutinosus,* the salamanders are not restricted to caves containing pools or streams.

Most lungless salamanders are nocturnal with the peak activity time for *P. glutinosus* around 23:00. Even during times of high activity, the salamanders do not travel great distances. The mean home range was given as 3.01 ± 0.613 m^2 by Yung (2000) and 14.4 m^2 by (Grover 1998). When defending their territory, slimy salamanders are quite aggressive towards their own species as well as competitor species. Because of restricted temperature and humidity requirements, even nocturnal activity is limited (Grover 1998). On the surface, *P. glutinosus* is able to forage beneath cover objects during dry and/or hot periods (Highton 1956). But, when the salamanders inhabit a cave they are not limited by surface climate changes and thus are able to forage virtually whenever necessary.

During winter, surface dwelling *P. glutinosus* retreat from under logs, stones, and other forest litter which are their normal habitats. They are not found at the surface during winter months, even during warm periods when other species of salamanders are active (Highton 1962). Little is known about where *P. glutinosus* go during this cold period.

Coon-in-the-Crack Cave I is a dry cave (no stream or sizeable pools) located in Carter Caves State Resort Park, Carter County, KY and is situated 50-100 meters above local base level. This cave, 212 meters in horizontal length, was once part of a larger cave, but became separated from the other section, Coon-in-the-Crack Cave II, due to substantial collapse of the ceiling (Kronk and Madigan 1988). This cave has two connection points with the surface (Figure 3). The near vertical main entrance is large enough for humans to enter, but the other opening has a diameter of approximately ten centimeters.

Figure 4. Downloading humidity and temperature data.

Caves provide an important habitat for various organisms, some of which cannot survive out of this unique environment; they also harbor species that periodically migrate into and out of them. Organisms that inhabit caves are called cavernicoles. Trogloxenes are terrestrial species that cannot complete their life history in caves but can survive for long periods in the cave environment (e.g., bats). Troglophiles are terrestrial species that can inhabit caves for the duration of their lives, but are not physically adapted to cave life (e.g., no loss of pigmentation and/or sight) (Hobbs 1992, Gillieson 1996, Moore and Sullivan 1997). Two salamander species, *Eurycea longicauda* (Long-tailed Salamander) and *Plethodon glutinosus* (Slimy Salamander), are troglophiles inhabiting Coon-in-the-Crack Cave I (Athy *et al*. 1998; see also Hutchison 1956 and Thibault et al. 1999).

Caves are divided into four ecological zones, based primarily on light, humidity, and temperature: entrance zone, twilight zone, variable temperature dark zone, and the constant temperature dark zone. Salamanders have been documented in each of these ecological zones (Moore and Sullivan 1997).

P. glutinosus, even at birth, respire through their skin. Thus, the ability to lay and hatch eggs in an environment absent of water allows *P. glutinosus* to procreate in a cave free of streams and pools, such as Coon-in-the-Crack Cave I. Conversely, *E. longicauda* must hatch their eggs in a wet environment because neonatal *E. longicauda* breathe by diffusion of water through gills. Thus, length and sex data, coupled with availability of water, can help determine whether salamanders are using the cave as a breeding ground and safe haven for their young.

Our hypothesis was that *E. longicauda* and *P. glutinosus* predominately inhabit the cave environment when the surface climate is not conducive to their survival (too dry, hot, or cold), and that female *P. glutinosus* use the cave as a breeding ground.

Methods

The study was conducted at Carter Caves State Resort Park, Carter County, Kentucky, USA. Once each month, a trip was made to Coon-in-the-Crack Cave I to collect data. Thirteen sites were established throughout the four ecological zones of the cave and two more sites were located on the surface, one next to the main entrance and one halfway between the two entrances (Figure 3).

At each of the sampling sites, data loggers recorded temperature of the air and/or ground for the duration of the study; five loggers also recorded humidity. The StowAway XT1 Electronic Temperature Data Loggers® recorded temperatures approximately every ten minutes. Humidity values were compiled at ten minute intervals by Hobo® data loggers (Figure 4). The sampling sites were used as points of reference when noting the location of individual salamanders relative to the ecological zones.

During each trip Coon-in-the-Crack Cave I was searched systematically, beginning at the entrance and ending at the small vertical crack leading to the surface (Figure 3). On the surface, an area with a five-meter radius around the main entrance was searched for salamanders because salamanders consume other organisms and may have left the cave periodically to feed.

The location of each salamander was recorded in relation to the previously determined sites and ecological zones. Additionally, the occurrence of all additional biota was noted.

Originally, every *P. glutinosus* was to be measured using the “mander masher,” a device designed and presented by Wise and Buchanan (1992). This apparatus, consisting of a sponge and small sheet of plexiglass, was found to be difficult to use with *P. glutinosus* because their size and strength required the use of pressure that was deemed harmful to the salamanders. Instead, a ziplock baggie was used to hold the salamanders while snout to vent length (SVL) was taken. Since two thirds of a salamander’s length comes from its tail, measuring snout to vent instead of snout to distal end of tail removed bias due to injuries (e.g., missing tails). The age class, adult or juvenile, was assessed based on juvenile *P. glutinosus* having a length of less than 5.0cm; any salamanders with a SVL greater or equal to 5.0cm were considered adults. Each *P. glutinosus* was weighed to the nearest half gram using a Pesola ® 120K scale. Any injuries previously incurred by the salamanders (e.g., missing or damaged tails) also were noted.

In order to establish the population size of the salamanders occupying Coon-in-the-Crack Cave I it was necessary to mark each salamander. One toe was clipped on each salamander to mark that it had been captured. If the salamander was found in the dark zone the first toe on its’ right front foot was clipped. On a salamander found in the light zone, the first toe on its’ left front foot was removed. Salamanders found in the entrance area had the first tow of the right rear foot clipped and the first toe of the left rear foot was clipped if the salamander was found outside the cave. Recaptured individuals received an additional toe clip only if they were found in a different ecological zone than the one in which they were previously marked. Every recapture was noted along with the zone where it was first captured. The size of the population of *P. glutinosus* using Coon-in-the-Crack Cave I was determined using Schnabel’s Index ($N = \sum AB / \sum C$) (Schnabel 1938).

Results

Systematic searches were conducted, once every month, from February 2000 until January 2001 in Coon-in-the-Crack Cave I. The data that follow were collected during each sampling period and are related to the habitation of the cave by the Slimy Salamander, *Plethodon glutinosus*.

Searches of Coon-in-the-Crack Cave I indicated that salamanders began using the cave as a refugium when surface temperatures began to reach 27 °C and only dropping to a low of 15 °C (Figures 5-8). At the same time, relative humidity would reach saturation levels but drop as low as 12%. *P. glutinosus* began to move into the cave gradually, building in density as the average temperature rose and the average relative humidity fell.

During the study period, temperatures ranged from 30.31 to –19.49 °C on the surface, a difference of 49.8 °C (Table 1). Surface relative humidities (%RH) also showed great variation, 102.8 to 3.4%, a 99.4 % difference. The entrance zone of Coon-in-the-Crack Cave I had a temperature fluctuation of 9.24 °C (12.55 to 3.31 °C). Relative humidity at the entrance was more stable than on the surface, varying 49.8%. The dark zone of the inner cave showed the greatest degree of stability for both temperature and humidity. The temperature only changed 1.17 °C over the entire year and relative humidity fluctuated by only 5.4%. These trends are readily apparent when examining data in Figure 6, a summary graph of surface and cave temperature, relative humidity, and *P. glutinosus* abundance. Table 1: Variability of temperature and humidity during the study in regard to specific study sites.

Table 1: Variability of temperature and humidity during the study in regard to specific study sites.

Temperature (°C)	Humidity (%RH)		
30.31	102.8	High	Surface
-19.49	3.4	Low	
12.55	103.7	High	Entrance
3.31	64.3	Low	
12.55	104.0	High	Dark Zone
11.38	98.6	Low	

Table 2: Summary of the division of *P. glutinosus* inhabiting Coon-in-the-Crack Cave I by sex and maturity.

Type	Study Total *P. glutinosus*
Males	6
Females	83
Unknown Sex	60
Adult	105
Juvenile	18
Inaccessible	26

Table 3. Mark and Recapture data obtained using the toe-clip method of marking captured *P. glutinosus*.

Month	Jun	July	Aug	Sept	Oct
Recaptures	0	9	7	6	4
New Captures	29	32	26	4	1

The population of *P. glutinosus* was estimated to be 326.78 using the Schnabel Index ($N= \sum AB/ \sum C$) (Schnabel 1938) and the data from Table 3.

Table 4. Distribution of resident *P. glutinosus* in the two ecological zones, the twilight zone and the dark zone.

Month	April	May	June	July	Aug	Sept	Oct	Total
Twilight Zone	0	4	13	11	10	5	1	44
Dark Zone	1	5	16	34	32	11	7	106

The dark zone of Coon-in-the-Crack Cave I was shown to be preferred 2.4 : 1.0 over the twilight zone (Table 4).

Discussion

A strong correlation was noted with increased surface temperature, decreased surface relative humidity, and higher densities of *Plethodon glutinosus* in Coon-in-the-Crack Cave I. Because dark zone temperature and humidity values remained virtually constant year-round the increase in salamander usage of the cave is correlated with incompatible surface conditions. Salamanders have no internal way to regulate temperature and water loss, having to do so by choosing beneficial micro-climates. The cave environment is an optimal microclimate for the Slimy Salamander and is utilized when other micro-climates are not available or as suitable, such as occur in epigean environments seasonally.

P. glutinosus inhabiting the cave is able to forage regardless of the epigean changes in temperature and humidity. Ordinarily the salamanders must wait for a cool, moist night to forage, to prevent being exposed to conditions that would cause them to desiccate, or they are limited to what food is under their cover object. Because of the perpetually cool and moist nature of the cave there are fewer limitations to the activity of the salamanders. The cave also serves as a shelter from predators. Most of the salamander's natural enemies are not cavernicoles of any type (i.e., they would rarely if ever occur in the cave environment). Some of the instability of the temperature and humidity in the dark zone, as shown in Figure 8, can be attributed to human impact (i.e., visitation by researchers), raising temperatures and lowering relative humidities.

The average home range of *P. glutinosus* is between 4 m^2 and 14.4 m^2 (Merchant 1972, Marvin 1995). Thus it is possible that the salamanders could leave the cave to forage during cool and moist nights during the summer months. However, we were unable to determine whether or not this actually occurs. The existence of a permanently humid environment may allow the salamanders to forage for extended periods of time on cool-moist summer nights or even for short periods on non-ideal nights. They have the ability to regain lost moisture by re-entering the cave following their excursion.

In April, *P. glutinosus* began to move into the cave most likely to avoid inhospitable surface climatic conditions. But, by November all of the salamanders had evacuated this important microclimate. These results indicate that *P. glutinosus* move closer to the surface during cool-moist weather. Similarly, the salamanders need the close proximity of the winter cold to lower their metabolism to 'hibernate' for the months when surface food is much less abundant.

The higher density of female compared to male *P. glutinosus* indicates their probable use of the cave as a breeding

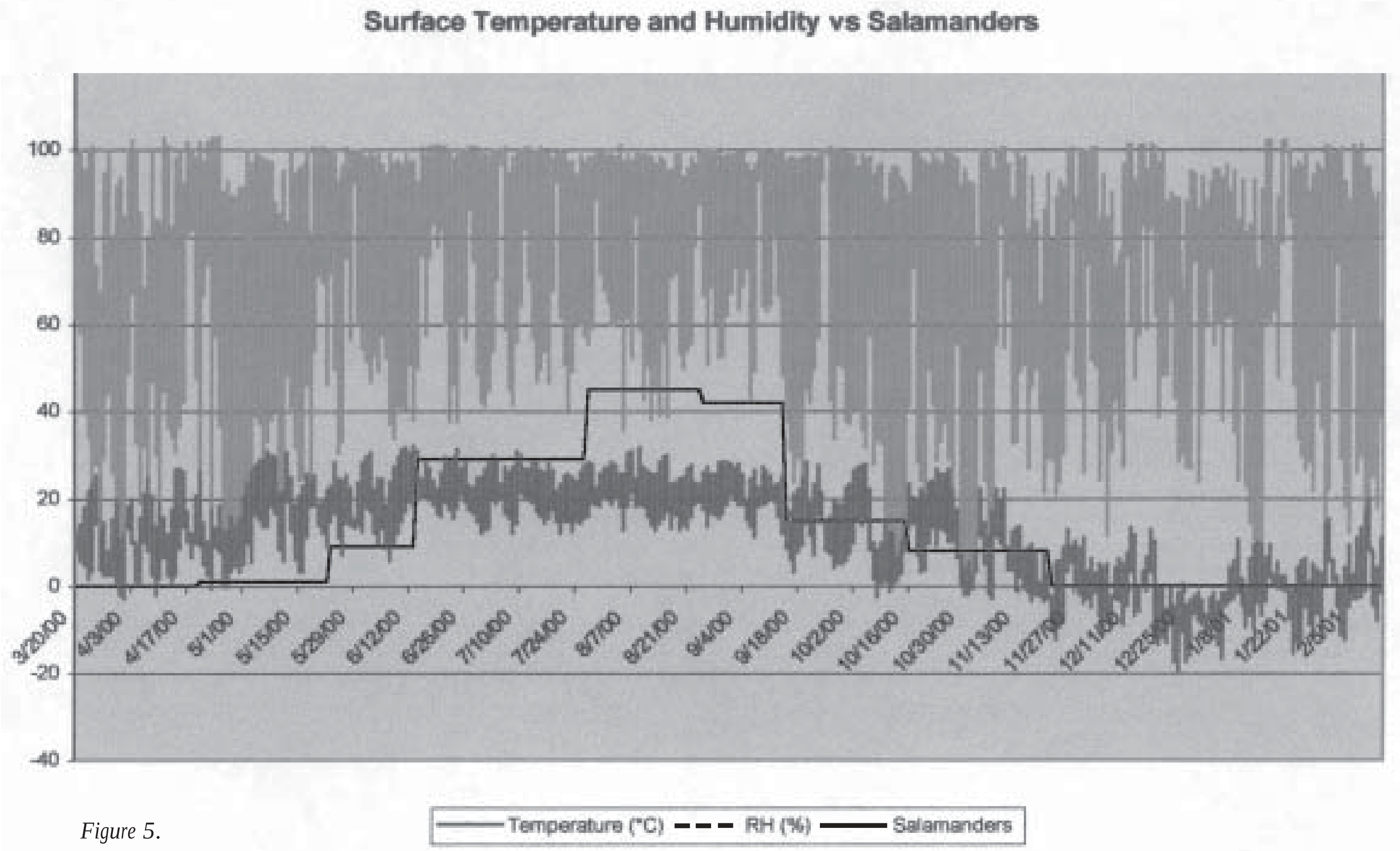

Figure 5.

ground. The presence of juveniles in the dark zone of the cave suggest that eggs likely hatch in the cave. Eggs are deposited between late spring and late summer (Yung 2000), the time during which Coon-in-the-Crack Cave I has the highest population of salamanders. The cave's high humidity and nearly constant temperatures are ideal for hatchling survival. The life history of *P. glutinosus* lacks the juvenile aquatic stage, so the salamanders are not restricted to caves containing pools or streams, as is the case for Coon-in-the-Crack Cave I (Highton 1956). The data in Table 2 indicate that the cave is used by female salamanders 13.8 times more readily than male salamanders, leading to the determination that females may use the cave as a breeding ground.

The results of this study demonstrate that *P. glutinosus* uses Coon-in-the-Crack Cave I as a preferred microhabitat primarily when it is more beneficial than any other available habitat. These times are probably when females are laying eggs and the eggs are hatching as well as during hot and dry epigean climatic conditions.

Acknowledgments

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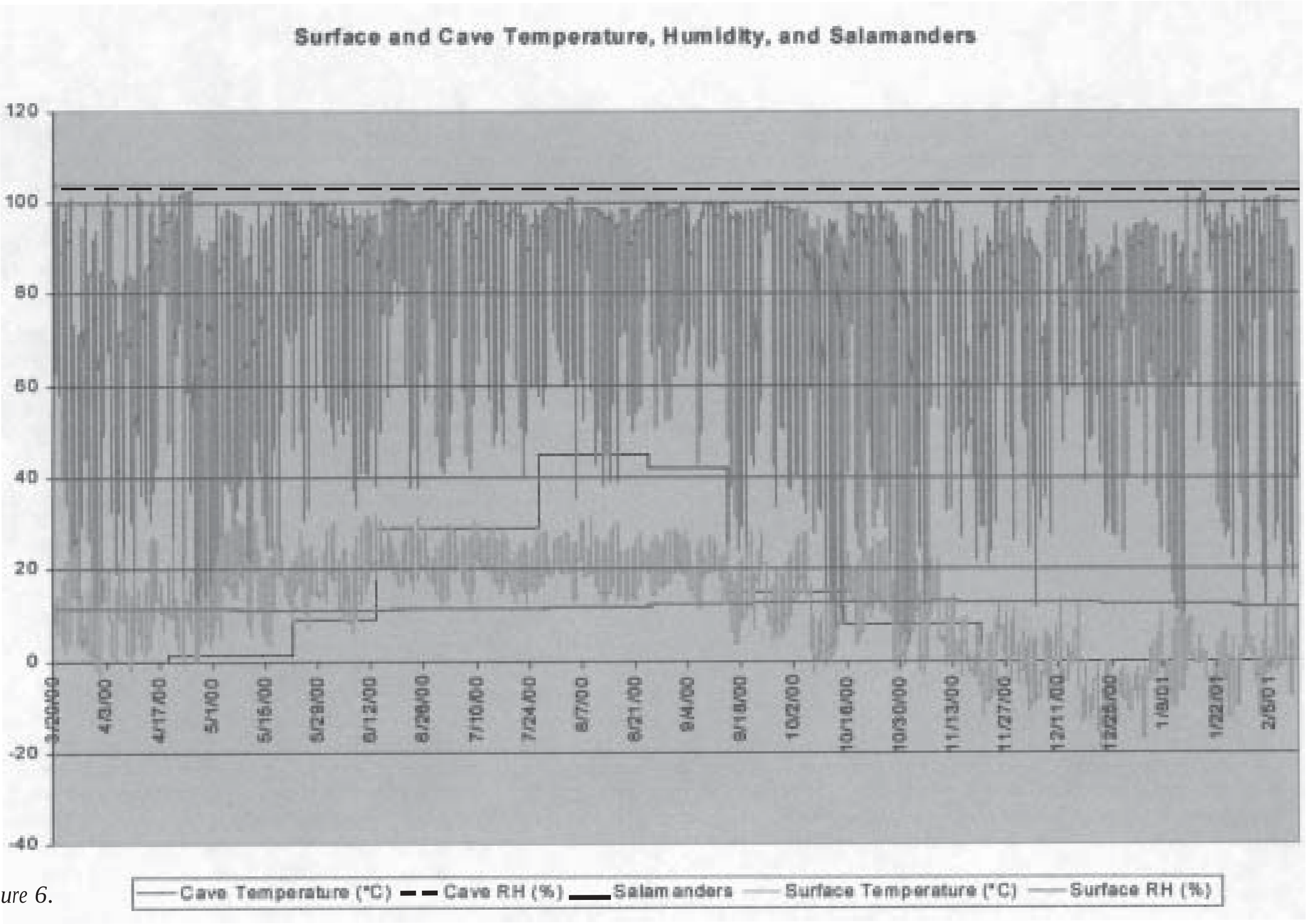

Figure 6.

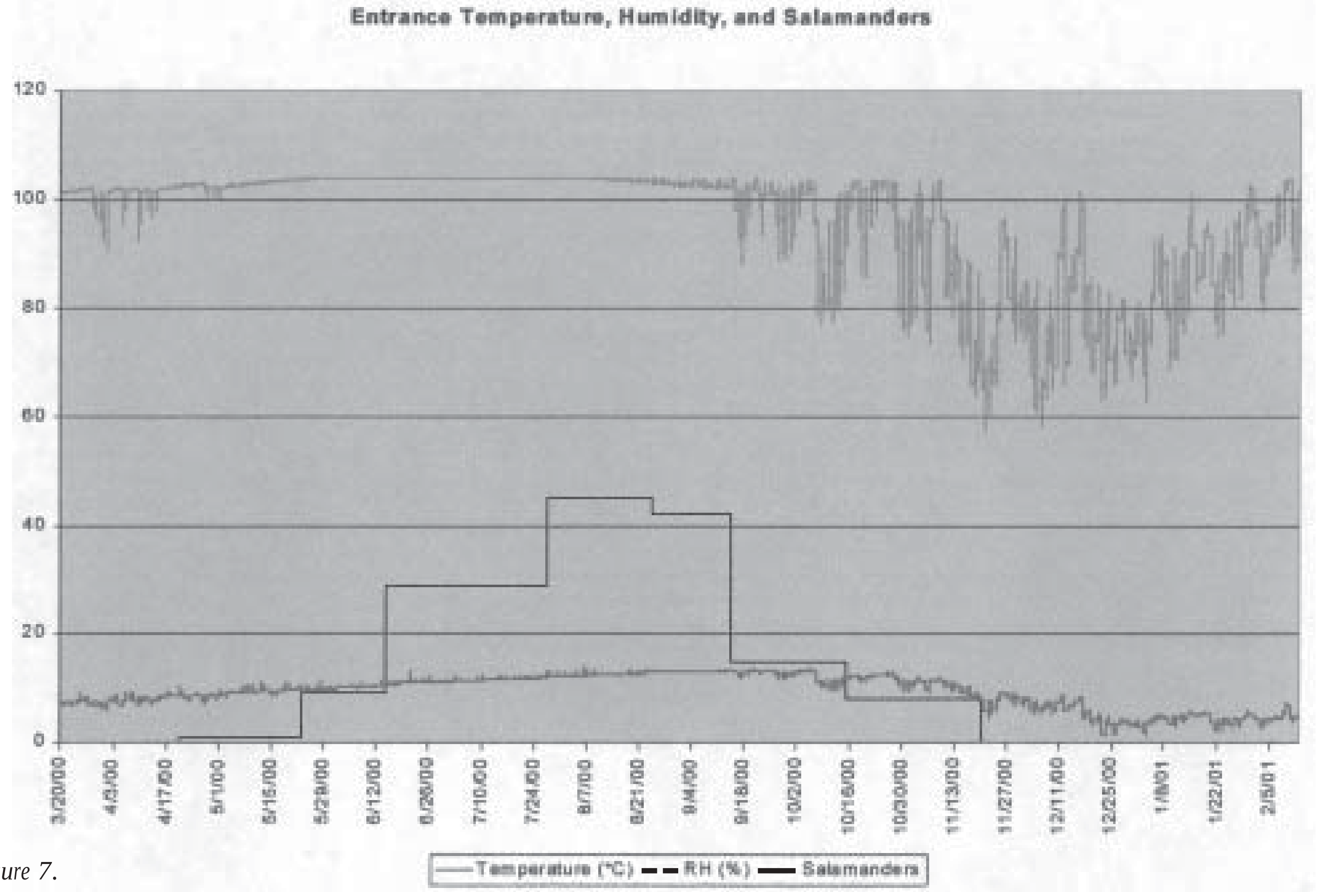

Figure 7.

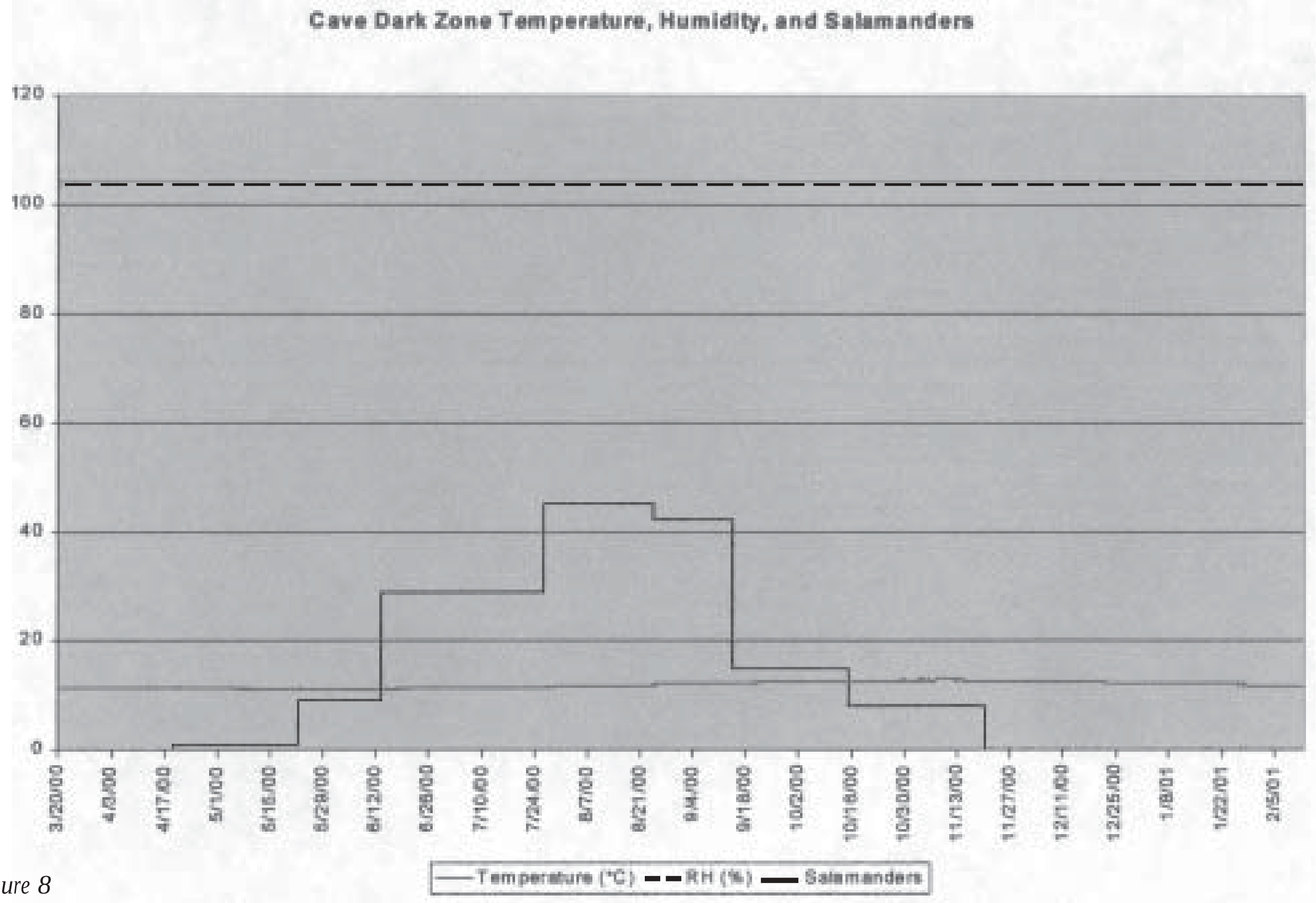

Figure 8

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RESEARCH

Description of a Small Cave in Adams County, Ohio

by Horton H. Hobbs III, NSS #12386 HM, CM, FE, WUSS #0001

By studying the Seaman 7.5 minute quadrangle map, it becomes apparent that a cave has been known from one of the prominent hills in Liberty Township, Adams County for a considerable period of time. With a name like Cave Hill, rumors of a cave in that topographic high existed in the caving community for decades yet it was not until 1953 that the entrance was located and the cave passages surveyed (see 1953 map by McClure - Figure 1). It was not entered again, except by locals, until 23 March 1962 when Fred Dickey, John Brannan and Jack Brooks located and resurveyed the cave (Brannan 1962)(Figure 2). It was located and surveyed again in late 1994 and early 1995 (Figure 3) in order to check for accuracy and to provide additional data for a biological study (Hobbs 1997); a total of 165m (541 feet) of mostly constricted horizontal cave was surveyed (Figure 4).

The bedrock layers of all of Ohio are sedimentary, derived from marine deposits formed during the Palaeozoic Era. Due in part to pressures associated with the formation of the Appalachian Mountains a little more than 200 MYA, these once flat layers of sediment were pushed upward, resulting in the Cincinnati Arch. It is likely that subsequent erosion removed the younger deposits and certainly glaciers played a roll in altering the topography of much of Ohio. The younger rocks (Mississippian, Pennsylvanian, and Permian) are found only in the eastern half of the state which is predominantly floored by sandstones and conglomerates whereas the western half is underlain by older (Ordovician, Silurian, and Devonian) limestones and dolomites (Forsyth 1989). It is in this older, predominantly Silurian dolomite bedrock that surface karst features are readily visible (Figure 5) and that a significant

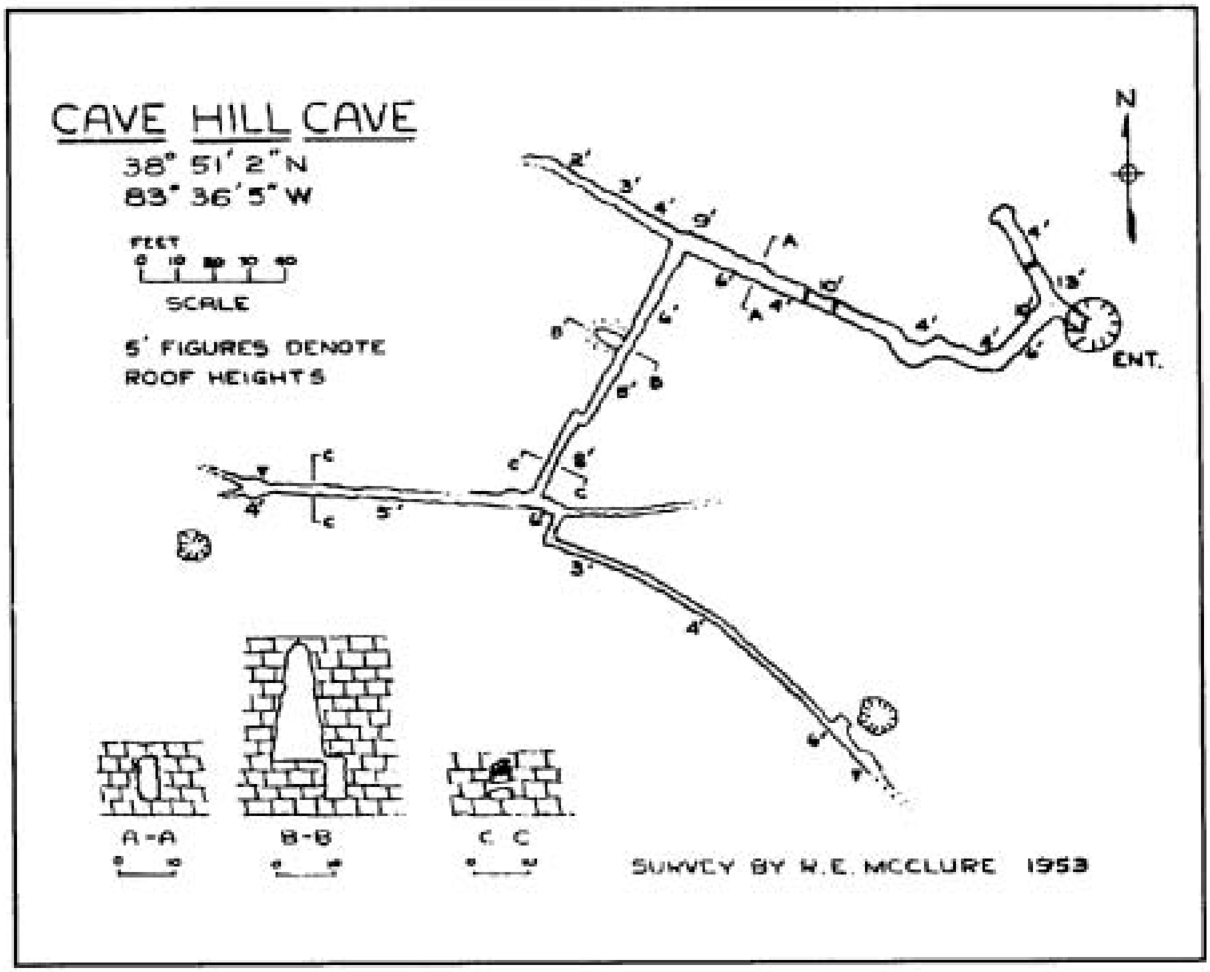


Figure 1. McClure 1953 map of Cave Hill Cave.

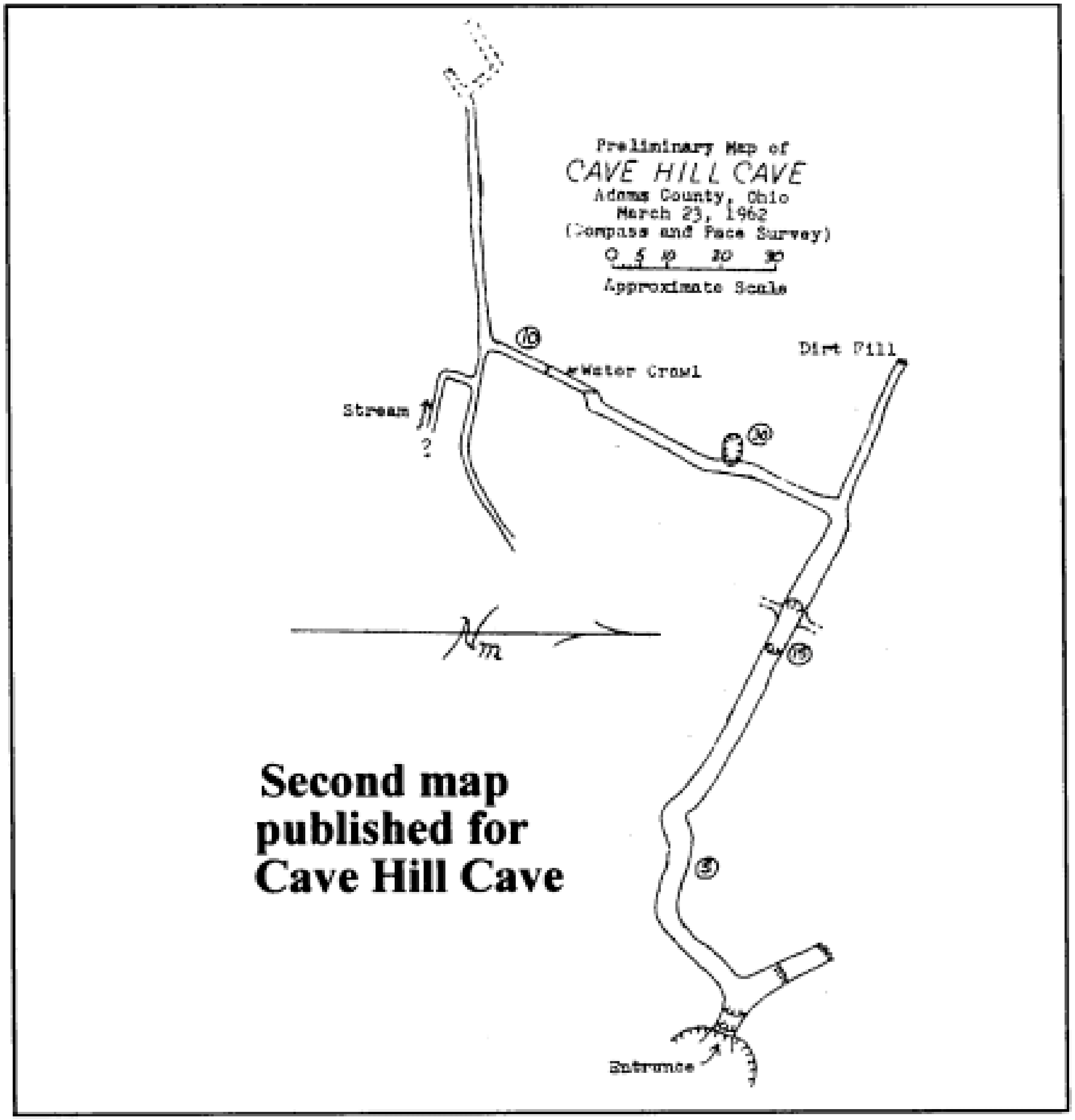
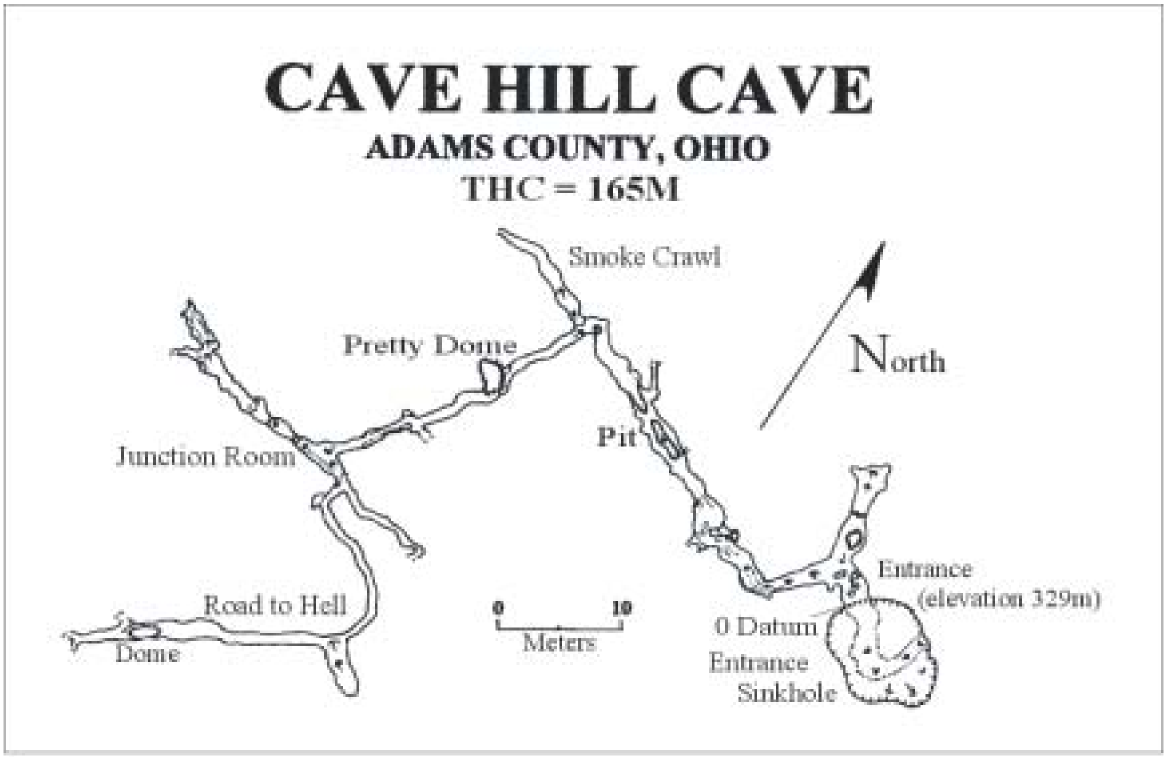


Figure 2. Dickey, Brannon, and Brooks 1962 map of Cave Hill Cave.

number of Ohio caves were formed by dissolution, including Cave Hill Cave.

The entrance to Cave Hill Cave is situated in the bottom of a steep-walled sinkhole only a few meters to the west of an old logging road at an elevation of approximately 329m (1080ft) (Figure 6). A sloping stoop-way leads to a point where the passage splits: turning to the north it extends for nearly 10m before ending in a steeply up-sloping passage whereas taking a left (southwest) at the Y leads to the remainder of the cave. Walking and some stooping along the sinuous, mud-floored tunnel (Figure 7) leads to a 4.5m deep pit (Figure 8). A slippery traverse over the top of the oblong pit, which is floored by an inaccessible small stream intersecting from the SSW, is required and the 2m high tube continues for about 10m before the ceiling lowers. A crawlway (Smoke Crawl) progresses to the northwest for 9.5m before becoming too small for continued progress but the main passage turns sharply to the south and is a mud-floored, hands and knees crawl although much of the year the floor of this passage is covered with several centimeters of water (Figure 9). Approximately one-third of the way down this muddy tube an offset, Pretty Dome - a flowstone-decorated 5m high dome, is encountered which is situated above and to the west. The main crawlway continues through a low passage, makes a jog to the west, and then continues low (Figure 10) for another 7m to a major intersection (Junction Room - Figure 11). Here the ceiling height reaches approximately 2.5m and to the right (west) the passage extends for approximately 15m, terminating in a low area directly beneath an old surface logging road (Figures 12, 13). To the left (east) walking passage extends for 3m and bends to the south where a gravel-floored, narrow tube heads off to the east and quickly becomes too narrow for further progress. The main passage continues south for about 2m and a right angle turn to the east leads to the rest of the cave (Road to Hell), which is a very constricted and tortuous crawlway for most of the remaining 35m. The Road to Hell is very tight but opens into an up-sloping room (Burn the Book Room) to the left over breakdown. The main passage continues to the southwest as a low crawl through a very tight Formation Squeeze that leads into a wider passage with a small dome and then terminates in about five meters with two very small passages, one entering from the west and the other from the south.

Cave Hill Cave, like so many caves in southwestern Ohio (see Hobbs 1984) is developed by dissolution along fractures in the dolomite bedrock, resulting in passages that tend to



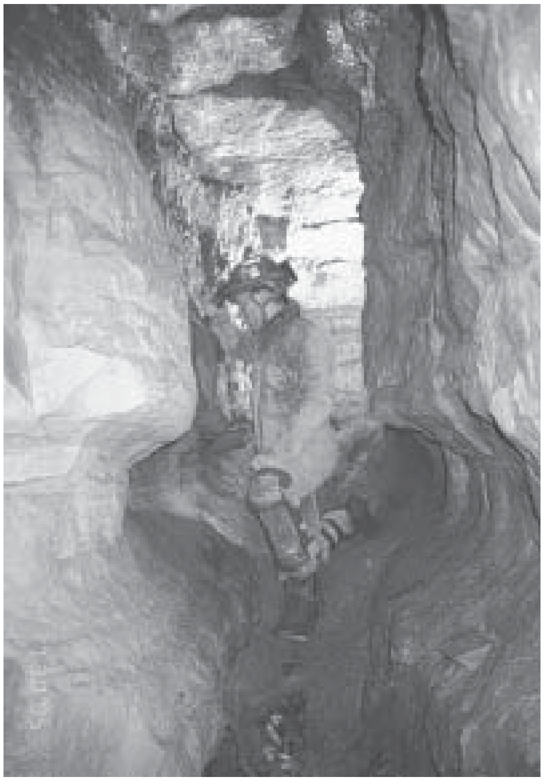
Above:
Figure 3. Hobbs 1996 map of Cave Hill Cave.

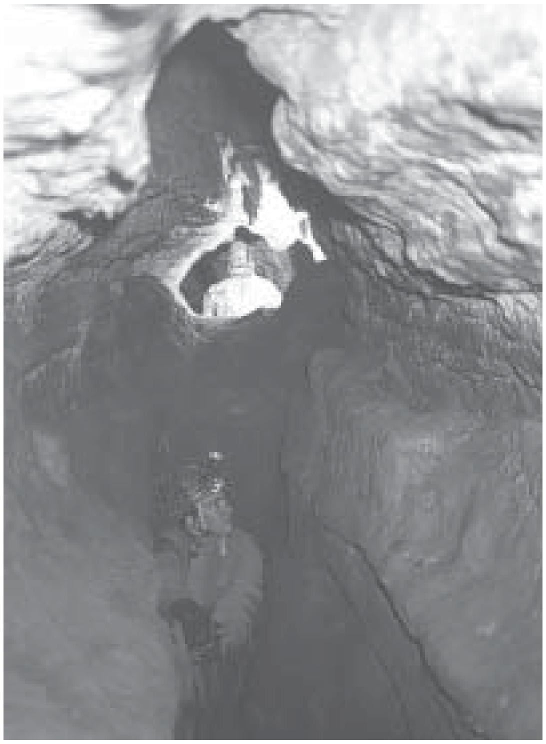
Right:
Figure 4. A muddy, cold, but happy survey crew after the last mapping trip (11 February 1995). Left to right: Megan Porter, Annette Engel, Horton Hobbs, Bill Stitzel and Howard Kronk.

Figure 5. Ohio Department of Natural Resources map showing portions of the state that are underlain by limestone or dolomite as well as locations of karst areas (http://www.ohiodnr.com/publications/water/karstmap.htm).

parallel one another or are situated perpendicular to each other along the orientation of joints (NW - SE or NE - SW). Major and minor joint sets along which Cave Hill Cave passages have formed are indicated in the Rose Diagram shown in Figure 14. The surface environs are conspicuously dotted with numerous sinkholes (Figure 15), many of which are oriented in a NW - SE alignment; however, investigation of these sinkholes has not resulted in the discovery of additional caves.

In this non-glaciated area of southwestern Ohio, caves have been characteristic features of the landscape and thus available for habitation by organisms probably at least since late Tertiary. Numerous fauna have indeed invaded Ohio caves (Hobbs and Flynn 1981) and at least five species of obligate cavernicoles occur in the state (Hobbs 1997). Within Cave Hill Cave numerous mud banks provide good habitat for the highly adapted troglobitic beetle, *Pseudanophthalmus krameri*, described by Krekeler (1973). This species is endemic to Cave Hill Cave yet it was not observed during repeated visits and intense sampling during 1994 - 1996. Hobbs (1997:23) offered no concrete explanation for its apparent extirpation and indicated that the cave "… is a very isolated locality on land that is currently well managed and protected. The immediate surface





Clockwise from upper left:

Figure 6. Entrance to Cave Hill Cave (photo by Matt Beversdorf, 2 April 1999).

Figure 7. Passage near the entrance where 1942 date was noted on the wall.

Figure 8. Main passage with caver, in foreground, sitting over oblong pit.

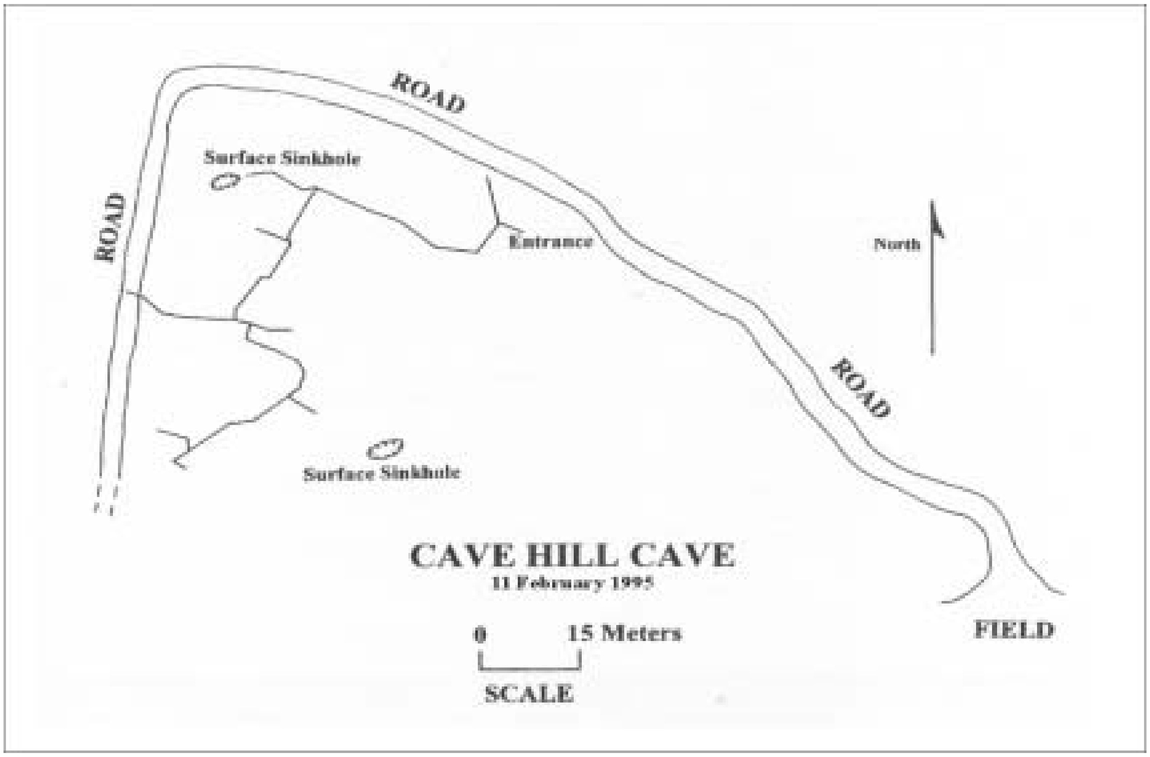
Figure 9. Crawlway passage below Pretty Dome, partially filled with water (typical water level for wet months).

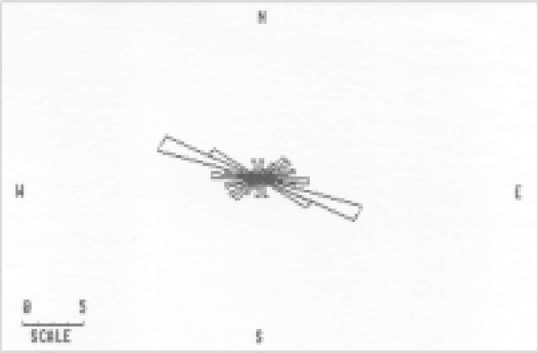
environs and the area directly overlying the cave consist primarily of secondary growth (mostly mixed mesophytic forest) and some adjacent fields. There are no obvious apparent perturbations (surface or subsurface) yet the beetle is extremely rare or is no longer present." Additional fauna noted in the cave on many trips during 1994 - 1996 include an unidentified oligochaete; an unidentified amphipod; the collembolan, *Sinella cavernarum* (Packard); the orthopteran, *Ceuthophilus brevipes* Scudder; heleomyzid and mycetophilid dipterans; the salamander, *Eurycea longicauda* (Green); the bat, *Pipistrellis subflavus* (Cuvier); and the raccoon, *Procyon lotor* (Linnaeus).

Top left:
Figure 10. Megan Porter surveying in Sinuous Crawlway between Pretty Dome and the Junction Room.

Top right:
Figure 11. Bill Stitzel in the Junction Room looking at sign informing visitors of a study being conducted in cave; note min./max. thermometer above sign.

Bottom:
Figure 12. Line plot of Cave Hill Cave passages shown with selected surface feature overlay.





Top left:
Figure 13. Toby Dogwiler standing in old logging road directly above passage (survey station B7) leading north out of the Junction Room.

Top right:
Figure 14. Rose Diagram for Cave Hill Cave.

Bottom:
Figure 15. One of many sinkholes characteristic of surface topography in the environs of Cave Hill Cave.

Acknowledgments

Appreciation is extended to the property owners of the land on which Cave Hill Cave is found, Patty and George Karr. They have been helpful and most interested in the survey of the cave as well as the biological study. To honor their wishes, the cave should be considered **CLOSED**.

The following individuals are generously thanked for their assistance with the survey of the cave: Toby Dogwiler, Annette Engel, Scott Engel, Howard Kronk, the late Steve Kronk, Megan Porter, Alex Schubert, Chris Stewart, and Bill Stitzel.

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Examination of the Movements of Crickets in Laurel Cave, Carter County, Kentucky

by Shannon E. Hill, NSS# 50206, WUSS# 467

Abstract

Ceuthophilis stygius (Scudder), the camel cricket, and *Hadenoecus cumberlandicus* (Hubbell and Norton), the cave cricket, are found in Laurel Cave in Carter County, Kentucky. During the warmer months the crickets move outside of the stygian environment to scavenge for food and then return to the cave. To determine where these crickets resided within the cave and how far each cricket moved, individuals were marked with phosphorescent paint. Crickets that were tagged as well as those too small were counted and their positions were recorded up to 80 meters from the entrance in the upper level of the cave. This procedure was done monthly from February to June 2002 (no March data). During this research 1190 crickets were counted and 160 were marked. Although only two crickets were recaptured there were many variables that hindered recapture including large population density, numerous hiding places, exoskeleton ecdysis, and the inherent difficulty in catching them. This study showed crickets forming clusters farther back in the cave during the cooler months and closer to the entrance in the warmer months. These clusters often have numbers of more then 100 crickets in one area.

Figure 1. Shannon tagging cricket (photo by Sara O'Donnell).

Introduction

Wingless crickets inhabiting caves are insects that live in the deep recesses of caves as well as near entrances. Two species found in Carter County, Kentucky are *Ceuthophilis stygius* (camel cricket) and *Hadenoecus cumberlandicus* (cave cricket) and both inhabit Laurel Cave, site of this study. They mostly eat other insects, fungi, and decaying matter. Though they have well-developed eyes, they most often use touch, air movements, vibrations, and odors to help them locate food (Crawford 1977). Their predators include salamanders, some reptiles, certain mice, screech owls, burrowing owls, and bats. These crickets live only about two years and are mature after six or seven molts.

H. subterraneus is a closely related species of *H. cumberlandicus*, and since there has not been much research done on *H. cumberlandicus*, *H. subterraneus* is used as an example to understand better *H. cumberlandicus*. *H. subterraneus* is more cave-adapted than *C. stygius* (Hubbell and Norton 1978). Individuals leave the cave about every three nights, as opposed to exiting nightly like *C. styguis*. *H. subterraneus* exit only on warm nights, even in the winter. Since individuals migrate less often during fall, winter, and early spring, they locate a few roosting sites within the cave, below which cave cricket guano accumulates. This guano can be an important food source to the cave community.

H. subterraneus is omnivorous and opportunistic in its feeding. Individuals normally eat ants and other terrestrial arthropods, but also will take advantage of ripe fruit and, if near cow pastures, cattle feces. "They have been known to nibble the ears of hibernating bats and supposed to have partially eaten Floyd Collins' ears after his death in Sand Cave" (Hubble and Norton 1978, pp.101). *H. subterraneus* sometimes eats cave beetles, which in turn are the cricket's predator, feeding on cricket eggs. Crickets eat more hypogean fauna during the colder months and forge more frequently outside of the cave environment in the warmer months.

There are two main sections of the cave that these crickets inhabit: the threshold and the dark zones. Each zone is subdivided into two smaller sections. The entrance zone is the first section of the threshold, having direct light from outside and temperature and humidity are affected directly by the surface climate. The second section of the threshold is the twilight zone, which receives indirect light from the surface, and the epigean environment also affects the temperature and humidity. Variable temperature and humidity characterize the outer dark zone. This is followed by the'"constant" temperature area, which also is referred to as the deep cave. Meteoric characteristics are humidity values near saturation and here temperatures approximate mean values of those of the geographic area in which the cave is located. Crickets are found in all of these zones.

Laurel Cave is developed primarily in the Missippian age Ste. Genevieve Limestone. The study area of the cave is a dry upper level, but does have some autogenic water sources that may bring in some limited organic material that is critical to the cave environment.

Methods and Materials

To determine cricket densities and activity a mark/ recapture method was used from February through June (no March data) in the dry upper level of Laurel Cave (Figure 1). Adult crickets found at each section were marked with phosphores-cent nail polish and paint made readily visible when exposed to black light. The paint that was used was tested prior to doing the experiment in the field. This was done over a few weeks in January 2002 in order to find what paints would stick to the waxy exoskeleton of the crickets. First fluorescene dye was tried, but it was too watery so it had to be mixed with Elmer's glue and white-out. The glue did not stick and once the white-out was mixed with the dye it was no longer black light-responsive. Finally, a paint (Palmer Paints, Troy, MI) and nail polish (Black Light Glow@FITCO) were found that were easily applied to the crickets and remained on the dorsal portion of the exoskeleton without harming the crickets. There were four different colors of paint used and they were applied with a toothpick to make up to six small dots on each individual (Figure 2). Since crickets had their own unique mark, this reflected the ecological zone in which the individual was first observed. On subsequent trips marked crickets were collected and individuals were identified with the aid of a portable black light (Fluorescent Auto Blacklite, #574558).

Results

Distribution and Movement patterns of crickets each month:

In February there were more cave crickets counted than camel crickets (Figure 3), with the largest concentration of crickets found between 10 and 30 meters from the entrance. At about 22 meters there were over 100 crickets located in a large cluster and beyond 32 meters there were few crickets observed. During February, 325 crickets were counted and 11 cave crickets and 4 camel crickets were tagged. The camel crickets seemed to be located further back in the cave. There were 306 cave crickets and 19 camel crickets found this month.

In April more cave crickets were observed than camel crickets (Figure 4). The cave crickets were located in the same area of the cave this month as they were in February. There were 224 cave crickets and 50 camel crickets counted this month. In April there were three large clusters of crickets at about 10 meter intervals starting at five meters; beyond 25m few were found. Of the 274 crickets counted, three cave crickets and 17 camel crickets were tagged during the month.

The greatest densities of camel crickets were noted in May even though cave crickets remained the dominant species in the community. There were 240 cave crickets (Figure 5).

169 camel crickets were counted the month of May (Figure 6). This was the largest camel cricket population observed throughout the study.

In May both species moved much closer to the entrance (Figure 5, 6), with most of the population located within the first seven meters. From about seven meters to 27 meters there was a sizable number of crickets counted but beyond 27 meters there were very few; 409 crickets were counted, three cave crickets and 87 camel crickets were tagged. This was the largest population density counted during the study.

Figure 2. Tagged cricket (photo by H. Hobbs).

In June there were similar patterns to May and there were significantly more cave crickets than camel crickets (Figure 7). There were 132 cave crickets and 47 camel crickets counted this month. In June the crickets were still clustered within the first seven meters, and beyond about 20 meters very few crickets were observed. This month 172 crickets were counted, three cave crickets and 27 camel crickets were tagged - this is a significantly lower density than observed in May.

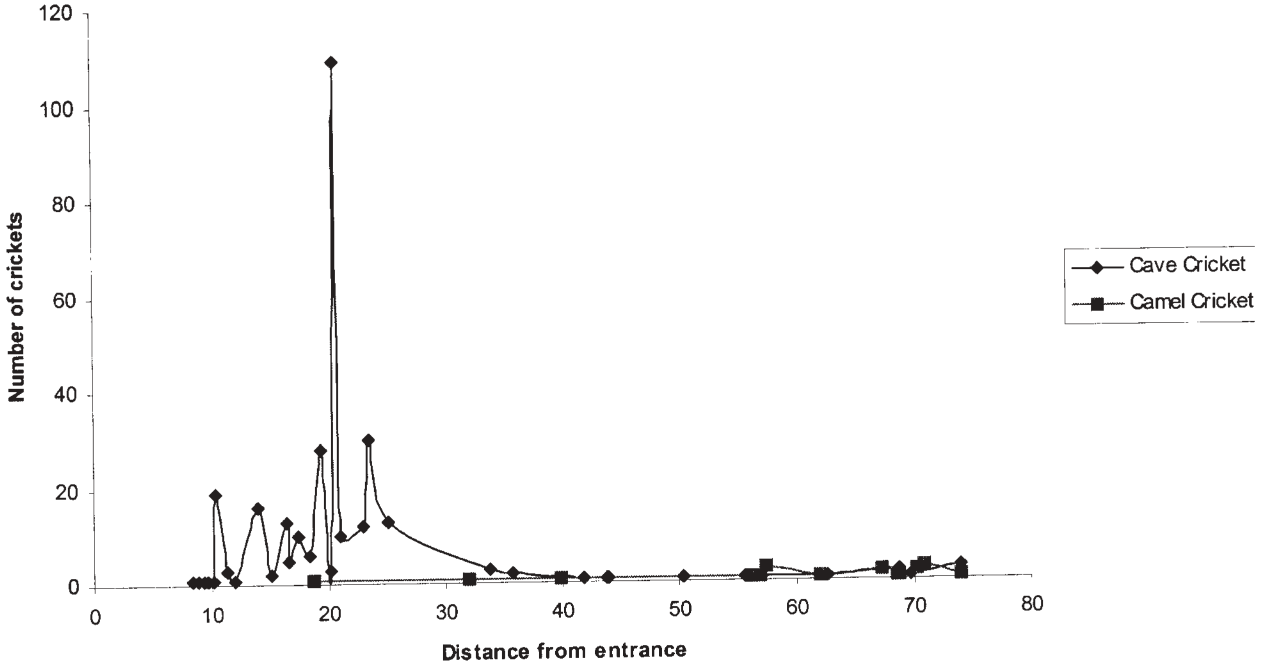

Figure 3. The density of cave and camel crickets observed in Laurel Cave during February 2002.

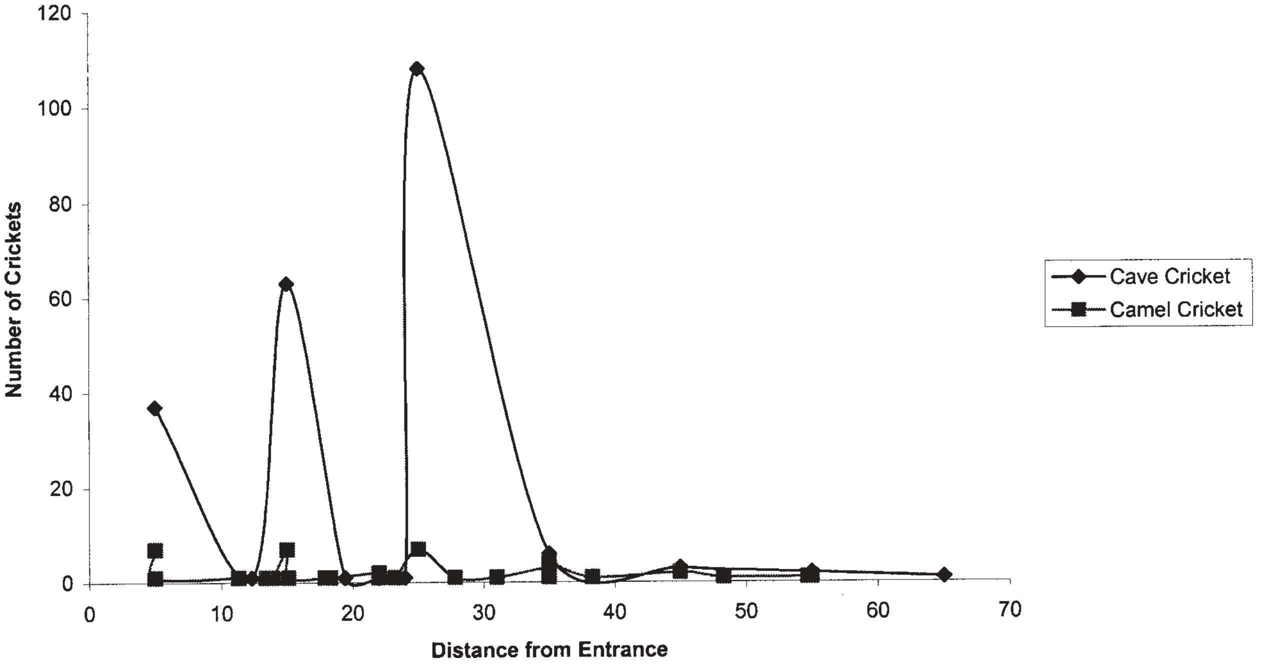

Figure 4. The density of cave and camel crickets observed in Laurel Cave during April 2002.

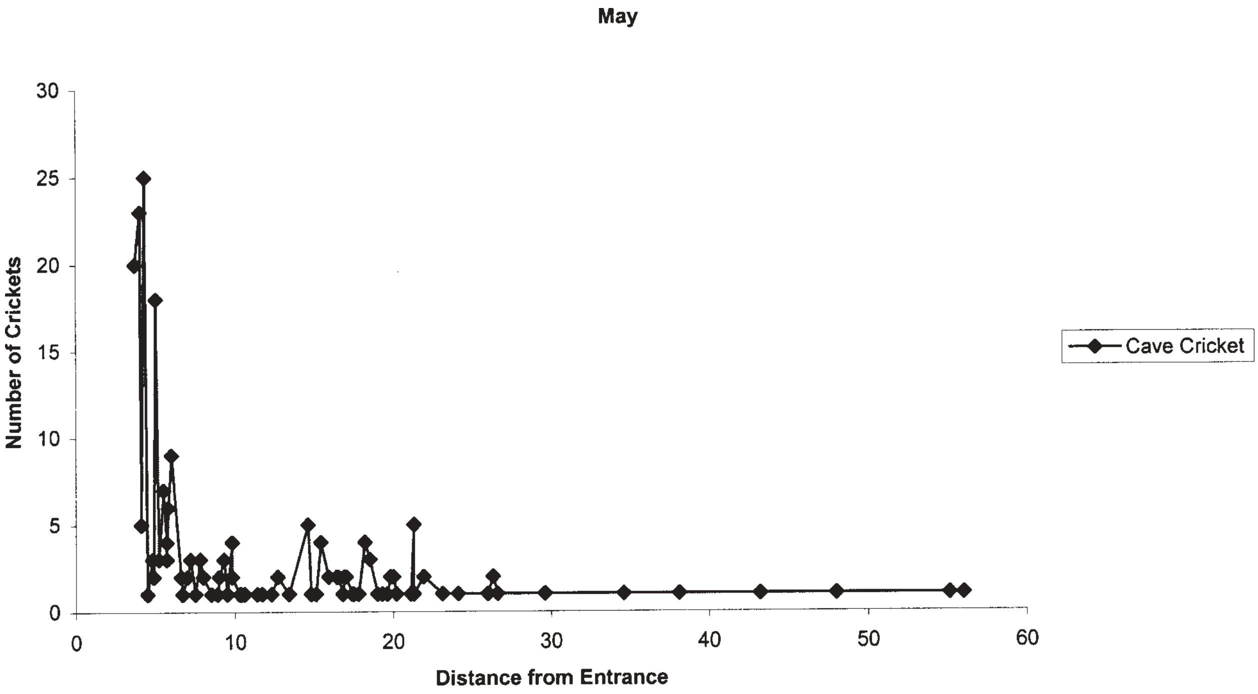

Figure 5. Density of cave crickets observed in Laurel Cave during May 2002.

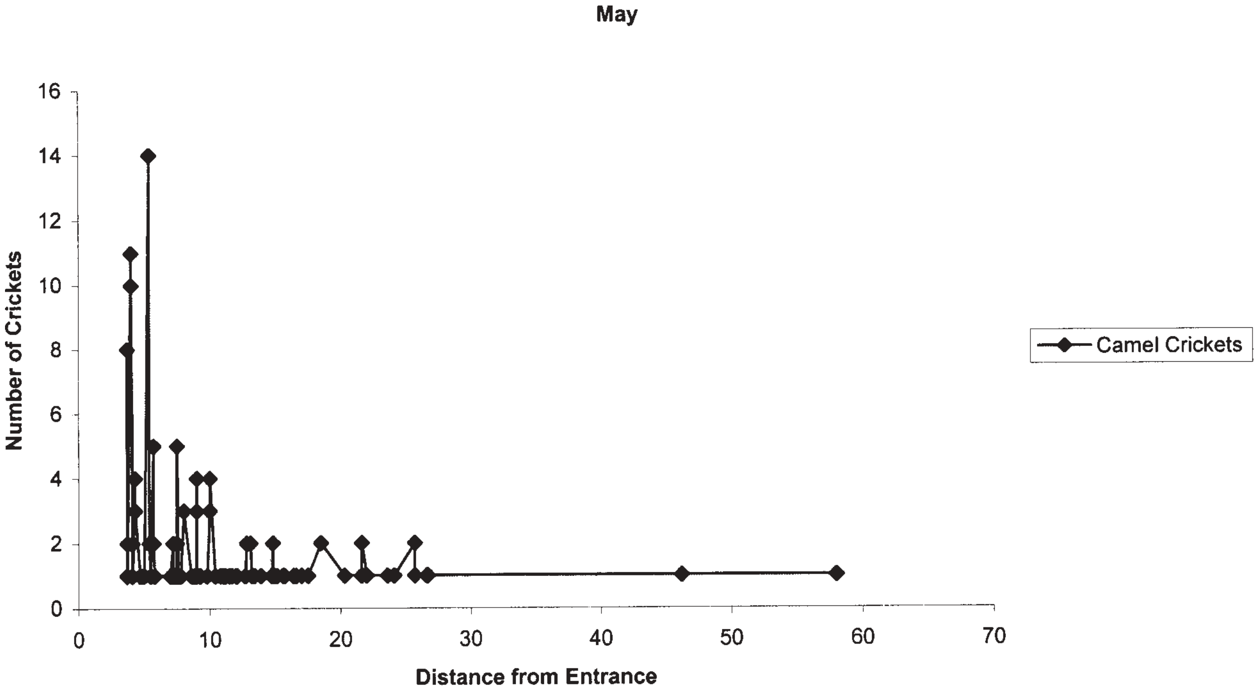

Figure 6. Density of camel crickets observed in Laurel Cave during May 2002.

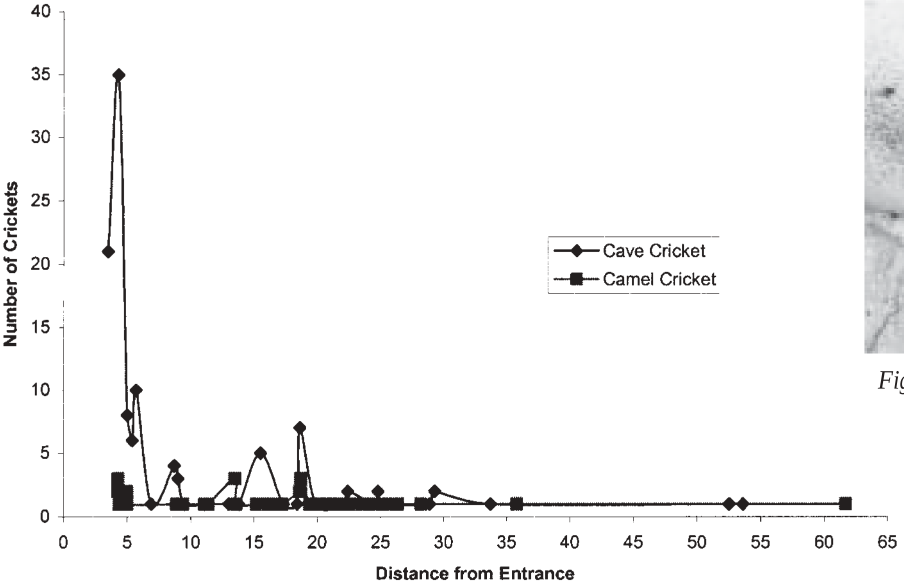

Figure 7. The density of cave and camel crickets observed in Laurel Cave during June 2002.

Figure 8. Crickets clustering on ceiling in Laurel Cave.

Discussion

This mark-recapture project indicates that crickets living in the upper dry level of Laurel Cave from January through June 2002 swarm near the entrance during warmer months and remain farther back during the cooler months, clustering under both conditions (Figure 8). I observed them in greatest densities in recessed areas, mostly on the ceiling. These clusters consisted of both large and small crickets of both species.

There were only two crickets that were definitely recaptured and one additional possible recapture. Few crickets were recaptured for a number of reasons: the crickets have many hiding places in the cave, they shed their exoskeleton (with them their tags) six to seven times during their life, which only lasts for two years, and they are difficult to catch. Because of these factors it is often hard to determine if tagged crickets are being recaptured since they may have molted one or more times since the last time they had been counted; they also spend time in small crevices where they could not be observed. The possible population of the months of April, May, and June are as follows: 3500, 19,305, and 2,385, respectively. Since so few crickets were recaptured, these numbers are likely grossly overestimated. To obtain these values the Schumacher-Eschmeyer Index (for estimating population size) was utilized (Schumacher and Eschmeyer 1943).

There were more cave crickets counted in the community than camel crickets. This could be because the camel crickets are less cave-adapted and because they need to forge outside of the cave more often for food. Since it is difficult to determine the difference between the two species when they are juveniles, in February and April there may be some error in the species counts because the crickets hatch in these early months.

In February the camel crickets were concentrated farther back in the cave and in April they were located closer to the entrance. Since this cricket is less cave adapted individuals should be located closer to the entrance so that they can do their forging more often. During February they lived father back in the cave, probably in response to colder air moving into the front section of the cave. In May and June all of the crickets were located closer to the entrance where they were staging to forge outside of the cave for food.

Acknowledgments

I want to thank Dr. Hobbs for his help in suggesting this research project. I also want to thank Lindsay McCullough, Laura Davis, Steve Weldon, Kristen Baughman, and Sara O'Donnell for helping on research weekends. I would also like to thank the Biology Department for funding the study.

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Sulfur Bacteria Effects on Speleogenesis and Cave Ecosystems: A Historical Investigation

by Samuel Moses Lloyd

Abstract

Some genera of sulfur bacteria are very unusual. Not only do they thrive under abnormal conditions of temperature and pH, but they have been found in studies of several caves throughout the world to have significant effects on speleogenesis and the cave ecosystems as well. They act as intermediaries in the reaction that changes hydrogen sulfide gases to sulfuric acid. It is this sulfuric acid that then plays a major role in the speleogenesis of some caves. Sulfuric acid dissolves the limestone when they come into contact, replacing the rock with gypsum deposits. The gypsum deposits provide surfaces for more sulfuric acid to form, which can drip and dissolve limestone on the floor of the caves. The deposits also can break off and fall from the walls and ceiling and be dissolved or transported out of the system in the cave stream below. These deposits breaking off also expose new limestone surfaces for the process to begin once again. The cave ecosystem also benefits from the presence of sulfur bacteria because in mediating these processes they also yield energy in the form of organic matter, which is consumed and energy is passed to higher species in the food web. Although this topic has been extensively researched in some ways, there is still much work to be done to understand about this topic.

The idea that sulfuric acid plays a role in the dissolution of caves and speleogenesis has been widely accepted. Moreover, there is much history to the research behind the theory. Palmer actually estimated that 10% of the world's caves were formed from sulfuric acid dissolution (Engel et al. 2001). It is not the most significant way in which caves form, yet many people have been intrigued by their uniqueness, and have studied them elaborately. Out of some of the earlier studies also rose an interest in the effects of bacteria on these cave systems. Sulfur bacteria are a group of bacteria that contains visible sulfur granules in their cells, breakdown organic matter to produce hydrogen sulfide, and use or store energy that is produced from the oxidation or reduction of sulfur or sulfur compounds (Summers 1995). In recent decades researchers have really tried to understand the magnitude of the effects these bacteria have on cave formation and cave nourishment.

The formation of caves rich with sulfur and gypsum deposits has been an important area of study over the last century. Some of the most famous places where these types of caves are found is in the Guadalupe Mountains in New Mexico, Movile Cave in Romania, Cueva de Villa Luz in Mexico, and in Frasassi Gorge in Italy (Engel et al. 2001). More importantly has been the study of how these caves actually form. The sulfuric acid theory has developed greatly throughout the last several decades. With so many specific conditions involved in cave formation, like the water sources for the cave, or even whether it is vadose or phreatic, it has been difficult to understand factors and reach definitive conclusions. Although some widely accepted ideas about sulfur cave formation are circulating today, the sulfuric acid theory and its connections to speleogenesis are still very much in the making.

One of the earliest developers of this theory was Principi, who in 1931 proposed that the contact between sulfidic ground waters and limestone was the main cause of formation in a small cave in Italy (Vlasceanu et al. 2000). However, discussion about the mechanics and sources of sulfuric acid did not take place until the 1970s. It was then that much debate occurred as the caves of the Guadalupe Mountains received much more intensive research. Stephen Egemeier was the first to propose in 1971 that one of the caves in this network, Carlsbad Cavern, was formed by sulfuric acid dissolving its walls (Jagnow et al. 2000). Egemeier also proposed a process called replacement solution. This is where H_2S gas that is released from water entering the caves through certain conduits reacts with oxygen, water, and calcite to form sulfuric acid. The sulfuric acid then dissolves the limestone walls, which results in the deposition of gypsum and sulfur on the ceilings and walls of the caves. These deposits then become so heavy that they break off and fall to the floor, exposing new limestone surfaces fresh to react with sulfuric acid. The gypsum breaking off the ceilings and walls is then either dissolved by or may be transported out of the system through cave streams (Hose et al. 1999). The next major proposal came from David Jagnow, who worked in the Guadalupes from 1971-1973. This work was important because he was one of the first to speculate on the origin of the sulfuric acid that was forming these caves. He proposed that the source of the acid came from the oxidation of pyrite. This proposal was critiqued after work was done in the same caves by Donald Davis in the early 1970s. Davis suggested that the hydrogen sulfide (H_2S), which was mixing with oxygen and oxidized water to produce sulfuric acid, had a hydrocarbon source, such as petroleum. Finally, much progress occurred in the work of Carol Hill during this time. In her studies of mineralogy in the caves, Hill tested a sample of gypsum from the wall of the cave and evaluated the endellite deposits on it. She found not only that they indicated the former presence of sulfuric acid, but that the gypsum also originated from hydrocarbons (Jagnow et al. 2000).

After more research was done in the 1980s and 1990s, the theory finally became more widely accepted by the geological community. In researching different studies done on sulfur caves throughout the world, there appeared to be a few similar theories that are accepted as valid ideas in describing the formation of these caves. For example, the current widely accepted theory treating speleogenesis in the Guadalupe caves is that the hydrogen sulfide first moves upwards along fractures in the ground. Once it reaches the oxidized ground water, it mixes with the water to form sulfuric acid, which then dissolves the limestone and creates large voids at or below the water table (Jagnow et al. 2000). However, there are other accepted ideas that deal with sulfuric acid processes once the caves become air-filled. One of these processes, which is the same as the process of replacement solution described by Egemeier, begins when hydrogen sulfide, which is released from water rising through cave conduits, is oxidized. Sulfuric acid is formed, which dissolves the limestone surfaces and converts them into gypsum. The gypsum eventually becomes heavy and breaks off the surface and is dissolved in the cave stream below. Finally, the other idea involved in sulfur cave formation is that when droplets of sulfuric acid, which are strongly acidic, form on gypsum and microbial filaments, they drip and dissolve the limestone on the cave floors. A great example of these latter two processes is found in Cueva de Villa Luz in Mexico (Hose et al. 1999).

Although the theories of how these sulfur caves form are widely accepted for a number of caves around the world, another question in recent decades has arisen— what is it that is actually driving the acid-forming processes? A significant step in answering this question came from Egemeier, who proposed in his studies during the 1970s that the process was biogenic (Nortup and Lavoie 2001). Studies done in several different caves at later dates would grow to support this notion. For example, studies done by Hubbard et al. (1986,1990) in Cesspool Cave, Virginia, also suggested that bacteria were involved with cave formation by contributing to sulfuric acid formation. He deduced this by observing three major genera of sulfur bacteria in the cave. They were *Thiothrix*, *Beggiatoa*, and *Achromatium*. Studies by Northup et al. (2000) in Lechuguilla and Cottonwood caves of the Guadalupe Mountains on the relations of microorganisms to dissolution and precipitation of cave features also have been helpful in discovering the significance of sulfur bacteria in caves. It is believed that some sulfur bacterial communities act as intermediaries in the reaction that oxidizes hydrogen sulfide to sulfuric acid. This is the acid that then dissolves the limestone and creates gypsum, which is deposited on the cave walls, and carbonic acid, which can participate in further dissolution, as byproducts (Vlasceanu et al. 2000). Studies done by Hose et al. (1999) in Cueva de Villa Luz in Mexico have shown that the bacterium genus *Thiobacillus* also plays a significant role in oxidizing hydrogen sulfide to sulfuric acid. Finally, a different study done by Vlasceanu et al. (2000) in Frasassi Gorge, Italy, supported the findings in Cueva de Villa Luz, reporting that *Thiobacillus* played a significant role in acid formation and thereby in the formation of Frasassi Gorge.

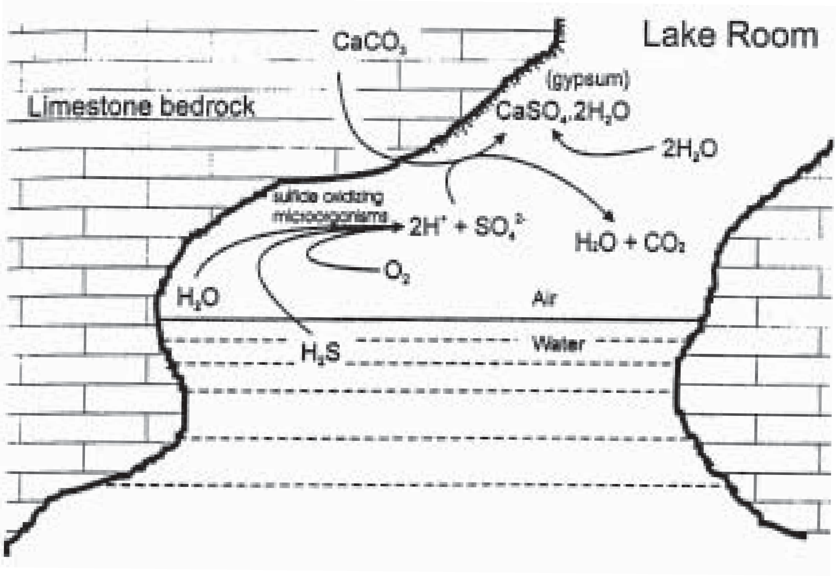

Figure 1. A model of dissolution by sulfuric acid in Movile Cave, from Sarbu (2000).

Moreover, the conditions under which these sulfuric acid forming reactions take place include being in specific ranges for temperature and pH. The conditions of some genera of sulfur bacteria seem to contrast greatly with the conditions and ranges of other bacteria. While most bacteria were found to live from 20-30 degrees Celsius and were found in caves with alkaline waters, the genus of sulfur bacteria, *Beggiatoa*, has been recovered in waters from 4-31 degrees Celsius (Summers 1995). The pH conditions of the sulfur bacteria that produce sulfuric acid also tend to be much more acidic than those of normal cave bacteria. For example, the pH values of some water samples in Movile Cave, Romania, were 3.7-4.2 because the sulfuric acid produced by the bacteria. On the other hand, in conditions in the same cave where water flowed through the limestone, the pH was 7.5-8 (Summers 1995). Another example is in Frasassi Cave, Italy, where samples of biofilms containing sulfur bacteria from the cave had a pH of less than 1.0 (Vlasceanu et al. 2000).

Although the conditions in caves in which some sulfur bacteria thrive seem far from normal, a number of studies on caves have found that some types of sulfur bacteria play a significant role in supporting cave ecosystems. The sulfur bacteria in some cases actually act as primary producers (Summers 1995). It is the general belief that these types of sulfur bacteria are chemoautotrophic. They yield energy in the form of organic matter by using the energy produced from oxidizing the hydrogen sulfide, which results in the fixing of carbon in the cave waters. This organic matter can then be consumed by other heterotrophic bacteria, as well as fungi in the mats of the water; these mats then support other species. One great example of this support structure is found in Movile Cave in Romania, where 48 troglobitic species are maintained by the chemoautotrophic bacteria genera *Beggiatoa* and *Thiobacillus* (Moore and Sullivan 1997). This makes Movile Cave the most "biologically diverse closed-cave system" in the world (Hose 1999). Since protozoa are the most significant consumers of bacteria, they also play an important role in maintaining higher trophic levels in caves (Summers 1995).

Other cave studies have found similar effects of sulfur bacteria as a food source for the ecosystem. Vlasceanu et al. (2000), in studying Frasassi Cave, which is similar in conditions to Movile Cave in that the food-web is based on chemoautotrophs producing organic material, found that terrestrial isopods played a significant role as a consumer of the microbial biofilms produced by the sulfur bacteria on the walls of the cave. Other grazers and macroinvertebrates also feed on the energy yielded by the sulfur bacteria of this cave (Engel et al. 2001). In another study done in Cueva de Villa Luz the researchers also found that the base of the food system was sulfur bacteria. Invertebrates and other microbes, sometimes called grazers, first feed on these bacterial colonies. Higher organisms in the food web, such as spiders, can then feed on these grazers. Another direct consumer of the sulfur-eating bacteria includes *Poecila mexicana*, a fish found in the stream of the cave. Pacas, which are large rodents, and even humans, are then important consumers of these fish in the caves (Hose 1999). Finally, Cesspool Cave in Virginia also has been investigated for consumption of organic material by higher trophic organisms. However, with no evidence of grazers in the cave, researchers believe that higher organisms are not feeding on the microbial mats. They believe this could be connected to the low nitrogen value and the high C:N ratio within the mats. This perhaps indicates that sulfur bacteria have no connection to being primary producers for this system. Researchers feel that the energy, in the form of organic matter produced by the sulfur bacteria of the caves, could either be processed heterotrophically by some unknown part of the cave system or transported out of the system via the cave stream (Engel et al. 2001).

Sulfur bacteria play a very important role in sulfuric-acid speleogenesis and sustenance of sulfur cave ecosystems. There are several cave systems throughout the world acting as examples, including the Guadalupe Mountains in New Mexico, Movile Cave in Romania, Cueva de Villa Luz in Mexico, and Cesspool Cave in Virginia. Studies of the processes in these caves have been going on for decades and yet there is much left to learn. Many qualitative investigations have set the base of information about the mechanics of cave formation and nourishment, but recently more quantitative studies were encouraged by researchers (Northup and Lavoie 2001). In conclusion, although it appears much has been discovered concerning the activities and roles of sulfur bacteria in caves, much is still to be understood and learned about the extent of their effects.

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A gypsum encrusted passage in Lower Kane Cave, Bighorn County, Wyoming (photo by H. Hobbs).

REVIEWS

Review of “Depth Chargers” by Gregory Crouch

by Bryan Welch, NSS# 22422, WUSS# 492

As the world community becomes more dependant on fossil fuels every day, certain groups are trying to raise awareness that the oil supplies will not last forever. While some people ignore these warnings, the government of Oman is taking it seriously. They have already started to encourage economic diversification so that the country will not plunge into poverty when the oil wells dry up. Fields they are exploring include copper mines, cookie factories, and tourism. After seeing the success of New Mexico’s Carlsbad Caverns, the Omani government hired Louise Hose of Chapman University to survey some of Oman’s largest caves. Armed with satellite-based global positioning technology to pinpoint the location of cave entrances, lasers to calculate interior volumes, and air monitors to check for harmful gasses, Louise and her team will systematically survey the caves, many of which have pit entrances more than 100 meters (350 feet) deep. They will also analyze water samples and inventory the fauna and flora above and below the surface. The hopes are that some of these caves will be safe enough but not too fragile for future tourists. If the caves cannot handle tourists, then at least the government will have a detailed account of physical and environmental information on these underground wonders. After the surveys were complete, Louise thought it was certainly possible to adapt some of these caves for tourism. However, she feels the cost may be prohibitive.

Crouch, Gregory. 2003. Depth Chargers. National Geographic, 203 (4): 38-55

A Review of “Going Deep” by Michael Ray Taylor

by Lindsay McCullough, NSS# 48931, WUSS# 469

“Take the Louisiana Superdome and bury it deep in the heart of a mountain. Send an underground river raging past the home team’s bench, carving away that side of the field until a deep canyon yawns where once the New Orleans Saints watched their postseason dreams slip away. Leave a rocky overlook on the visitors’ sideline. From the rafters two hundred feet above this spot, hang a nylon climber’s line about the diameter of your middle finger. Let it dangle and sway. Now imagine a narrow ledge from which you can grab the top of this rope, and you’ll have a pretty good picture of where I am. Or soon will be.”

So begins Michael Ray Taylor’s account of the struggle to save the future of Rumbling Falls Cave in Fall Creek Falls State Park, Tennessee. The article tells the story of a group of cavers, headed by caving legend Marion O. Smith, working hard to map and explore the miles of passage discovered by chance in 1997 by caver Fred Hutchison. The team was looking for an “old man’s mapping project,” as Smith called it—a cave that a few friends could survey in a Sunday afternoon. Instead they discovered an underground world of huge rooms, roaring waterfalls, and a river of pure spring water supporting “nearly a dozen species of aquatic cave life found in fewer than 10 other locations in the world—and two small organisms found nowhere else.” The team’s desire to protect the cave and be the first to explore its depths was so strong that they kept their amazing discoveries a secret from everyone.

However, when the fragile ecosystem of Rumbling Falls Cave is threatened by the construction of a sewage treatment plant in a nearby town Smith and the rest of the team know they must act. In doing so they must battle not only the determination of local politicians, but also the wounded pride of those that felt unjustly excluded by the team’s secrecy. Author, Michael Ray Taylor, honestly and skillfully portrays the glaring consequences of the political controversy that often results from the clash of human and environmental interests and wounded egos. This is an enlightening read for any member of the caving community sensitive to the ongoing effort to protect our valuable subterranean resources; and more importantly, the often-irreconcilable demands of courtesy and the explorer’s need “to see places that only a few skilled and determined—and sometimes lucky and greedy—cavers can reveal in world so thoroughly explored.”

Taylor, Michael Ray. 2003. Going Deep. Sports Illustrated, 98(9): 62-68.

REVIEWS

A Review of "Subterranean Surprises" by Evan Hadingham

by Ashley Hanson, WUSS# 521

Interesting discoveries dealing with caves formed from sulfuric acid are being made. Before the exploration of Lower Kane cave, only dead caves, such as Carlsbad cave had been researched. Now, through the article *Subterranean Surprises* by Evan Hadingham, the workings of a live cave are revealed to us, as well as possible cancer treatments and a new angle on the origins of life.

Despite the uncomfortable setting: 75-degree heat, sticky humidity, a rotten stink, and toxic gas, Lower Kane is a goldmine of information. As an active sulfide cave, scientists are able to witness the forming of a cave, something not done until now. The scientists not only saw formations of gypsum, but also striking pools with vibrantly colored bacteria mats, and spidery filaments of microbes. Oddly enough, these bacteria not only are speeding the formation of the cave, but are also being tested as anticancer agents. These bacteria are similar to some found in the deep zones of the ocean, as well as far underground in close proximity to volcanoes. Also, each bacteria mat has a plethora of microbes and bacteria, feeding off the abundant sulfur and each other. One scientist even discovered a new species of microbe.

It baffles many that such livelihood can be found below the surface, hidden away from the sunlight. Yet, it brings up the idea that life evolved underground, when Earth was young and hostile. Building off that idea, scientists feel that it is also possible there is life on subsurface Mars, and Jupiter's Europa. The tantalizing world of Lower Kane resolved many uncertainties about sulfide caves, but also induced many other, more diverse questions. The answers Lower Kane can give us have only just begun to be tapped.

Hadingham, Evan. 2002. Subterranean Surprises. *Smithsonian Magazine*, October 2002.

A Review of "Underneath Alaska" by Bruce Brewer

by David Wilson, WUSS# 527

Bruce Brewer—writer, photographer, and caver based in Tallahassee Florida wrote a stirring article of the massive new caves being discovered *Underneath Alaska*. Brewer was 60 feet beneath the surface of the Tongass National Forest on Kosciusko Island; just one of a thousand islands in the region. So far about 600 caves have been found in the Tongass area. These caves are home to many organisms and many of these magnificently decorated caves are disappearing because of logging and urban sprawl.

Through his superb detail and visual language, Brewer brings us along, deep into the caves, and provides the experience of exploration with his team. Brewer brings us into cave K-109 that begins as a small hole no bigger than a basketball hoop. Immediately rare formations are already noticed in the 40-degree air as the team spots "moon milk" which is a bubbly coating made of calcite clinging to the narrow wall.

Gino Albert, a caver from Chicago accompanying the team, descends through a small fissure; "misty air and the curving walls of the fissure obscure the bottom." "Oh my God! I don't believe this! This is the best cave on the island," exclaims Albert! Brewer is now anxious to go down and Albert is ecstatic by the 20x20 foot chamber. Stalagmites rise from the floor and stalactites line the ceiling, which bristles with "accretions of crystallized minerals that have been leached out of the rock by percolating water and deposited over thousands of years, the chamber look like something out a Dr. Seuss book." This is unquestionably the most decorated cave in the Tongass with its crystal drapery and a central stalagmite, one of the largest formations in any cave in the Tongass. These formations along with 'soda straws' were expected, but not in such abundance.

Due to mining, sprawl, and logging, caves have been disappearing. The logging of the Tongass region has been a source of "lawsuits, investigations, conservation campaigns and political wrangling." According to Brewer, logging can change the way water flows into a cave and they can be clogged up by "slash and silt". Logging in the region presents a danger as the local Forest Service is supposed to take special precautions to protect cave entrances. However these issues have apparently

REVIEWS

been absent from their agenda and the Forest service only performed cursory investigations on Tongass's Heceta Island. As a result, a huge timber sale needed to be restructured.

The magnificent caves in the region have produced paleontological and archaeological material containing 41,600-year-old bear skeletons and 9,800-year-old human remains. This evidence is helping to alter theories of human migrations into the Americas. Also the drainage and mineral content in Tongass causes fish to grow faster and healthier and trees of spruce, cedar, and hemlock to grow in massive size. Despite the environmental and historical importance of these caves, half of Tongass's most productive terrain has already fallen under the ax.

Brewer provides a vivid description of the caves and their landscape along with the surface. He also describes the importance of caves in the region and in general along with the dangers to these caves and others. The article is filled with spectacular images of the caves, which brings the reader deeper into the experience of exploration. The article also provides information on how to take action and support the Alaska Rainforest Conservation Act as well as opportunities and information for cave exploration of the Tongass caves and others. Brewer, exploring the wonders of the Alaska caves, begins with cave K-109 and nicely frames the article with his departure from the cave, "leaving K-109 to the darkness."

Brewer, Bruce. 2002. Underneath Alaska. Sierra, 88(2): 34-39.

POSTCARD GALLERY

Right:
Grotto de Remouchamps - Le débarcadère "Au Précipice." Belgium

Above:
Grottes De Han, Le Lac D'Embarquement. Belgium

Right:
Crystal Caves, Bermuda

COMMENTARY

First Time Caving Experience

by Kevin Fitzgerald.

spe•lunk•er ; (spĭ lŭng´ ker) *n.* One who explores caves chiefly as a hobby; a caver.

Not many people are in this elite group, not many at all. In late January 2003, I was an ordinary civilian, going to school and acting like everyone else. When that day ended, so did my existence as a regular student of books. The following early morning, I was registered and sitting in a big white bus with fifteen other brave souls, heading to a destination unknown and feeling the apprehension. Crawl-a-thon, my fist major caving experience, was about to change how I saw the world and learned from Mother Earth. We parked, straightened the kneepads, crossed the road, and dove into a drain hole. The entrance was a tight fit, rocky crawl, but opened up into a small room with smooth white stones and the occasional pop can and unidentified plastic things. Once we passed through the washout of rocks and built up mud, the cave was more easily traversed. After a few minutes of squeezing, wiggling, hunch walking, rolling, and sitting, I realized that the beauty of the cave is not only the stalagmites, stalactites, cave formations, and occasional hibernating bat sightings, but the idea of what mud on your hands and dirt in you nose evokes. Within a cave, you become, if only for the crawl, one with the Earth. Camping can also bring on this feeling, but not having the wide-open sky above, only rock and earth surrounding you on all sides, brings a true and unadulterated oneness. After some big rooms, we reached our exit. One hundred feet of splits over rushing cold water bring us to a dead end. The crawl out has been washed closed. Without sunlight or a watch, time seems to be an abstract thought ticking in the back of your head, tiredness however is the true timekeeper and according to my watch, I have all day. The turn around only means one thing, more butts and shoes in my face and another squeeze out the way I came in.

Emerging covered in mud and a little more tired than when I entered, I had marks on me that could never be washed away. I was for one, no longer ordinary, I was now a spelunker, one of those crazy people usually on the cover of National Geographic. I was changed in another way too; I was forever stuck with the sweet memories and camaraderie of Mother Earth. My first extravaganza was a success.

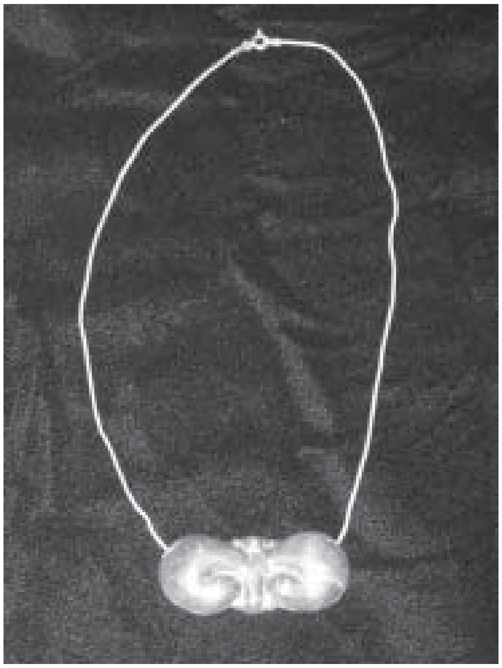
I am back to the books now, but whenever I get a whiff of dirt or spy my eternally dirty boots, the memories come flooding back to me. The warmth of the breeze as I enter, dark passages, light from the small heads crawling ahead of me, the short glimpse of slow formation growth, all of these images are forever mine. I cannot wait to shed these cloths of a student of books and once again become a student of Mother Earth, deep, deep inside where the only option is to crawl and learn.

Original Silver Jewelry

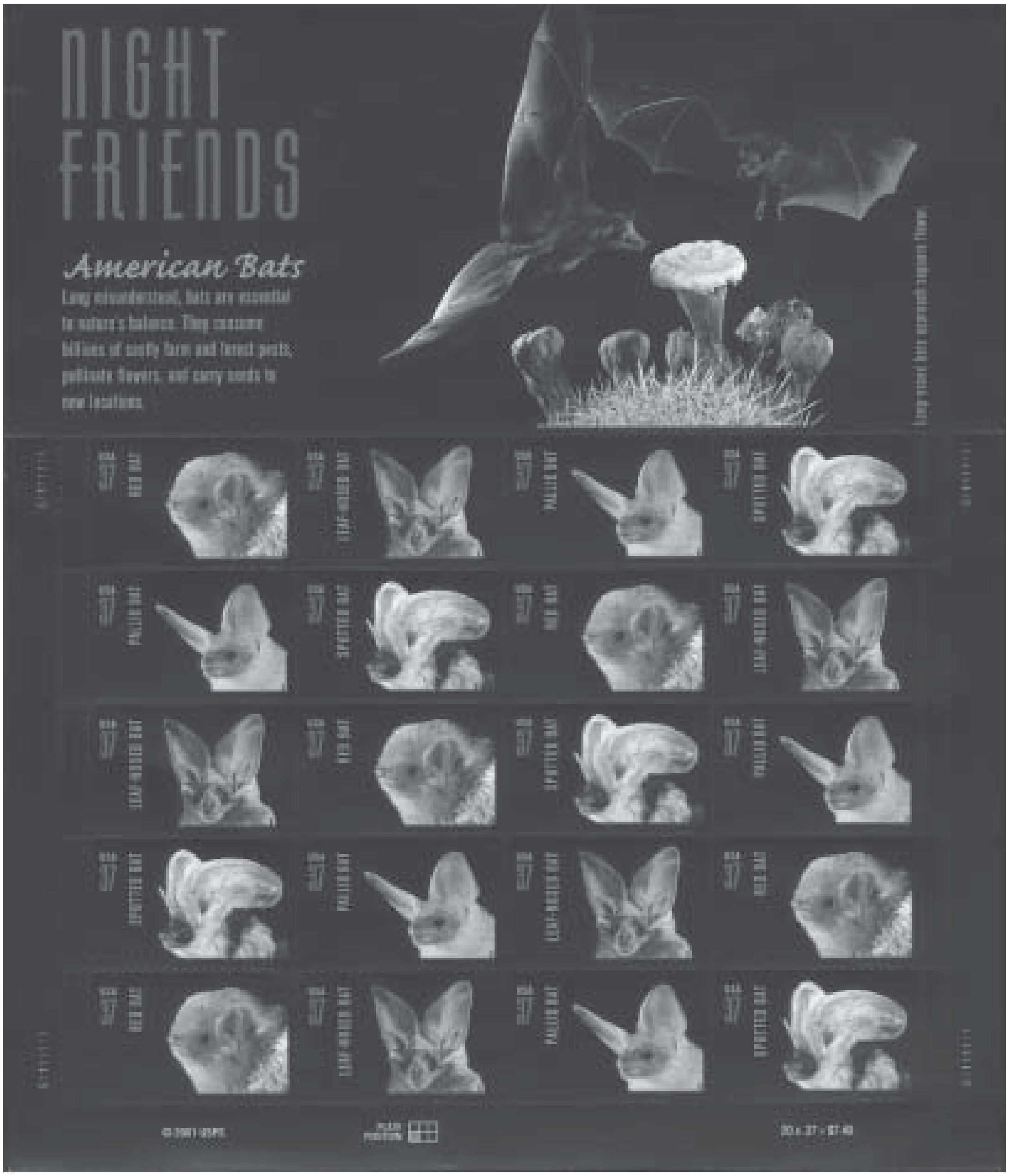
by Vittoria Curl NSS# 23500, WUSS# 497

Left: Fu (oriental bat), silver pendant.

Below: Argenta Spelunca I, silver medallion and chain.



COMMENTARY



Night Friends

Now you can let everyone know that you are a caver. The post office has released four full-color 37-cent stamps depicting bats (shown above in black and white, see back cover for color image). Featured on the stamps are:

The red bat, found throughout much of North America. The red bat is solitary, roosting alone in dense foliage. When it hangs upside down by one foot, its predators may be fooled by its resemblance to a dead leaf.

The pallid bat is found in western North America, where its pale, sandy color allows it to blend with its desert surroundings.

The spotted bat, which lives in the western United States, British Columbia, and Mexico where the staple of its diet is believed to be moths. Its ears, the largest of any bat on the continent, measure nearly two inches.

The leaf-nosed bat, a resident primarily of caves or abandoned mines in Southern California, Nevada, Arizona, and northern Mexico. Its large ears allow it to hear the extremely faint sounds of insects such as grasshoppers and caterpillars walking amid dense foliage, and its large eyes provide excellent night vision.

COMMENTARY

Bat Humor

Code of Conduct for bats at Carter Caves

1. Bats may not stay up past 8:30 am.
2. All bats must present their ID card at the entrance to the cave.
3. Bats should only poop on cavers if the caver is a real jerk.

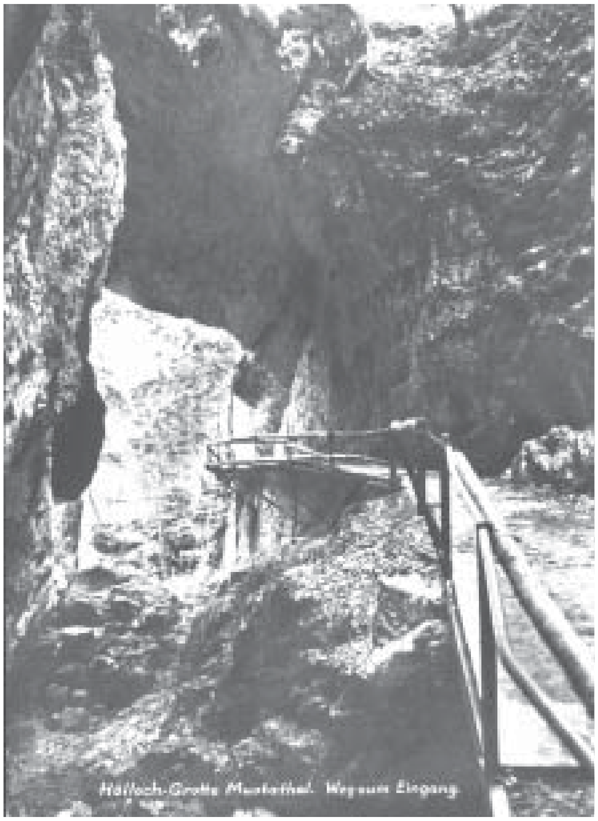
-Author Unknown

A Bat Story

A vampire bat came flapping in from the night covered in fresh blood and parked himself on the roof of the cave to get some sleep. Pretty soon all the other bats smelled the blood and began hassling him about where he got it. He told them to knock it off and let him get some sleep but they persisted until finally he gave in. “OK, follow me,” he said and flew out of the cave with hundreds of bats behind him. Down through a valley they went, across a river and into a forest full of trees. Finally he slowed down and all the other bats excitedly milled around him. “Now, do you see that tree over there?” he asked. “Yes, yes, yes!” the bats all screamed in a frenzy. “Good,” said the first bat, “Because I DIDN’T!”

-Author Unknown

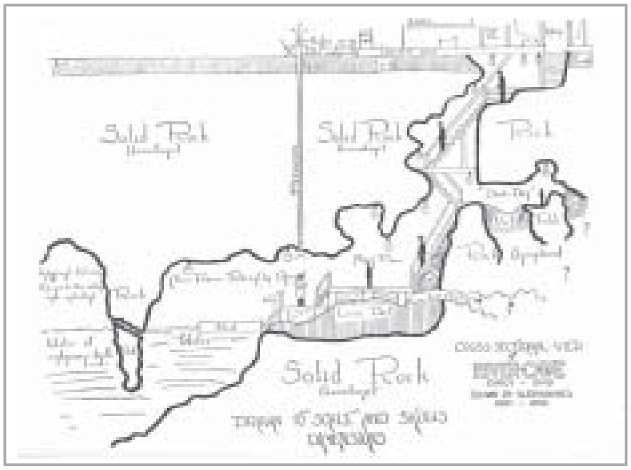
POSTCARD GALLERY



Hölloch-Grotte. Switzerland

Predjamski Castle, Slovenia

PHOTO AND POSTCARD GALLERY



Above: Underground River Cavern, Wyandot Co., Ohio.

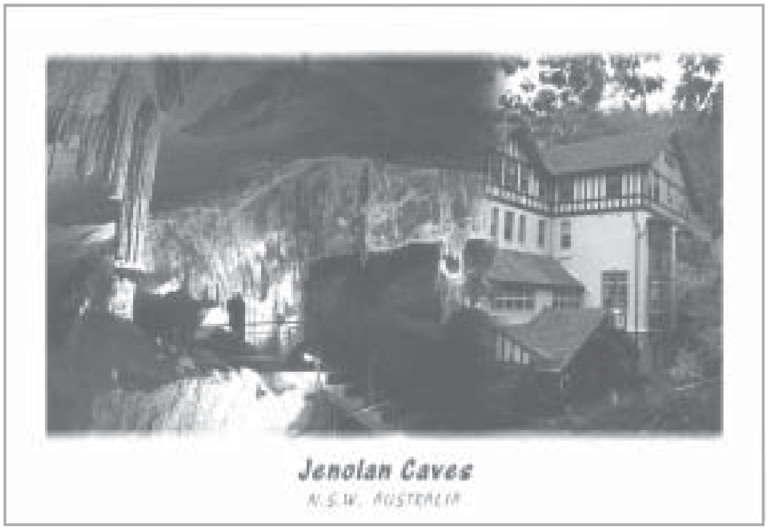
Right: Postojnska Jama - 1825, Slovenia

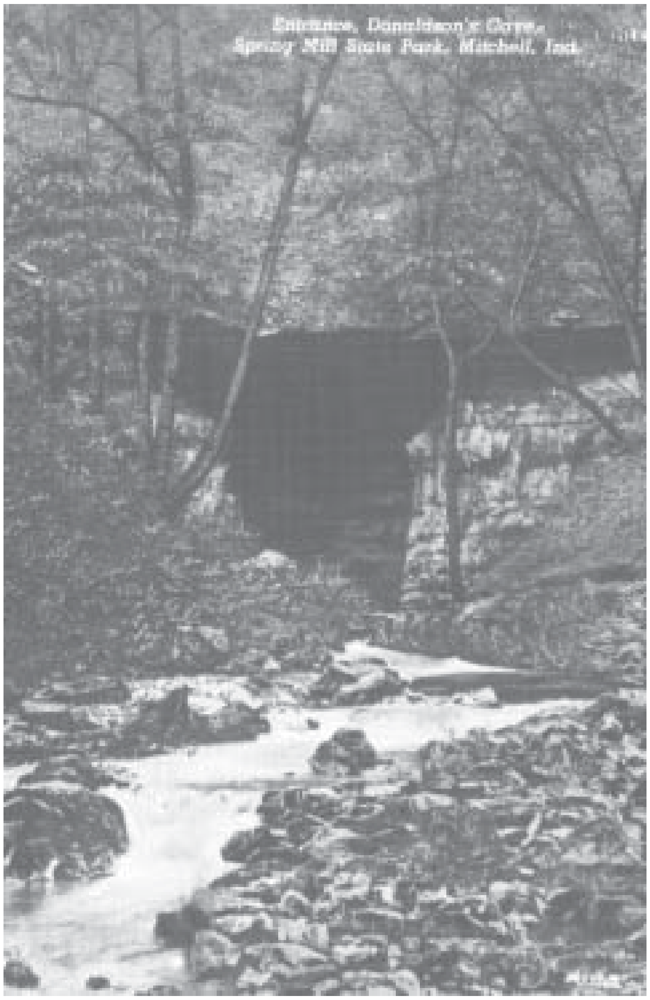
Below: Grotte De Niaux - Ariege, France

Left: Grotte Du Pech-Merle, France.

Above: The Serbian-bombed town of Zavala, Bosnia/Herzegovina. And we think we have cave land-owner problems! (photo by H. Hobbs III)

PHOTO AND POSTCARD GALLERY





Clockwise from upper left:

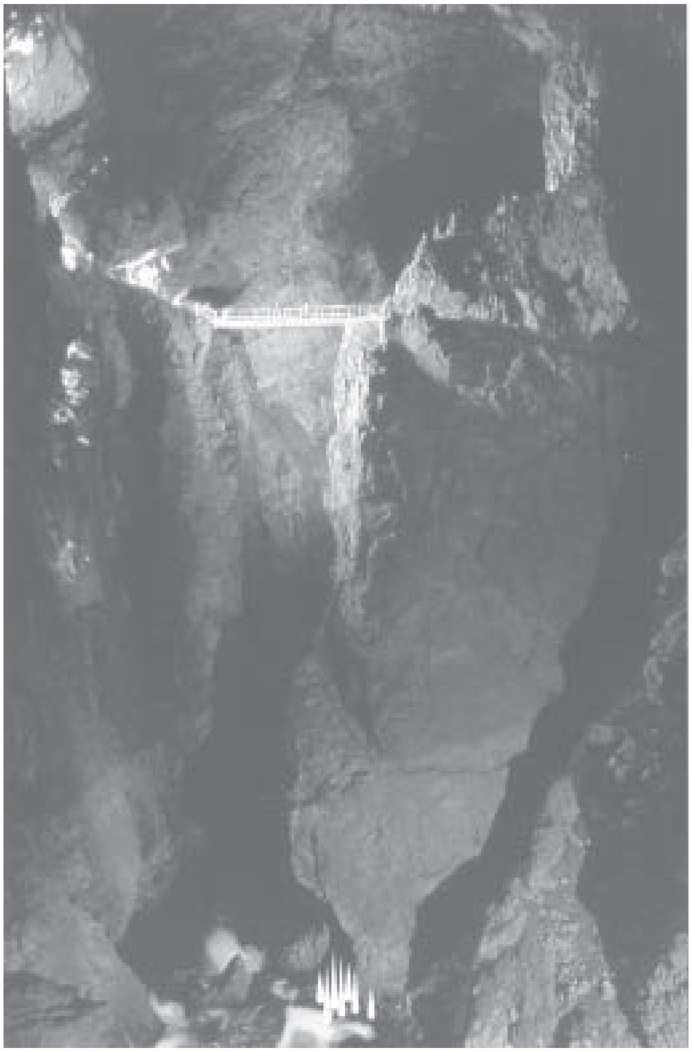
Jenolan Caves, New South Wales, Australia

Entrance, Donaldson's Cave, Spring Mill State Park, Lawrence Co., Indiana.

Big step over the edge. (photo by H. Hobbs III)

Preparing for the BIG one! (photo by H. Hobbs III)

PHOTO AND POSTCARD GALLERY



Left: Škocjanske jame, Slovenia

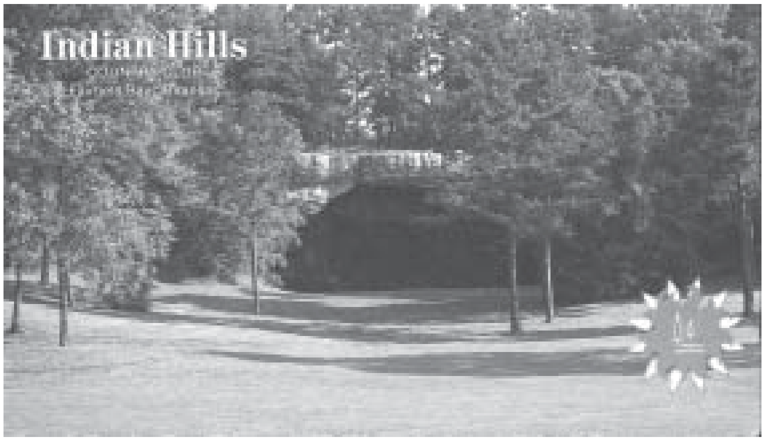
Above: Ruakuri Cave, Waitomo Cave, New Zealand

Below: The Cavern Cafe, Sonora, Mexico. 72° average the year ’round.

Bottom left: Dobsǐnská l’adouá jaskynǎ

Bottom right: St. Beatushöhlen, Switzerland

PHOTO AND POSTCARD GALLERY



Clockwise from upper left:

Shelter Cave, Fairfield Bay, Van Buren Co., Arkansas.

Kristen Baughman and Lindsay McCullough viewing ice stalagmites in Cascade Cave, Carter County, Kentucky (photo by H. Hobbs).

Meta menardi (Latreille) *in Ochre Cave, Ponte de Veia, Italy (photo by H. Hobbs).*

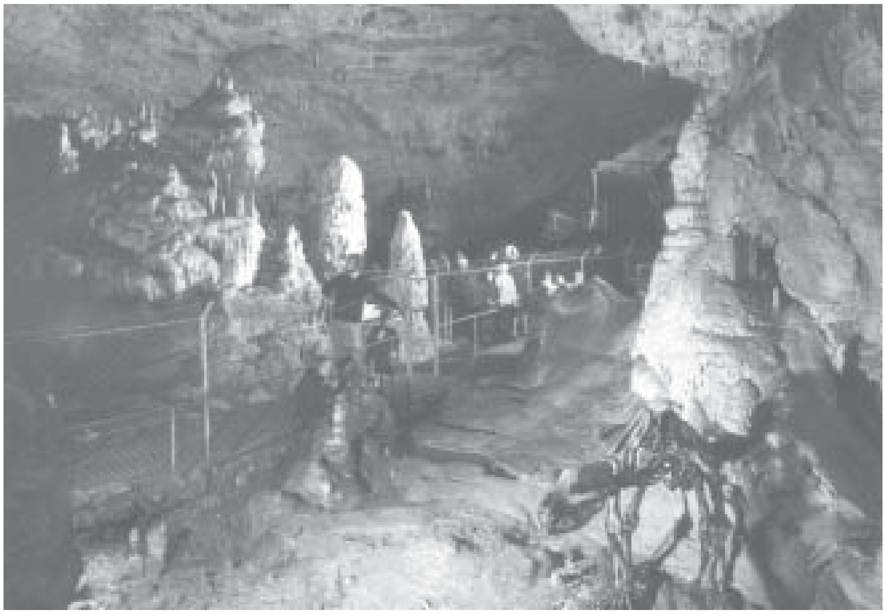
Dolemedes *sp. in Kohm's Cave, Ste. Genevieve County, Missouri (photo by H. Hobbs).*

Kristen Baughman, Lindsay McCullough, and Becki Lawyer in twilight zone of one of the entrances to Cascade Cave, Carter County, Kentucky (photo by H. Hobbs).

PHOTO AND POSTCARD GALLERY

Left: Conch Bar Caves, Grand Caicos.

Below: Bärenhöhle, Germany



Above: Fern Grotto, Kauai, Hawaii

Right: Lascaux II, France

PHOTO AND POSTCARD GALLERY

Katrina Mabin, Annette Engel and Dr. Libby Stern of the University of Texas conducting research in Lower Kane Cave, Bighorn County, Wyoming (photo by H. Hobbs).

Gypsum Trail, Lower Kane Cave, Bighorn County, Wyoming (photo by H. Hobbs).

EDITORIAL POLICY: Manuscripts treating basic research in any aspect of speleology will be considered for publication. They must not have been previously published, accepted for publications, or be under consideration elsewhere.

All manuscripts are to be in English. Metric and Celsius units must be used, and SI units are preferred. The CBE Style Manual, the Handbook for Authors of Papers of the American Chemical Society, and Webster's Ninth Collegiate Dictionary are useful guides for matters of form and spelling.

The original of the manuscript must be typed double-spaced on one side of white bond paper approximately 8.5 x 11 inches, leaving margins of one inch. Use triple-space above headings. Submit three copies for prompt review. Number pages consecutively at the top right-hand corner. Underline scientific names of genera and lower categories. Acknowledgments should be on a separate, double-spaced page. Each figure and table must be referred to in the text. Text references are by author, followed by year of publication. The sequence of material in the manuscript should be as follows.

1. The *title* page should include the title, author's name, affiliation and mailing address.

2. The *abstract* should not exceed one double-spaced page. It should contain a summary of significant findings and note the implications of these findings.

3. The *introduction*.

4. *Methods and materials*.

5. *Results*.

6. *Discussion*.

7. *Literature Cited*. List all publications refered to in the manuscript alphabetically by first author on a separate sheet of paper (double-spaced). Each citation must be complete, according to the following examples:

   Journal Article:

   Peck, S.B 1974. The food of the salamanders *Eurycea lucifugá* and *Plethodon glutinosus* in caves. NSS Bulletin, 36(4): 7-10.

   Book:

   Moore, G. W., and N. Sullivan. 1997. Speleology: Caves and the cave environment. St. Louis, Missouri: Cave Books.

   Chapter:

   Hobbs, H.H. 1992. Caves and springs *IN*, C.T. Hackney, S.M. Adams, and W.A. Martin (eds.), Biodiversity of Southeastern United States/Aquatic Communities. John Wiley & Sons, pp. 59-131.

8. *Figures and Tables*. Should be self-explanatory, with caption. Each table should start on a separate sheet. Headings and format should be consistent.

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