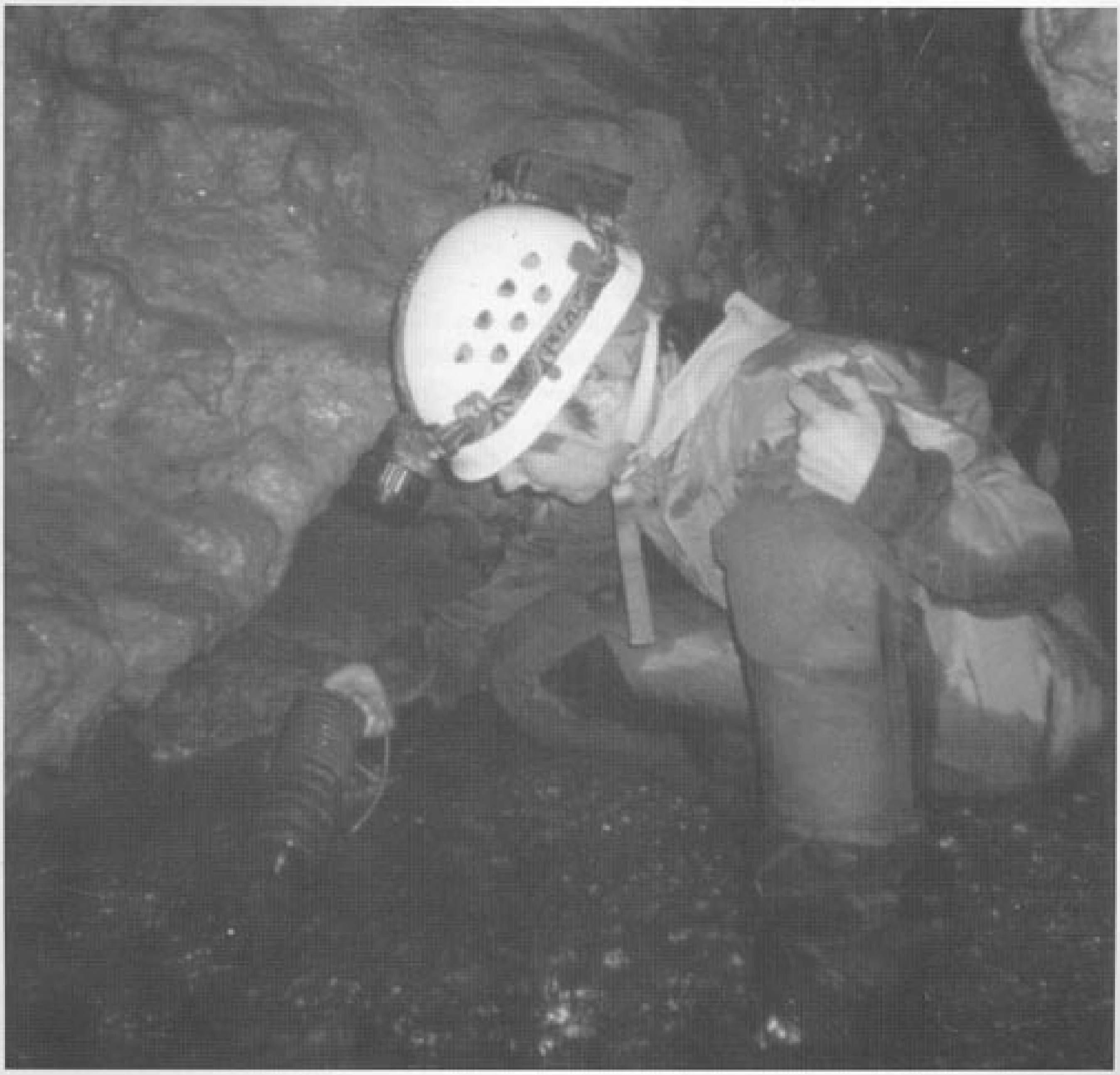
PHOLEOS

Journal Of The Wittenberg University Speleological Society

Volume 19 (1, 2)

May 2001



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 $100.

Meetings

Meetings are held every Wednesday at 7:00 p.m. when Wittenberg University classes are held. Regular meetings are in Room 319 in the Science building (corner of Plum and Edwards – 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.

GROTTO ADDRESS
Wittenberg University Speleological Society
c/o Horton H. Hobbs III
Department of Biology
Wittenberg University
P.O. Box 720
Springfield, Ohio, USA 45501-0720

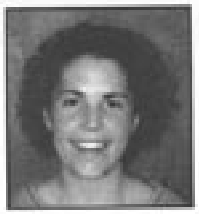
Tel. (937) 327-6484
FAX (937) 327-6487

PHOLEOS

VOL. 19, Issues 1, 2
May 2001

CONTENTS

ISSN: 0733-8864



CO-EDITOR'S NOTE

If the opposite of ascent is decent and the opposite of climbing up is climbing down — can the opposite of mountaineering be — spelunking? Apparently, it is. Spelunking, also known as caving, offers an alternative to all those adventurers disappointed that the world's tallest summits have been conquered. Spelunkers have the chance to discover underground haunts never before viewed by humans. Each year caves draw thousands of adventure-seeking tourists to the underground grottos.

Caving demands both strength and boldness. It combines the techniques of various sports — mountaineering, orienteering and diving — to explore the most remote places on earth. The journey only becomes more enthralling as one climbs, crawls, swims and squeezes their way through the cave. Through this surrealistic dream world, many have experienced a host of emotions from paralyzing fear to fascination and ultimately complete amazement. This is the essence that the contributors of *Pholeos* have felt and you will soon discover.

Happy reading!
Sara O'Donnell
WUSS # 0473
NSS # 48842

FRONT COVER: Beth Hagen checking a multiple plate Dendy stream sampler in Freelands Cave, Adams County, Ohio.

OFFICERS

President

Matt Hazelton
Box # 1409
Wittenberg University
P.O. Box 6100
Springfield, OH 45501
s02.mhazelton@wittenberg.edu
WUSS# 0449

Vice President

Lindsay McCullough
Box # 2777
Wittenberg University
P.O. Box 6100
Springfield, OH 45501
s03.lmccullough@wittenberg.edu
WUSS# 0469

Secretary

Kristen Baughman
Box # 2870
Wittenberg University
P.O. Box 6100
Springfield, OH 45501
s02.kbaughman@wittenberg.edu
WUSS# 0464

Treasurer

Steven Weldon
Box # 3459
Wittenberg University
P.O. Box 6100
Springfield, OH 45501
s03.sweldon@wittenberg.edu
WUSS# 0489

Co-Editor

Sara O' Donnell
Box # 3012
Wittenberg University
P.O. Box 6100
Springfield, OH 45501
s03.sodonnell@wittenberg.edu
WUSS# 0473

Co-Editor

Ben Grostic
Box # 2890
Wittenberg University
P.O. Box 6100
Springfield, OH 45501
s04.bgrostic@wittenberg.edu
WUSS# 0496

Faculty Advisor

Horton H. Hobbs III
hhobbs@wittenberg.edu
WUSS# 0001

RESEARCH

A Biological and Physicochemical Assessment of Freeland's Cave, Adams County, Ohio (1998-1999)

by Elizabeth M. Hagen, WUSS# 0400, NSS# 36267 and
Kathryn A. Gogolin, WUSS# 0448

Abstract

Freeland's Cave, Adams County, is one of the most significant karst features in Ohio. It is currently the longest surveyed cave (708m total horizontal length) and supports the greatest diversity of aquatic and terrestrial fauna (37 species) of any cave in the state. One species of importance is the troglobitic carabid beetle, *Pseudanophthalmus ohioensis*, which is endemic to Freeland's Cave. The cave is hydrologically connected to a surface sinkhole that has had long-time use by locals as a refuse dump. The objective of this research was to compare current (November 1998-October 1999) species abundances, distributions, and physicochemical characteristics to previous studies conducted in 1987 and 1996. The density of *P. ohioensis* varied seasonally, with population size highest during the months of July through September, and lowest from February through June. Population size ranged from 0 to 38 visible beetles per visit to the cave. Most species tended to utilize the cave in summer and fall months, but exceptions were the moth, *Scoliopteryx libratrix*, and the bat, *Eptesicus fuscus*, which entered the cave only during winter months. Precipitation and season affected physicochemical characteristics. Air temperature ranged from 10-12 °C and water temperature varied from 7-11 °C in the constant temperature zone, dissolved oxygen concentration fluctuated from 8-12mg/L, and pH values ranged between 5.65-9.20. Nitrate and phosphate levels were slightly higher compared to previous research, while sulfate amounts were somewhat lower. Low amounts of iron and copper concentrations suggest little contamination from the surface sinkhole. Data from this study were similar to ranges of 1987 and 1996 studies.

Introduction

Freeland's Cave, Adams County, Ohio, is a significant solution cave based on its size (708m total horizontal length) and its rich biota (Mitchell and Hobbs 1987) (See Hobbs 1986 for a full description). A large surface sinkhole, approximately 20 meters in diameter, is situated at the southern end of the cave near "Alky Crawl" (Figure 1). This sinkhole is hydrologically connected to the cave's main passage and prior to this study was used as a local dump. Large appliances including stoves and refrigerators, many forms of garbage, and leaking, rusting drums of unknown materials contaminated the sinkhole. These wastes could potentially leach into the cave system polluting the stream and harming the biota. Cave fauna are highly sensitive to disturbance, therefore a contaminated sinkhole could greatly hinder species diversity. Conse-

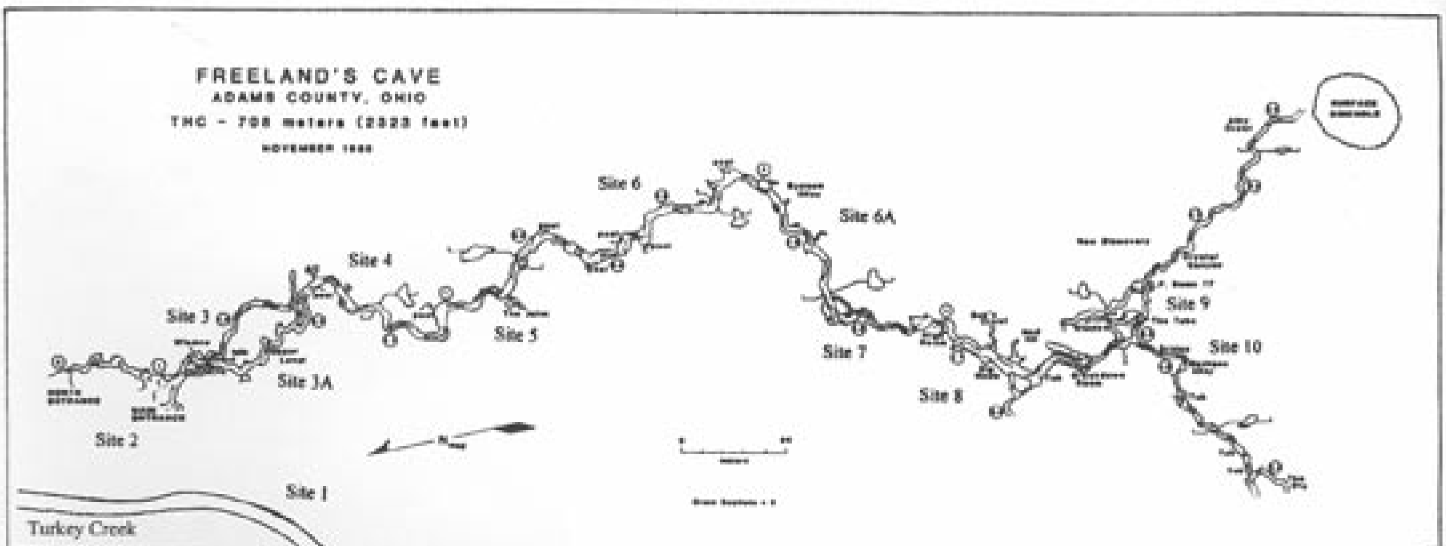


Figure 1. Freeland's Cave map indicating study site locations.

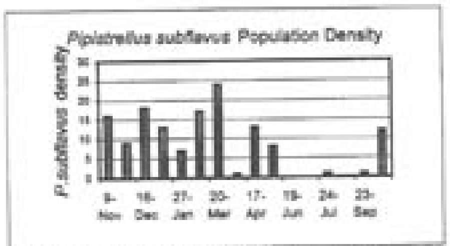


Figure 2. Total number of *P. subflavus* observed on each visit to Freeland's Cave, November 1998 to October 1999.

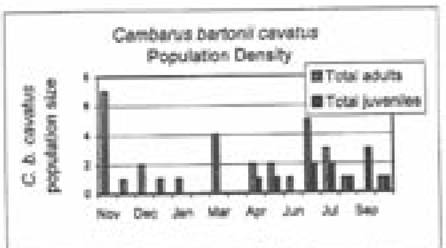


Figure 3. Total number of *C. b. cavatus* observed during each visit to Freeland's Cave, November 1998 to October 1999.

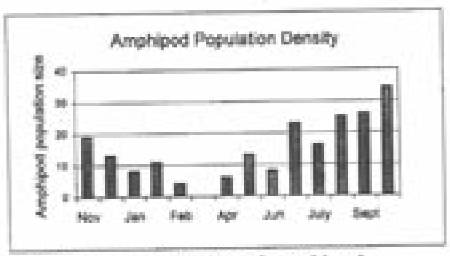


Figure 4. Total number of amphipods observed during each visit to Freeland's Cave, November 1998 to October 1999.

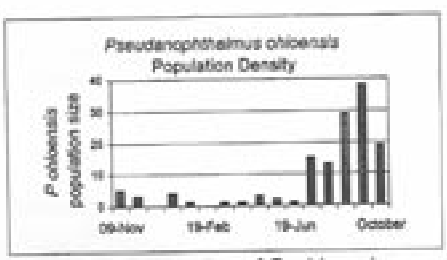


Figure 5. Total number of *P. ohioensis* observed during each visit to Freeland's Cave, November 1998 to October 1999.

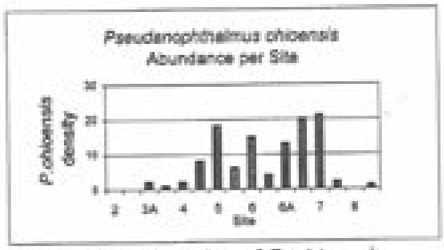


Figure 6. Total number of *P. ohioensis* observed at each site throughout Freeland's Cave, November 1998 to October 1999.

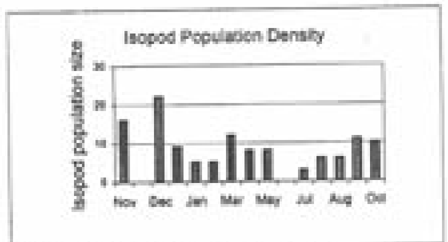


Figure 7. Total number of isopods (Caecidotea sp. and *Lirceus* sp.) observed during each visit to Freeland's Cave, November 1998 to October 1999.

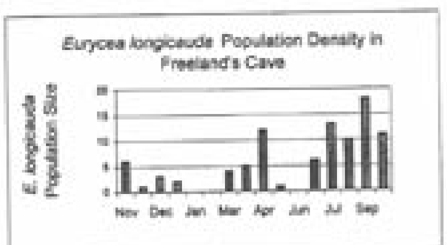


Figure 8. Total number of *E. longicauda* observed during each visit to Freeland's Cave, November 1998 to October 1999.

quently, 15.4 tons of trash were removed from the sinkhole during November 1998 and April 1999 by several different local organizations and caving grottos (Athy 1999).

The cave habitat provides a stable environment to study species diversity, which is due to its nearly constant temperature, high humidity, and complete darkness. Temperatures remain stable due to the insulating capabilities of the cave walls, ceiling, and reduced airflow (Gillieson 1996). Humidity is at or very close to saturation, which is necessary for several terrestrial cave adapted animals (e.g., beetles, millipeds). Aside from the entrance areas no natural light penetrates the cave. According to Poulson and Culver (1969), a higher degree of stability within the cave environment results in increased biodiversity.

The aquatic and terrestrial biota of Freeland's Cave is quite diverse (Hobbs 1986). One species of importance is *Pseudanophthalmus ohioensis*, a blind, terrestrial, troglobitic carabid beetle that is endemic to Freeland's Cave. The genus, *Pseudanophthalmus,* highly specialized cave-adapted beetles, is represented by 145 isolated species in the eastern United States (one of five families, and 237 species of troglobitic beetles in North America) (Culver and Hobbs 2000). *P. ohioensis* is a significant part of the Freeland's Cave community that includes at least 36 additional species of aquatic and terrestrial biota.

Previous studies conducted in Freeland's Cave include the collection of biological and physicochemical baseline data beginning in 1985 through 1987 by Mitchell and Hobbs (1987). A second study of the biological and physicochemical quality of the cave with specific attention to *Pseudanophthalmus ohioensis* occurred in 1996 by Hobbs (1996). There are two objectives of this current (1998-1999) research. The first was to determine the community structure and distribution in Freeland's Cave. The second objective was to make comparisons of current species abundances, distributions, and physicochemical characteristics to previous studies conducted in 1985 and 1996 to determine whether or not the sinkhole has altered the physicochemical characteristics of the stream within the cave. Additionally, seasonal effects on the stream and biota were assessed.

Methods

Biological and physicochemical characteristics of Freeland's Cave were studied monthly from November 1998 through October 1999. Study sites followed the cave's main stream passage except for one terrestrial site located in the upper level (Site 3A - Figure 1). Sites were selected to obtain comparative data with previous studies. However, in addition to the sites sampled by Hobbs and Mitchell (1987), sites 1, 6A, 9, and 10 were added (sites 9 and 10 were later dropped in May 1999).

Population counts were made at each site by searching the stream, substrate, and all crevices for aquatic and terrestrial cavernicoles within five-meter sections at each testing site. To assess the *Pseudanophthalmus ohioensis* population the entire front 300m of terrestrial cave habitat were searched. Additional biota observed between sites were recorded as well.

Baiting and trapping techniques were utilized at several sites to obtain a more complete biological assessment. Traps were set seasonally and checked within 2-4 days as well as on each return visit to the cave. Different traps were set to attract both aquatic and terrestrial fauna. Multiple plate Dendy traps, which provide a habitat for aquatic biota, were set at sites 3, 5, 6, 7, and 8, and remained in the cave stream throughout the study. Pitfall traps, 8cm deep, baited with Limburger cheese were set at sites 3, 3A, 5, 6, 6A, 7, 8, and 9 to attract terrestrial cavernicoles. Mesh bags baited with shrimp were attached to rocks and left in the stream to attract aquatic species, mainly isopods and amphipods. These traps were set at sites 3, 4, 5, 6, and 8.

Terrestrial biota were classified as troglobites, troglophiles, trogloxenes, and accidentals. Aquatic species followed a similar classification except the prefix *stygo* was used (i.e., stygobites). Fauna were catalogued according to microhabitat such as stream (pool and riffle substrates that ranged from silt to cobble sized particles), mud banks, cave walls, and ceiling. Substrate where the organisms were found was noted to assess the habitat preferences of the biota.

Physicochemical characteristics measured include nitrate-nitrogen, soluble reactive phosphorous, sulfate-sulfur, total iron, copper, ammonia, water hardness, turbidity, pH, salinity, specific conductance, dissolved oxygen concentration, percent oxygen saturation, relative humidity, and air and water temperatures. Copper and ammonia parameters were dropped during the study because results were negligible. Precipitation data were recorded daily by the West Union, Adams County weather station November 1998 through October 1999 (National Climatic Data Center 2000), which is approximately 20km southwest of Freeland's Cave. Daily high and low surface temperature data were recorded by the Hillsboro, Highland County weather station, located approximately 35km northwest of the cave, for the duration of the study (National Climatic Data Center 2000).

Three water samples were collected at all stations, when possible, and placed into acid washed polyethylene one liter Boston bottles. Samples were collected at selected sites moving upstream in order not to disturb sample sites. Nitrate, phosphate, sulfate, iron, copper and ammonia concentrations were determined using a Hach DREL/2010 Water Quality Laboratory Kit spectrometer. Water hardness was assessed using a Hach Digital Titrator, and turbidity was recorded with a Hach Turbidometer model #2100P. All Boston bottles were placed in a light-tight cooler and water

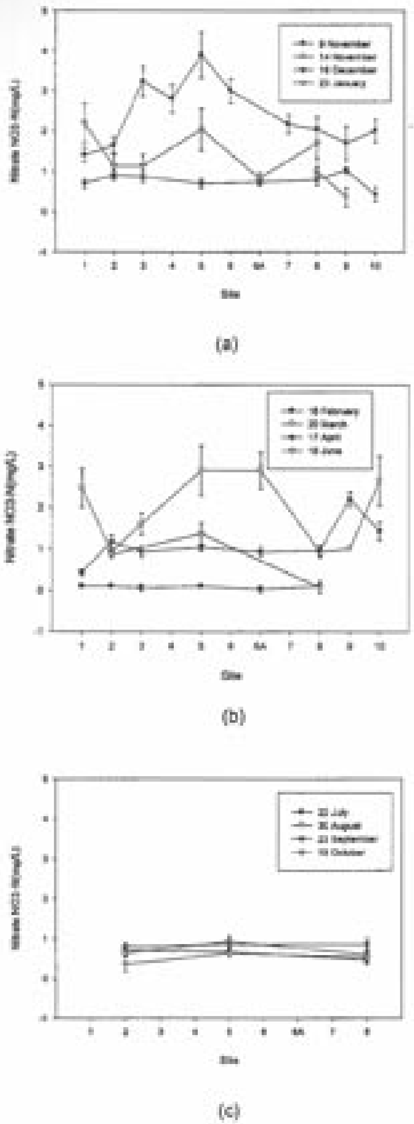


Figure 9. Nitrate-nitrogen profiles for Freeland's Cave, Adams County, Ohio from November 1988 to October 1999. Error bars indicate ± S.E.

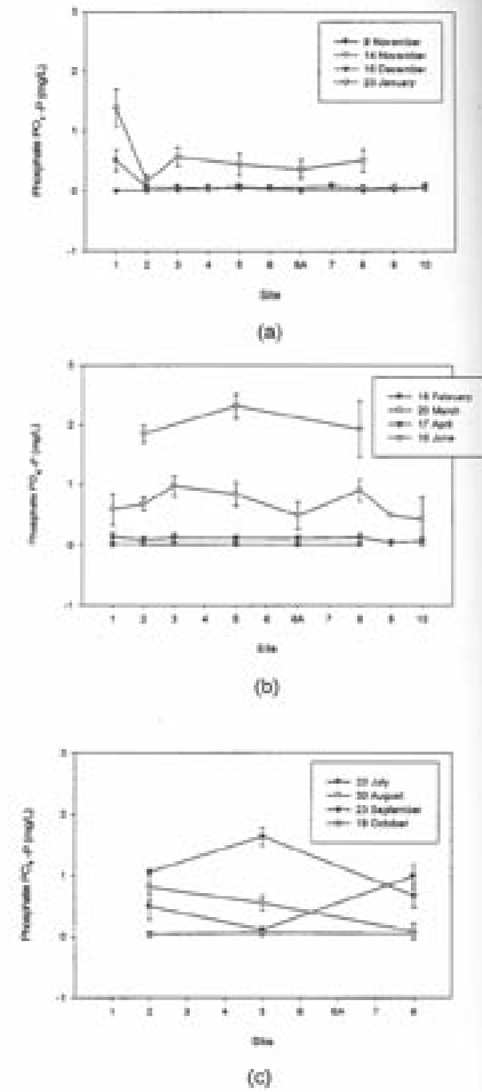


Figure 10. Soluble reactive phosphorous profiles for Freeland's Cave, Adams County, Ohio from November 1998 to October 1999. Error bars indicate ± S.E.

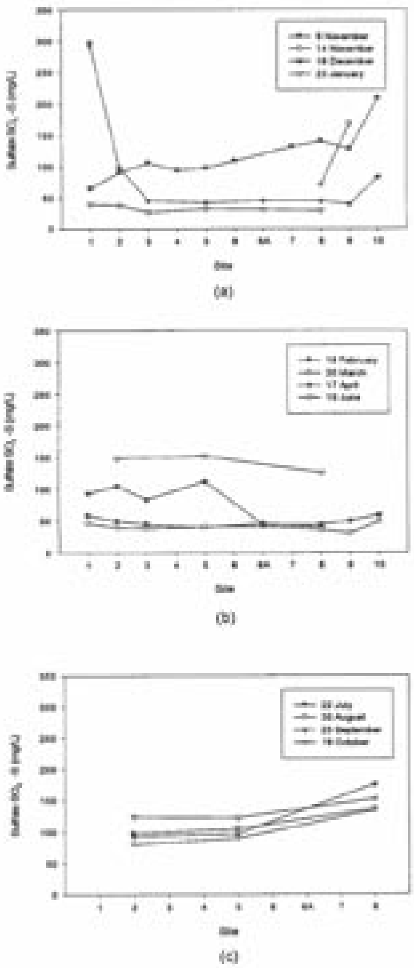


Figure 11. Sulfate-sulfur profiles for Freeland's Cave, Adams County, Ohio from November 1998 to October 1999. Error bars indicate ± S.E.

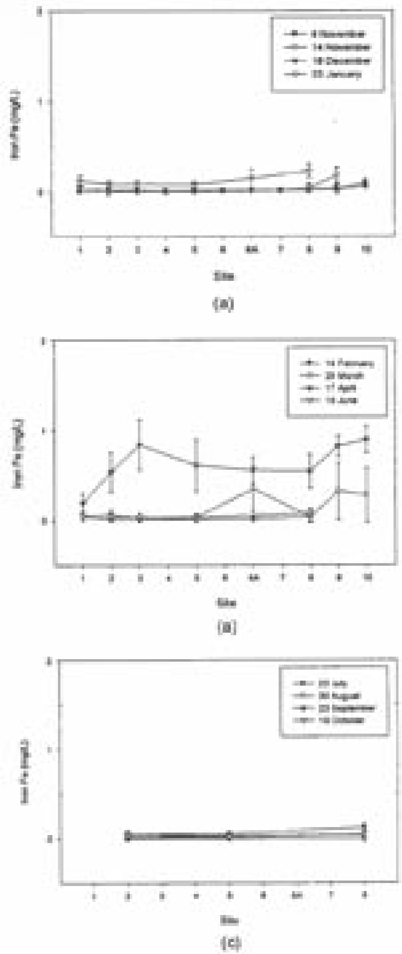


Figure 12. Total iron profiles for Freeland's Cave, Adams County, Ohio from November 1998 to October 1999. Error bars indicate ± S.E.

chemistry analyses were completed within 24 hours of sampling time.

To measure pH, salinity, specific conductance, and water temperature a YSI model 63/100 pH/salinity/conductance/temperature meter was utilized at each aquatic site. Dissolved oxygen concentration and percent oxygen saturation levels of the stream were obtained with a YSI model 55 dissolved oxygen meter.

StowAway XTI Electronic temperature data loggers, enclosed in submersible cases, were placed at various aquatic and terrestrial sites throughout the cave. Data loggers were set and retrieved three times during the study duration: 18 February 1999 - 15 April 1999, 17 April 1999 - 22 July 1999, and 24 July 1999 - 19 October 1999. Data collected from data loggers initiated on the surface were not retrieved due to theft of the data loggers.

Results

Biological

A total of 37 different species of biota has been identified in Freeland's Cave (Table 1). Twenty-six additional cavernicoles were identified in comparison to previous studies (Hobbs 1986). The greatest number of species observed was classified as troglophiles, with a total count of 1107 individual troglophiles. Pitfall traps set at several sites attracted large numbers of springtails, *Sinella cavernarum*, thereby significantly increasing the number of troglophiles observed. Trogloxenes and stygophiles also had high occurrences of 554 and 452, respectively. In Freeland's Cave only *Pseudanophthalmus ohioensis* is classified as a troglobite and the total of 136 individual troglobites reflects the total number of carabid beetles seen throughout the yearlong study. *Caecidotea* sp. is the only stygobitic cavernicole identified in Freeland's Cave.

Trends associated with season and locations within the cave were noted with several fauna. The former most likely results from preferred habitat at respective sites (i.e., greater densities of *P. ohioensis* were found at sites with mudbanks). Correlations associated with season were seen with the moth *Scoliopteryx libratrix*, the big brown bat *Eptesicus fuscus*, the solitary bat *Pipistrellus subflavus*, the crayfish *Cambarus bartonii cavatus*, the amphipod *Gammarus minus*, and the carabid beetle *P. ohioensis*. Both *S. libratrix* and *E. fuscus* utilized the cave environment only during winter months. Furthermore, because both species prefer colder temperatures they were found near the cave entrance in the twilight zone. *P. subflavus* was found throughout the entire area of study, yet the population size fluctuated with season. Higher counts, ranging from 7-24, were made during colder months (November through March), while bats were rarely seen utilizing the cave during warmer months (July through September) (Figure 2). The average number of *P. subflavus* observed per trip was nine and the number of bats seen per visit ranged from 0 to 24. Aside from *P. subflavus* and *E. fuscus*, the Little Brown Bat, *Myotis lucifugus*, also was identified in Freeland's Cave. However, *E. fuscus* and *M. lucifugus* densities were low and each of these species was observed only on one visit to the cave. The crayfish, *C. b. cavatus*, was found consistently throughout the year along the stream in all cave zones (Figure 3).

Table 1. Total biota observed in Freeland's Cave

SPECIES	CLASSIFICATION
Planaridae - plannaria	SP
Gastropoda Pulmonata - snail	A
Gastropoda Pulmonata - slug	A
Annelida - earthworm	A
Caecidotea sp. - an unidentified aquatic isopod	SB
Lirceus sp. - aquatic isopod	SP
Haplophthalamus danicus (Budde-Lund) - terrestrial isopod	TX
Gammarus minus (Say) - amphipod	TP
Cambarus (Cambarus) bartonii cavatus (Hay) - crayfish	SP
Orconectes sp. - crayfish	SX
Meta ovalis (Gertsch) - spider	TP
Diplopoda - milliped	TP
Acari - mite	TX
Lycosidae - wolf spider	TX
Leiobunum bicolor (Wood) - phalangid	TX
Pardosa sp. - spider	TX
Hesperochernes sp. - psueudoscorpion	TP
Sinella cavernarum (Packard) - springtail	TP
Ceuthophilus brevipes (Scudder) - cricket	TX
Gryllidae - surface cricket	TX
Gerridae - water strider	SX
An unidentified Carabidae Coleoptera - ground beetle	TP
Pseudanophthalmus ohioensis (Kreckler) - beetle	TB
Amoebaleria defessa (Osten Sacken) - fly	TX
Culicidae - mosquito	TX
Heleomyza brachypterna (Loew) - fly	TP
Tipulidae - crane fly	TX
Scoliopteryx libratrix (Linnaeus) - moth	TX
Desmognathus f. fuscus (Rafinesque) - salmander	SP
Eurycea longicauda (Green) - Long-tailed salamander	SP
Gyrinophilus porphyriticus (Green) - salamander	SP
Pseudotriton ruber (Lateille) - Northern red salamander	TP
Rana pipiens pipiens (Schreber) - frog	SX
Eptesicus f. fuscus (Beauvois) - Big Brown Bat	TX
Myotis lucifugus (LeConte) - Little Brown Bat	TX
Pipistrellus subflavus (Curier) - Eastern Pipistrelle Bat (Solitary Bat)	TX
Peromyscus sp. - mouse	TX

*Trogloxenes (TX), Troglophile (TP), Troglobite (TB), Accidentals (A), Stygoxene (SX), Stygophile (SP), and Stygobite (SB)

Population counts ranged from 0 to 7 individuals seen per visit and averaged 3. However, the juvenile crayfish population directly correlated with season. Juvenile crayfish (<5cm in total length) were seen in the entrance pool at Site 2 April though October. The amphipod, *G. minus*, population size increased during warmer months to 16 to 34 individuals per visit and decreased to only 0 to13 during cooler months (Figure 4). The average number of *G. minus* counted per visit was 15 and the largest abundance was located in the entrance pool.

Pseudanophthalmus ohioensis population density increased significantly July through October. Population size ranged from 0 to 38 observed beetles per visit to the cave, with population counts ranging from 13 to 38 July through September and 0 to 5 November through June (the average number of beetles seen throughout the year was 8) (Figure 5). *P. ohioensis* density was highest at sites 5-7 throughout the course of study (Figure 6). Previous data, collected between 1994 and 1996, indicated no seasonal trends and lower beetle densities (Hobbs 1996). However, visits to the cave were on a less frequent basis and baiting methods were not utilized.

Additional trends were observed with certain aquatic biota. Isopod density, both the unpigmented *Caecidotea* sp. and pigmented *Lirceus* sp., within the cave stream averaged eight and ranged from 0 to 22 isopods per visit (Figure 7). *Lirceus* were found mainly in the entrance pool at Site 2, the number varying from 0 to 20. The density of isopods counted at sites deeper within the cave system ranged from 0 to 9 per site. The greatest numbers of the Long-Tailed Salamander, *Eurycea longicauda*, were found between sites 4 and 6. Population densities were 0 to 18 per cave visit with larger numbers observed July though October (Figure 8).

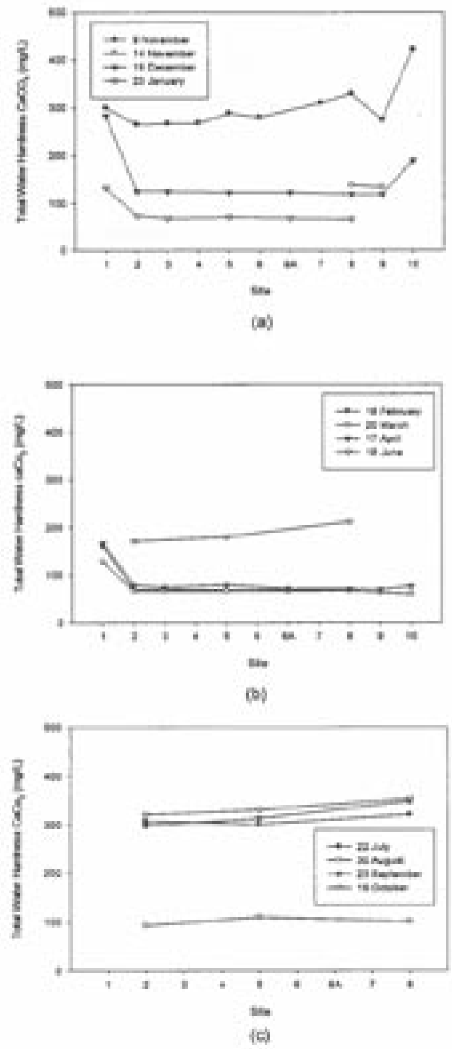


Figure 11. Sulfate-sulfur profiles for Freeland's Cave, Adams County, Ohio from November 1998 to October 1999. Error bars indicate ± S.E.

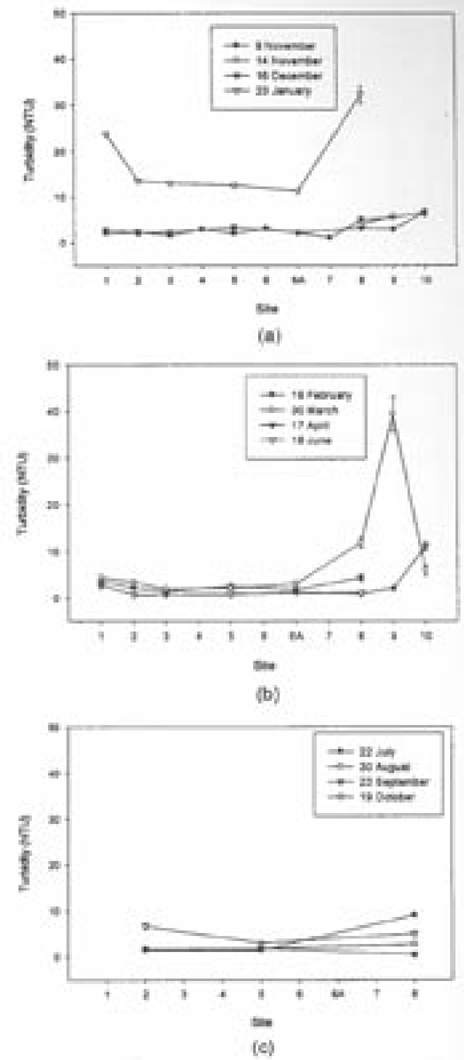


Figure 12. Total iron profiles for Freeland's Cave, Adams County, Ohio from November 1998 to October 1999. Error bars indicate ± S.E.

Physicochemical characteristics

Several physicochemical parameters were measured throughout Freeland's Cave to assess stream quality. Nitrate-nitrogen (NO_3-N) concentrations fluctuated greatly from 0.03mg/L at Site 6A on 18 February to 3.9mg/L at Site 5 on 9 November (Figure 9a-b). Yet, nitrate levels were fairly consistent during most testing times, ranging from 0.03mg/L to 0.93mg/L with no trends observed throughout the cave stream (Figure 9a-c). Soluble reactive phosphorous (PO_4-P) levels steadily remained between 0.0-1.0mg/L in the cave stream (Figure 10a-c), although elevated concentrations were recorded in June and September (Figure 10b-c). No trends were determined along the cave stream. Nitrate levels were fairly similar to the study conducted in 1985-1986, while phosphate levels were slightly higher in previous studies; however, both results are within expected ranges (Table 2).

Sulfate-sulfur (SO_4-S) concentrations commonly fluctuated around 40-150mg/L, yet an outlying measurement was recorded at Site 1 in December (Figure 11a-c). No definite trends were seen moving upstream from the entrance to Site 8. Sulfate ranges were slightly lower in the 1985-1986, but no substantial difference was present (Table 2).

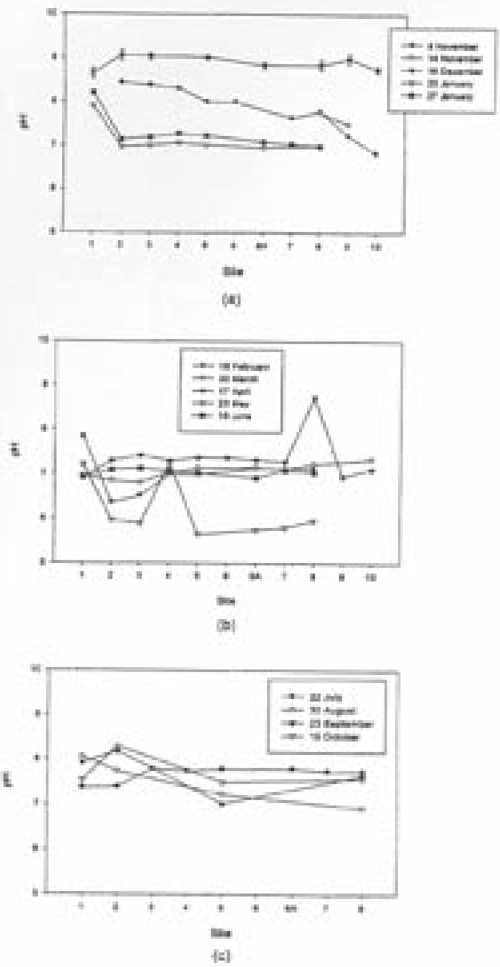


Figure 15. pH profiles for Freeland's Cave, Adams County, Ohio from November 1998 to October 1999. Error bars indicate ± S.E.

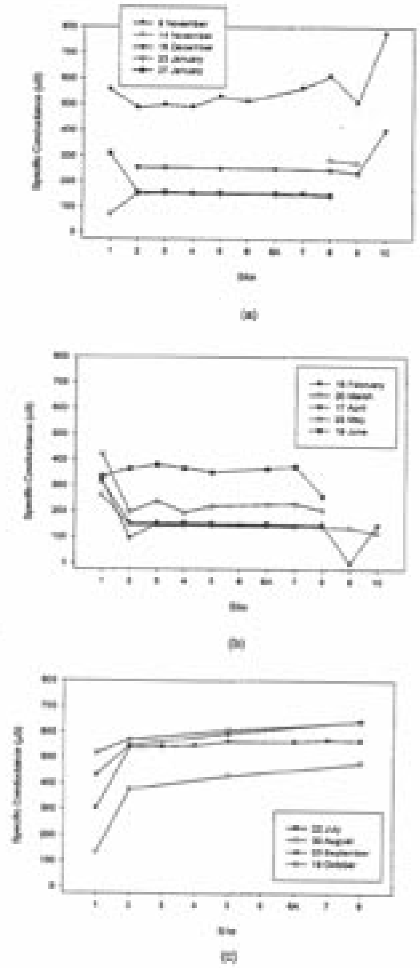


Figure 16. Specific conductance profiles for Freeland's Cave, Adams County, Ohio from November 1998 to October 1999.

Total iron (Fe) concentrations were consistently around 0.0 to 0.25mg/L except in April when iron levels fluctuated from 0.19mg/L in Turkey Creek to 0.89mg/L at Site 10 (Figure 12a-c). Additionally, April iron concentrations were high throughout the entire cave in comparison to other testing dates. Iron concentrations were fairly consistent with previous studies (Table 2). Copper values were consistently low, varying from 0.0-0.3 mg/l. This parameter was omitted in January because results were negligible.

Water hardness ($CaCO_3$) levels varied greatly, ranging from 65-350mg/L with one outlier of 422mg/L present at Site 10 in November (Figure 13a-c). Levels remained fairly constant throughout the cave length, while epigean Turkey Creek consistently had higher ion concentrations than the cave stream December through April.

Turbidity (NTU) was fairly low throughout the study, remaining around 0.1-9.0 NTU (Figure 14a-c). However, increased turbidity readings were recorded in January and at Site 9 in March, increasing up to 40 NTU (Figure 14a-b). When low water levels were present it was difficult to keep from disturbing the stream sediments and the third sample often was highly turbid; therefore samples that were significantly affected during collection were excluded from any statistical analyses. Turbidity levels were slightly higher than those in previous studies (Table 2).

The pH fluctuated from 5.65 to 9.20 throughout the study duration; however, levels remained fairly alkaline (Figure 15a-c). The pH readings only dropped below 6.00 in May (possibly due to a faulty meter) (Figure 15b). No trends were determined throughout the cave stream length. In previous studies pH levels ranged from 5.86 to 8.05, and were fairly consistent with the current data (Table 2).

Specific conductance varied greatly from 14µs/cm to 777µs/cm (Figure 16a-c). Values January through April were consistently at 150 µs/cm with measurements increasing in Turkey Creek to around 300 µs/cm (Figure 16a-b). Specific conductance in November and June though October were higher, commonly ranging from 350µs/cm to 640µs/cm (Figure 16a-c). Ion concentrations remained fairly constant throughout the cave length aside from differing measurements in Turkey Creek. Specific conductance data collected from 1985-1986 ranged from 84.8 to 413µs/cm (Table 2).

Oxygen concentration stayed within 8-10mg/L and did not fluctuate greatly throughout the cave (Figure 17a-c). Dissolved oxygen levels in Turkey Creek, however, often differed from levels recorded in the cave stream, depending on season. Oxygen concentrations measured on 23 January were significantly lower, ranging from 3.15 to 5.35mg/L, however, most likely this was due to a malfunction of the probe (Figure 17a). As one would anticipate, oxygen saturation percentages followed the same trends of oxygen concentration, ranging from 70%-90% and cave stream saturation's differing in comparison to Turkey Creek (Figure 18a-c). Again, oxygen saturation values recorded in January were significantly lower than other testing dates (Figure 18a). Oxygen concentrations recorded in 1986 ranged from 7.61 to 14.42mg/L, the average oxygen concentrations, however, were within expected ranges of current data (Table 2).

Water temperature throughout the cave varied moderately, fluctuating from 6 to 13°C depending on season (Figure 19a-c). However, cave stream temperatures fluctuated less in comparison to Turkey Creek due to epigean seasonal variation. Towards the entrance the water temperature ranged from 6°C in March to 13°C in August, but beyond "The Joint," stream temperatures only varied 3.5°C from 7.5 to 11°C (Figure 20a-b). Air temperature within Freeland's Cave became increasingly more constant deeper into the cave. While epigean temperatures ranged from -20°C to over 37°C (National Climatic Data Center 2000), the air temperature recorded at Site 3 was less variable with temperatures ranging from 5 to16°C (Figure 21a). In the deeper cave zone (Site 8) the air temperature only varied 2°C from 10 to 12°C (Figure 21b).

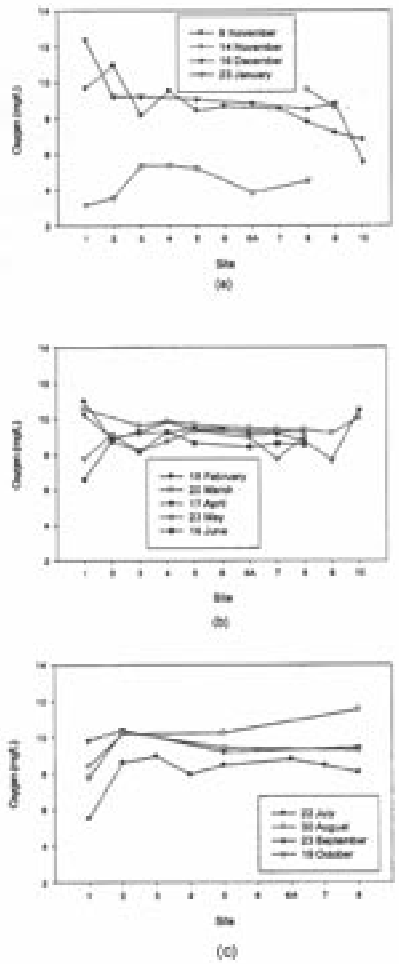


Figure 17. Dissolved oxygen concentration profiles for Freeland's Cave, Adams County, Ohio from November 1998 to October 1999.

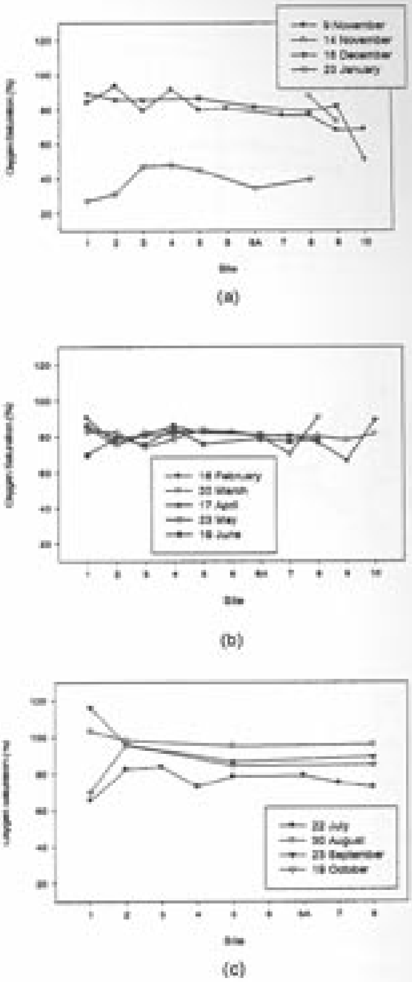


Figure 18. Oxygen saturation profiles for Freeland's Cave, Adams County, Ohio from November 1998 to October 1999.

Discussion

Biological

Freeland's Cave is considered a rich cave both in terms of aquatic and terrestrial species biodiversity. Generally, an environment with high water quality and ample niches will support a high diversity of fauna. However, a species will not necessarily occur in all caves, habitats, or microhabitats even if conditions seem optimal for survival. In part this is due to very limited opportunities for dispersal (highly adapted cave fauna must remain underground) and because of the scarcity of food in cave ecosystems. Caves that support two or three species of troglobites or stygobites are considered rich in biota (Poulson and Culver 1969). Freeland's Cave supports 37 total terrestrial and aquatic fauna, including one endemic, troglobitic beetle, *P. ohioensis* and one stygobitic isopod, *Caecidotea* sp.

Freeland's Cave provides the stable environment necessary to support terrestrial cave adapted fauna that are more susceptible to habitat changes. Caves often provide refugia for biota, and while aquatic fauna can more easily move through groundwater to better suited conditions, terrestrial biota are limited to air filled cracks and crevices within the cave habitat. While the deep cave zone remains a stable environment due to fairly constant temperature, humidity, and complete darkness, some seasonal trends are present that are affected mainly by surface temperatures and precipitation levels. A strong correlation was found with bat species and their seasonal use of the cave. *P. subflavus* population size greatly elevated October through March, and significantly decreased June through September (Figure 2). Furthermore, the few individuals observed during summer were not hibernating, as were the bats counted during winter months. In winter the abundance of *P. subflavus* increased deeper into the cave system where temperature increased and was more constant, while *E. fuscus* were observed at the cave entrance due to their preference for colder temperatures.

Aside from seasonal trends, relationships with preferred habitat conditions associated with site number were observed. The Freeland's Cave environment offers of a wide variety of habitats for cave biota to occupy including mud banks, stream (pool and riffle substrates ranging from silt to cobble sized sub-

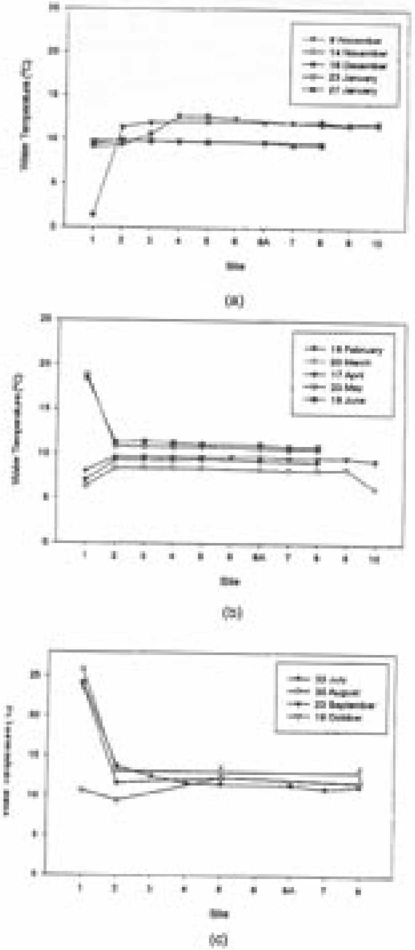


Figure 19. Water temperature profiles for Freeland's Cave, Adams County, Ohio from November 1988 to October 1999. Error bars indicate ± S.E.

strate), cave walls, and ceilings. Additionally, a positive correlation exists between species diversity and substrate availability (Poulson and Culver 1969). Within the cave, amphipod distribution was associated with sites having preferred available habitat. Certain aquatic fauna showed no correlation with season or position within the cave. Adult *Cambarus b. cavatus* were identified throughout the cave stream in fairly consistent numbers during the year, although the number of juvenile crayfish identified was elevated April through October at the entrance pool (Figure 3). Other semi-aquatic biota including *Eurycea longicauda*, however, showed definite trends with site number and season. *E. longicauda*, found along the stream banks and cave walls, had high population densities in April when numerous young were observed and July through September as adults when water levels and air temperature were elevated (Figure 8).

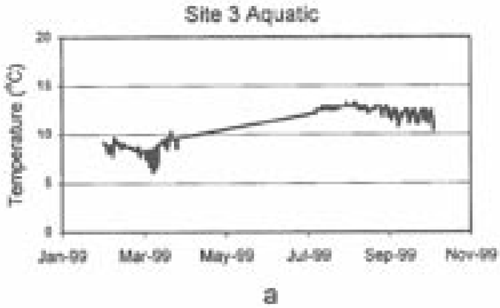
Amphipods and isopods tended to dominate the stream biota, including both pigmented and pigmentless forms. However, the number of pigmented individuals was significantly higher than the number of biota lacking pigment. While amphipod population density increased April through October, isopod abundance was greatest November through January and the largest numbers of amphipods and isopods were consistently observed in the entrance pool (Figure 4 and 7). Throughout the cave the distribution of amphipods remained fairly consistent aside from slight increases in population size at sites 3 and 5, yet this may be due to the influence of baits set at those sites. Isopod abundance also increased at Site 7.

Amphipod and isopod population densities correlated with microhabitat availability. Freeland's Cave stream tends to alternate between riffle and pool areas with amphipod and isopod preferred habitat associated with the underside of rocks and gravel in the riffle section or in small cobble and gravel filled pools alongside the faster flowing water. Population density of amphipods and isopods collected in Benedict's Cave, Greenbrier County, West Virginia was five times greater in riffle sections than in pools (Culver 1982). This is related to a higher amount of dissolved oxygen and more food availability of detritus trapped within the substrate. Furthermore, the underside of rocks provides a place for amphipods and isopods to feed as well as for protection from predators (e.g., salamanders). Culver (1982) found the only known predator of cave amphipods and isopods to be the salamander, *Gyrinophilus porphyriticus*, also identified in Freeland's Cave (Table 1). *G. porphyriticus* tended to concentrate in pools along the cave stream. Additional cavernicoles that feed on isopods and amphipods include *Cambarus b. cavatus*.

Pseudanophthalmus ohioensis abundance throughout the year greatly increased July through September (Figure 5). Available preferred habitat, primarily mud banks present at certain sites, positively correlated with an increased number of beetles (Figure 6). Precipitation from June through October was less frequent but higher in volume, maintaining the moisture level of the mud banks, but exposing more optimal habitat during times of less rainfall for the carabid beetle. *P. ohioensis* commonly was found in the front section of the cave on mud banks or on moist sand and gravel near stream level and was seen in highest quantities at sites 5 though 7. By comparing current results with those of previous studies, *P. ohioensis* seems to have a modestly large population size with an average of 11 beetles (range 0-38) observed on each visit. Undoubtedly additional beetles inhabit the cave yet remain cryptic and were not visible on study days. Freeland's Cave maintains a fairly stable environment, aside from human disturbance and occasional flooding, to support the *P. ohioensis* population. If current conditions in Freeland's Cave remain constant, the beetle population can maintain its presence in the cave ecosystem.

Physicochemical characteristics

Physicochemical parameters in addition to biological characteristics must be analyzed in order to form a complete ecosystem assessment. Water quality has a direct effect on biota, particularly aquatic fauna. Current velocity, substrate, temperature, and oxygen are the four most important physicochemical variables impacting stream biota (Allan 1995). In order to support life dissolved oxygen levels should range from 8 to 10mg/L. Yet, ground water can exhibit low dissolved oxygen and high carbon dioxide concentrations due to microbial processing of organic matter as it passes through the soil (Allan 1995). Freeland's Cave stream only indicated lower dissolved oxygen levels moving upstream from Site 9 to Site 10, close to "Methane Alley."



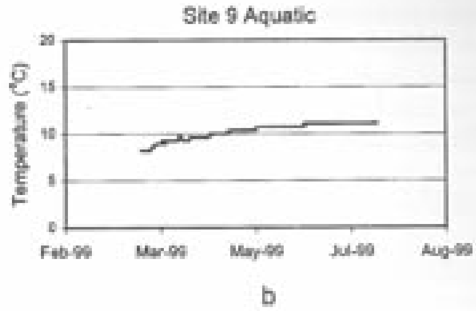
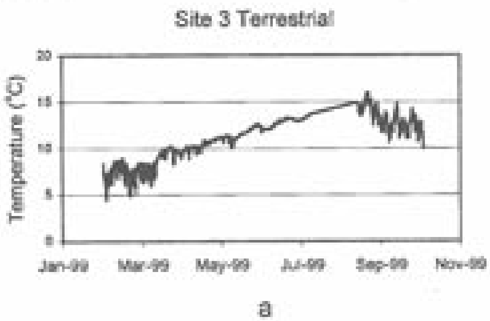


Figure 20. Water temperature recorded by Hobo data loggers set throughout Freeland's Cave stream.



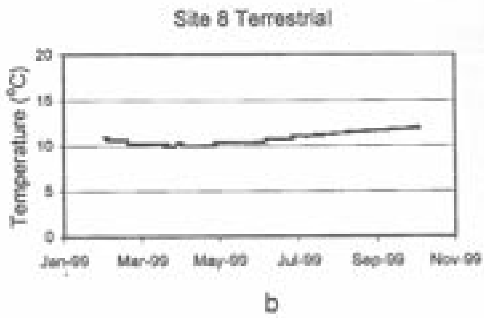


Figure 21. Water temperature recorded by Hobo data loggers set throughout Freeland's Cave.

Elevated decomposition rates of organic matter occurred at Site 10, resulting in a higher biochemical oxygen demand and the production of carbon dioxide and methane. Aside from a decrease in dissolved oxygen concentration at Site 10, oxygen levels remained fairly constant throughout the cave length (Figure 17a). A significant decrease in oxygen was not present because Freeland's Cave is a shallow cave and water is mixed often in riffles and small cascades as it moves rapidly through the cave system.

During warmer months (May through November), the dissolved oxygen saturation was greater in Freeland's Cave stream in comparison to Turkey Creek due to the cooler cave stream temperatures (Figure 17a-c). Lower dissolved oxygen concentrations were recorded in Freeland's Cave stream than in Turkey Creek during winter months when the temperature of the surface stream was colder than the cave stream. These trends were expected because colder water holds more oxygen in solution than warmer water.

Nitrate-nitrogen, phosphate-phosphorous, and sulfate-sulfur concentrations remained fairly constant throughout the cave, and were highly dependent on precipitation and water levels (Figure 9a-11c). Aside from the November testing date, nitrate, phosphate, and sulfate concentrations increased when little rainfall preceded sampling (National Climatic Data Center 2000). Lowered concentrations during times of elevated precipitation were due to dilution of the ions in solution.

Low levels of iron were found in the cave stream, possibly due to low levels of iron in the bedrock (Figure 12a-c). Ammonia concentrations were higher towards the back of the cave, because of increased accumulation and breakdown of allochthonous organic material in those areas. Copper concentrations were found in small quantities throughout the cave, suggesting little contamination from the surface sinkhole.

Turbidity remained fairly low throughout the study (0.1-9.0 NTU) (Figure 14a-c). However, turbidity was a difficult parameter to measure accurately due to the difficulties in collecting water without disturbing the samples due to the shallow stream, low ceiling, and significant amount of crawling necessary in certain areas of the cave. Difficulties were elevated during times of low water levels. Turbidity was high in the cave stream in March and October when no rainfall had occurred for several days, resulting in low stream levels (National Climatic Data Center 2000). However, increased precipitation disturbed sediments and caused more turbid waters in January and July, especially towards Site 8.

Freeland's Cave represents a dynamic system due to continuous chemical interaction between the stream and carbonate rich bedrock. Cave streams are buffered to resist changes in pH due to dissolved carbon dioxide, carbonic acid, bicarbonate, and carbonate ions in solution (Allan 1995). Freeland's Cave stream tended to be alkaline with pH commonly ranging from 7 to 8 (Figure 15a-c). Alkaline conditions are due to higher concentrations of calcium and

Table 2. Ranges and mean values of physicochemical data for Freeland's Cave (15 November 1985 - 5 August 1986).

Site		1	2	4	5	6	7	8
Nitrate (mg/L)	mean	1.12	-	-	-	-	-	1.19
	range	0.5-2.4	-	-	-	-	-	0.8-1.99
Phosphate (mg/L)	mean	0.24	-	-	-	-	-	0.13
	range	0.04-1.57	-	-	-	-	-	0.04-0.36
Sulfate (mg/L)	mean	39.86	-	-	-	-	-	42.08
	range	26.3-61	-	-	-	-	-	29.9-61.0
Iron (mg/L)	mean	0.015	-	-	-	-	-	0.03
	range	0.0-0.07	-	-	-	-	-	0.0-0.08
Turbidity	mean	0.067	-	-	-	-	-	0.045
	range	0-1.0	-	-	-	-	-	0-4.0
pH	mean	7.38	7.22	7.14	6.98	7.02	6.93	6.82
	range	6.51-8.05	6.36-7.59	6.14-7.92	6.06-7.7	6.06-7.87	5.9-7.85	5.86-7.81
Specific Conductance (µS/cm)	mean	191.97	193.83	155.3	166.34	164.72	150.93	172.66
	range	113.363	109-413	881.1-307	88.6-309	85.8-342	84.8-309	103.3-341
Dissolved Oxygen* (mg/L)	mean	12.21	11.52	11.59	10.03	11.78	11.7	10.67
	range	9.56-14.06	7.79-14.09	9.09-14.42	7.61-13.32	9.87-14.23	9.97-14.01	9.20-13.53
Water Temp (C)	mean	10.9	10.5	10.4	10.4	10.3	10.3	10.2
	range	7.6-15.0	7.7-13.0	7.7-13.0	7.9-13.0	8.2-12.3	7.9-12.4	7.9-12.6
Air Temp (C)	mean	15.43	10.84	11.92	12.05	12.27	11.97	11.86
	range	2.0-22.8	2.2-14.4	10-14.8	10.6-14.5	10.6-14.4	10.6-13.9	10.6-13.9
Relative Humidity	mean	80.78	90.81	95.36	98.18	98	98.82	99.55
	range	73-88	75-95	90-100	95-100	93-100	95-100	95-100

*Dissolved oxygen was only recorded in March, July, and August 1986.
(Hobbs 1996)

magnesium bicarbonate and carbonate ions in solution resulting from dissolving bedrock. Specific conductance values indicate the total dissolved ions in solution and are important in determining water buffering capabilities. Specific conductance remained fairly constant throughout the cave length but varied between testing dates (Figure 16a-c). From November through January specific conductance decreased each month due most likely to dilution from increased precipitation. Precipitation tended to increase slightly November through January, causing higher cave stream levels. Specific conductance values were lowest in February through March due to frequent rainfall and snowmelt and increased March through July as rainfall events became less frequent throughout the summer. Highest values occurred in times of little rainfall directly prior to the sampling date, as in November and on days surrounding sampling, including July, September, and October. Water hardness exhibits a similar trend to specific conductance, with elevated readings in November, July, September, and October (Figure 13a-c).

Freeland's Cave stream temperature remained fairly constant in comparison to great variations in the temperature of Turkey Creek throughout the year. Groundwater temperature is usually within 1°C of the mean annual air temperature (Allan 1995). However, the stream temperature of Freeland's Cave ranged from 8.5 to 13°C, which was within the average surface low and high temperature of 6.12 to 17.54°C (Figure 19a-c) (National Climatic Data Center 2000). The mean surface temperature for Adams County is between 6.12 and 17.54°C, therefore, the cave stream temperature likely corresponds closely with the actual mean surface temperature of the area. Furthermore, the cave stream temperature varied more than 1°C because Freeland's Cave is a shallow cave with several inputs of epigean water and the stream only runs though the cave for approximately 708m (Hobbs 1986).

Ambient air temperature within cave systems tends to remain fairly constant, and approximates the surface mean annual temperature. While Mammoth Cave exhibits temperatures of 13.6 to 13.9°C in remote areas of the cave (Culver 1982), smaller cave systems, such as Freeland's Cave, will have a higher degree of fluctuation of air temperature and an even greater variation at the entrance. Yet, in deep areas of the cave the temperature will remain reasonably constant. The ambient air temperature in Freeland's Cave ranged from 9.88 to12.00°C in Site 8, however, in Site 3, closer to the surface, the temperature varied between 4.34 to15.96°C (Figure

21a-b). The deep cave air temperature range of 9.88 to 12.00°C falls within the surface temperature low and high of 6.12 to 17.54°C.

This study compared species abundances, distributions, and stream physicochemical characteristics with previous studies conducted in 1987 and 1996. Current data were similar to those from 1987 and 1996 and conclusions on observed trends were based mainly on precipitation and season. However, anthropogenic influences have impacted the Freeland's Cave ecosystem, including possible contaminants from the sinkhole leaching into the cave, graffiti, and caver disturbance. While cave ecosystems provide a stable environment for cavernicoles, several threats do exist. These threats include using the cave as a refuse dump, inadequate sewage systems polluting groundwater, road construction, landfills, closing cave entrances, deforestation and other land use changes altering water flow, insecticides and herbicides impacting fauna, mining and quarrying eliminating cave habitats, and human visitors impacting fauna (Gillieson 1996). Using the sinkhole overlying Freeland's Cave as a refuse dump can potentially greatly impact biota. Obligate cavernicoles are highly sensitive to pollutants and disturbances that can eliminate certain fauna, especially species isolated by high degrees of adaptations. Populations of cavernicoles often are very small and even limited only to a few individuals within a cave system. This is especially critical for endemic species, such as *Pseudanophthalmus ohioensis*, because sinkhole contaminants could destroy an entire species.

In conclusion, there were several trends based on season and precipitation. The low amounts of copper and iron suggest little current contamination from the sinkhole. Clearly, in order to preserve the *P. ohioensis* population, Freeland's Cave should be protected. Stricter measures must be enforced to prevent sinkholes from being used as local dumps, and visitation to the cave should be limited to prevent further disturbance. Future research should be conducted to assure a sustainable population of *P. ohioensis*. Cave fauna are fragile resources and conservation methods are necessary to preserve the biodiversity within cave ecosystems.

Acknowledgments

Our special thanks go to Dr. Horton H. Hobbs III who served as an advisor and made several trips to the cave. Additional assistance in the field was provided by Jackie Bellwood, Matthew Beversdorf, Frank Buschelmen, Jared Embree, George Hagen, Matt Hazelton, Rob Payn, Andy Roberts, Gina Sagel, and Matt Shively. We also wish to thank Erin Athy, Michelle Miller, and Heather Parker who helped with lab work. Funding and support was provided by the Faculty Research Fund Board at Wittenberg University.

Literature Cited

Allan, J. David. 1995. Stream ecology: structure and function of running waters. London: Chapman and Hall, pp23-42.

Athy, Erin. 1999. Freeland's Cleanup: Members of WUSS cleanup Freeland's sinkhole. *Pholeos*, 18(1):2-3.

Culver, David C. 1982. Cave Life: Evolution and Ecology. Cambridge: Harvard University Press, 189pp.

Culver, David C. and H. H. Hobbs III. 2000. U.S. troglobites and stygobites. http://www.karstwaters.org/kwidata.htm (posted August 2000).

Gillieson, D., 1996. Caves: Processes, Development, Management. Cambridge: Blackwell Publishers Inc., 324pp.

Hobbs III, H.H. 1986. A description of one of Ohio's most significant caves. *Pholeos*, 6(1):4.

Hobbs III, H.H. 1996. An Assessment of Three Candidate and Two Additional Troglobitic Invertebrate Species for Possible Listing As Federally Endangered or Threatened Species. Final Report, Division of Wildlife, Ohio Department of Natural Resources, 130pp.

Mitchell and H.H. Hobbs III. 1987. Biological and physicochemical baseline data for selected Ohio caves. Ohio Journal of Science, 87(2):51 (abstr.).

National Climatic Data Center. 2000. National Climatic Data Center. http://www4.ncdc.noaa.gov/ (posted April 2000).

Poulson, Thomas L. and David C. Culver. 1969. Diversity in terrestrial cave communities. Ecology, 50(1):153-158.

PHOTOS FROM FREELAND'S CAVE

Photo by Katie Gagelin

Photo by Katie Gagelin

Above left: Pit fall traps were used to collect terrestrial biota.

Above right: Beth Hagen sampling the biota in Freeland's Cave.

Below: Turkey Creek upstream of the cave entrance.

Above: The crayfish, Cambarus bartonii cavatus, *were often found along the cave stream.*

Below left: Checking biota along the stream bank.

Below right: Measuring the water quality in Turkey Creek.

Photo by H. Hobbs

PHOTOS FROM FREELAND'S CAVE

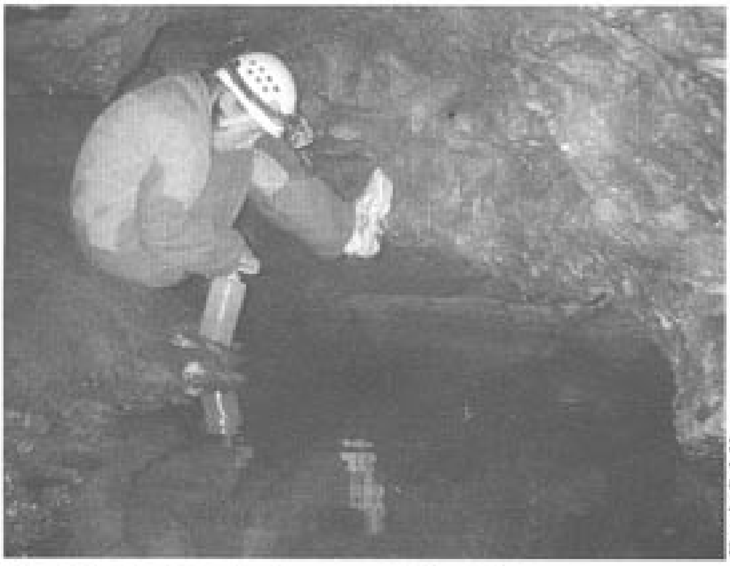


Photo by Beth Hagen

Above: Katie Gogolin is collecting water samples from the cave stream.

Below: Freeland's Cave Sinkhole during the November 1998 cleanup. Notice the large appliances such as refrigerators and stoves that were disposed of in the sinkhole.

Photo by Beth Hagen

Photo by Beth Hagen

Above: Freeland's Cave Sinkhole after the second cleanup in April 1999.

Below: Over 15.4 tons of garbage were removed during the sinkhole cleanups.

Photo by Beth Hagen

A Comparison of Salamander Populations in Cobble Crawl and Coon-in-the-Crack I Caves, Carter Co., KY

Erin Athy, WUSS# 0397, NSS# 44199
Kate Grieco
Beth Hagen, WUSS# 0400, NSS# 36267

Abstract

Previous research indicates that troglophilic terrestrial salamanders prefer moist conditions and temperatures of 13-24°C. This study investigates the environmental preference of salamanders *Plethodon glutinosus* and *Eurycea longicauda* in active stream verses dry cave environments. On 26 September 1998, two cave systems in Carter County, Kentucky were assessed for salamander populations in relation to the stream condition. Salamander species were counted, identified, and lengths were measured in Coon-in-the-Crack Cave I, a dry cave, and in Cobble Crawl Cave, an active stream cave. Hobo and StowAway data loggers recorded the temperature and humidity over a period of 24 hours. Eighteen *Plethodon glutinosus* were identified in Coon-in-the-Crack I while one *Eurycea longicauda* and two salamander larvae forms that could not be identified were found in Cobble Crawl. The data disproved the hypothesis that an active stream system is more conducive for terrestrial salamander life and diversity. Coon-in-the-Crack I provides a more stable environment for the salamander species *P. glutinosus*.

Introduction

Although cavernicoles share the common and essential bond of inhabiting many crack and crevice habitats of caves, a distinct diversity is quite prevalent among these cave-dwelling creatures. One such significant difference is the level of adaptation present in cavernicoles. Four major levels of terrestrial cavernicoles are defined as accidentals, trogloxenes, troglophiles, and troglobites (Moore and Sullivan 1997).

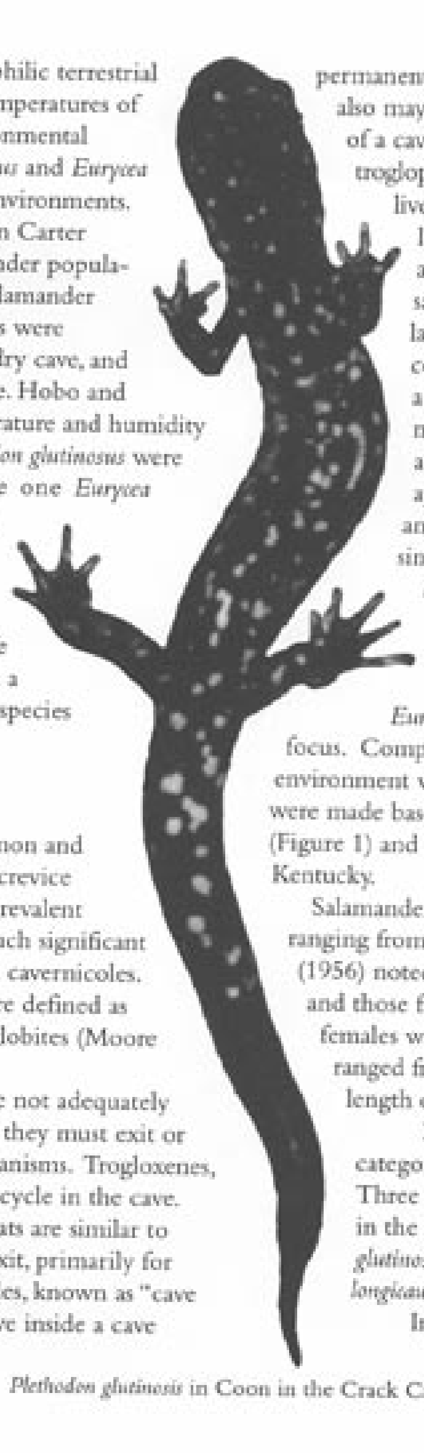
Accidentals are those organisms that are not adequately adapted to live in a cave; in order for survival they must exit or consequently become prey for other cave organisms. Trogloxenes, cave guests, cannot complete their whole life cycle in the cave. These organisms such as raccoons, bears, or bats are similar to accidentals in that they too must eventually exit, primarily for feeding purposes (Gillieson 1996). Troglophiles, known as "cave lovers," are unique due to their ability to thrive inside a cave permanently without any serious threat to their survival, yet also may make their habitat just as easily outside the depths of a cave. Even more unique is the fact that although troglophiles are able to survive as cave dwellers all their lives, no physical signs of adaptation are apparent (e.g., loss of pigment or elongated appendages) (Moore and Sullivan 1997). Such organisms include salamanders, crayfishes, and numerous insects. The last category of terrestrial cavernicoles, troglobites, constitutes those organisms that must remain within a cave for survival. As a result, troglobites such as millipedes and spiders show distinct physical signs of adaptations such as small, fragile bodies, thin appendages, longer antennae, lack of pigmentation, and heightened senses with the exception of sight since most troglobites are blind (Gillieson 1996, Moore and Sullivan 1997).

The project discussed in this paper centers on troglophilic salamanders. Two species, *Plethodon glutinosus* (Slimy Salamander) and *Eurycea longicauda* (Long-tailed Salamander), are the focus. Comparisons of salamander populations in a dry cave environment versus a cave environment with an active stream were made based on findings in both Coon-in-the-Crack Cave I (Figure 1) and Cobble Crawl Cave located in Carter County, Kentucky.

Salamander length indicates the age of the salamander, ranging from juvenile to adult. Previous studies by Hutchison (1956) noted total length measurements of adult *E. longicauda* and those findings indicate a majority of adult males and females with a length of about 14-17.5cm and juveniles ranged from about 8-10.7cm. *P. glutinosus* can grow to a length of 17cm (Cowley 1998).

Both species respire through their skin and are categorized as lungless salamanders (Cowley 1998). Three major groups of lungless salamanders are found in the eastern U.S.: Woodland, Brook, and Dusky. *P. glutinosus* falls under the Woodland division while *E. longicauda* fits into the Brook division (Neumann 1998).

In general, salamanders are often found in cool,



Plethodon glutinosis in Coon in the Crack Cave.

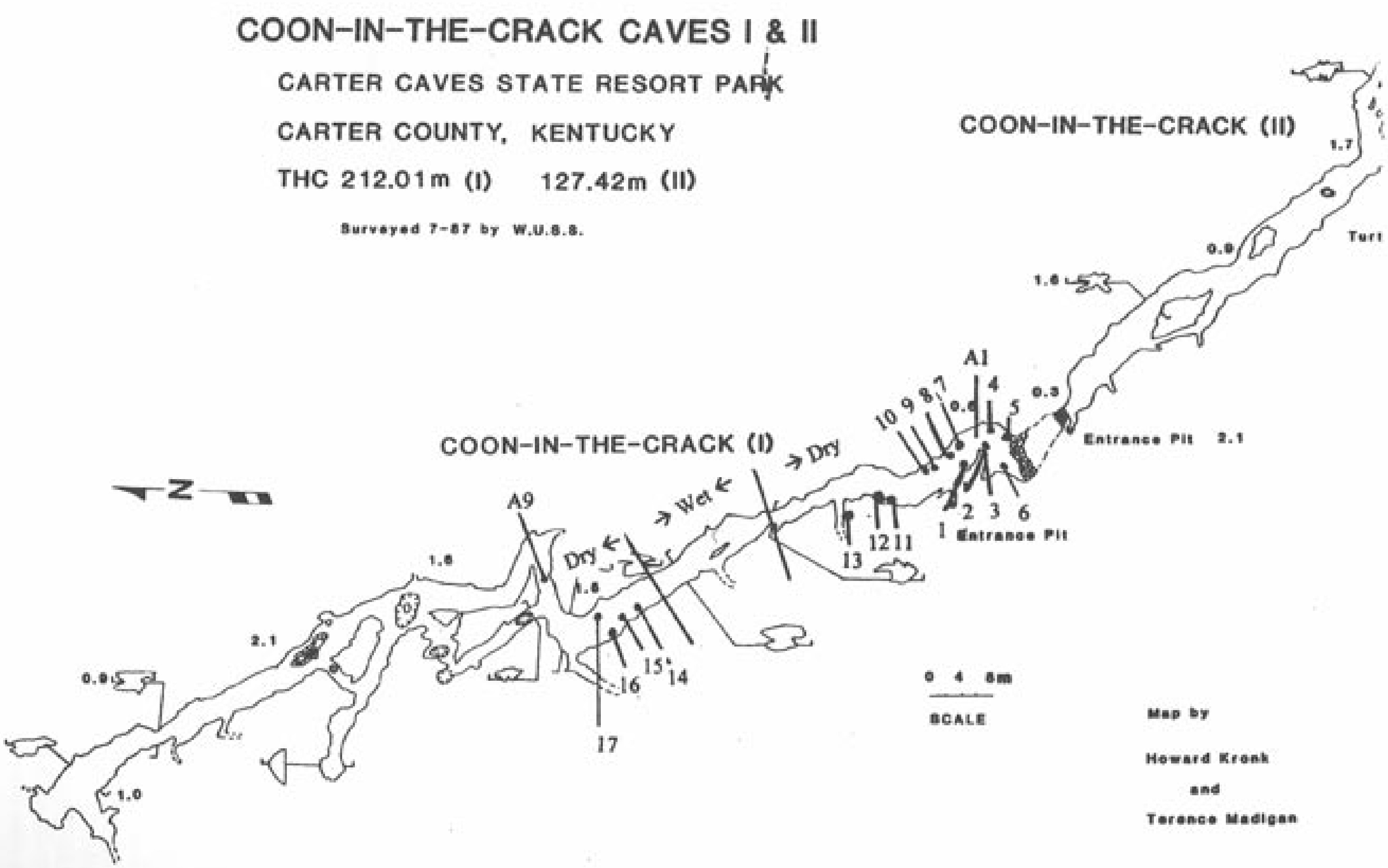


Figure 1: Location of *P. glutinosus* and moisture conditions in Coon in the Crack Cave I (Kronk andMadigan 1998)

damp areas and require moist conditions for survival. Consequently, humidity plays a principle role in their environment and their distribution. High humidity (near 100%) is a must; low-humidity conditions can kill salamanders after only a few hours. Although moisture is essential, actual submergence is not always necessary and can be harmful. For example, *P. glutinosus* can drown in a pool because this species is entirely terrestrial. In fact, *P. glutinosus* lay their eggs in moist areas on land whereas most salamander species, including *E. longicauda*, lay their eggs in water. The salamander *E. longicauda* is capable of swimming and their young are aquatic from the moment they are hatched.

Salamanders require a temperature of approximately 13°C to 24°C. Specifically, the ideal temperature range for lungless salamanders is 13°C to 21°C. Temperatures of 29°C or higher are considered a dangerous threat to salamander survival (Neumann 1998).

All salamanders are classified as carnivorous. They eat mostly insects, small spiders, worms, and crickets. Yet it is not uncommon for them to eat plants as well (Neumann 1998). Flies compose a significant percentage of their diet. Experiments involving the dissection and study of the digestive tract of both *E. longicauda* and *P. glutinosus* performed by Peck (1974) showed that dipterans such as Chelorethida, Coleoptera (beetles), and Orthoptera (crickets) are common prey of *E. longicauda*, while Acarina (mites), Coleoptera (beetle), and Hymenoptera (wasps) are prey of *P. glutinosus*. In addition, *P. glutinosus* has a tendency to eat smaller items such as small podurid Collembola (springtail) (Peck 1974). Barr found snails, millipedes, flies, as well as moss and limestone fragments in salamander stomach analysis (1967).

The two Carter County, Kentucky cave systems studied were Coon-in-the-Crack I, lacking an active stream passage, and Cobble Crawl, with an active stream running throughout its length. Coon-in-the-Crack I is a dry, solution cave, approximately 212 meters in length, and rarely receives human visitation. The floor is predominantly silt covered. Cobble Crawl, on the other hand, is a generally narrow, elliptical passage with an active stream that drains through the cave passage. The stream is of medium to high velocity as indicated by the presence of smooth, smaller-sized cobble. This cave also has a tendency to flood, as indicated by the presence of sticks and mud on the cave ceiling. Various sandbars are located throughout the cave's passage, there are few speleothems, and the cave is visited by cavers much more frequently than Coon-in-the-Crack I.

The hypothesis for this study is that an active stream cave environment is more conducive to cave salamander life and diversity than an inactive cave stream environment.

Methods

Coon-in-the-Crack Cave I and Cobble Crawl Cave, two caves within close proximity of each other in Carter Caves State Park, Carter County, Kentucky, were studied. On 26 September 1998 the caves were entered at approximately 16:00 and salamanders were looked for in every possible crevice and passage. When one was found it was identified, its length, zonation (e.g., entrance, twilight, intermediate, and dark zones) in which it was found, and location (e.g., floor, shelf, etc.) were determined. Location also was noted on a map of Coon-in-the-Crack Cave I, but not in Cobble Crawl Cave since no map exists. In addition, the general moisture conditions and substrate where the salamander was located were recorded.

StowAway temperature data loggers and Hobo humidity data loggers, triggered by another student group, recorded data every minute and a half and were left in the caves for 24 hours. In Coon-in-the-Crack Cave I, a data logger measuring temperature was placed in the entrance pit and data loggers measuring both humidity and temperature were placed at survey points A1 and A9 on the floor and ceiling, respectively (Figure 1). In Cobble Crawl Cave, data loggers measuring temperature were placed 10 meters inside the downstream entrance and one-third of the distance through the cave, both on the ceiling.

Results

In Coon-in-the-Crack Cave I, eighteen *P. glutinosus* were located and measured mostly on ledges in dry to moist silt (Table 1). Salamanders were not found deep in the cave beyond survey station A9 (Figure 1) in the colder temperature zone of the cave (Figure 2). Moisture conditions varied throughout the cave passage (Table 1). In the extremely wet/muddy areas, salamanders were absent, but were present on either side of the muddy area where the passage was drier (Figure 1). More *P. glutinosus* were seen, but either moved quickly away from our lights and were unable to be measured, or were hidden almost completely in cracks. Humidity was constant at 100% and temperature varied between 12-15°C from the entrance to survey points A1 and A9 (Figures 2 and 3).

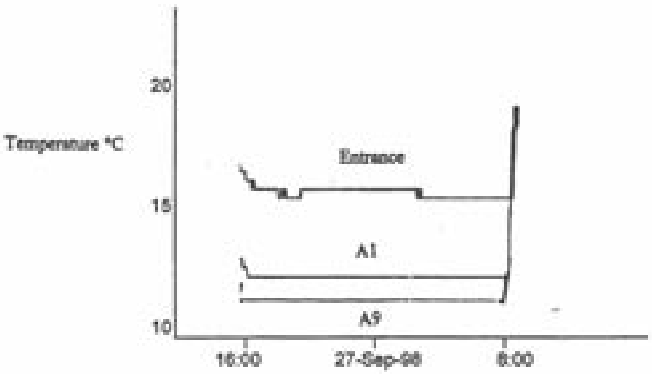
Cobble Crawl Cave was significantly less populated. One *E. longicauda* was found in a dry side passage above stream level (Table 1). Two salamander larvae, believed to be *E. longicauda*, were discovered in the stream, down passage (Table 1). The temperatures collected from the data loggers indicated a range of 13.5-14°C (Figure 4). No humidity data were available for Cobble Crawl Cave.

The lengths of all individual *P. glutinosus* ranged from 6-21cm and the one *E. longicauda* found was 9cm. The two larvae forms believed to be *E. longicauda*, were approximately 3 centimeters in total length (Table 1).

Discussion

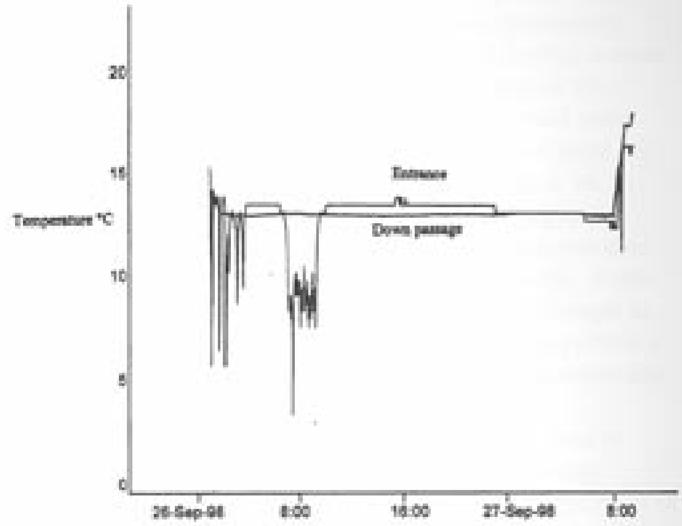
In comparing the active stream passage of Cobble Crawl Cave and the dry cave passage of Coon-in-the-Crack Cave I, a correlation between the salamander species *P. glutinosus* and *E. longicauda* and preferred habitat was determined. The salamanders surveyed do not prefer the active stream cave environment of Cobble Crawl Cave, but prefer the dry cave

Figure 2: Temperature in Coon-in-the-Crack Cave I at entrance, A1, and A9
Set: 16:00 26 Sept. 1998
Retrieved: 9:00 27 Sept. 1998



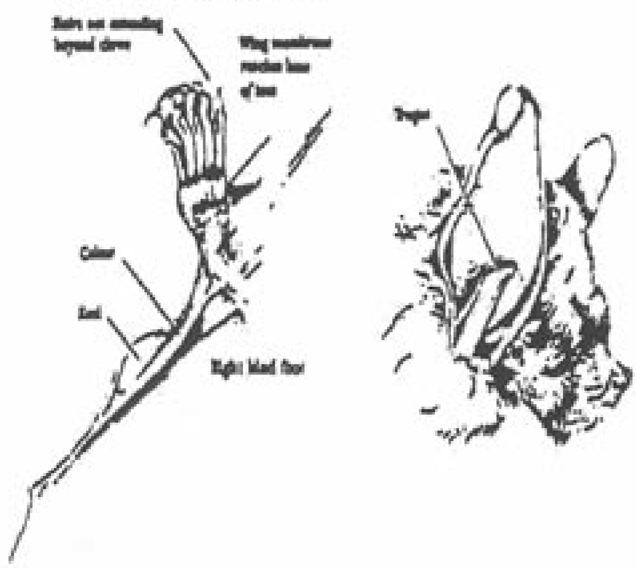
Coon-in-the-Crack Cave I 26 September - 27 September 1998

Figure 4: Temperature in Cobble Crawl inside downstream entrance and one-third of the way down passage
Set: 1:00 26 Sept. 1998
Retrieved: 9:07 27 Sept. 1998



Cobble Crawl Cave 26 September - 27 September 1998

Figure 3: Humidity in Coon-in-the-Crack Cave I at A9
Set: 16:00 26 Sept. 1998
Retrieved: 10:0 27 Sept. 1998



Coon-in-the-Crack Cave I 26 September - 27 September 1998

environment of Coon-in-the-Crack Cave I where eighteen *P. glutinosus* were recorded. One *E. longicauda* and two larval salamander forms, believed to be *E. longicauda*, were identified in Cobble Crawl Cave. The active stream of Cobble Crawl is not conducive for *P. glutinosus* survival, but facilitative for *E. longicauda*. The majority of our findings were in Coon-in-the-Crack Cave I. Therefore, the drier cave is preferred for salamander life in comparison to an active stream cave, thereby disproving our hypothesis.

In this study the size of total salamander length was recorded. *P. glutinosus* lengths ranged from 5-21cm and the *E. longicauda* found was 9cm. These data can indicate the age of the salamanders ranging from juvenile to adult. However, information showing if the tail was attached was not recorded, so the measurements do not completely indicate the age of the salamanders. Information on the age of the salamanders pertains to salamander preference toward active stream verses dry environments because salamanders in the larval stage are aquatic and "breathe" by exchanging gases utilizing gills. As the salamanders mature they lose their gills and exchange gases through their skin (Moore and Sullivan 1997). *P. glutinosus* found in Coon-in-the-Crack Cave I were all adults and therefore respired through their skin. Furthermore, *P. glutinosus* are terrestrial and cannot survive in the extremely wet conditions of an active stream as found in Cobble Crawl Cave.

P. glutinosus reside primarily in cracks and crevices. In Coon-in-the-Crack I most of the Slimy Salamanders we found in cracks and on ledges along the cave walls and floor. The salamanders surveyed in Coon-in-the-Crack I were found in the moderate to dry sections of the cave and not in the wet sections (Figure 1). *P. glutinosus*' tendency to drown if conditions are too wet and the locations of salamanders in the cave with regards to moisture level further indicate the *P. glutinosus*' preference towards drier, inactive stream passages such as in Coon-in-the-Crack Cave I. Furthermore, the rising and lowering water level in Horn Hollow Stream directly affect Cobble Crawl Cave as indicated by the stick and leaf litter deposited along the ceiling. Coon-in-the-Crack Cave I, however, is located 50-100m above stream level in a hillside and is not influenced by a stream. Therefore, Coon-in-the-Crack Cave I is an ideal habitat for *P. glutinosus* because it is not susceptible to flooding.

Table 1. Data Chart for Coon-in-the-Crack Cave I and Cobble Crawl Cave

Coon-in-the-Crack I Cave

	Species	Total length (cm)	Zonation	Location	Moisture conditions where found
1	*P.glutinosus*	5	Twighlight	Crack in wall	Dry rock
2	*P.glutinosus*	9	Twighlight	Floor	Dry silt
3	*P.glutinosus*	10	Twighlight	Floor	Dry silt
4	*P.glutinosus*	21	Twighlight	Floor	Dry silt
5	*P.glutinosus*	11	Twighlight	Floor	Dry silt
6	*P.glutinosus*	17	Twighlight	On breakdown pile	Dry rock
7	*P.glutinosus*	12	Twighlight	Crack in wall	Moist rock
8	*P.glutinosus*	20	Twighlight	Crack in wall	Moist rock
9	*P.glutinosus*	14	Twighlight	Crack in wall	Moist rock
10	*P.glutinosus*	16	Twighlight	Crack in wall	Moist rock
11	*P.glutinosus*	17	Twighlight	Ledge on wall	Moist silt
12	*P.glutinosus*	12	Twighlight	Ledge on wall	Moist silt
13	*P.glutinosus*	18	Intermediate	Ledge on wall	Moist silt
14	*P.glutinosus*	18	Intermediate	Ledge on wall	Moist silt
15	*P.glutinosus*	9	Intermediate	Ledge on wall	Moist silt
16	*P.glutinosus*	6	Intermediate	Ledge on wall	Moist silt
17	*P.glutinosus*	11	Intermediate	Crack in wall	Moist silt
18	*P.glutinosus*	10	Intermediate	Ledge on wall	Moist silt

Cobble Crawl Cave

	Species	Total length (cm)	Zonation	Location	Moisture conditions where found
1	*E.longicauda*	9	Twighlight	Crack in wall	Dry rock
2	Unidentified larvae	Approx. 3	Intermediate to dark	Stream	\\\
3	Unidentified larvae	Approx. 3	Intermediate to dark	Stream	\\\

Our data show that Cobble Crawl's stream passage is too active for *P. glutinosus* salamanders. The salamanders may be washed out of the cave due to its high tendency to flood with high velocity waters. Furthermore, the number of crevices and passages in Cobble Crawl Cave that are protected from flooding are scarce. These conditions further exemplify why the Slimy Salamander was not found in Cobble Crawl Cave. *E. longicauda* prefer wetter conditions, but due to the lack of an upper level and crevices away from flooding waters, fewer numbers of salamanders were found.

Though the dry cave passage did not have running water, there was still sufficient moisture to sustain salamander life since the humidity of Coon-in-the-Crack Cave I is at 100% (Figure 3). Because lungless salamanders absorb oxygen though their skin, 100% humidity is needed for these salamanders to sustain life. Caves provide ideal environments for salamanders because humidity levels in most caves reside at or close to 100%. However, the aquatic salamander larvae found in Cobble Crawl Cave need to be submerged in a stream or pool environment in order to exchange gases via gills. No aquatic larval forms were found in Coon-in-the-Crack Cave I because the conditions are not suitable, (e.g., no drip pools, stream passages, etc.) *E. longicauda* prefer active stream passages because they have the ability to swim and can survive in wetter conditions as well as in areas with 100% humidity. The temperature of the twilight and intermediate zones of the cave is variable in comparison to the constant temperature of the deep cave. This is due to the influence of the entrance(s) and circulating air. The constant temperature zone of caves is usually defined by the air temperature hovering near the mean annual temperature of the surface and is buffered from air movements by the cave walls and roof (Gillieson 1996). In Coon-in-the-Crack Cave I the temperature was 15°C at the entrance of the cave and 12°C in the variable temperature zone of the cave (Figure 2). In Cobble Crawl Cave the temperature obtained at the entrance was 14°C and 13.5°C deeper in the cave (Figure 4). The lungless salamander species studied require a temperature of 13-21°C to support life (Neumann 1998). Therefore, the temperature conditions where salamanders were found in both caves were adequate for both *P. glutinosus* and *E. longicauda* species. Furthermore, *P. glutinosus* were found closer to the entrance and in the twilight to intermediate zones of Coon-in-the-Crack Cave I and not in the variable zone; the temperature in the variable zone is one degree below the optimum temperature for lungless salamanders (Neumann 1998). Therefore, the salamander species reside closer to the entrance in the preferred temperature range. Another reason for finding salamanders mainly near the entrance might be because the salamanders often leave and therefore do not venture deep into the cave

Both salamander species surveyed are troglophiles; therefore, the surface close to the entrance could be inhabited with salamander species. Furthermore, salamanders are heterotrophic and their food supply is more abundant outside of the cave ecosystem. It is reasonable that our data collected show the highest number of salamanders in the twilight to the intermediate zones of the caves, aside from the two larval forms found in the stream closer to the mid section of Cobble Crawl Cave, if the salamanders leave the cave to feed. But, even if the troglophilic salamanders complete their life history inside the cave, it is justifiable to find salamanders close to entrances where the highest amounts of allochthonous materials enter the cave system. Areas with high concentrations of allochthonous materials have higher amounts of energy and therefore, potentially higher biodiversity, meaning more food for salamanders.

Conclusion

In this study all visible salamanders were assessed. Measures were taken to search all crevices, yet there is always the high probability that more salamanders were still hidden. In our data collection we made a population count without the use of baiting techniques such as pitfall traps set with food. By utilizing baiting and trapping methods we might have attained a more accurate count of the salamander population sizes. Also, collecting more than one data set would provide a more precise salamander population count. Surveying the salamander population size over seasonal changes would determine if this was a peak time for the salamanders to enter the cave system. Salamander hibernation cycles need to be assessed to determine whether or not the large population found in Coon-in-the-Crack Cave I resulted from increased numbers of salamanders entering the cave for winter. A year long study would gather information on seasonal changes in relation to salamander population density as well as provide a more accurate population census by obtaining numerous data sets.

Information on recent weather data could be used to determine the condition of the stream running through Cobble Crawl Cave. Recent storms in the area might result in flooding of the cave that could have washed out salamanders, causing lower population counts. A weather gauge left outside of the cave entrance would measure rain levels.

When studying salamanders helmet lights frightened the salamanders, so red covers over the lights would shield some of the white light. The other species of biota found in the cave can serve as indictors of the salamanders' food source to determine if the salamanders were eating other cave biota or if their diet consisted of epigean fauna, indicating that the salamanders left the cave system to feed. To fully determine the salamanders diet, however, the stomach contents of individual salamanders would need to be assessed.

Further study is necessary to assess more completely *P. glutinosus* and *E. longicauda*. Also, other cave systems could be surveyed to determine a stronger correlation between active versus inactive cave streams and salamander preferences.

Literature Cited

Cowley, M. 1998. http://www.nsis.org/wildlife/amph/sal-lungless.htm. Lungless Salamanders, pg. 2 10/7/98*

Gillieson, D. 1996. Caves: Processes, development, management. Cambridge, MA: Blackwell Publishers.

Hutchison, Victor H. 1956. Notes on the Plethodontid Salamanders, *Eurycea lucifuga* (Rafinesque) and *Eurycea longicauda longicauda* (Green). Occasional Papers National Speleological Society, 3: 1-24.

Kronk, H. and T. Madigan. 1998. Coon-in-the-Crack Caves I & II. *Pholeos*, 8(2):6-7

Barr, Thomas C. 1967. Ecological studies in the Mammoth Cave system of Kentucky. International Journal of Speleology, 3:147-204.

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

Neumann, C. 1998. http://www.escape.com/~iggyden/textfiles/salamand.tx. Salamanders, pg. 1,2. 10/7/98*

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

* Date refers to when web page was accessed.

The Indiana Bat (*Myotis sodalis*): Biology, Behavior and Conservation

by Victoria Parisi WUSS# 490

ABSTRACT

The Indiana Bat (*Myotis sodalis*) is a medium sized *Myotis* bat, closely related to the brown bat (*Myotis lucifugus*). *Myotis sodalis* weighs approximately 6-9 grams, and is about 4 cm long. They navigate like other Chiroptera using echolocation. They prefer small bodied insects to maintain their diet. The average lifespan of a banded Indiana Bat was recorded between 14-15 years, although some have lived to be 20 years of age. Karst topography yielding limestone caves are preferred hibernacula. Hibernation is crucial to the survival of the species in which the bat enters a prolonged state of torpor. Disturbance of the Indiana Bat during this time may lower its chance of survival into the spring. Roosting in riparian forests is a crucial habitat for the Indiana Bat, especially for maternity roosts. The Indiana Bat is a Federally Endangered Species as of March 11, 1967. There has been a severe population decline since the 1950s. Several factors contribute to the decline, including human disturbance and vandalism, gating caves, logging and timber sales, and natural disasters. The United States Forest Service in conjunction with the US Fish and Wildlife Service must work together to maintain the Indiana Bat populations. The efforts thus far have shown a continual decrease in the populations. Education of the public and grants for research are key in reestablishing the Indiana Bats.

DESCRIPTION (See **Figure 1.** in **APPENDIX**)

Physical Characteristics

The Indiana Bat (*Myotis sodalis*) is considered a medium sized *Myotis* weighing between 6-9 grams (Wolflin 1997) and is closely related to the Little Brown Bat (*Myotis lucifugus*). Its head and body length range from 4.1-4.9 centimeters(cm), with a forearm length between 3.5-4.1cm (Wolflin 1997), and a wingspan range of 23.9-26.7cm (ODW 1998). The female forearm on the average is larger than the male's (Newell 1997). [See Figure 2. for general diagram of bat.] A distinctive physical feature of the Indiana Bat is a keeled calcar (See Figure 3.), a cartilaginous projection from the ankle extending toward the tail that supports the trailing edge of the flight membrane. They tend to have delicately small hind feet with shorter hairs that do not extend beyond the toenail (Cole 2000). Their teeth are representative of their diet (insectivore) and are small and sharp. This includes a set of molars with almost no surface for grinding their prey.

The fur of the Indiana Bat lacks luster. It is a dull, grayish chestnut color and the basal portion of the hairs on the back are a dull lead color. The ear and wing membranes have a dull appearance and flat coloration. The fur on the chest and belly is a lighter, pinkish-cinnamon color.

Navigation

Like that of other species of the Chiroptera order, the Indiana Bat uses echolocation to navigate. Echolocation is a highly evolved process that has given bats the ability to utilize the night sky. As the bat emits sound waves, its echoes are analyzed, building a sound picture of its environment (Altringham 1996). Bats emit the sound waves used in echolocation in pulses. The pulses are frequency modulated (FM) and/or constant frequency (CF) calls (Altringham 1996). Echolocation also is used to hunt their prey. However, echolocation only works over short ranges, and eyesight must be crucial to their navigation (Altringham 1996). More research must be done on the importance and sophistication of this tool used by Chiroptera.

Diet

The diet of *Myotis sodalis* consists mainly of small, soft-bodied insects. After emerging from hibernation in the spring, it forages in the treetops along the riparian (stream and river) forests, floodplains, upland forests, fields and pastures. The subcanopy of the forest is the prime location for sustaining the Indiana Bat's diet, requiring a 60 to 80% degree of overstory for optimal foraging (Cole 2000). It is estimated that one bat will forage over 11.2 acres in midsummer (GWF 1998).

The Indiana Bat feeds heavily after its migration for the winter. This occurs during the months of September through November. Their peak time for feeding is 1-2 hours after sunset and before sunrise (ODW 1998). Feeding patterns will change during different stages in the Indiana Bat's life. The reproductively active females and juveniles exhibit the greatest variety in their diet due to their increased energy needs (Cole 2000). The Indiana Bat requires drinking water, utilizing streams, small ponds, wetlands and road ruts during summer months.

In a study by Kurta and Whitaker (1998), the analysis of Indiana Bat fecal pellets determined what constituted the diet of *Myotis sodalis*. A total of 382 fecal pellets was examined from a maternity colony in Vermontiville, Eaton Co., Michigan. Of the pellets examined results concluded the bat ate mostly Trichoptera (caddisflies; 55.1% volume), Diptera (true flies; 25.5%), Lepidoptera (moths; 14.2%), and Coleoptera (beetles; 1.4%). The remaining 3.8% consisted of six other insect orders and spiders. The most important of the six other families of insects were Chironomidae (midges; 4.1%) and Culicidae (mosquitoes: 2.7%). They are not crucial in the diet of the Indiana Bat, but were present in the fecal pellets on a consistent basis in 22 of the 27 collections. Mosquitoes also made up 6.6% of the female diet during pregnancy. (Kurta and Whitaker 1998) [See Table 1. for the complete analysis of the fecal pellets for the diet of the Indiana Bat.] Kurta and Whitaker found that four other unpublished surveys yielded approximately the same results as their research. The diet of *Myotis sodalis* also includes Hymenoptera (bees and wasps), Plecoptera (stoneflies), Homoptera (leafhoppers and treehoppers), Neuroptera (lacewings), and Hemiptera (true bugs) (Cole 2000).

Life Span

The Indiana Bat has been estimated to survive up to 20 years. This extended life span may be due to their low reproductive rate (ODW 1998). Survivorship percentages have been calculated from banded bats. The banded individuals were divided into age groups. The results indicated females had a 76% survival rate from 1-6 years versus the males with 70% survival rate for the same age group (Cole 2000). In the age group consisting of bats 6-10 years old, females had a 66% survival rate as opposed to the male rate at 36% (Cole 2000). The oldest banded individuals were between 14-15 years of age. Females tend to have a longer life span than the males.

Habitat

The geographic location of the Indiana Bat consists of karst topography and riparian woods in the eastern United States. This region may stretch as far as the western edge of the Ozark region in Oklahoma to southern Wisconsin, east to Vermont and as far south as northern Florida. The Bat Population Database (1998) recorded Indiana Bat colonies in counties of the following states: AK, AL, CN, FL, GA, KY, IA, IL, IN, MA, MI, MO, NC, NY, OK, PA, SC, TN, VA, VT, WI, and WV. Indiana Bats in those states may reside in dying trees or caves. For winter hibernation, limestone caves are preferred. However, abandoned mines and tunnels have attracted Indiana Bats (Cole 2000).

Winter Hibernation

In September, the hibernation process begins for the Indiana Bat. Most bats will chose a limestone cave to fulfill their need for specific climatic conditions. Caves are ideal hibernacula because of their constant temperature and humidity. They will begin their hibernation in the warmer parts of the cave in early fall to stay alert and forage for food. The ideal temperature at this time is 10 degrees Celsius (Cole 2000) with an average relative humidity of 87 percent (Wolflin 1997). In the Indiana Bat's southern range, they move into deeper parts of the cave where the temperature is colder. The hibernacula have the ability to trap large volumes of cold air, signaling hibernation when the temperature drops (Cole 2000). Indiana Bats prefer caves with stable winter temperatures between 4-8 degrees Celsius (Wolflin 1997). In the Indiana Bat's northernmost range bats will avoid the coldest sites to reduce the risk of freezing to death.

Hibernation occurs primarily from October through April (Cole 2000). In winter hibernation, individuals have been found in tight compact clusters of approximately 300-500 bats per square meter (Wolflin 1997). They also may be found hibernating with groups of Gray Bats (GWF 1998). Each Indiana Bat hangs individually from the ceiling in that cluster with its head and forearms showing. Every eight to ten days, hibernating individuals awaken and spend an hour or more flying about or to join a small cluster of active bats before returning to hibernation (GWF 1998). This occurs primarily in September and October. Females tend to emerge from hibernation first in late March to early April. By late April, most of the bats have left their hibernacula in which they migrate to their summer habitats (Wolflin 1997). Some males will spend the summer in the area of their winter hibernaculum.

The Indiana Bat hibernates successfully due to torpor. In this process, an animal allows its body temperature to fall below its active, homeothermic level (Altringham 1996). This process allows for nearly no fluctuation of body temperature when the air temperature changes. The fall of the body temperature is slow and controlled, and is maintained within narrow limits (Altringham 1996). The physiology of torpor can be defined as a (1) reduction of body temperature within one to two degrees Celsius in a controlled manner; (2) fall in body processes such as breathing rate, heart rate, oxygen consumption, and metabolic rate; (3) restricted blood flow to certain vital organs; and (4) arousal ability spontaneously and independently regardless of the temperature (Altringham 1996). Therefore, hibernation is a daily state of torpor.

Hibernation is a crucial process in the survival of *Myotis sodalis*. One of the most devastating causes for decline in Indiana populations is human disturbance. The largest decline occurred in the 1960s through the 1980s (Cole 2000). Bats build up their fat reserves sufficiently enough to get them through to the spring. Human traffic into caves can cause bat arousal with the ability to deplete 68 days of the *Myotis*'s fat supply for a single disturbance (Cole 2000). Too many disruptions can be detrimental to the survival of the Indiana Bat through winter hibernation.

Roosting Sites

It is important for any animal to have protection or refuge from predators as well as extreme temperatures. This protection also is crucial for raising young. In temperate North America biologists have determined that small insectivorous bats (5-20g) roost in trees having hollows and crevices (Foster and Kurta 1999). The Indiana Bat chooses a roost to protect and raise their young after emerging from hibernation in late March, early April. There are two types of roosts that suit the bat before returning to its winter hibernaculum. These roosts are classified as summer and fall.

In the spring, the females emerge from hibernation before the males and begin to migrate toward their summer habitats. These bats will use temporary roosts until reaching summer destinations. Four conditions must be met for an Indiana Bat to choose the "suitable" roosting site by: (1) the condition of the tree, dead or alive; (2) the quantity of loose bark; (3) its solar exposure (for raising young) and location in relation to other trees; and (4) its spatial relationship to water sources and foraging areas (Cole 2000). Floodplains and riparian forests are the ideal primary roosting and foraging sites (Cole 2000). Upland forests are attractive to them because of the scattering of suitable trees, primarily dead, standing with loose bark.

Many tree species have been studied as to their importance to the Indiana Bat's summer roosting sites. Class I trees providing a roost are: silver maple, shagbark hickory, shellbark hickory, butternut hickory, green ash, white ash, eastern cottonwood, red oak, post oak, white oak, slippery elm, and the American elm (Wolflin 1997). Other trees designated as roosts may include the American beech, black gum, black locust, pines, sassafras, sourwood, sweet birch, and yellow buckeye (Cole 2000). As the bark from the dead or injured tree springs away, the Indiana Bat finds shelter and protection beneath. However, the species of the tree is not nearly as important as the space available for the bats to roost (Wolflin 1997). The trees are usually 22cm or larger in width (Wolflin 1997).

Maternity colonies of the Indiana Bat form primary and alternate roosts. Colonies will have at least one primary roost located in openings or at the edge of forest stands and an alternate roosts in the interior of the forest. Primary roosts with "snags" (dead trees) are used most frequently because of the direct solar radiation that supplies warmth for raising young (Wolflin 1997). Alternate roosts are more shaded, and have a greater appeal in the presence of precipitation or when the temperature is above average. Shagbark hickories have been found to possess the suitable characteristics for alternate roosts (Cole 2000). The bats change their roost throughout the summer an average of once every 2.9 days (Foster and Kurta 1999). The average number of different roosts ranges from five to eighteen, and some studies have shown as few as two roosts or as many as thirty-three (Cole 2000). Female bats are very loyal to their summer roosting habitat and will return each year.

In the fall, male bats roost in the trees throughout the day. The characteristic fall roosts are more exposed to sunlight as opposed to the spring-summer roosting sites (Cole 2000). Males have been found roosting between 2.4 and 5.6 kilometers away from their hibernacula (Cole 2000). Switching of roosting sites amongst the males occurs from day to day. Fall roosting sites provide a sufficient habitat to support "swarming," an important process in facilitating reproduction (see REPRODUCTION).

REPRODUCTION

The breeding period of the Indiana Bat occurs within the first ten days of October (GWF 1998). Research has shown that some limited mating may occur in the spring before hibernating colonies disperse for summer roosts (GWF 1998). Mating takes place in large rooms at night, close to the cave entrance and on the ceilings. Males are polygamous, mating with several females before hibernation. They play no active role in raising the young.

The Indiana Bat undergoes "swarming" as fall approaches and hibernation nears. This activity consists of the bats roosting outside the cave during the day along with mass congregation around their hibernaculum and other non-hibernaculua. This process continues for several weeks to replenish fat reserves and facilitate mating before entering into hibernation (Cole 2000). This behavior is particularly beneficial for the males; hibernation occurs later than the female bat so that the male may mate as much as possible before winter. As soon as the female has mated she will go into hibernation. The males enter hibernation in November and emerge after the female in April.

Ovulation and fertilization do not occur directly after copulation. Females store sperm through the winter and becomes pregnant via delayed fertilization soon after emerging from hibernation (Wolfin 1997). The gestation period occurs between May and June, approximately 49-56 days (ODW 1998). In maternity roosts (small, widely scattered colonies), a single young is born to each female per year. Females then lactate from June to July to provide milk to the young. The juvenile bat requires 25-37 days to become independent feeders and develop into the flying stage. Maternity roosts disperse in late August in preparation for mating and hibernation.

CONSERVATION

A Federally Endangered Species

Myotis sodalis was officially listed as endangered on 11 March 1967 under the Endangered Species Preservation Act of 15 October 1966. It remains an endangered species because of immense decline in its population numbers. The Endangered Species Act extended full protection to the Indiana Bat in 1973. In 1999, the U.S. Fish and Wildlife Service published a Draft Revised Recovery Plan to: (1) update information on the life history and ecology of the Indiana Bat, especially information on summer ecology gathered since 1983; (2)

highlight the continued and accelerated decline of the species; (3) continue site protection and monitoring efforts at hibernacula; and (4) focus new recovery efforts toward research in determining the factor or factors causing population declines (Cole 2000). The recovery plan focuses on conducting necessary research for survival and recovery, including genetic information, and possible chemical contamination in hopes to coordinate and implement conservation and recovery of the species (Cole 2000).

The 1996 Technical Draft Indiana Bat Recovery Plan estimates the Indiana Bat population at only 352,000 bats (Wolflin 1997). Populations have shown a 60% decrease since monitoring in the 1960s. Kentucky lost 180,000 bats and Missouri lost 250,000 bats between 1960 and 1997 (Cole 2000). The significant decrease in population numbers has prompted the declaration of critical habitats. Six critical winter hibernacula have been declared in Missouri (USACE 2000), one in Tennessee, two in Kentucky that includes Bat Cave in Carter County (GWF 1998), and one hibernaculum in Illinois and West Virginia (Wolflin 1997). Not only are there critical habitats, but the Indiana Bat Recovery Plan has divided hibernation sites into three priority levels. Priority I hibernacula consist of more than 85% of the Indiana Bat population (greater that 30,000 bats since 1960) and are located in Indiana, Kentucky, and Missouri (Cole 2000). Priority II hibernacula consist of 50 to 29,999 bats and are found in the above mentioned states, Arkansas, Illinois, New York, Ohio, Tennessee, Virginia, and West Virginia (Cole 2000). Priority III hibernacula are found again in the above mentioned states as well as Alabama, Connecticut, Florida, Georgia, Iowa, Maryland, Massachusetts, Michigan, Mississippi, New Jersey, North Carolina, Oklahoma, Pennsylvania, South Carolina, Vermont, and Wisconsin. The priority III hibernacula house 1 to 499 bats (Cole 2000).

Reasons for decline

The decline in the Indiana Bat population can be attributed to human interference and natural hazards. Human disturbance was a serious cause of Indiana Bat decline between 1960 and 1980 (Cole 2000). Disturbance during hibernation incites arousal of the bat, and a serious depletion of fat reserves affecting survival rates. The bat may be unable to survive until the following spring. Indiana Bat mortality directly due to human action was documented in 1960 at Carter Caves State Park in Kentucky. Three youths committed an act of vandalism that ultimately led to the death of 10,000 Indiana Bats. They tore masses of bats from the ceiling and trampled them to death (Cole 2000). In Thornhill Cave in Kentucky, an estimated 255 Indiana Bats were killed in January 1987 by shotgun blasts (Cole 2000). Bat banding programs with intentions of monitoring bat populations have had a deleterious effect. Again, the disruption of hibernating bats depletes their fat reserves, and thus their ability to survive into the spring.

In response to human impact on the decline of Indiana Bats, cave gates have been installed in a number of caves throughout karst regions. However, in an attempt to protect the species, harm has been done. Gates erected at the entrance of caves impair the ability of the bats to enter the cave (Cole 2000). The gates change the air flow into the cave, thus affecting the air trapped to signal hibernation. Warmer cave temperatures do not facilitate the drop in Indiana Bat metabolic rates to save fat reserves. An example of such a tragedy occurred in Kentucky when gating caves has created a loss of 250,000 bats since the 1950s (Cole 2000).

Johnson et al. (1998) published a study attributing overwinter weight loss of Indiana Bats to human visitation of Indiana caves. Three caves were studied: Wyandotte Cave, Ray's Cave, and Batwing Cave. Batwing Cave was chosen to represent the undisturbed population of bats, since it is closed to human visitation in the winter (Johnson et al. 1998). The results of the study concluded that female bats lost more weight than males, concurring with previous studies of overwinter weight loss of other species. This is most likely due to early entrance of females and the late entrance into hibernation by the male bats. In support of the assumption made by the researchers, Batwing Cave yielded the smallest percentage of weight loss for both males and females (see Tables 2. and 3.). Ray's Cave was visited more than Batwing Cave. Wyandotte Cave had the highest percentage of human visitation, averaging 2.8 tours per day. It also had warmer roosting temperatures. Wyandotte Cave had the greatest weight loss amongst the bats (Johnson et al. 1998). The results of the research also reinforced the importance of conservation attempts. Although the Indiana Bat has been a federally endangered species since 1967, populations are still declining in caves prohibiting human visitation.

Indiana Bats are subject to natural disasters and hazards that cause decline in population. Bat Cave at Mammoth Cave State Park in Kentucky was flooded, drowning a significant number of Indiana Bats (Cole 2000). Hibernation of the Indiana Bat requires cooler temperatures. If they choose cooler portions of caves that tend to be near entrances, the cold air can become trapped and it is possible that they may freeze to death (Cole 2000). Bat Cave in Shannon County Missouri saw a decline in the Indiana Bat population due to low temperatures. In 1985, the population was 30,450 roosting on the ceiling to escape the severe cold. A survey in 1987 recorded a population of 4,150 bats in that same cave. The ground was littered with bat bones suggesting that they froze to death in hibernation (Cole 2000). Bats also hibernate in mine shafts, and death may occur due to collapse.

Poisoning due to pesticides and herbicides may be another cause of decline in Indiana Bat populations. Since they are insectivorous, it is possible they may ingest a poisoned insect. Indirectly, the use of herbicides may decrease crucial vegetation that comprises the bat habitat. The numbers and diversity of the insects may decrease (Wolflin 1997).

Logging and timber sales occurring throughout the forests also may add to the decline of Indiana Bat population. Forest Watch declared on 28 May 1999 that the United States Forest Service had failed to protect the Indiana Bat in Green Mountain National Forest in Vermont. The issue at large was the logging and timber sales that took place in Green Mountain National Forest. Indiana Bats roost in the trees in Green Mountain National Forest. The US Department of the Interior declared it the responsibility of the US Forest Service to abide by the Endangered Species Act and its Clear Mandate and Procedural Framework, which were not being satisfied (Forest Watch 1999). By this mandate, it must be determined whether the logging and timber sales have a direct effect on the Indiana Bat population. Once it is decided whether the actions under way in the Green Mountain National forest "may affect" the protected species, they must inform the US Fish and Wildlife Service to take appropriate steps to protect the endangered species (Forest Watch 1999). This action may include a halt in logging and timber sales. To conjure the idea that the Indiana Bat would not be significantly impacted by proposed logging and road building in Green Mountain National Forest is "capricious" (Forest Watch 1999).

Protection and management

There are ways to protect the Indiana Bat, though the species continues to decline. The most important and possibly most difficult way to protect the bat is to prevent disruption to its hibernacula. Preventing visitation of humans into caves in which bats were hibernating would thwart a disturbance causing depletion of fat reserves. Avoiding the modification of riparian and stream habitats can help keep the population from decline. The removal of timber should be minimized and at least 30 meters of vegetation should be spared on each side of the stream bank if trees must be removed (MDC 2000) in the riparian zone. Dead trees are an important part of the Indiana Bat's habitat. If at all possible, the trees in which the bats reside should be spared. Population trends should be monitored consistently and reported to the US Fish and Wildlife Service. Education is an extremely important part of conservation and survival of the species. Grants and funding from the government would help in meeting research needs.

Gating caves properly can have positive effects on Indiana Bat populations. Using an appropriately designed cave gate can restore proper air flow (Cole 2000). Wyandotte Cave in Indiana had a dramatic population increase after installing a gate that air flow was again normal. Populations of Indiana Bats have increased as obstructions preventing air flow were removed (Cole 2000).

CONCLUSION

The Indiana Bat is an amazing creature, from its biology to its behavior. Its ability to navigate using echolocation and its method of hibernating due to torpor are amazing biological feats. The unfortunate reality remains that this animal is under appreciated. Due to this lack of appreciation for the Indiana Bat, it faces extinction. After 33 years of status as a federally endangered species, the Indiana Bat populations continue to decline. Despite the gating of caves and the careful monitoring, protection of the bat is a problem larger than anticipated. The logging and timber sales directly affect the habitat preferred by the bat. Pollution and degradation of water quality pose threats. The bats have turned to road ruts as water sources. The use of pesticides and herbicides may directly cause poisoning or indirectly cause destruction of habitat and declination of the insect population.

The Indiana Bat is a tiny animal, weighing only 6-9 grams, however its impact on the ecosystem of a cave is immeasurable. Bat waste or guano is an important energy source in a cave, since the ecosystem relies primarily on organic matter that enters into caves from streams or wind. Through education and the US Fish and Wildlife Service, the Indiana Bat may have a chance to reach the numbers it once had. The protection of every species that inherits the earth no matter how large or small, should be of utmost importance to us.

Literature Cited

Altringham, John D. 1996. Bats: Biology and Behavior. Oxford University Press, NY, 262pp.

Bat Population Database. 1998 http://www.mesc.nbs.gov/_scripts/B...p?GenusSp=*Myotis+sodalis*&B1=Submit

Cole. Brian P. Letter. United States Forest Service 7 April 2000 http://www.cs.unca.edu/nfsnc/nepa/final.ib-bo3.htm.

Forest Watch. United States Forest Service Failure to Protect the Indiana Bat on the Green Mountain National Forest: Request for Relief and Summary of Relevant Findings-Notice of Intent 28 May 1999. http://www.forestwatch.org/lib/indiebat/noi.html

Foster, Rodney W. and A. Kurta. 1999. The Roosting Ecology of the Northern Bat (*Myotis septentrionalis*) and Comparisons with the Endangered Indiana Bat (*Myotis sodalis*). Journal of Mammology, 80(2):657-672.

Georgia Wildlife Federation. The Indiana Bat. 16 November 1998 http://www.gwf.org/library/wildlife/ani_indianabat.htm

Hobbs, Horton III. 2000. Cave Ecology Manual. Wittenberg University, 308 pp.

Johnson, Scott A., Brack, Virgil Jr., and R.E. Rolley. 1998. Overwinter Weight Loss of Indiana Bats (*Myotis sodalis*) form Hibernacula Subject to Human Visitation. American Midland Naturalist. 139:225-261.

Kurta, Allen and J.O. Whitaker Jr. 1998. Diet of the Endangered Indiana Bat (*Myotis sodalis*) on the Northern Edge of Its Range. American Midland Naturalist. 140:280-286.

Missouri Department of Conservation. Endangered Species Guidesheet: Indiana Bat (*Myotis sodalis*). 2000. http://www.conservation.state.mo.u.../endangered/endanger/bat/index.htm

Newell, Toni Lynn. 1997. The Regents of the University of Michigan: Undergraduate Research Opportunities Program. 25 February. http://animaldiversity.ummz.umich.edu/accounts/*Myotis*/m_*sodalis*

Ohio Division of Wildlife. Wildlife Notes: Indiana Bat. 1998. http://www.dnr.state.oh.us/odnr/wi.../publications/wildnotes/inbat.html

United States Army Corps of Engineers. "Endangered Species Documentation DRAFT BIOLOGICAL ASSESSMENT: Monarch Chesterfield Levee Raise Project. Effects of The Monarch-Chesterfield Levee Raise on: Bald Eagle, Indiana Bat and Pallid Sturgeon." Appendix H. St. Louis District Corps of Engineers. 18 July 2000. http://www.mvs.usace.mil/pm/chesterfield/Appendicies/AppendixH.html

Wolflin, John. Letter. 1997. United States Department of the Interior: Fish and Wildlife Service. 16 September 1997. http://www.fs.fed.us/gwjnf/indianabatbo.html

APPENDIX

Kingdom: Anamalia
Phylum: Chordata
Class: Mammalia
Order: Chiroptera
Family: Vespertilionidae
Subfamily: Vespertilioninae
Genus: *Myotis*
Species: *Myotis sodalis*

Figure 1. The classification system of the Indiana bat *Myotis sodalis*.

Indiana Bat (*Myotis sodallis*)

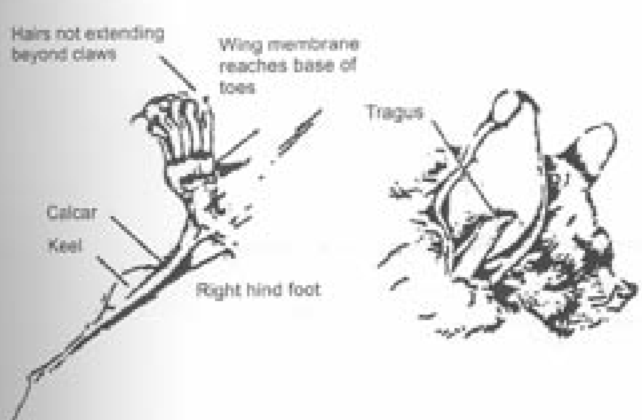


Figure 3. The keeled calcar. Notice the small delicate hind feet (Hobbs 2000).

THE INDIANA BAT (*Myotis sodalis*)

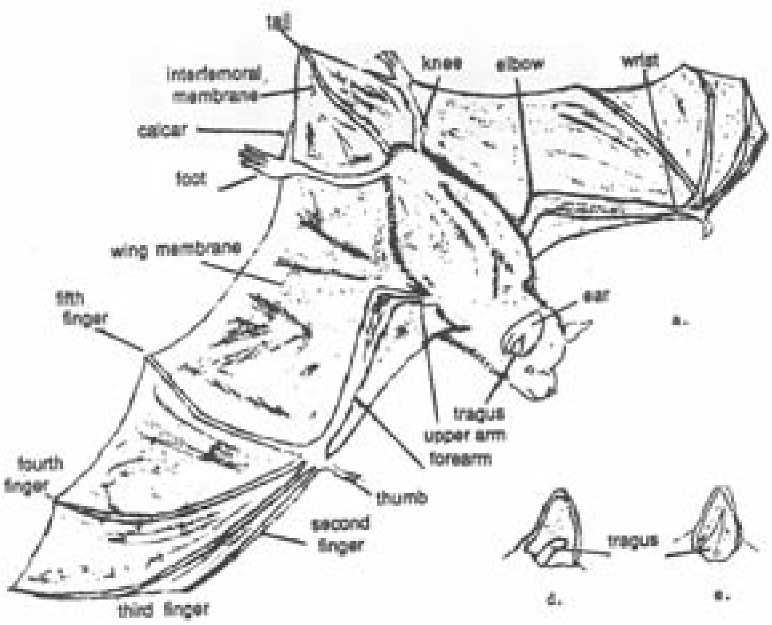


Figure 2. The general diagram of a bat. Take note of the location of the calcar. A keeled calcar is a specific characteristic of *Myotis sodalis* (Hobbs 2000)

Table 1. Percent volume of foods eaten by *Myotis sodalis* in Michigan based on the analysis of fecal pellets (From Kurta and Whitaker 1998).

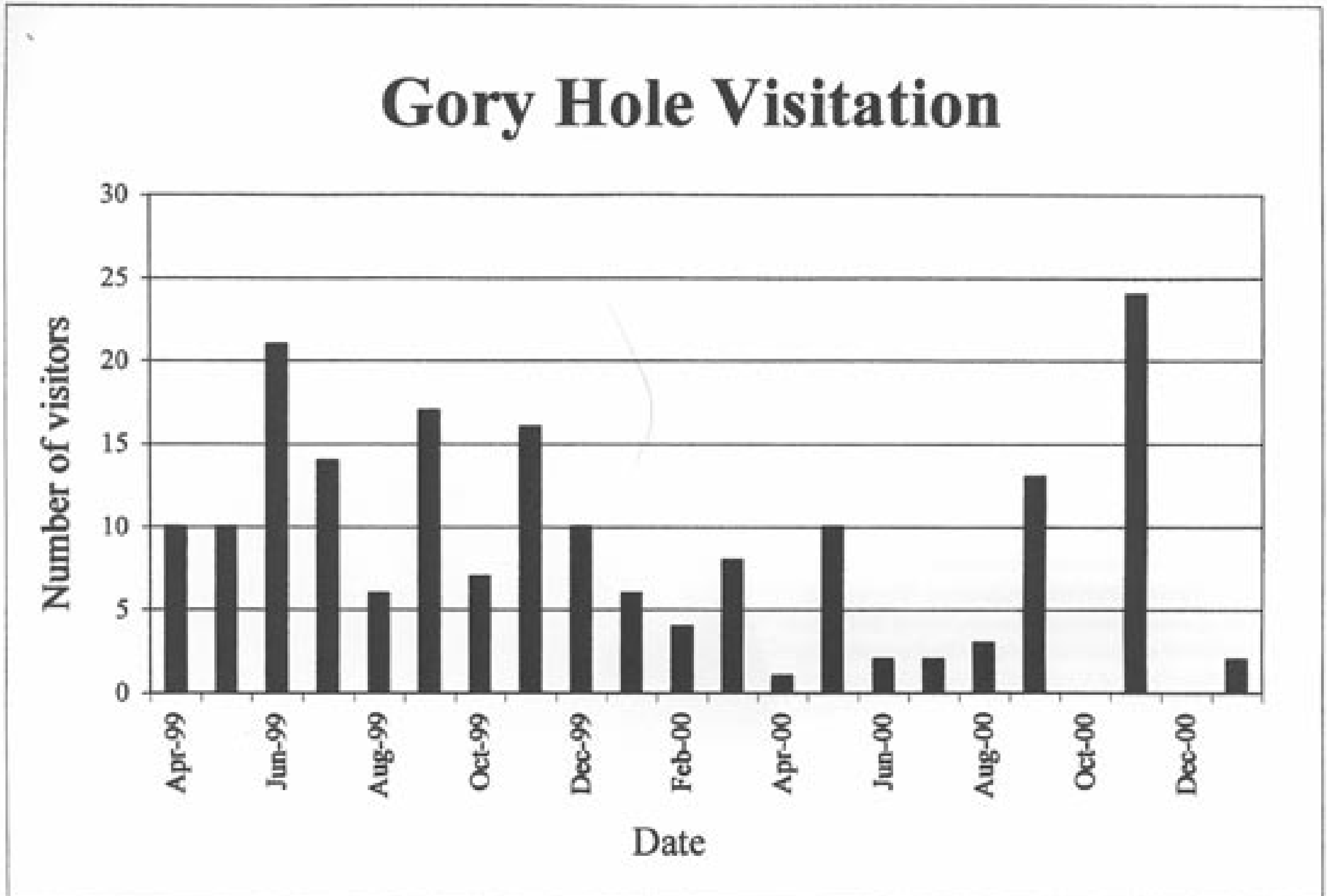
Taxon	Percent-volume			
	1993 (n = 293)	1994 (n = 101)	1995 (n = 48)	Total (n = 382)
Trichoptera	47.7	71.4	56.5	55.1
Diptera (all families)	31.8	15.0	17.0	25.5
Chironomidae	2.6	7.8	2.7	4.1
Culicidae	4.2	0.6	0.4	2.7
Tipulidae	0.3	0	1.6	0.4
Dolichopidae	0.02	0	0	0.01
Lepidoptera	16.6	8.8	14.8	14.3
Coleoptera (all families)	0.7	1.5	4.8	1.4
Scarabaeidae	0.9	0	2.0	0.3
Curculionidae	0.3	0	0	0.02
Dytiscidae	0	0.5	0	0.1
Hymenoptera (all families)	1.3	0.5	1.3	1.1
Ichneumonidae	1.3	0.1	1.2	1.0
Formicidae	0	0.2	0	0.07
Neuroptera (Hemerobiidae)	0.2	0.9	4.6	0.9
Araneae	1.0	0.3	0	0.7
Unidentified insects	0.2	0.7	0.7	0.4
Hemiptera (all families)	0.3	0.05	0.3	0.3
Lygaeidae	0.06	0	0	0.04
Homoptera (all families)	0.2	0.4	0	0.2
Cicadellidae	0.2	0.4	0	0.2
Aphididae	0	0.1	0	0.04
Plecoptera	0	0	0.4	0.05
Ephemeroptera	0.04	0	0	0.03
Total for orders	100.04	99.6	100.4	100

Table 2. The mean autumn and spring body weight (g) of the Indiana Bat in the three chosen hibernacula (From Johnson et al. 1998).

Cave	Seasonal sampling period	Females			Males		
		$\bar{x}$	SD	n	$\bar{x}$	SD	n
Batwing	Autumn 1989	8.64	0.79	94	7.29	0.69	290
	Spring 1990	6.62	0.37	39	6.21	0.40	9
	Autumn 1990	8.95	1.00	50	7.34	0.81	336
	Spring 1991	6.45	0.52	156	5.76	0.32	149
Ray's	Autumn 1989	8.78	1.27	316	7.22	0.71	268
	Spring 1990	6.35	0.39	219	5.82	0.36	156
	Autumn 1990	9.48	0.67	303	7.17	0.81	347
	Spring 1991	6.37	0.47	208	5.98	0.34	127
Wyandotte	Autumn 1989	8.78	0.55	200	7.18	0.73	261
	Spring 1990	6.34	0.45	135	5.84	0.28	15
	Autumn 1990	9.07	0.99	73	7.29	0.77	382
	Spring 1991	6.37	0.68	55	5.90	0.53	76

Table 3. The overwinter weight loss in percentages for male vs. females in southern Indiana from 1989-1990 (Year 1) and 1990-1991 (Year 2) (From Johnson et al. 1998).

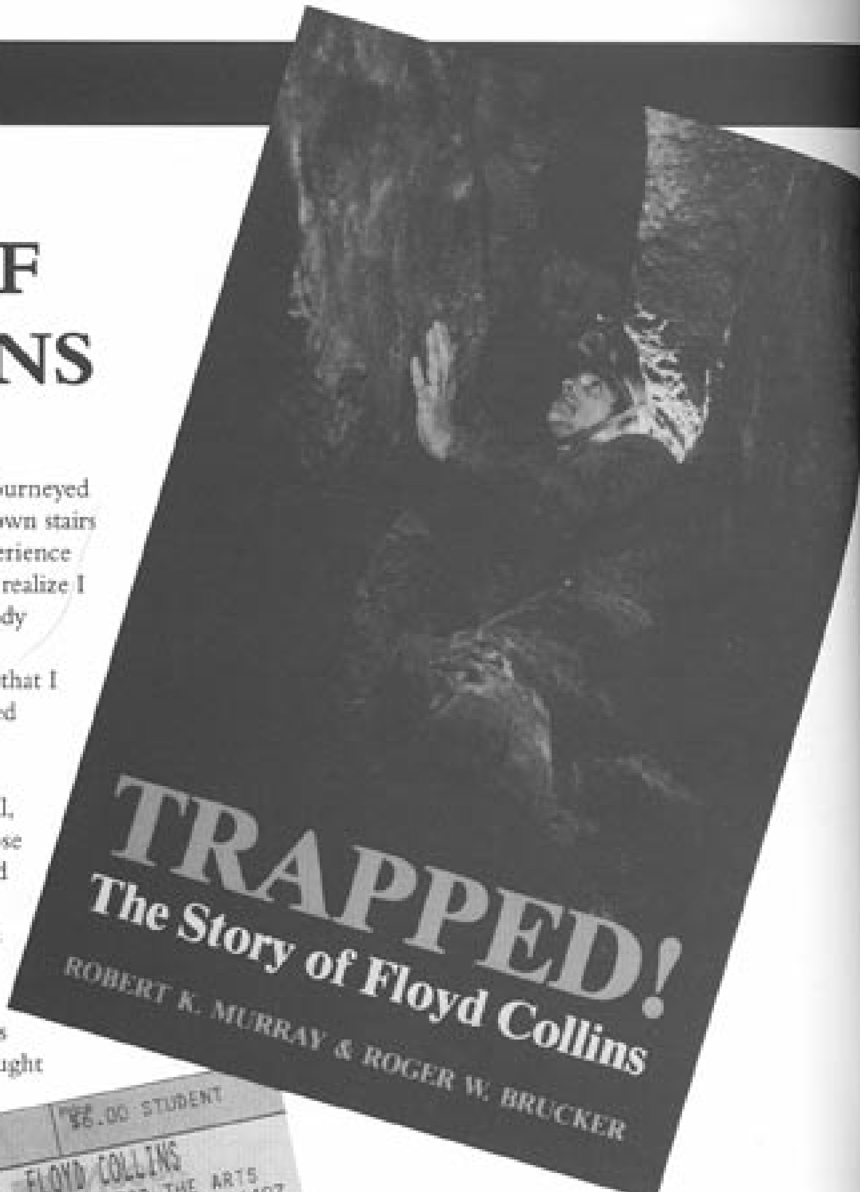
	Year	Cave		
		Batwing	Ray's	Wyandotte
Females	1	23.4	27.6	27.8
	2	27.9	32.8	29.8
Males	1	14.8	19.4	18.7
	2	21.6	16.5	19.1



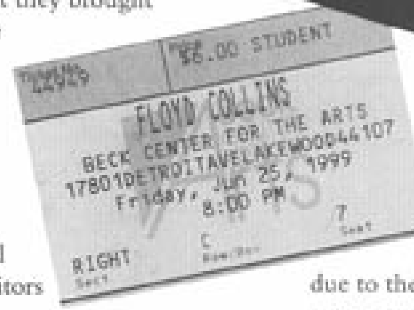
The Wittenberg University Speleological Society installed a register at the bottom of the entrance drop in Gory Hole, Laurence Country, Indiana in November 1993. The graph depicts a somewhat bimodal frequency distribution pattern of visitation during the April 1999 to January 2001 time period, with greater visitation occurring in June 1999 and November 2000.

A REVIEW OF FLOYD COLLINS

by Beth Hagen WUSS# 0400, NSS# 36267



This past June, I with two other WUSS cavers, journeyed deep underground; okay, really we only descended down stairs into a dark theater, but that was close enough to experience the Ohio premiere of Floyd Collins. Now you must realize I was weary going to this theatrical event as I had already listened to the soundtrack. All I can say to give the soundtrack justice is that it is unlike any other music that I normally listen to. The style was Americana combined with bluegrass, but the lyrics were so corny it soon became unbearable. However, I must say that I was pleasantly surprised with the production. The musical, while taking some theatrical liberties, stayed fairly close to the historical account of Floyd Collins as portrayed in Robert Murray and Roger Brucker's "Trapped! The Story of Floyd Collins" (1979). The musical was complete from yodeling in order to find new cave passage to Floyd talking to cave crickets in his time of insanity, close to his death. The song lyrics at times were fairly ridiculous, but I must admit that they brought humor to the play. I especially enjoyed the newspaper reporters rendition of "Is That Remarkable?" with the lyrics "Who's got the scoop poop!"



The production did provide some history of cave warfare of the early 1900's and the desire to steer eager visitors away from the great Mammoth Cave to the local hole in the ground. In order to redirect visitors from Mammoth Cave your cave either had to have direct access to the Cave City Highway or have its entrance ahead of Mammoth's (Murray and Brucker 1979). Floyd's cave had neither. Therefore, he was trying for the third best option, he wanted to discover a cave even more beautiful than Mammoth. Floyd was in search of his "Great Sand Cave" when he became trapped.

As an active caver, I was a bit disappointed to see much of the play take place above ground at the entrance of the cave with Floyd trapped underneath. Most of the play focused on the family and towns' corruption resulting from becoming famous and the desire to strike it rich quick through the whole ordeal. Floyd's brother, Homer, who in the beginning of the play wanted to help rescue Floyd the most, leaves for Hollywood to make a movie. Considering the time span of the rescue lasted sixteen days this was quite a feat! Other cast members included Skeets Miller, a reporter with the Courier Journal who was as small as a mosquito. As in the real rescue, he was one of the few persons who made it to Floyd's side in the cave. He was able to provide an accurate, personal account of Floyd's condition despite the prevalent yellow journalism occurring due to the other reporter's need for a story. H.T. Carmichael, a non-caver from the Kentucky Rock and Asphalt Company also appeared at the scene ready to take control of the situation and build a shaft down to Floyd. One further interesting aspect of Floyd's life was the suggestion of an incestual relationship between Floyd and his sister Nellie. I was not aware of this facet of Floyd's life and so I am not aware if this was a historical account or perhaps the director took artistic liberties in the production. Whatever the case, maybe there was a reason why Nellie was recently released from an asylum and always was in unstable mental health.

Yes, while we were probably the only cavers in the audience (we scouted the parking lot for bat stickers and failed to find any other than the one stuck on our own vehicle), it was a worthwhile weekend...even if it wasn't spent underground!

Murray, Robert K., and Roger W. Brucker. Trapped! The Story of Floyd Collins. Lexington: The University Press of Kentucky, 1979.

RESEARCH

Bat Guano: Its Role and Impact on the Cave Ecosystem

by Carrie Funderburg

Abstract

Caves are naturally low in energy due to a lack of primary production. With no direct sunlight past the entrance, photosynthetic plants cannot survive and thus cannot form the base of the cave ecosystem as they do in epigean communities. Some caves are supported by strains of autotrophic sulfur bacteria. For the most part, however, caves cannot depend on any autotrophism to provide their basic energy source and instead must acquire energy in other forms. One energy source may be allochthonous material – organic matter from the outside that makes its way into the cave. This input of energy is not predictable enough to sustain large cave communities. One of the few steady, predictable, and adequate sources of energy for caves comes in the form of bat guano (dung). It lies at the center of specialized communities. It contributes to the structure of the cave itself, holds important pieces of history, and can be and has been used extensively by man. Bat guano is essential in the life of the cave and plays many other roles as well, and because of this, we must work to preserve bats and the guano they produce.

Introduction

Guano is described as "large accumulations of dung, often partly mineralized, including rock fragments, animal skeletal material and products of reactions between excretions and rock" (Gillieson 1996:307). In caves, the largest contributors of guano are bats, although crickets and birds play a part as well. Guano deposits appear in caves that are frequented by one of any number of species of bats. Bats are trogloxenes; organisms that inhabit caves at some point in their life history but are not fully adapted to living in caves without ever leaving. Bats remain in the caves much of the day (being nocturnal) and in the winter months during hibernation. However, they must go to the surface to feed during active months and so are classified as trogloxenes. Most bats are insectivores, and there is not a sufficient supply of food available for them in the cave ecosystem. "A bat commonly eats, on the average, about half its weight in insects every day that it is not hibernating" (Moore and Sullivan 1997:111). Bats are one of our best natural controls of pests, and the guano they produce supplies the cave with much needed energy.

Characteristics

The guano that bats leave behind is produced often more rapidly and in greater quantities than it decomposes. "Their constant movement between the outer world and the cave habitat continues to replenish the guano piles" (Ashley, 1995:476). Because of this, guano piles up in the spaces where bats roost, most commonly in domed rooms within the dark zones of caves. Guano can be packed down into layers, or it can appear as a "dark, molasses-like fluid" (Elliott 1981:105). It often forms the floor upon which visitors walk. Some heaps can "occupy most of the cavity in...caves, and the open space through which we walk is but a small component" (Gillieson 1996:10). Most cavers find bat caves rather uncomfortable to be in because of the guano. There is a characteristically strong ammonia odor produced during the breakdown of the bats' nitrogen-rich feces and urine. This environment may not be ideal for humans, but a host of other organisms rely on the guano in order to survive.

The environment inside and outside the caves that bats inhabit plays a very large role in determining the characteristics of the guano pile itself. Not all bat-inhabited caves contain these piles. Large supplies of dung build up only in caves that satisfy the microclimatic or social requirements of the bat colony and where there is a low chance of flooding or active cave streams (Gillieson 1996). If bats inhabit caves with active water flow, the guano never builds up-it is flushed out of the system. When a bat colony finds a roost site that suits its needs, it often returns to the same roost location used in previous years. These spaces may be used as over-wintering, mating, or maternity sites. By revisiting former sites, the bats set up a fairly constant guano pile. Partially because of the large and relatively predictable amounts of guano, the energy availability is much higher in tropical caves than those in temperate regions. "Caves in the tropics would yield higher proportions of organic matter...from authigenic bat guano and its by-products" (Gillieson 1996:9). They also accumulate more allogenic organic matter than in temperate regions, and some use tree roots as energy sources. Caves (tropical or temperate) that provide the optimum environments for bats and for the development of guano piles can boast very thick deposits. For example, caves in the Carlsbad Caverns system and near the Grand Canyon contain piles up to 12m thick (Moore and Sullivan 1997), and some Sarawak and Australian caves exhibit piles up to 20m thick (Gillieson 1996). Given the optimal conditions, guano piles can become significant cave features.

Impacts on Caves

Although they are characteristically carved out of limestone, caves exhibit an abundance of different minerals, especially in their speleothems. Guano can serve to introduce some of these minerals, often in the form of nitrates and phosphates (Fig. 1). These minerals can form through the leaching of guano, its decomposition, or its interactions with the materials around it. "Where guano is in contact with limestone, calcium-rich phosphate minerals form. Where it is in contact with clay earth, aluminum-rich and magnesium-rich phosphates are the resultant species" (Hill and Forti 1997:163). When it is first produced, guano has a much higher percentage of nitrogen than phosphorus. However, as time passes, the nitrogen is leached out, and phosphates become the largest components. The nitrates then contribute to the mineralogy of the cave, often aiding in the formation of saltpeter or other nitrogenous minerals. "Gypsum is almost always a by-product of the leaching of bat guano, and therefore it is one of the most common bat guano minerals" (Hill and Forti 1997:190). The majority of minerals formed from guano are phosphates. Whereas the nitrates are fairly soluble, the phosphates remain in the guano and interact with other materials in the cave, forming an array of cave minerals. "More than 40 of the known cave minerals contain phosphorus derived from bat droppings" (Moore and Sullivan 1997:70). This complex suite of phosphates can then contribute to the cave formations. In the case of Muierii Cave, Romania, phosphates leach down through fractures in the limestone and react with it to produce the speleothems in the Red Room (Moore and Sullivan 1997). Phosphates give these formations their coloration. In addition to affecting caves' geology, guano can affect their hydrology as well. In Devil's Icebox Cave, Missouri, for example, the decomposition of bat guano appears to change the composition of the stream water during the period the bats are in the cave (Engeln and Wicks 1996). The microbial decomposition of the feces produces carbon dioxide. As the karst stream passes over the decomposing guano, the partial pressure of CO2 in the water increases, thus altering its composition. Bat guano generates products that have the ability to alter the cave's geology and hydrology.

Guano also functions as an important energy source in cave ecosystems. Caves in general are considered to be nutrient-poor. Most ecosystems in the world base their food webs on primary producers. In the hypogean ecosystem, however, there are very few primary producers. "Because cave environments essentially lack an autotrophic component, all cave communities must depend on exogenous organic material" (Hobbs 1992:84). This makes the cave ecosystem an incomplete ecosystem. Chemoautotrophic bacteria are for the most part the only producers found in caves, and they are found in few caves. Because of this, the remainder of energy needed to maintain life in a cave must be provided in the form of additional nutrients from outside sources (Fig. 2).
By providing a stable input of energy, guano supports many cave communities. It "has high nutritional value and is fed on by various animals as well as providing a rich medium for fungi and bacteria" (Gillieson 1996:208). Guano piles have significant potential as an energy supply because of the essential nutrients they contain. "Waste material deposited by cavernicoles serve as nutrient reservoirs" (Hobbs 1992:77). These reservoirs are crucial in sustaining the life of the cave.

As an energy source, guano forms the basis of specific communities. It can support a huge amount of biomass because of the energy it provides. For instance, "some bat fleas have been known to reach densities of 11,000 per square meter" (Elliott 1981:102). This is one of the few regions in a cave where many organisms can survive. The organisms that depend on guano can afford to be "r strategists" because there is not a scarcity of energy. "A large and variable food supply and associated microclimatic variation would result in selection for the high productive rate" (Poulson 1972: 57). These organisms do not need to give up expensive characteristics such as functional eyes and pigments, as the typical "K strategists" in caves do. Guano communities are "made up of a small

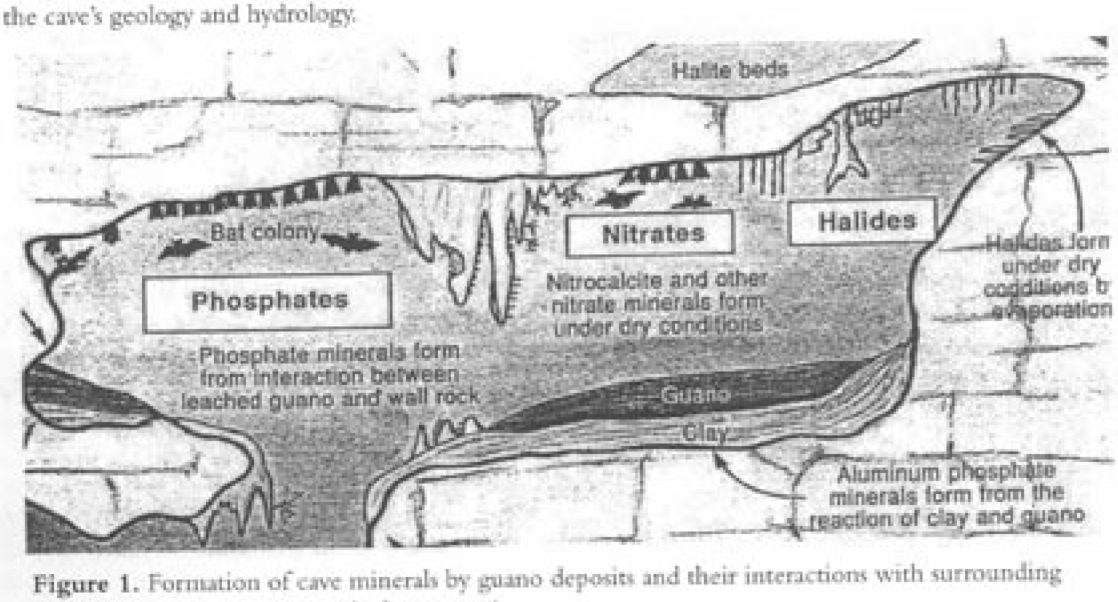


Figure 1. Formation of cave minerals by guano deposits and their interactions with surrounding soil. (Hill and Forti 1997: inside front cover)

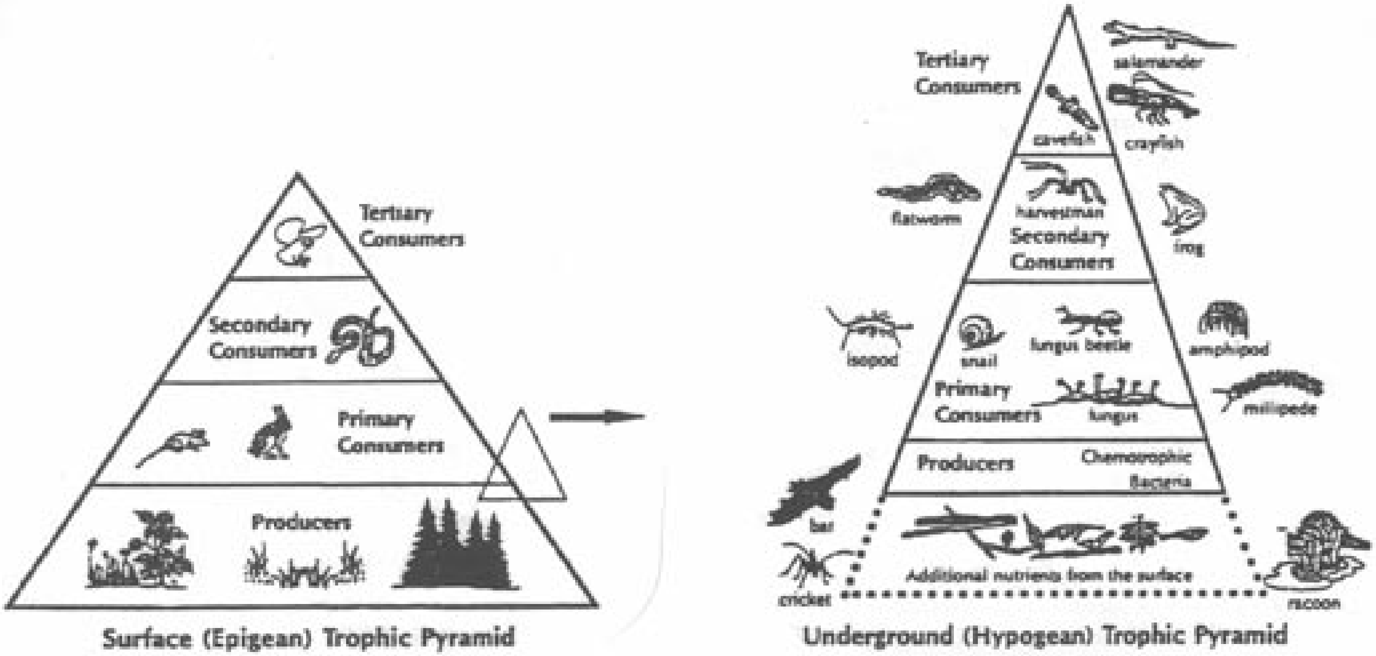


Figure 2. Comparison of energy input in epigean and hypogean environments (Ashley 1995: 474).

number of species that have evolved to exploit a very specific niche" (Gillieson 1996:233). These organisms are often named guanophiles, or guanobites. "Guano piles function as distinct and complex ecosystems" (Hobbs 1992:84), so many organisms that have adapted to life within a guano community are found only in guano heaps. These communities display dynamics, just as many surface ecosystems. The bats only use caves for certain periods of time. When they leave, the organisms that depend on the guano as a source of energy must find a way to survive. "Either the organisms on the heap become inactive, neither growing nor reproducing, or their population declines markedly" (Gillieson 1996:232). Then, when the bats return, the piles become places of great activity once again. "The food pulse that is initiated every year when the bats return to a cave greatly affects energy availability and also the community of guanobites" (Hobbs 1992:85). During these periods of high activity, the temperature of the heaps can rise 10°C in one week (Poulson 1972). The organisms that inhabit guano piles do not only use them as an energy source, however. Their structure provides a large surface area for colonization, and a depth in which adults can lay their eggs and vulnerable larvae can burrow and hide. The specialized communities that depend on bat guano exhibit characteristics that are different from most of the other communities within the cave.

The cavernicoles that depend on guano are highly specialized. They are not specialized as many troglobitic forms are, but are adapted in their own way to the demands of life as a guanophile. "Few troglobites are found in the vicinity of large bat guano deposits-the conditions are usually not right" (Elliott 1981:102). According to a prominent theory, troglobites evolve through evolutionary pressures that cause natural selection for features that expend less energy, such as depigmentation and loss of eyes. Because these pressures do not exist in guano heaps, troglobitic forms have not evolved there. Food webs in guano communities start with heterotrophic bacteria and fungi that use the guano as a food source. These life forms feed on the guano and its components, and in doing so, they "release chemical compounds for further use as nutrient material for other organisms" (Moore and Sullivan 1997:79). Without these, the guano would be of no use to the cave ecosystem. In this way, "decomposer organisms are perhaps more important to hypogean communities for the role they play in energy transfer than they are in epigean communities" (Ashley 1995:476). In hypogean communities, they play an integral role in freeing up the large amounts of energy that lie in otherwise unusable organic matter. The heterotrophic bacteria and fungi are the first step in a food web that contains some very specialized species. The majority of these are tiny invertebrates. "The succession of fungi on bat guano seems to favor subcommunities dominated by mites and flies with pseudoscorpions as the major predator" (Poulson 1975:49). The cavernicoles that live on guano piles are not very large, but they can be quite numerous, especially for a cave community. "The heaviest concentration of cave life is where guano abounds" (Moore and Sullivan 1997:111). These organisms can include beetles, guano mites, guano flies, protozoa, nematodes, pseudoscorpions, and various other types of cavernicoles (Fig. 3 and 4).

Impacts on Man

Guano provides man with many resources. Historically and today, it has been mined globally for use as a fertilizer. "The mining of cave guano deposits is a worldwide phenomenon" (Gillieson 1996:238). The high amounts of nitrates and phosphates make guano a valuable commodity, especially in the agricultural sense. "The mining of bat guano for agricultural purposes has occurred throughout Australia" (Hamilton-Smith 1998:387). In our own country, there is a history of guano mining. "In Bat Cave, Arizona, extensive mining of bat guano for fertilizer continued until about 1960, and small guano-mining operations continue in other caves today" (Moore and Sullivan 1997:145). Today this novelty can find its way into flower shops and such where one can take home a bag for a small price. Guano also plays a role in the formation of saltpeter, which has been mined for years. "When saltpeter earth was leached in the process of making gunpowder, the dissolved calcium and nitrate ions were removed and, upon evaporating the mother liquor leachate to dryness, a very deliquescent, nearly solid, thick slurry of nitrocalcite was obtained" (Hill and Forti 1997:158). This material was used historically as a component of gunpowder and was mined heavily during the War of 1812 as well as the Civil War (Gillieson 1996). This process involved a very large operation, with many men and much equipment moving into the cave (and often harming the cave in doing so). Guano aids in the formation of saltpeter through the nitrates it supplies. "Bat guano can enrich cave earth in nitrate (as in the case for saltpeter caves)" (Hill and Forti 1997:158). As water passes over the guano, the soluble nitrates are leached out and seep into the earth, interacting with the soil and supplying it with added nitrogen. Although destroying the natural caves in doing so, man has mined bat guano and the saltpeter it produces for many years.

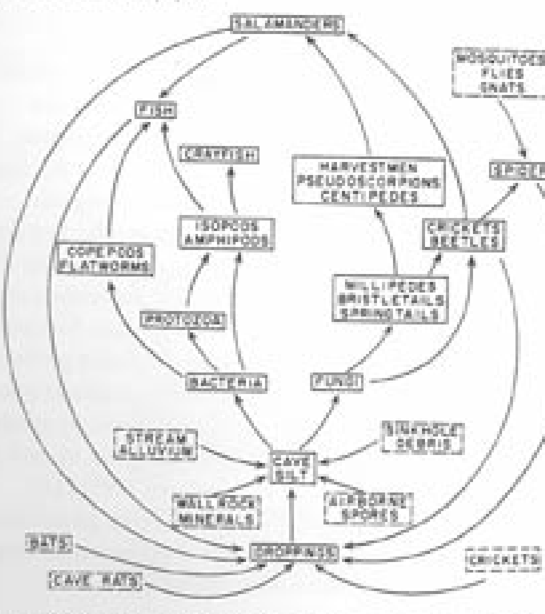


Figure 3. Sample food web in a cave environment (Moore and Sullivan, 1997:117).

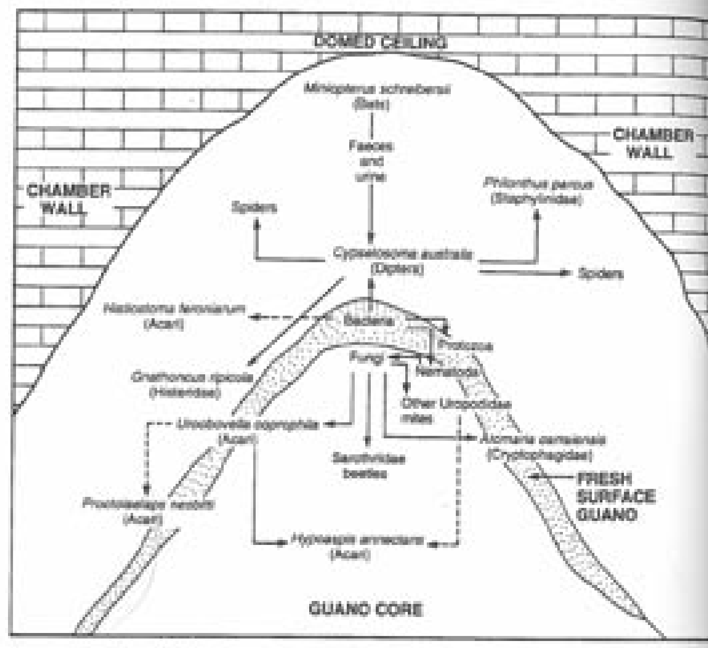


Figure 4. Simplified food web of the Carrai Bat Cave, Australia, guano pile ecosystem. (Gillieson 1996:232).

Caves can serve as windows into the past. They preserve history very well because the cave environment is fairly static. One can see cave paintings made by prehistoric man and interpret what his lifestyle was like. Layers in the speleothems may serve to display what past epigean conditions included. However, "cave histories gained solely from examination of evidence in the open, air-filled cave may neglect crucial information contained in or buried by the sediments" (Gillieson 1996:10). In passing over the bat guano deposits, for example, scientists may overlook valuable information they possess. For instance, they can offer data regarding prehistoric tectonic activity, as done in the south Carpathian Mountains in Romania. "Evidence of Palaeo-seismic activity inside the guano deposit allow a chronology of regional seismic events during the Holocene Period to be drawn up" (Carbonnel et al. 1999:367). In addition to Palaeo-seismic information, they can hold palynological information as well. Palynology is a branch of palaeo-environmental science that studies pollen species and their abundance in the past. The outside world holds little record of past palynology because when exposed to the air, the grains decay. Underground, especially in bat guano deposits, the pollen may be preserved for extended periods of time and studied to reveal what the palaeo-environmental conditions entailed. For example, "bat guano from two adjacent...cave sites in Eastern Spain have been studied palynologically to elucidate the potential of cave sediments for palaeoenvironmental reconstruction" (Camacho et al. 2000:603). Besides preserving palynological data, bat guano can preserve remains of archaeological significance. For example, in Gran Dolina, Spain, scientists examined a pit cave containing layers of various sediment strata, including bat guano. These strata contained human remains that as a result of palaeomagnetic measurements were shown to be a quarter of a million years older than was previously thought for the migration of the earliest humans into Europe (Moore and Sullivan, 1997). Bat guano functions as a preserver of valuable prehistoric information in addition to its many other uses.

Despite its many roles as a beneficial resource, bat guano is not always useful to humans. Bat guano contains nutrients for the fungal growth of *Histoplasma capsulatum*, the fungus that cause histoplasmosis (Granados et al. 1997). Histoplasmosis can occur as an acute or chronic pulmonary infection, and it is endemic to many areas in North, South, and Central America. Prolonged exposure to bat guano increases the likelihood of contracting histoplasmosis because the guano provides optimal conditions for fungal growth. "*Histoplasma capsulatum* grows well in soil enriched with bird or bat guano, infection being acquired through the inhalation of airborne spores" (Conte et al. 1999:229). Particularly in Mexico, where it is often considered an epidemic, those with specific occupations are at high risk for contracting histoplasmosis (Fig. 5). "Workers considered as having a high probability of *H. capsulatum* contact [are]: cave-tourist guides, peasants that collect bat guano for its use as fertilizer, and gamecock handlers" (Granados et al. 1997:139). Although it occurs very rarely, sometimes bats have the fungus already in their intestines-it does not always grow secondary to the dung accumulation. In Nigeria, for example, after the testing of a study group of bats for the presence of *H. capsulatum*, "of the 35 [bats] examined, only one yielded this fungus from its intestinal contents" (Dupont et al. 1994:151). Some humans also may display a respiratory allergy to guano. "In the Sudan, many asthmatic patients attribute their symptoms to inhalation of bat droppings" (El-Ansery et al. 1987:316). Aside from medical problems attributed to prolonged exposure to bat guano, the cave environment caused by guano and its decomposition is often repulsive. "Cave explorers may find crawling into a guano cave unpleasant because of the guano's mushy consistency and fetid ammoniac odor, and also because of the innumerable beetles, ticks, lice, and mites that swarm over it" (Moore and Sullivan 1997:111). These types of surroundings may deter all but the most devoted explorers. "Some of the large bat caves of the southwest and Mexico are intriguing ecosystems that deserve more study. However, the heat, stench, flies, and ammonia can be quite disagreeable" (Elliott 1981:102). Bat guano is essential to organisms that live in the caves, but to humans it can be quite detrimental, or at least make a cave an uncomfortable environment.

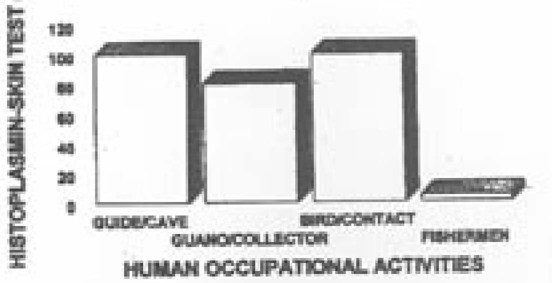


Figure 5. Positive histoplasmin-skin test percentages vs. occupational activities. Individuals referring different occupational activities were considered. Skin test was performed as described in Figure 1 and only those individuals with inflammatory reaction and induration area ≥25 mm in diameter were plotted.

Conservation Implications

Because of the role they play in cave environments, guano ecosystems need to be preserved. However, "cave bats and bat guano ecosystems are a special management problem" (Poulson 1975:51). Over the years, bats' numbers worldwide have dropped. "More than 50% of American bat species are in severe decline or already listed as endangered. Losses are occurring at alarming rates worldwide." (Bat Conservation International 2000). The main causes of this decline seem to be human disturbance and insecticide poisoning, with a small amount caused by the banding of bats (Elliott 1981:105). In order to preserve the bat guano communities, the bats themselves must be preserved and protected. This is no easy task. Because of their longevity, sensitivity to insecticides, and their limited reproduction (usually only one offspring per year), bats are particularly vulnerable to biological amplification and extinction. "Bats require special microclimates for summer nursery colonies and for winter hibernation, and human activity at either time can be sufficient to kill bats or make the colony leave the cave, often permanently" (Poulson 1975:51). Ruining the bats' habitat in turn destroys the habitat for the guanophiles by eliminating their dependable energy source. If bats evacuate a cave system, the organisms that depended on their guano have little chance of survival. In order to ensure the subsistence of guano communities in caves, bats themselves must be protected. To protect bats, we must protect their habitats.

Cave conservation poses a difficult problem. Many caves are used as a source of revenue for parks, and keeping all people out of caves is impossible. Determining which cave systems deserve to be protected is another issue altogether. In one strategy, three criteria have been proposed for assigning conservation value to caves that harbor bat populations: species richness, abundance, and the presence of species of special concern (Arita 1995). The best route of action in protecting a cave is yet to be determined. Some insist that gates are the only way to keep humans out and to preserve the cave environment. However, gating caves can change the microclimate of the cave and force the bats to leave anyway. Some gates are "unfriendly" to bats because they can change the airflow in the cave, and some do not allow bats to navigate easily between the bars. "Each species requires a particular microclimate combination of wind, moisture, and temperature, especially in winter hibernating sites...Gating entrances...will ruin the microclimate for bats" (Poulson 1975:51). However it is done, human visitation (especially during the bats' hibernation period) must be limited. "The reason is that awakening from and returning to hibernation over a several hour period uses as much fat energy as staying in hibernation 2 to 3 weeks" (Poulson 1975:51). If bats use up their fat reserves before the end of hibernation, they are often doomed. With no way to get food, they cannot replenish their reserves and will effectively starve to death, never awakening from hibernation in the spring. The bats' roosts must be protected, but as with all conservation schemes, the exokarst region must be accounted for as well. Because bats rely on insects as a food source, and because they are vulnerable to biological amplification, insecticides pose a huge threat to bat populations. For this reason, insecticide use in the surrounding karst areas must be monitored as well. Through a compilation of management techniques, bats and the guano communities they support can be protected and preserved.

Conclusion

Bat guano is a vital resource in the life of a cave. It provides the cave with minerals and cavernicoles with nutrients. It serves as a valuable reserve of energy in an otherwise energy-barren ecosystem. Guano is also a resource to man, with possible uses as fertilizer, gunpowder, and as a basis for th[e] examination of prehistoric conditions and events. Its benefits outweigh the effects it has in harboring some diseases and creating an uncomfortable atmosphere. Because of all of its advantages, this resource must be protected. As the number o[f] bats decline, it becomes obvious that the specialized guano communities may disappear if something is not done. Conservation measurements must be taken to ensure that bat guano does not vanish from the cave ecosystem.

Literature Cited

Arita, Hector T. 1995. The conservation of cave-roosting bats in Yucatan, Mexico. *Biological Conservation*, 76:177-185.

Ashley, David C. 1995. Introduction to Cave Ecology: energy and nutrients in cave habitats. *MCKC Digest*, 2(2):473-476. *Bat Conservation International*. (October 10, 2000).

Bat Facts and Trivia. Bat Conservation International. Accessed 10/15/00 at www.batcon.org/

Camacho, C. N., J. S. Carron, M. Munuera, J. Navarro, and A. R. Prieto. 2000. An experimental approach to the palynology of cave deposits. *Journal of Quaternary Science*, 15:603-619.

Carbonnel, Jean-Pierre, Vasil G. Decu, Didier Klein, and Phillipe Olive. 1999. Bat guano deposit Holocene datings in the South Carpathian Mountains (Romania): tectonic implications. *Earth and Planetary Sciences*, 328:367-370.

Conte, D., T. Masini, R. Pometta, C. Trovato, and A. Viviana. 1999. Chronic pulmonary histoplasmosis in a patient with a recent history of tuberculosis and persistent round lung lesions. *European Journal of Clinical Microbiological Infectious Disease*, 18:229-231.

Dupont, B., H. C. Gugnani, L. Kaufman, and F. A. Muotoe-Okafor. 1994. A natural focus of *Histoplasma capsulatum* var. *duboisii* is a bat cave. *Mycopathologia*, 127(3):151-157.

El-Ansery, E. H., D. J. Gordon, A. J. N. Taylor, and R. D. Tee. 1987. Respiratory Allergy to Inhaled Bat Guano. *Lancet*, 1(8528):316-318.

Elliott, William R. 1981. An Introduction to Biospeleology. *NSS*, 10847F:100-108.

Engeln, J. F. and C. M. Wicks. 1997. Geochemical Evolution of a Karst Stream in Devil's Icebox Cave, Missouri, USA. *Journal of Hydrology*, 198:30-41.

Gillieson, David 1996. *Caves: Processes, Development, and Management*. Blackwell Publishers, Inc., Massachusetts, 324pp.

Granados, Julio, Amelia Perez-Mejia, Maria Lucia Taylor, and Jesus K. Yamamoto-Furusho. 1997. Immunologic, genetic and social human risk factors associated to histoplasmosis: Studies in the State of Guerrero, Mexico. *Mycopathologia*, 138:137-141.

Hamilton-Smith, Elery. 1998. Much ado about very little: Bat guano mining at Naracoorte, South Australia. *Australian Zoologist*, 30(4):387-391.

Hill, Carol and Paolo Forti. 1997. Cave Minerals of the World: Second Edition. *National Speleological Society, Alabama*, 463pp.

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

Moore, George W. and Nicholas Sullivan. 1997. *Speleology: Caves and the Cave Environment*. Cave Books, St. Louis, Missouri, 176pp.

Poulson, Thomas L. 1972. Bat guano ecosystems. *National Speleological Society Bulletin*, 34: 55-59.

Poulson, T. L. 1975. Management of biological resources in caves. *National Cave Management Symposium Proceedings*, Albuquerque, NM. 46-52.

PHOTOS

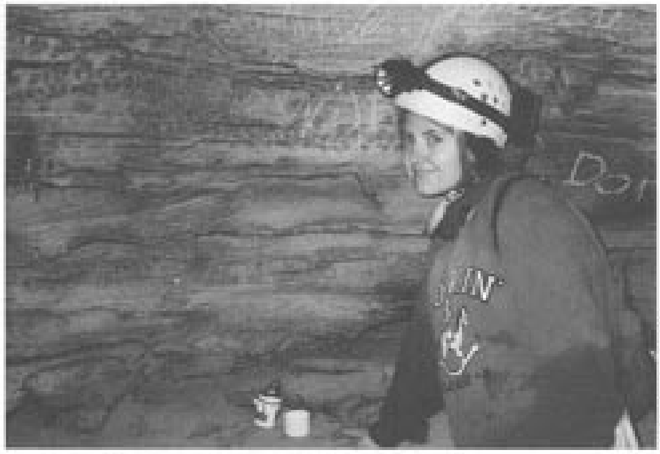


Photo by H. Hobbs

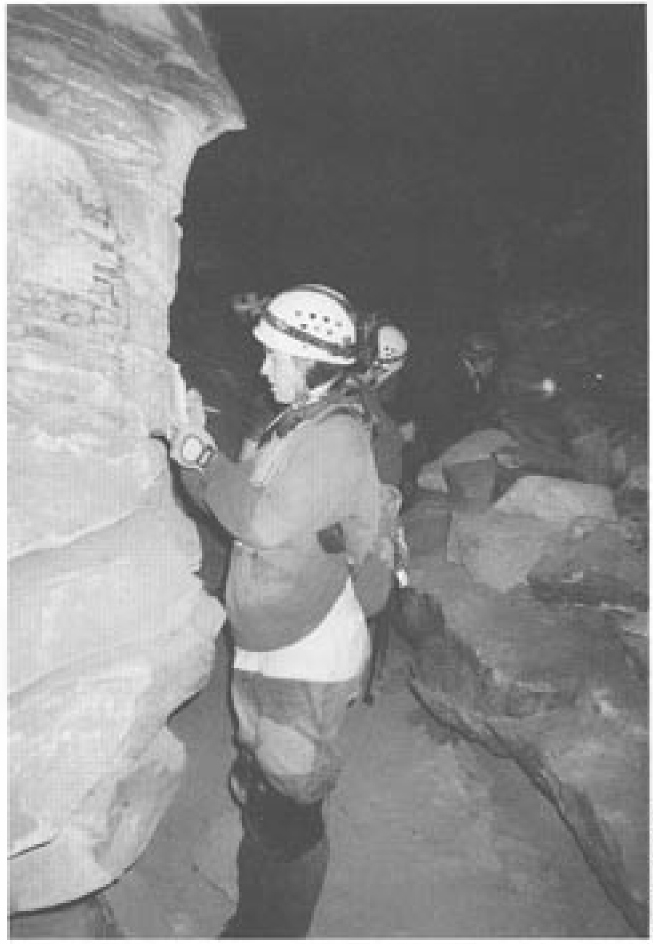


Photo by H. Hobbs

Above: *Taking a break by data logger I 18. Notice the graffiti on the wall in Saltpetre Cave, Carter County, Kentucky (September 1997).*

Right: *Taking careful notes about the placement of the data loggers. Saltpetre Cave, Carter County, Kentucky (September 1997).*

Below: *The University of Florida Bat House (Gainesville, Alacha County, FL) was constructed in 1991 under the guidance of Jackie Bellwood. Both the Brazilian Free-tailed (*Tadarida brasiliensis cynocephala*) and the Southeastern (*Myotis austroriparius*) bats moved in by January 1995 and the house currently supports a maternity colony in late spring of each year.*

Photo by H. Hobbs

PHOTOS

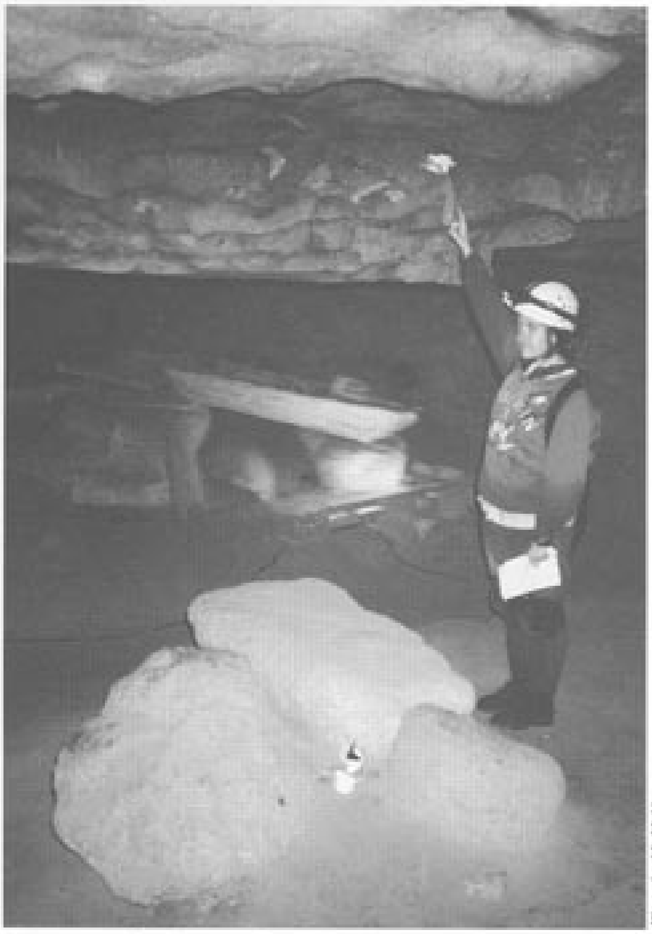
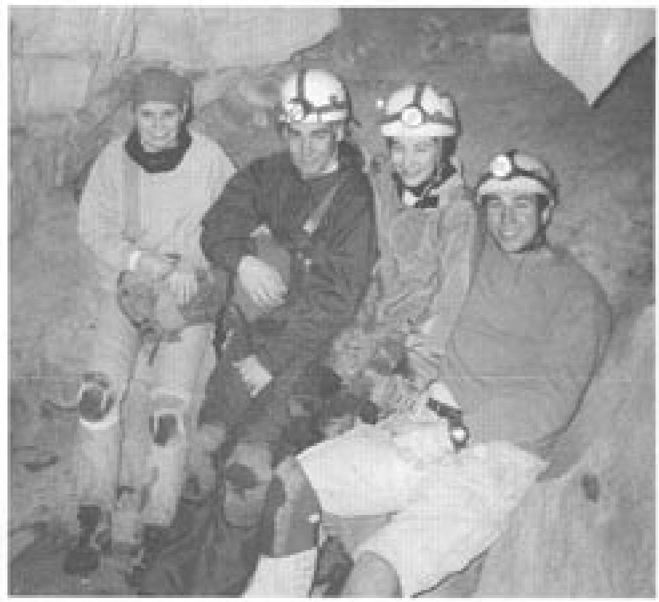


Photo by H. Hobbs

Pointing out the placement of H5 near the ceiling and H3 in the center of the remains of the contents of a saltpetre vat in Saltpetre Cave, Carter County, Kentucky (September 1997).

Bill Stitzel and Nikki Orkins view a bat hibernating on a maximum-minimum thermometer in Canyon Cave, Carter County, Kentucky.



Crawlathon 2000 - January 29, 2000. Fern Cave, Carter County Kentucky.

Ann Gentile and Abby Slavin in Carter Cave, Carter County, Kentucky.

New Property Pit

by Beth Hagen WUSS# 0400, NSS# 36267

New Property Pit (THC:70.9m, TVC 12.9m) is located on recently acquired land of Carter Caves State Resort Park in Carter County, Kentucky. The pit entrance is approximately 2.23m long and 1.0m wide; the pit depth is 11.15m (Figure 1). A log partially plugs the lower 5.78m of the pit, making rappelling and climbing a bit of a challenge (Figure 2)! Many bones were observed at the bottom of the pit including those of a cow and a turtle shell. The entrance pit intersects a horizontal cave passage that ends 15.7m in the southeast direction, but the passage to the northwest opens into an impressive dome area 10m long by 8m wide.

The dome is separated from the surface by only a few meters of epikarst at best and includes several speleothems and a waterfall. Two groups of Indiana Bats were found hibernating on the dome wall and ceiling. In addition, several Eastern Pipistrelle bats, millipeds, and two species of cave crickets were observed in the dome room. A tight crawl in the southeast direction quickly terminates at the stream level. The main cave passage continues to the west in a hands and knees crawl. The cave remains a crawl for several meters before opening up into a passage 2.6m in height. Several directional helectites and stalactites decorate this crawl, while stalactites cover the standing passage (Figure 3). Standing is only possible for a few meters before the passage again becomes a hands and knees crawl. Several Gastropoda fossils are embedded along the cave walls and ceiling. The cave continues as a crawl for approximately 29m before terminating.

Photo by H. Hobbs

Photo by H. Hobbs

Photo by H. Hobbs

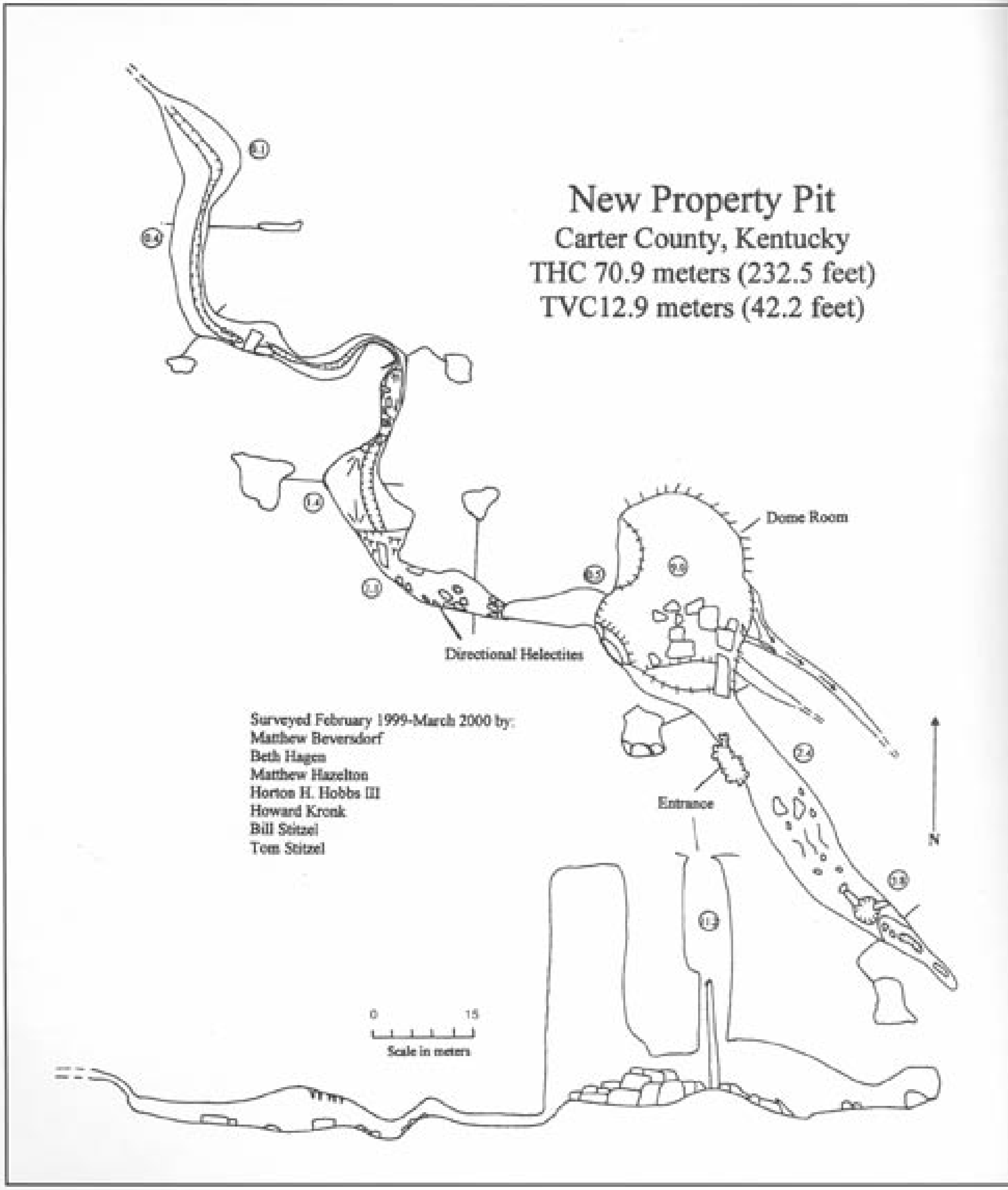
Above left (Fig. 1): *Bill Stitzel climbing out of New Property Pit.*

Lower left (Fig. 2): *A saturated log blocks the lower portion of the entrance pit.*

Above right(Fig. 3): *Directional helectites decorate the cave passage.*

FAUNA LIST

Milliped
Gastropoda-snails
Oligochaeta
Collembola-Springtail
Hadenoecus sp.-cave cricket
Ceuthophilous sp.-camel cricket
Culicidae-mosquito
Meta ovalis-spider
Plethedon glutinosus-slimy salamander
Myotis sodalis-Indiana Bat
Pipistrellus subflavus-Eastern Pipistrelle

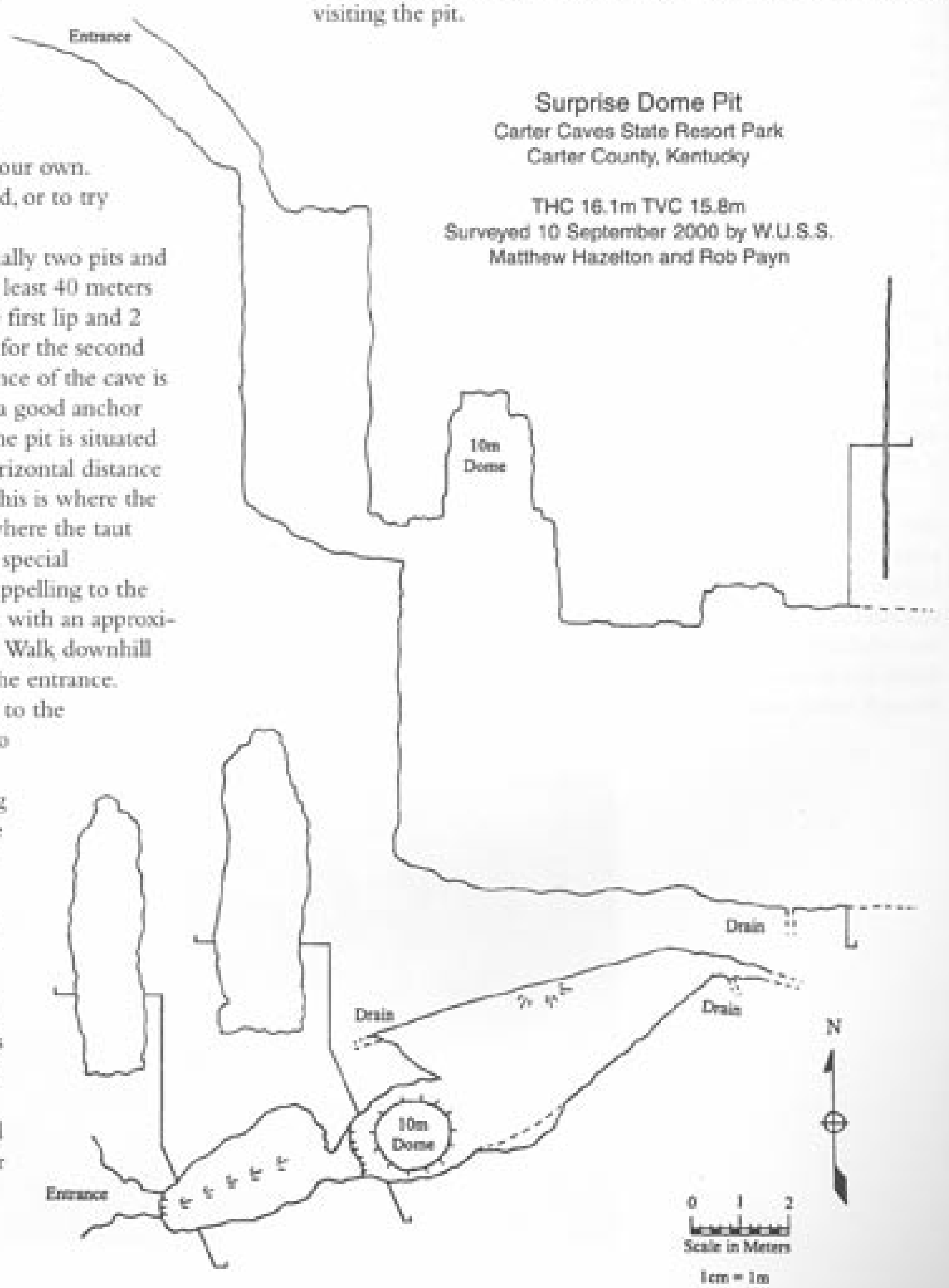

New Property Pit
Carter County, Kentucky
THC 70.9 meters (232.5 feet)
TVC12.9 meters (42.2 feet)
Dome Room
Directional Helectites
Entrance
N
Surveyed February 1999-March 2000 by:
Matthew Beversdorf
Beth Hagen
Matthew Hazelton
Horton H. Hobbs III
Howard Kronk
Bill Stitzel
Tom Stitzel
0
15
Scale in meters

Surprise Dome Pit

by Matthew Hazelton, WUSS# 0449, NSS# 47187

Surprise Dome Pit is developed within the Mississippian limestones of Carter Caves State Resort Park, Carter County, Kentucky. To drop the pit, proper vertical gear is required: static climbing rope, seat harness, safety (e.g., a Jumar), rappelling device (rappelling rack recommended), leather gloves, an ascending system including at least three attachment points to the rope, and at least two other people with complete sets of vertical gear and appropriate training. Proper instruction on the use of all vertical gear should be acquired before attempting to use it on your own. A pit is no place to learn to rappel, ascend, or to try out that new system.

Descending Surprise Dome Pit, actually two pits and drops, requires the use of a single rope at least 40 meters (m) long as well as a 5m rope pad for the first lip and 2 wrap-around rope pads, each 0.5m long, for the second drop. Eight meters south from the entrance of the cave is a tree 45cm in diameter which provides a good anchor point for safe rigging. The entrance of the pit is situated within a small sinkhole which, after a horizontal distance of only 1.5m, has a vertical drop of 8m; this is where the 5m rope pad should be used (pad everywhere the taut rope touches rock or the ground, paying special attention to the lip of the drop). After rappelling to the bottom of the first pit, you are in a room with an approximate width of 1.5m and a length of 3m. Walk downhill while staying to the right, your back to the entrance. You will come to a window which leads to the 'surprise' dome. The same rope is used to rappel into the second dome-pit. Use wrap-around rope pads when descending the second drop, one pad where the rope hits the sharp lip of the ceiling and one where it hits the sharp bottom lip. You must wiggle and contort to pass through the window and begin rappelling the second drop. Of course, stay on rope while passing through the window. The second drop is about 7m long and brings you into a room 2.5m by 9m. Looking up you will see a dome 10m high. Continue on into the room and you will notice a remarkably straight wall on your left and another straight wall with a shelf approximately 1m high. Look around and you are sure to notice a large skull (no, not human) and possibly Slimy (*Plethodon glutinosus*) and Longtail (*Eurycea longicauda*) salamanders and Solitary bats (*Pipistrellus subflavus*). At the back of the room you will see that the 5m tall ceiling does not lower but the width of the room becomes an impassable 0.1m. There are two drains in the lower room, one at the front and the other at the back. Nothing is known about water levels during heavy rains so make intelligent and safe decisions about visiting the pit.



"Spelunking"

by Ben Grostic, WUSS# 0496

You could call this article a simple reflection on my first caving experience because that is what it is. As a Wittenberg freshman, I left for my first caving trip on 29 September, 2000. We (the Wittenberg University Speleological Society) went to Carter Caves in Kentucky. What an experience!

Reflecting on this experience, I started to wonder why we (the WUSS members) are even interested in caving. I came up with some interesting thoughts on the matter. It may be because of the risk factor or adventure that caving holds for us. The fact that it is so different from other events that "normal" college students participate in may also be a reason. The never-ending promise of finding that new cave may be the drive for some. Perhaps the most intriguing factor that keeps us caving deals with our sense of exploration. College is where everyone expects to find himself or herself. We are constantly encouraged to explore our interests and inner selves. Caving is just a physical tangent of this thinking. People who are exploring their minds may be attracted to physical exploration of the world. I do not know if these are the reasons I decided to go caving, and it does not really matter. The point is that I went.

If I had to pick two words to describe this caving trip, they would be "sensory overload." I had never really even seen a cave before, and suddenly I was crawling around inside them. I never knew where I was going or for how long I was going to have to do that fun commando crawl. I was confused and overwhelmed by the sights at the same time. I ran into strange lizard like animals, bats, spiders, and cave crickets. I sloshed through water, squeezed through tight spaces, and climbed rocky crevices. Also, I have never seen more thick, clayish mud or been more covered by it in my life! Unfortunately, you can not call what I did "caving." "Caving" requires some basic knowledge and skill of which I did not have. No, I was definitely not "caving." I was "splunking!" That is all there is to that.

Seriously though, my first caving trip was a positive experience for me. I was able to confront some of my fears which I think is always a good thing to do. These basic fears included an unexpected claustrophobic feeling in a cave called Bowel (which just happened to be full of nice brown water) and the classical avoidance of bats. It is hard to avoid bats in a cave, and as for Bowel, there is only one direction to go, FORWARD! Whatever fears I felt were dealt with on the spot. The strength of the group was the reason they did not become big deals. The "veterans" in our group had such a relaxed and unconcerned manner about them that there was no real way for me to become overwhelmed with fear. It was truly an awesome feeling to experience. Here I was "flipping out" and all of these other students were only thinking about getting to the chamber of the cave. Their calmness kept me calm too, and I was able to have more fun because of it.

Now I am back at Wittenberg where people walk on the ground instead of crawling beneath it. Life is back to "normal," whatever that means. I have had time to comprehend what my senses took in on the trip. I have determined that caving is AWESOME (as if I really had to think about it)! The only other thing I can conclude is that I will visit those caves again.

Shower time. Life after Bowel Cave, Carter Country, Kentucky.

INFORMATION FOR CONTRIBUTORS

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 publication, 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 doubled-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 four 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 referred 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:

   Article: Peck, S.B. 1974. The food of the salamanders *Eurycea lucifuga* 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.

Address all manuscripts and correspondence concerning editorial matters to

Editor, *Pholeos*
c/o Horton H. Hobbs III
Dept. of Biology
Wittenberg University
P.O. Box 720
Springfield, Ohio 45501-0720.

PHOTOS

Above: Logo of the Laboratoire Souterrain du CNRS, Moulis (Ariege, France), established in 1948.

Right: Rob Payn climbing out of Gargoyle Pit in Canyon Cave, Carter County, Kentucky.

Below: WUSS trip to Cincinnati to see the IMAX film, Journey Into Amazing Caves 11 April 2001.

Photo by H. Hobbs

WITTENBERG UNIVERSITY

Department of Biology
Ward Street at
North Wittenberg Avenue
Post Office Box 720
Springfield, Ohio
45501-0720

First Class
U. S. Postage
PAID
Springfield, OH
Permit No. 30