

STATUS, HABITAT PREFERENCES, AND MANAGEMENT  
OF SOUTHWEST WISCONSIN BATS

by

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A Thesis

submitted in partial fulfillment of the  
requirements for the degree

MASTER OF SCIENCE

College of Natural Resources

UNIVERSITY OF WISCONSIN

Stevens Point, Wisconsin

May 1983

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## PREFACE

This thesis, submitted in partial fulfillment of the requirements for a Masters of Science Degree in Natural Resources, is written for publication in the Transactions of the Wisconsin Academy of Arts, Letters and Sciences. The editorial policy of the Wisconsin Academy is that the style of the text be that of scholarly writing in the field of the author. Therefore, the style of this paper follows that of the Journal of Wildlife Management. Additional data collected in the study and not included in the paper is appended as a part of the thesis.

## Abstract

This project was an investigation of the status of the Indiana bat (Myotis sodalis) in Wisconsin. The Indiana bat is a federally endangered species that has been collected only once in the state. The objectives of the project were: to determine 1) the status of the Indiana bat and other bat species in southwest Wisconsin; 2) habitat preferences of southwest Wisconsin bat species; and 3) the amount and types of human use of select caves.

The Indiana bat was not captured during spring and late summer bat trapping at cave entrances, summer mist netting in a variety of habitats, or during monthly surveys of 11 caves and mines in southwest Wisconsin in 1981.

The little brown bat (M. lucifugus) was most common, followed by Keen's myotis (M. keenii), red bat (Lasiurus borealis), big brown bat (Eptesicus fuscus), eastern pipistrelle (Pipistrellus subflavus), and hoary bat (L. cinereus), respectively, in summer. Winter hibernating populations of little brown bats were most abundant, followed by big brown bats, eastern pipistrelles, and Keen's myotis, respectively.

Summer habitats having greatest bat relative abundance were dry-mesic northern forests, mesic northern forests, xeric southern forests, dry-mesic southern forests, and mesic southern forests, respectively. The 2 habitats

showing greatest bat species diversity were dry-mesic northern forest, and mesic southern forest respectively. Little brown bats showed the highest foraging diversity index, followed by Keen's myotis, red bats and big brown bats, respectively. Bear Creek Cave, Atkinson's Diggings, Pop's Cave and Roger's Cave had the most stable microclimates for overwintering bats and relatively large hibernating bat populations. Other caves, with similar microclimates, harbored few or no bats.

Caves were used by humans during the period of bat hibernation (October-April). Five of 8 caves had evidence of use as party sites.

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Many bat species are imperiled chiefly because of extensive habitat loss and disturbance during hibernation (Greenhall 1973, Humphrey and Cope 1976, Mohr 1953, 1972, Stebbings 1970, Tuttle 1979). The Indiana bat (Myotis sodalis), found only once in Wisconsin, in an abandoned Grant County mine (Davis and Lidicker 1955), was placed on the Federal endangered species list in 1967. An estimated 90% of the known population winters in only 3 caves and 1 mine in Kentucky and Missouri (Greenhall 1973). The Indiana bat has recently been reported in Iowa (Bowles 1981) and southern Michigan (Kurta 1981), and seems to be established in Illinois (Barbour and Davis 1969). The status of the Indiana bat and other bat species in Wisconsin was known only by the relative numbers of museum specimens (Jackson 1961, Long 1976). Bat habitat preference information for Wisconsin is lacking. The effects of human activity in caves used by hibernating bats have not been determined for Wisconsin caves. The prior occurrence of the Indiana bat, the proximity to states with known Indiana bat populations, and the abundance of natural caves, abandoned mines and diverse summer habitats made southwest Wisconsin a likely study area to search for this species, and to study other bats endemic to the region.

The objectives of the study were to determine: the status of the Indiana bat and other bat species in southwest Wisconsin, habitat preferences of southwest Wisconsin bats, and the type and amount of human use of southwest Wisconsin caves. The study was conducted from June 1980 - April 1982.

I acknowledge and thank the following: Michael Johnson and Jeff Laursen for field assistance; Drs. Raymond Anderson and Charles A. Long for their help; Vicki Hanrahan for her support and help in preparation of the manuscript; The Nature Conservancy for their permission to study Bear Creek Cave; area landowners for allowing access to the caves; Mike Barden of the Wisconsin Speleological Society for his help in locating caves in southwest Wisconsin; and Dr. Merlin Tuttle of the Milwaukee Public Museum for his aid as a source of information. Financial support for this project was provided by the United States Fish and Wildlife Service and Wisconsin Department of Natural Resources (study no. 102, 1979 -1981), and the University of Wisconsin - Stevens Point, through grants to Dr. Charles A. Long.

## STUDY AREA

This study was conducted in Grant, Crawford, Vernon, Richland, Sauk, Iowa and Lafayette counties in southwest Wisconsin. These counties encompass 40% (5387 sq. mi.) of the unglaciated Driftless Area (Fig. 1). Most of this unglaciated land is in Wisconsin with the remainder extending into northwest Illinois, northeast Iowa, and southeast Minnesota, and is characterized by steep topography and an abundance of natural caves and mines. More than 70 sinkholes have been reported in Vernon, Crawford and Richland counties, and many of these provide access to caves (Paull and Paull 1977). Many sandstone bluffs are present in this unglaciated region. The Driftless Area was a "biotic refugium" or "topographic island" allowing the survival of many organisms during the last (Wisconsin) glacial period (Zimmerman 1970). The great topographic diversity of this region produces a wide range of microhabitats. Deep shade, moisture seepage and cool air drainage into the valleys support isolated relict stands of northern mesic forest on north- and east-facing slopes of the deepest ravines and valleys (Zimmerman 1970). Most of the study area is covered by southern xeric forest type described by Curtis (1959). Relict stands of pine (*Pinus strobus*, *P. resinosa*) persist on rocky outcrops. Most level and gently sloping areas in this area have been utilized for agriculture.

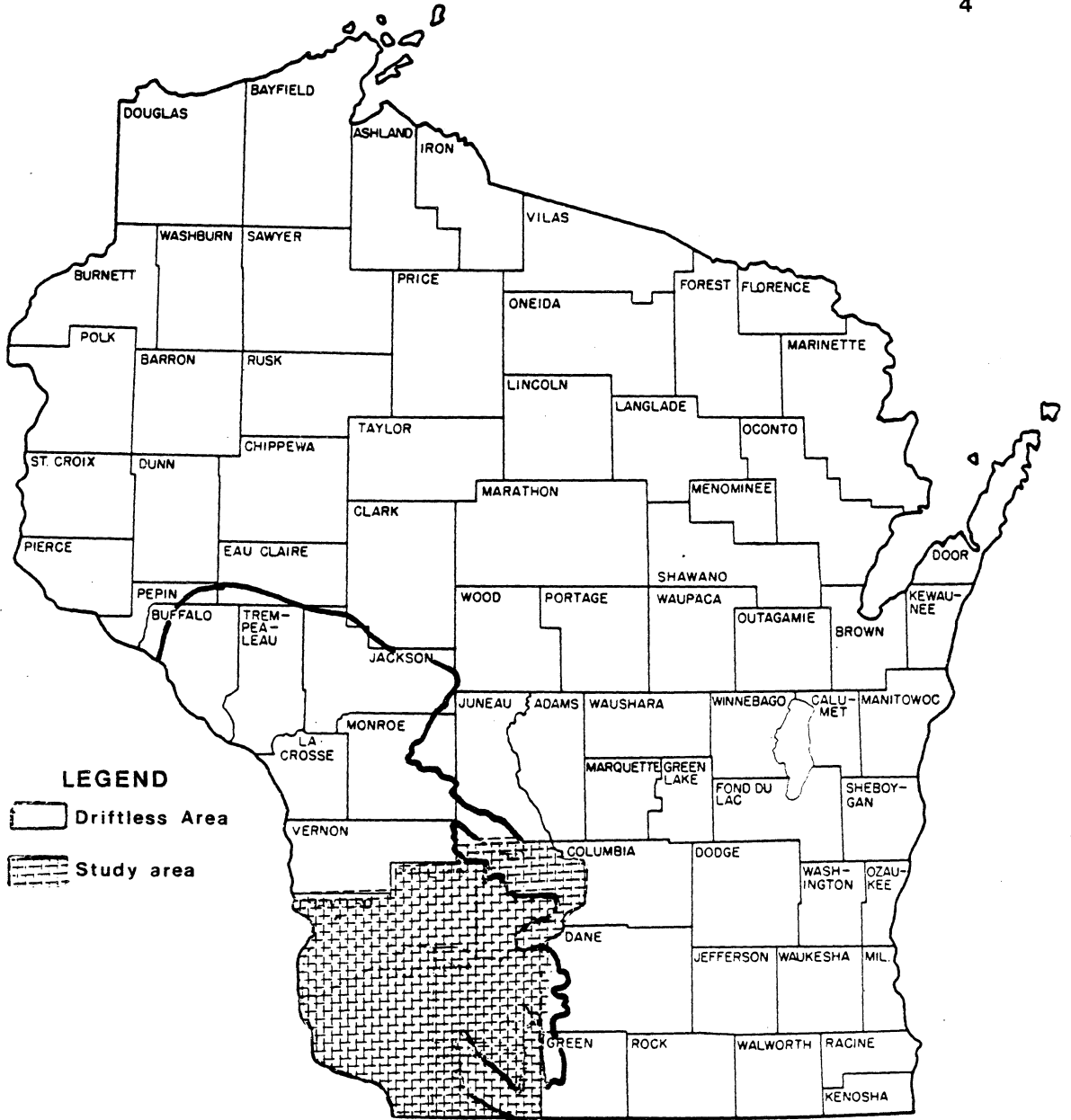


Fig.1. Study area in unglaciated region of southwest Wisconsin.

Numerous permanent small streams and rivers flow through the area and provide a food source of aquatic insects and drinking water for bats. The Wisconsin River with extensive island and flood plain habitats also flows through the study area.

## METHODS

### Summer Habitat Survey

Aerial photographs of the study area were examined to determine locations for mist-netting bats. Areas of dense foliage adjacent to streams were identified on the aerial photos and marked on Wisconsin Highway Department county road maps. Vegetation was inventoried by the point-quarter method (Curtis 1959). A random transect was established in the area adjacent to each mist net location. Transect data were analyzed and habitat types were classified according to Curtis (1959).

### Trapping

Mist-netting for bats was conducted during 28 May - 18 August 1981. Mist nets were 5.5 x 2.1 m or 9.1 x 2.1 m with 36 mm mesh fine gauge nylon. Grant, Crawford, Vernon, Richland, Sauk, Iowa, Lafayette, Jefferson and Waukesha counties were sampled. Mist nets were placed over streams and positioned under overhanging vegetation to catch

foraging bats. Nets were set for approximately 2-3 hrs after the onset of dusk, a period when bats were most active. Captured bats were identified, sexed, and released. Voucher specimens were prepared for the Museum of Natural History, UW-SP.

A Tuttle bat trap (Tuttle 1974) was used to trap bats at the entrances to 3 caves with overwinter populations, during spring (7 April - 7 May) and late summer (13 August - 18 September). Bear Creek Cave was trapped during 13 nights (spring and summer), Atkinson's Diggings for 14 nights (spring and summer), and Roger's Cave for 6 nights (spring and summer). The trap was modified by using 5-pound monofilament line instead of steel wire (Kunz and Anthony 1977), and made collapsible similar to the traps used by Tideman and Woodside (1978). The monofilament line was more available and suitable for trap construction than steel wire. The collapsibility of the trap and its smaller dimensions (91 x 121 cm) facilitated transport. The Tuttle trap was used in preference to mist nets because of its reported capture efficiency (Tideman and Woodside 1978) and suitability for operation by a single attendant. The trap also allowed time for careful examination of bats for identification. Blankets were placed around the edges of the trap to reduce the area through which the bats flew (Tuttle 1974).

## Cave and Mine Survey

Sixty-one caves and abandoned mines in Vernon, Crawford, Grant, Richland, Sauk, Iowa and Lafayette counties, were investigated to determine potential as bat hibernacula during 1980. Inquiries were made of Wisconsin Department of Natural Resources (WDNR) area offices, local historians, private citizens, and the Wisconsin Speleological Society (WSS) regarding locations of caves in the study area. W. A. Broughton, United States Geological Survey, provided locations of approximately 49 old mines in Iowa, Lafayette and Grant counties. The caves and mines were located and identified as being accessible by humans. Twenty-one caves and abandoned mines that appeared suitable for bats were entered at least once and examined for presence of bats: 11 of these were regularly visited from January - December 1981. Temperature, relative humidity (RH), and bat numbers were recorded at each cave during 1981.

Temperatures (Yellow Springs Instruments Telethermometer) at ground level ( $T_g$ ), in the air ( $T_a$ ), and on the cave wall ( $T_w$ ) were taken at various sites within each cave during each visit. The telethermistor probe was taped to a padded-tip conduit extension to minimize the transfer of body heat to the thermistor and to facilitate temperature measurement of areas beyond arms reach. Relative humidity

was measured with a Bendix Psychron psychrometer, at sites where temperatures were recorded.

The use of caves by humans became evident after the initial visit to the caves. Therefore a questionnaire was developed to ascertain the types of human activities in caves. Cave visitors were asked to complete 1 questionnaire per group. Questionnaires, in covered plastic jars, were placed in 8 select caves from October 1981 to April 1982, the hibernation period for southern Wisconsin bats. This is the period when bats are most vulnerable to disturbance.

## RESULTS AND DISCUSSION

### Summer Bat Habitat Preferences

Six habitat types were classified according to Curtis (1959) (Table 1). Species and foraging diversities were calculated for each habitat type and species respectively (Kunz 1973). The equation  $H' = \sum_{i=1}^s P_i \log_{10} P_i$  was used where  $H'$  is the diversity in a sample,  $s$  is the number of species in an area (species diversity) or the number of foraging areas occupied by a species (foraging diversity), and  $P_i$  is the proportion of individuals taken in the  $i^{\text{th}}$  category. Species diversity indicates the extent to which bat species forage in a given habitat. Foraging diversity indicates the amount of ecological specialization, with

Table 1. Relative abundance (RA)<sup>a</sup>, species diversity<sup>b</sup> of bats in southwest Wisconsin, by habitat. (Number of net-hours per habitat type in parentheses).

Species	HABITATS											
	Northern forest dry-mesic (5.8)		Northern forest mesic (6.2)		Southern forest xeric (17.5)		Southern forest lowland (20.8)		Southern forest dry-mesic (14.7)		Southern forest mesic (29.7)	
	RA	N	RA	N	RA	N	RA	N	RA	N	RA	N
Little Brown Bat	129.3	75	104.8	65	109.1	191	88.0	183	84.4	124	68.0	202
Red Bat	17.2	10	11.3	7	0.6	1	1.9	4	0.7	1	11.1	33
Keen's Myotis	3.4	2	17.7	11	5.7	10	2.4	5	4.8	7	3.0	9
Big Brown Bat	20.7	12	4.8	3	1.1	2	0.0		0.7	1	2.7	8
Eastern Pipistrelle	12.1	7	0.0		1.1	2	0.5	1	0.0		0.3	1
Hoary Bat	5.2	3	0.0		1.7	3	1.0	2	0.0		0.3	1
Total	187.9	109	138.7	86	119.4	209	93.8	195	90.5	133	85.5	254
Species Diversity (H)	.456		.341		.184		.089		.133		.295	

<sup>a</sup>Computed by dividing the number of individuals of each species by the number of mist net hours times 10

$$b_H' = \sum_{i=1}^s P_i \log_{10} P_i$$

the highest values indicative of broad habitat preferences and low values indicating more specialized habitat preferences (Kunz 1973).

The order of habitat types, by species diversity indices, were northern dry-mesic, northern mesic, southern mesic, southern xeric, southern dry-mesic, and southern lowland forests, respectively. The extent to which bats utilize these habitats while foraging can be attributed to the proximity of roost sites. Humphrey (1975) hypothesized that the distribution and abundance of colonial nearctic bats is determined largely by the availability of suitable roosts. High bat diversity characterizes areas where all types of roost structures occur and low bat diversity characterizes areas where some roost-types are missing. Northern dry-mesic forest has high roost availability and southern lowland forest low roost availability in southwest Wisconsin.

A large number of farm buildings are located throughout southwest Wisconsin contributing to the abundance of little brown bats. The abundance of this species probably leads to the exclusion of some other bat species, thus reducing overall bat abundance and diversity. Kunz (1973) found big brown bats most abundant in Boone county, Iowa, followed by red bats, Keen's myotis, silver-haired bats and little brown bats, respectively. He attributed the

abundance of big brown bats to man-made shelters near the sampling sites. Little brown bats are most abundant in southwest Wisconsin presumably for the same reason that big brown bats are most abundant in Iowa. Big brown bats and eastern pipistrelle abundance may be reduced in southwest Wisconsin due to competitive exclusion by little brown bats.

The high bat species diversity in northern dry-mesic and mesic forests (Table 1) may be due to the availability of roost sites other than man-made structures. Sandstone cliffs in these areas favor Keen's myotis. Tree-dwelling red bat and hoary bat abundance reflects the presence of trees providing necessary roosting requirements, as discussed by Constantine (1966). Mesic forests in general have a thick canopy which decreases reflected light from the forest floor and wind velocity within the forest (Curtis 1959). Both factors are important to tree-roosting bats. Southern xeric and dry-mesic forests show low relative abundance of tree-dwelling species.

Low bat species diversity in southern lowland forests is unusual since elms and maples are prevalent. Tree-dwelling bats in Iowa showed a preference for elms (Constantine 1966). The low diversity could be a product of my inability to capture foraging bats due to deep water or to an absence of overhead canopy along the Wisconsin River that allowed bats to avoid the nets.

Foraging diversities for southwest Wisconsin bats (Table 2) differ from those found for the same species in Iowa (Kunz 1973). Big brown bats and Keen's myotis had the highest foraging diversity indices in Iowa indicating broad habitat preferences. Red and hoary bats had lower indices indicating more specialized habitat preferences. Community composition and foraging distribution are influenced in part by factors relating to the proximity of roost sites. In southwest Wisconsin, little brown bats had the greatest foraging diversity index, followed by Keen's myotis, red bats, and big brown bats, respectively. The high index for little brown bats is due to this species' abundance, indicating broad habitat preferences. Little brown bats, Keen's myotis and big brown bats are "refuge species" (they occupy caves, man-made structures and trees) and exhibit broader preferences due to broader acceptances of various roost types (Kunz 1973). The lower foraging diversity index for big brown bats is probably again indicative of some competitive exclusion by little brown bats. Tree-dwelling species exhibit lower indices due to more specialized preferences. Lower indices for hoary bats and pipistrelles probably are due to the small sample size.

Table 2. Foraging<sup>a</sup> diversity indices for bats mist-netted May-August 1981, in southwest Wisconsin based on the relative abundance of habitat given in Table 1.

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<u>Species</u>	<u>Foraging Diversity H'</u>
Little Brown Bat	0.769
Keen's Myotis	0.643
Red Bat	0.600
Big Brown Bat	0.437
Hoary Bat	0.391
Eastern Pipistrelle	0.220

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$$a_{H'} = \sum_{i=1}^s P_i \log_{10} P_i$$

## Status

### Indiana bat (M. sodalis):

The Indiana bat was not collected during spring or late summer trapping at cave entrances, summer mist-netting, or the cave survey. Rupprecht (1980) did not encounter Indiana bats during a year-long bat trapping study at Neda Mine, the largest known bat hibernaculum in southeast Wisconsin. The absence of the Indiana bat from trapping samples in southwest and southeast portions of the state indicates this species normally does not use Wisconsin caves or mines for hibernation.

The absence of Indiana bats from summer mist-netting samples could be due to the difficulty in capturing this species, absence from the habitats sampled, or the uncommon occurrence of this species at the northern extreme of its range. Humphrey et al. (1977) stated that Indiana bats forage around tree crowns thus requiring special capture techniques. However, Kurta (1981) in southern Michigan, and Bowles (1981) in south-central Iowa captured Indiana bats using techniques similar to those employed in this study. In Indiana, this species forages primarily in flood plain and riparian trees and has established nursery colonies in shagbark and bitternut hickories (Carya ovata and C. cordiformis) (Humphrey et al. 1977). Most of these

tree species are prevalent in the study area, indicating summer foraging and breeding habitats are available in southwest Wisconsin. The probable reason for not collecting the Indiana bat in summer mist net samples is the scarcity of this animal from the northern limits of its geographic range. Indiana bats regularly return to their same hibernacula (LaVal and LaVal 1980), which accounts for the clumped and local distribution in Kentucky and Missouri. The energetic cost of flight is great (Kunz 1980); therefore long spring migrations to northern foraging areas in Wisconsin would not be advantageous, especially for heavy pregnant females. LaVal and LaVal (1980) surmised that Indiana bats did not fully utilize the available summer habitat in Missouri. Therefore, this animal is an unlikely summer resident in Wisconsin since it can exploit available local resources in Missouri and avoid long migrations between summer and winter habitats.

Indiana bats were not present due to unsuitable cave microclimate in southwest Wisconsin caves and mines. Caves with large overwintering Indiana bat populations in Kentucky and Missouri had  $T_w$  of 4-8 C (Humphrey 1978). Microhumidities were 75-100% in these caves, and no preference for humidities was exhibited among the bats.

Relative humidities in southwest Wisconsin caves were similar. However, low cave temperatures depend on strong air circulation and the occurrence of very large passages situated below and near the entrance (Tuttle and Stevenson 1977). Therefore, the outside climate and shape of the cave determine whether a cave's microclimate is suitable for hibernating Indiana bats.

The configuration of all 11 caves and mines in this study are unsuitable to trap cold air and keep cave air and wall temperatures between 4-8 C for the duration of the Indiana bat hibernation period. The Indiana bat is therefore an unlikely winter resident in southwest Wisconsin due to the animal's attachment to its established southern hibernacula and to the variable microclimate of Wisconsin caves and mines. Since the species is not established in Wisconsin hibernacula, it would not be expected to forage here in summer.

Little Brown Bat (M. lucifugus):

This bat was the most abundant species in southwest Wisconsin, which is similar to the findings of Jackson (1961), Long (1976) and Rupprecht (1980). A total of 523 individuals were captured during spring and late summer trapping. Females were more abundant than males in spring (Table 3), illustrating the differential departure strategy of the sexes after hibernation. The earlier female

Table 3. Numbers and relative abundances<sup>a</sup> of bats trapped at southwestern Wisconsin cave entrances during spring (7 April-7 May) and summer (13 August-18 September), 1981.

Species	N	Male		Female				
		Spring (44) <sup>b</sup>	Summer (56)	Spring (44)	Summer (56)			
Little brown bat	41	0.93	226	5.77	65	1.48	59	1.68
Keen's myotis	84	1.91	57	1.43	16	0.36	9	0.30
Eastern pipistrelle	24	0.32	51	1.75	10	0.23	14	0.33
Big brown bat	2	0.04	3	0.30		0.00	1	0.20
Total		3.20		9.25		2.07		2.51

<sup>a</sup>Computed by dividing the number of individuals of each species and sex by the number of trap hours per season.

<sup>b</sup>Number of trap hours per season

departure facilitates fertilization of the ovum and decreased competition for food between pregnant females and males (Rupprecht 1980). Increased bat abundance in late summer trap samples indicates the onset of fall swarming (Fenton 1969).

Summer mist-netting yielded 459 males and 380 females. This species was also the most abundant in all 6 habitat types (Table 3). Little brown bats are more abundant in rural areas than in undeveloped areas (i.e. areas without buildings or cultivated land). These animals use man-made structures (house attics, barns, sheds) and occasionally hollow trees for nursery colonies and roosts, and typically roost near water (Barbour and Davis 1969, Fenton 1970). Southwestern Wisconsin is predominantly rural with an abundance of man-made structures providing potential nursery colony and roosting sites for this species.

Little brown bats comprised 58.4% of the total number of bats counted in the cave survey. This animal has the largest range of body temperature known in vertebrates (Barbour and Davis 1969) making it capable of acclimatizing to habitats marginal or exclusive to other bat species (e.g., Indiana bats). Therefore little brown bats are widely distributed and successful throughout their range. McManus and Escher (1971) reported an optimum temperature preference of 2 C for little brown

bats in a New Jersey mine. Hibernating little brown bats in southwest Wisconsin were present at cave temperatures of 7-10 C. The adaptability of little brown bats to a wider hibernaculum temperature range (2-10 C) permits this species to occupy a larger number of potential hibernacula successfully (Hock 1960, Twente 1960).

Red Bats (Lasiurus borealis):

Red bats did not appear in trapping samples or in the cave survey since this species does not ordinarily use caves. Jackson (1961) and Long (1976) considered this bat to be the most abundant in Wisconsin's southernmost counties. Red bats ranked second in abundance during summer mist-netting, being most abundant in northern and southern mesic and northern dry-mesic forest situations (Table 1). Red bats prefer edge habitats where specific roost conditions are available (Constantine 1966). They tend to forage in groups over riparian, flood plain and upland forest, and over streams and rivers (LaVal and Laval 1979). Jackson (1961) observed this species foraging in the same area each evening approximately 600-1,000 yds from their day roosts. The tendency to forage in groups and near day roosts indicates aggregation in habitats with suitable conditions. The relative abundance in northern and

southern mesic and northern dry-mesic situations indicates that southwestern Wisconsin habitats are suitable for red bats.

Keen's Myotis (M. keenii):

This bat was more abundant in spring trap samples than pipistrelles although both species occurred in similar numbers during late summer trapping (Table 3). Rupprecht (1980) reported this species to be 3rd in abundance in southeastern Wisconsin. Jackson (1961) reported this bat to be rather scarce in the state and possibly more abundant in the north. The relative abundance during spring trapping coincides with its emergence from hibernation in mid-April which typically preceded little brown bat and pipistrelle emergence (Rupprecht 1980).

The prevalence of this species in northern mesic and dry-mesic forest habitats (Table 1) corroborates the observed tendency of this species to day roost in cliff crevices (Barbour and Davis 1969). Cliffs were adjacent to mist net sites in 4 of the 6 northern forest habitats sampled. The relative abundance of this species in northern habitat types also supports Jackson's (1961) contention that this species may be more abundant in the northern portion of the state. In Missouri this species forages predominantly among trees in hillside and ridge

forest as opposed to riparian and flood plain forest (LaVal et al. 1977). If this is true in Wisconsin, the relative abundance of Keen's myotis may have been underestimated in this study.

Keen's myotis comprised only 2.7% of the bats counted in the cave survey. The number could be low due to difficulties in distinguishing this species from little brown bats at a distance or in clusters, and its tendency to crawl into cave crevices during hibernation (Caire et al. 1979) where it can easily be overlooked. However, Barbour and Davis (1969) state that this species is never abundant and irregularly distributed in caves.

#### Big Brown Bat (Eptesicus fuscus):

Big brown bats were least abundant in trap samples (Table 3). Big brown bats enter hibernation after the onset of freezing temperatures in late fall, and emerge in late March or early April (Rupprecht 1980). Trapping in late summer ceased before a large influx of big brown bats occurred, and commenced in spring after many had already left the caves.

Big brown bats ranked 4th in relative abundance during summer mist-netting. This species is extremely common around the habitations of man. It favors roosts in human dwellings and typically does not feed more than several hundred yards from its roosts (Barbour and Davis

1969). Therefore, it is not abundant in remote areas. Eighty-three percent of the big brown bats captured in northern dry-mesic forest were mist-netted at a single location. This site was near a small farm where big brown bats were probably roosting. Mutual exclusion has been noted between big brown bats and little brown bats in nursery colonies (Humphrey 1975). The low abundance of big brown bats from the study area could be due to competition with more abundant little brown bats.

Big brown bats comprised 20.1% of the bats counted in caves. Populations in 2 caves accounted for 82% of the number of big brown bats encountered during the winter. Bats were tightly clustered in groups of 60-100 individuals in areas where temperatures were 0-3 C. These bats were typically found near entrances to caves but were occasionally found hanging singly in the cave interior.

Eastern Pipistrelles (Pipistrellus subflavus):

This species ranked 3rd in trap samples (Table 3). Pipistrelles are the smallest bat species in Wisconsin and enter hibernation early in the fall before food resources are depleted or the first autumnal frost (Rupprecht 1980). Early entrance into, and a delayed exit from, hibernation allows this small-bodied species to minimize the chances of encountering freezing weather and periods of low food availability.

Pipistrelles ranked only 5th in summer mist net samples. This species is typically solitary and forages in small areas around large trees (Barbour and Davis 1969). The pipistrelles' low observed abundance may be a product of its solitary habits and restricted foraging areas. Davis and Mumford (1962) stated that pipistrelles are uncommon or absent from regions where little brown bats are abundant. The abundance of little brown bats could account for the low pipistrelles population in southwest Wisconsin.

Pipistrelles hibernate with other species in southwest Wisconsin caves. This species accounted for 18.7% of total winter bat numbers. Pipistrelles were typically found hanging singly in warmer cave regions where temperatures were between 8-12 C. They prefer warm cave temperatures due to its small body size. (McNab 1974).

#### Hoary Bat (Lasiurus cinereus):

This migratory species, like the red bat, does not overwinter in Wisconsin. The summer abundance of hoary bats was lowest of the 6 species collected (Table 2). Barbour and Davis (1969) report sexual segregation throughout most of the summer range; however, 4 males and 5 females were captured together in southwestern Wisconsin. A male and female were captured in the same evening on 2 occasions. Hoary bats were most abundant in northern

dry-mesic forest although conclusions regarding habitat preference are difficult due to small sample size. Hoary bats prefer roosting conditions similar to those of red bats (Constantine 1966). The preference for northern dry-mesic forest by red bats may indicate a coincident preference for this habitat type by hoary bats (Table 1).

#### Cave Survey

The presence of winter hibernacula, in addition to summer roosts and foraging areas, influences bat distribution (Humphrey 1975). Little brown bats, Keen's myotis, big brown bats, and eastern pipistrelles comprise the hibernating bat species in southwest Wisconsin caves and mines. The suitability of 11 of these caves and mines as winter bat hibernacula was assessed in 1981.

Cave temperature and relative humidity determine the distribution of bat species in area caves. Entrance size, number and position of entrances, passage size, contour and slope, overall cave volume, distance of greatest volume from entrances, amount and seasonal timing of entry of surface water, air flow and annual range of outside temperature strongly affect cave temperature and relative humidity (Tuttle and Stevenson 1977). Caves isolated from outside influences will assume a cave temperature closely approximating the mean annual surface

temperature (MAST) of the particular geographic region. A MAST between 2-12 C provides cave microclimatic conditions suitable for winter hibernacula but not for summer bat use (Tuttle and Stevenson 1977). The MAST in southwest Wisconsin was 8.2 C for 1981 (U.S. Dept. Commer. 1981). Deviations from MAST in a cave environment result from air exchange with the outside environment. Relative humidity was between 90-100% in all caves and mines in the study area and is not considered to be a limiting factor for hibernating southwestern Wisconsin bats.

The results of the cave survey are grouped into 3 categories: 1) abandoned lead mines, 2) caves with total winter populations of greater than 200 bats, 3) caves with total winter population of less than 200 bats. Cave air temperature trends in the 3 categories and their relation to MAST are presented in Figure 2.

Three Lafayette county mines are representative of the 1st category. The configuration of these mines promotes air flow leading to greatly fluctuating cave air temperatures (Fig. 2). Large passage size, presence of 2 entrances introducing an air cross-flow, smooth wall contours, and lack of structural diversity and air baffles all increase air movement through the mines. This air exchange causes instability of cave air and wall temperature. Big brown bats are the only hibernating bat

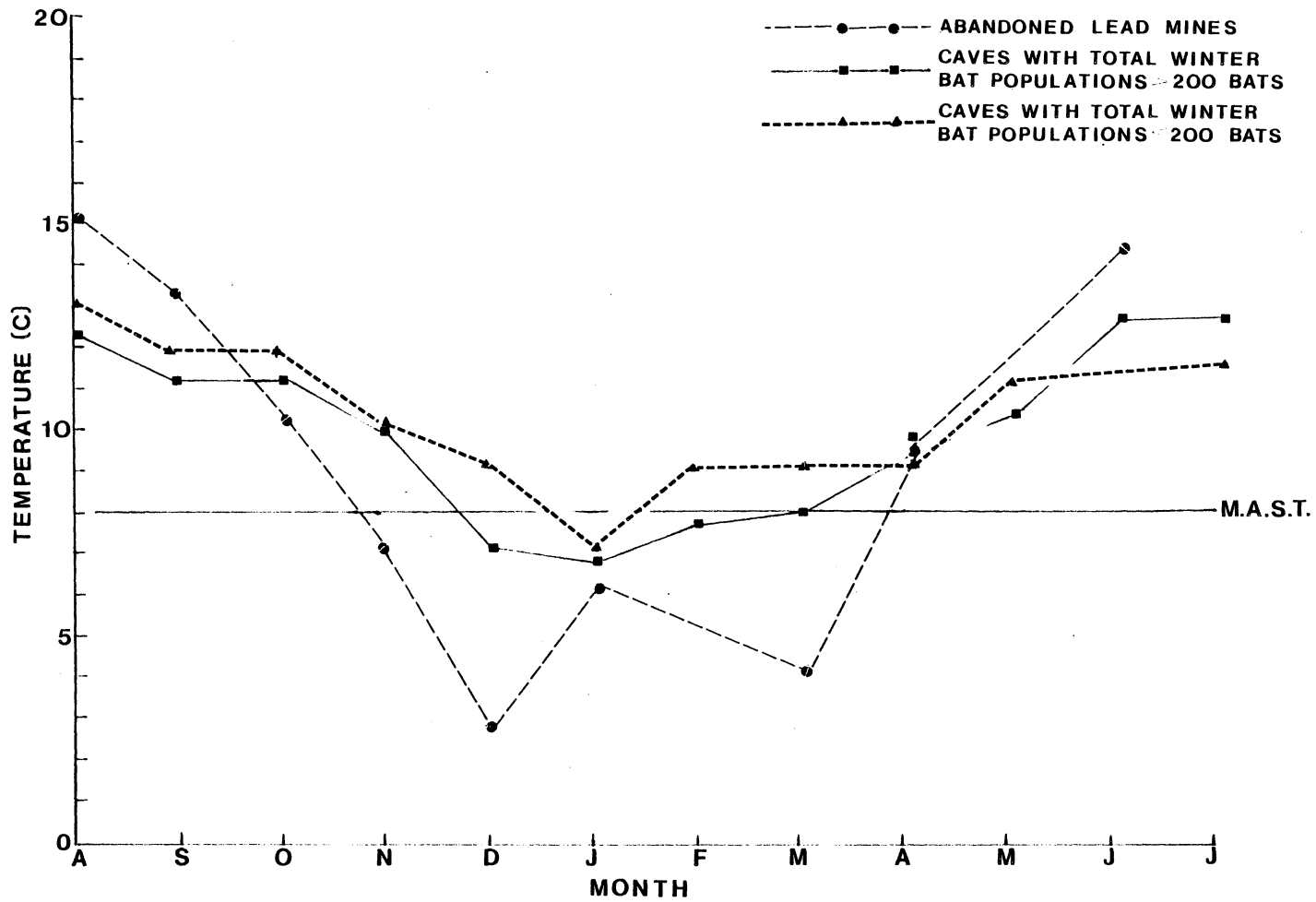


Fig.2. Mean monthly cave air temperatures for 11 southwestern Wisconsin caves and mines, 1981.

species in Wisconsin which can withstand the cool temperatures in these mines. An occasional pipistrelle was found in 1 mine where air flow was minimized and temperatures were warmer. The unstable cave temperatures make these 3 mines largely unsuitable for hibernating bats with the exception of big brown bats.

Natural caves, in general, differ from the mines in having less variable cave temperatures, a smaller single entrance, smaller and more varied passage size, uneven walls, varied slope, more structural diversity and greater length. These factors contribute to minimizing cave air flow and stabilizing cave temperatures near MAST. Surface water enters caves in the form of percolating groundwater which drips from the ceiling and forms shallow pools in many of the caves. Surface water entering the cave environment in this way exerts little influence on cave temperature since it is brought into thermal equilibrium with the cave walls as it percolates through the rock.

Four caves contained significant winter bat populations, in southwestern Wisconsin, in 1981 (Fig. 3). Bats use these caves because the cave temperatures approximate or drop below MAST and thus provide bats with a temperature range which provides physiological advantages for hibernation. Cave structure differs in each of the 4 caves but each has characteristics that reduce air flow and make the cave suitable for overwintering bats.

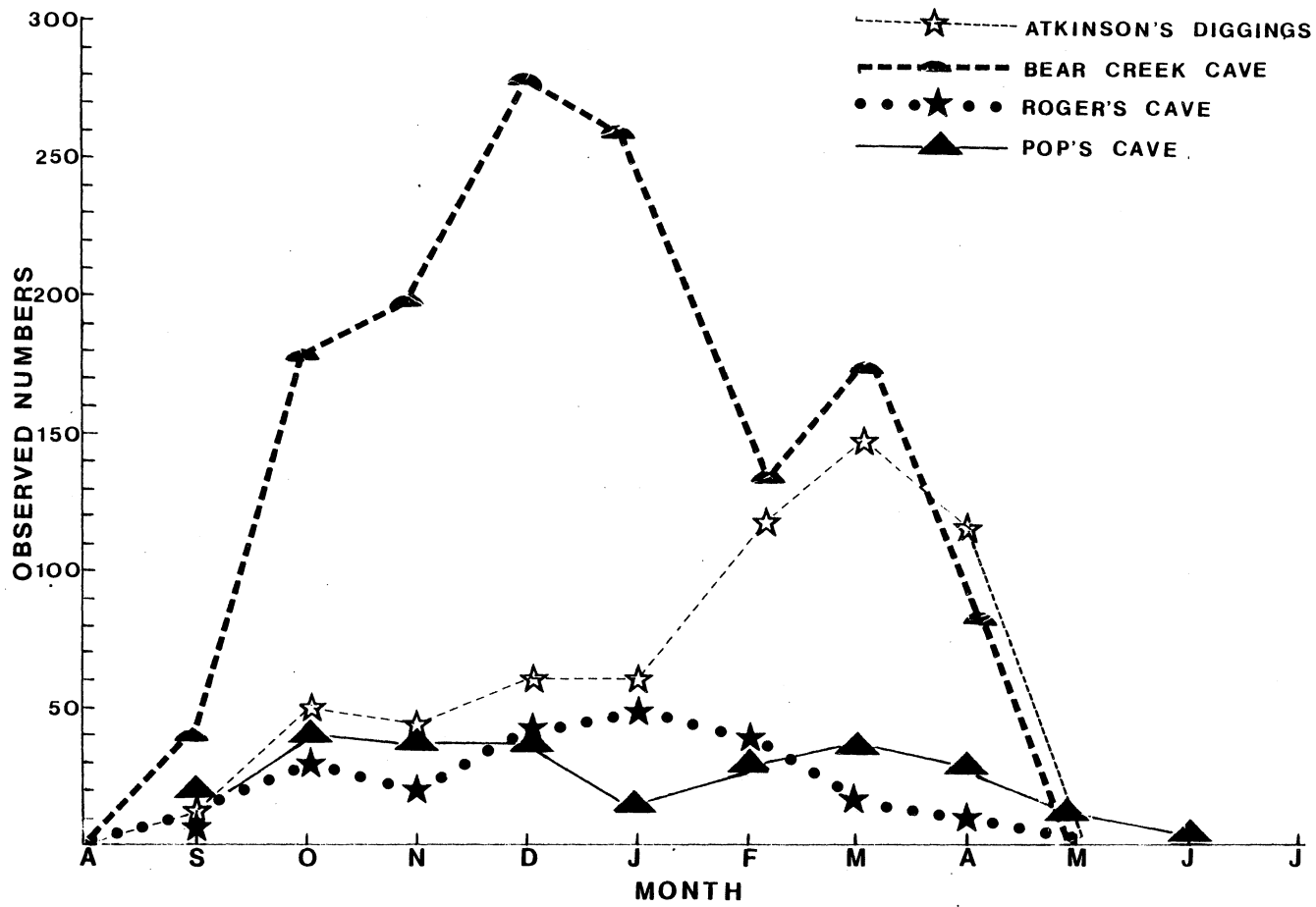


Fig. 3. Numbers of bats in southwestern Wisconsin caves, 1981.

Atkinson's Diggings, Grant County, is the abandoned lead mine where the Indiana bat was previously found (Davis and Lidicker 1955). This mine has 2914 m of passage with numerous shafts to the surface. Only a portion of the mine was surveyed during this study. The large number of passages and small crawl-spaces provide structural diversity and reduced air flow allowing bats to find different temperatures to suit various physiological functions during hibernation, i.e., conserving energy reserves and timing ovum fertilization (Racey 1969). Cave temperatures near the entrance were between 0-10 C and between 7-11 C farther into the cave. Clusters of bats rarely occurred in Atkinson's Diggings due to higher cave temperatures.

Bear Creek Cave, Sauk County, is a unique situation in southwestern Wisconsin. This cave is owned by The Nature Conservancy and is gated to prevent human entry but allow unimpeded passage of cave animals. Opened by quarrying operations in 1954, this cave had a bat population of >150 bats in 1975 (Ehr 1976). In December 1981, the population was 280 bats.

Air flow into this cave is minimal due to the small entrance, constricted cave passages and large rocks which obstruct air flow along the cave floor. The mean cave air and wall temperatures were between 6-12 C and 7-11 C respectively, for the interior portion of the cave. The

entrance passage ( $T_w = -1.5-5.0$  C) supports the largest overwintering population of big brown bats encountered in this study. Cave wall temperatures in the 2 rooms containing the majority of the bats were 7-12 C.

The large change in bat numbers between December and March (Fig. 2) could indicate movement of bats out of the cave or into cracks and crevices where they escaped detection. The decline in bat numbers in Bear Creek Cave corresponds to a rise in bat numbers at Atkinson's Diggings; however, bats were not marked to detect intercave bat movement.

Roger's Cave, Iowa County, has an initial downward slope from the entrance allowing cold air to flow in and become trapped. Overall cave air and wall temperatures were thus cooler ( $T_a = 7-11$  C,  $T_w = 7-10$  C) than in Bear Creek Cave and Atkinson's Diggings. The single entrance, and a passage constriction between the first 2 rooms, inhibits air flow and reduces cave temperature fluctuations. Bat numbers are significantly lower than in Bear Creek Cave and Atkinson's Diggings (Fig. 3) due to reduced cave temperature range and smaller cave size.

Pop's Cave, Richland County, is a sinkhole cave with front and back sections. The front section declines steeply from the entrance to a large room providing cooler cave temperatures similar to Roger's Cave. A small

passage separates front from back and restricts air flow between the 2 sections. Cave air and wall temperatures differed by 1 C between front and back sections from November-March, 1981. The front section was cooler ( $T_a = 6.0-11.5$  C,  $T_w = 6.5-10$  C) than the back section ( $T_a = 7.0-10$  C,  $T_w = 7-10$  C). Little brown bats and pipistrelles moved from the front section to the back section or moved out of the cave from October-December, 1981. No little brown bats were found in Pop's Cave in January, 1981, thus there was a decrease in the total bat population (Fig. 3).

The 3rd category consists of 4 caves with features limiting suitability as bat hibernacula. Haines Cave, Crawford County, was the warmest cave in the study ( $T_a = 10-14$  C,  $T_w = 9-13$  C). This cave lacks the structural diversity to provide a temperature range conducive to hibernating bats. Cave temperatures in the single large room were consistently between 10 and 12 C. The warm cave temperatures and lack of structural diversity accounts for only 1 bat being observed in Haines Cave during this study. Bogus Bluff Cave, Richland County, is situated on a Wisconsin River bluff, has 3 entrances, smooth contour walls and near absence of air baffles leading to a strong air flow throughout the year. Cave air and wall temperatures showed wide fluctuation

( $T_a = 5-16$  C,  $T_w = 7-14$  C). Strong air flow influences cave temperatures and is a desiccating factor for hibernating bats (Tuttle and Stevenson 1977). Bogus Bluff cave lacks the structural diversity to provide bats with a refuge from the strong air flow hence only a small number of transient bats were observed. Star Valley Cave, Crawford County, is a sinkhole cave with 2 branches. This cave is susceptible to an inflow of surface water during spring melts and fall rains. Portions of the main branch have standing water and an interior room can become completely flooded. Surface water may affect cave temperature but cave air and wall temperature fluctuates little during the year ( $T_a = 8-12$  C,  $T_w = 7-11$  C). Air flow is restricted due to turns and constrictions in the cave passageway. A small cluster of Myotis spp. was observed during the winter but was too high for identification. Star Valley Cave apparently could support a larger bat population. Boscobel Bear Cave is a sinkhole cave with steep descent into the cave's large main room. Temperatures along the floor of the large room were 1-2 C cooler than temperatures in an elevated back passage. The large room and back passage are connected by small 0.3 x 0.3 m crawl spaces which limit airflow. Eastern pipistrelles were found near the ceiling of the large room and in the back passage where temperatures

were probably warmer. Several little brown bats were seen near the floor of the large room.

### Questionnaire

Questionnaire results are summarized in Table 4. The questionnaire return percentage, visit duration and number of people per visit indicate extensive human cave use during the bat hibernation period, with the exception of Bear Creek Cave (no responses). Questionnaire results and observations indicate human cave use is detrimental to southwest Wisconsin cave environments. Three of the 8 caves showed no evidence of use as party sites. Bear Creek Cave is gated, Roger's Cave is located near the landowner's home, and Pop's Cave, a state scientific area, is regularly cleaned up by the WSS. The remaining 5 caves showed a great deal of use as party sites. Graffiti on cave walls, presence of beer cans and bottles, theft of questionnaire containers from 2 caves, profanity written on questionnaires, and the discovery of a bat sealed in a plastic film container indicate the use of these caves by individuals with little regard for the cave environment or inhabitants.

Although Pop's Cave showed no signs of use as a party site, a cave register positioned at the entrance indicated that it had hundreds of monthly visitors. The presence of humans near hibernating bats can cause the bats to

Table 4. Factors characterizing human use of southwest Wisconsin caves determined by voluntary questionnaire and observation from October 1981 to April 1982.  
(Number of questionnaires placed at each cave in parentheses.)

Cave	Number Questionnaires Returned	Return (%)	Duration of visit ( $\bar{x}$ hrs)	People per visit	Affiliated with caving organization (%)	Observed signs of use
Atkinson's Diggings (25)	20	80.0	5.8	7.3	15.0	flourescent graffiti, discharged .22 shell, refuse present
Pop's Cave (50)	7	14.0	5.0	5.7	28.0	cave register
Haine's Cave (25)	11	44.0	2.4	6.4	63.0	refuse present
Bogus Bluff Cave (25)	15	60.0	1.7	4.7	27.0	well defined trail to cave, refuse present, fire remains at entrance, graffiti
Roger's Cave (25)	2	8.0	3.0	4.0	100.0	
Star Valley Cave (50)	2	4.0	2.0	4.5	0.0	graffiti (1914 to present) refuse present, fire remains
Boscobel Bear Cave (25)	2	8.0	2.0	4.0	50.0	refuse present, used cans of camping fuel, graffiti

arouse from hibernation which is detrimental to the animal. The Star Valley Cave landowner estimated human cave use at 40-50 people/month in summer and 10-20 people/month in winter. This amount and type of use in winter would adversely affect hibernating bats and may be a major reason for few bats overwintering in this cave.

#### MANAGEMENT IMPLICATIONS

Southwestern Wisconsin bats may be experiencing population reduction due to an increased demand for wood as fuel and to improved home energy efficiency which decreases available summer roosts and foraging areas. New architectural styles, energy efficient homes, and extensive logging have eliminated most potential little brown bat roost sites in Indiana and Kentucky which has caused a decline of little brown bat populations in these states (Humphrey and Cope 1976). Improved home energy efficiency and cutting of woodlots for fuel and for pasturage is common in southwest Wisconsin. Without appropriate roosts, bats will not inhabit an area (Humphrey 1975). Henshaw (1972) maintains that bats are incapable of recovering from decimation due to their inability to adapt quickly to a changing environment.

Winter hibernacula are important to "refuging bat species" (Kunz 1973). Southwest Wisconsin has many

available caves and mines although many of them are inappropriate for overwintering bats. Caves found to contain overwintering bat populations also showed human use during the bat hibernation period. Bear Creek Cave showed the least human activity and the largest bat population. Significant overwintering bat populations can be sustained only if hibernaculum conditions are suitable and human disturbance is eliminated during the hibernation period (October-April). The microclimatic conditions in Bear Creek Cave are similar to other caves with fewer bats in the study area. If Atkinson's Diggings, Rogers Cave, Pop's Cave and Star Valley Cave were afforded protection similar to Bear Creek Cave they might support large bat populations. Lack of data makes determination of former southwestern Wisconsin hibernating bat populations difficult. Cave conditions limit bat use in some cases. However the amount of human cave use during the bat hibernation period may be a major cause for the small bat populations in southwest Wisconsin caves.

Gating and fencing cave entrances are the most effective means of eliminating human disturbance, but gate construction must be carried out carefully (LaVal and LaVal 1980, Tuttle 1979). Erection of informative sign posts describing the vulnerability of overwintering bats may also deter human winter cave visitors. Cooperative

agreements between government agencies and private landowners can be used to restrict access to caves during critical periods. Public education is an integral component of bat management. Government officials and private citizens must be made aware of the ecological significance of bats. Bat disease problems should be put in perspective. The prevalence of rabies infection in unbiased samples is typically 0.05% or less in some regions (Constantine et al. 1979); therefore the role of bats as rabies vectors is exaggerated in many cases.

Bat survival depends upon summer and winter roost preservation and protection. Wisconsin protects only federally endangered species and affords no protection to the other bat species. Increasing or sustaining Wisconsin bat populations can be achieved only by habitat preservation and public education.

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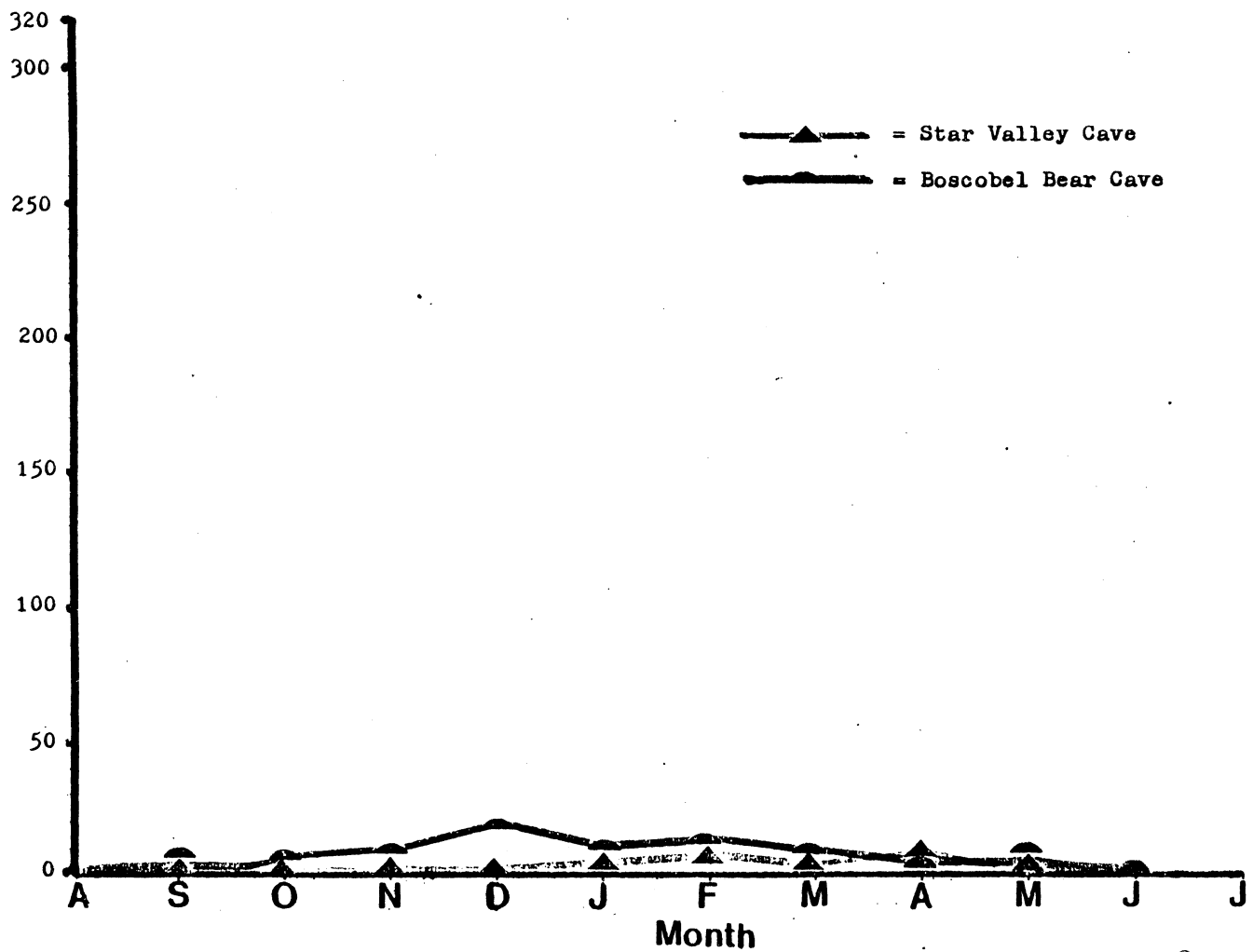
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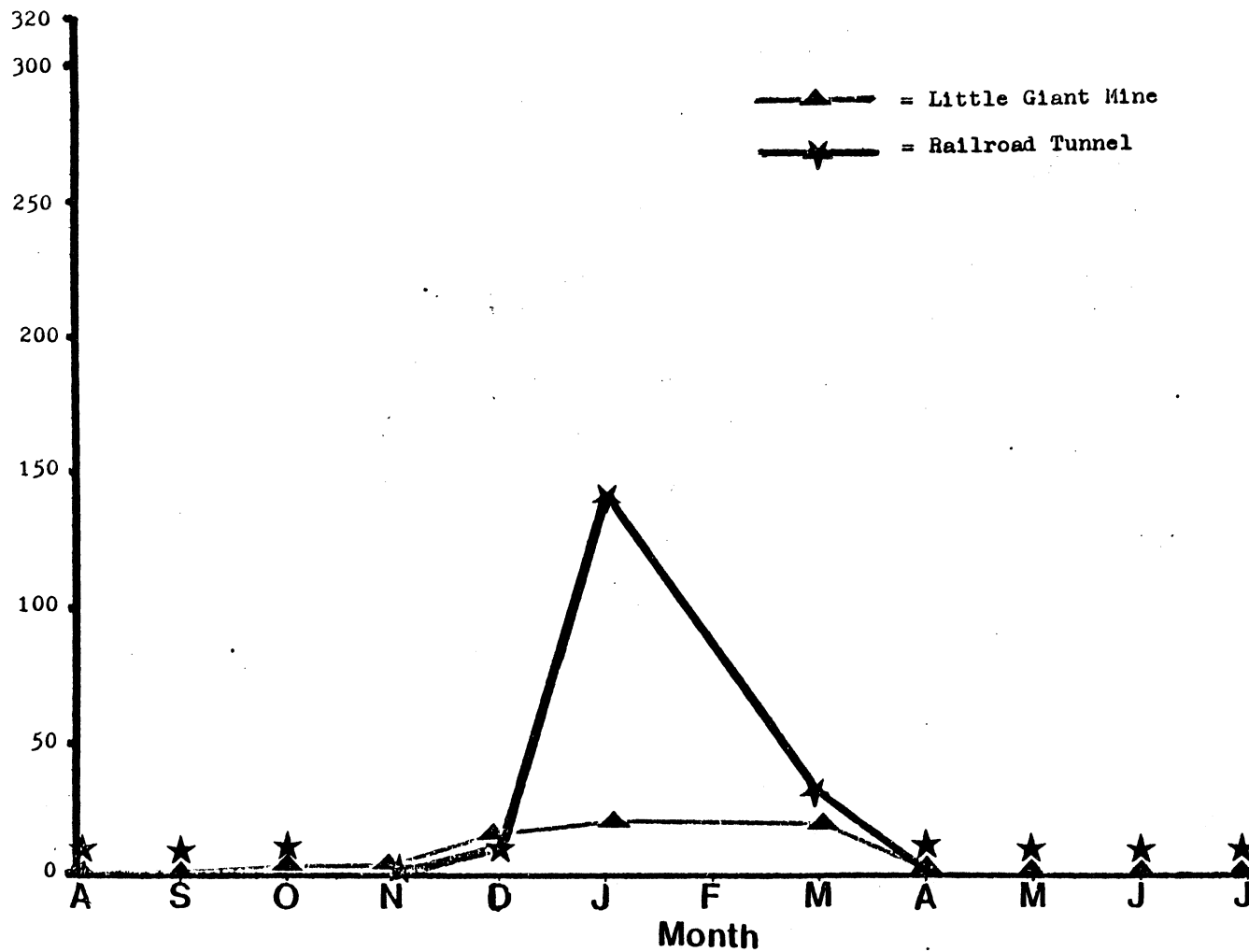
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## **APPENDICES**



Appendix 1. Number of bats in southwestern Wisconsin caves, 1981.



Appendix 2. Numbers of bats in southwestern Wisconsin caves, 1981.

Appendix 3. Profile of physical parameters in southwestern Wisconsin caves and mines, 1981.

Little Giant Mine

Cave temperature range: Wall ( $\bar{x}$ ) = 3.5-16°C  
Air ( $\bar{x}$ ) = 4.0-17°C

Entrance: Size = 5 ft x 6 ft  
Number = 2 (slight elevational difference)  
Position = SE, S (built into hill, no preceding vegetation, protected by hill to north, unprotected from south. Preceded by rubbish heaps and mine rubble.)

Passage size: 5 ft-37 ft wide  
6 ft-13 ft high

Mine length: 470 ft (153.3 m)

Contour: Passages straight, on one level, all interconnected without air baffles. Walls relatively smooth. Perpendicular passages upthrust from main passage (4-5 ft)

Slope: Level

Amount and timing of surface water entry: Rear portion of mine flooded by groundwater. Floor of mine dry, little or no water on walls.

Air flow: Size and smooth contour of passages, presence of 2 entrances introducing a cross-flow of air, facilitate large amounts of air movement. Small size of mine, lack of air baffles and large flow of air do not allow  $T_a$  and  $T_w$  to stabilize in mine.

Comments: The large temperature range ( $T_a$  and  $T_w$ ) indicates a large flow of air through the mine throughout the year. Monthly mean  $T_a$  and  $T_w$  from March to April increase 4.8°C and 3.4°C respectively and between November and December  $T_a$  and  $T_w$  decreased 4.5°C and 3.5°C respectively. RH is sufficient to maintain the water balance in bats although it only reaches upper 90's-100% in the back portions of the mine where an occasional pipistrelle was found. Big brown bats were found in exposed areas near the entrance, pipistrelles were found further back in perpendicular cross cuts where air flow minimized.  $T_a$  and  $T_w$  fluctuated every month of the survey. January, February, May and June readings not taken.

Galena Level Mine

Cave temperature range: Wall ( $\bar{x}$ ) = 6.0-12°C  
 Air ( $\bar{x}$ ) = 5.0-14°C

Entrance: Size = 11 ft x 6 ft (partially blocked by rubble)  
 Number = 1  
 Position = SE (Entrance preceded by cut into hillside which is overgrown with vegetation. Shaft from top of hill intersects passage within 40 ft from entrance.)

Passage size: 11 ft-56 ft wide  
 6 ft-11 ft high (In large room and in east passage passage height greater.)

Mine Length: 800 ft (243.8 m)

Contour: Passages straight or with slight curves, on one level, all interconnected. Large room had many stone pillars and old rotted pilings. Walls smooth.

Slope: Initially downward to level

Amount and timing of surface water entry: Puddles formed from ceiling seepage and in places floor was soft and mucky. Back passage flooded.

Air flow: Fluctuation in temperature indicates large air flow.

Comments: Only 1 pipistrelle was found in mine on 8 visits in 1981. Temperature fluctuation not as great as in Neighbor Mine and Tailroad Tunnel because of lack of second entrance.  $T_a$  and  $T_w$  fluctuation from March to April was 2.7°C and 1.2°C respectively.

Railroad Tunnel

Cave Temperature range: Wall ( $\bar{x}$ ) = 2.0-15.0°C  
 Air ( $\bar{x}$ ) = 0.0-15.0°C

Entrance: Size = 15 ft x 21 ft  
 Number = 2  
 Position = E and W (the W entrance had preceding cut into hillside)

Passage size: Main tunnel = 15 ft x 21 ft x 535 ft (WxHxL)  
 North room = 80 ft x 5 ft x 123 ft  
 South room = 74 ft x 6 ft x 138 ft

Contour: Main passage walls smooth. Several large rubble piles inside mine, largest laying near center of main passage and coming to within 3 ft of ceiling. N room almost circular with series of pillar near center. Tunnel off N room straight and without baffles. S room large and low ceiling. N and S room entrances largely covered with rubble making openings smaller.

Slope: Uneven, due to rubble pile.

Amount and timing of surface water entry: Ceiling seepage. Large puddles formed in N and S rooms. Much of floor area covered by water in S room by end of 1981. Main passage dry excepting for ice stalagmites in winter near W entrance.

Airflow: In main passage airflow great due to size of entrance and passage. Air flow detectable where rubble pile causes constriction. No bats present in main passage due to large fluctuation of temperature and airflow. Airflow in N and S rooms restricted due to rubble blocking entrance. Dual entrance to each room could allow for cross-flow of air and air circulation to occur. Bats found in Railroad Tunnel were big brown bats. Bats were found in the same position from month to month, in a depression in the ceiling. Bats clustered greatly in January, but largely dispersed by March. Big brown bats only bat that can withstand rapid and large changes in cave microclimate. The bats buffer themselves somewhat via clustering in a depression.

Adkinson's Diggings

Cave temperature range: Wall ( $\bar{x}$ ) = 7.0-13.0°C  
 Air ( $\bar{x}$ ) = 7.0-13.0°C

Entrance: Size = 5 ft x 8 ft  
 Number = 1 known (According to mining diagram  
 10 openings to mine)  
 Position = SW (Entrance at base of N-S trending  
 ridgeline approximately 20 ft above  
 valley floor. Entrance preceded by  
 long valley through which a stream  
 runs.)

Passage size: 4 ft - 10 ft wide  
 4 ft - 20 ft high

Mine length: 9561 ft (2914.3 m)

Contour: Passage walls smooth. Mine fill restricts air  
 flow. Many branch passages, low crawlspaces  
 making a complex layout.

Slope: Level

Amount and timing of  
 surface water entry: Water entering cave in form of  
 ceiling seepage. No puddles or  
 streams of water down walls found  
 except at 1 location in the mine.

Air flow: Appeared minimal.

Comments: Large number of branch passages and small  
 crawlspaces provide structural diversity and  
 reduced temperature fluctuations due to decreased  
 air flow. In January  $T_a$  ranged from 4.0-9.0°C,  
 and  $T_w$  = 5.0-9.0°C, where little brown bats  
 were found.  $T_a$  ranged from 7.0-9.0°C, and  $T_w$  =  
 7.0-9.0°C where pipistrelles were found. Very  
 little bat clustering occurred presumably  
 because of higher cave temperatures than those  
 found in Kentucky by Henshaw and Folk (1966).  
 They found  $T_a$ , in places of permanent bat clustering,  
 to drop from 11°C (September) to 3°C (February)  
 and rise to 8°C (May). They found no bats  
 hanging 50 ft further into the cave where  $T_a$  was  
 consistently warmer at 7-10°C.

In January, February, and March predominantly  
 more bats found further into the cave. An  
 occasional big brown bat was found in the caves  
 warmer interior. A total of only 7 big brown  
 bats were found in Adkinson's Diggings throughout

Adkinson's Diggings (continued)

Comments: the study. Pipistrelles were found at  $T_a$  and  
(Cont.)  $T_w$  as low as  $4.0^{\circ}\text{C}$ , but were typically found at  
higher temperatures of  $8.0-11^{\circ}\text{C}$ . Keen's myotis  
was scarce but as progress towards spring  
(March and April) detect more because more  
became noticeable as the time of emergence  
approaches. Keen's myotis found at  $T_a$  and  $T_w$   
of  $5.0-11^{\circ}\text{C}$  but at cooler temperatures ( $5.0-^w$   
 $8.0^{\circ}\text{C}$ ) in February, March and April. Little  
brown bats most abundant followed by pipistrelles,  
Keen's myotis and big brown bats respectively.

Bear Creek Cave

Cave temperature range: Wall ( $\bar{x}$ ) = 7.0-11°C  
 Air ( $\bar{x}$ ) = 6.0-12°C

Entrance: Size = 2 ft x 2 ft  
 Number = 1 (Barred entrance only one used significantly by bats thus only entrance considered.)  
 Position = W (Located at base of vertical cliff made by quarrying operations.  
 Approach to cave entirely open without vegetation.

Passage size: Irregular, varied.

Cave length: 950 ft (289.6 m) of passage

Contour: Uneven, large broken blocks in big room.  
 Passages into big room, Leprechaun's Ballroom and Flat Room small and low. Breakdown in Big Room makes floor very uneven. Breakdown and formations in Junction Room leave small connecting passage. Big Room up to 12 ft in height. Leprechaun's Ballroom with formation has ceiling height of 7 ft, Flat Room ceiling height 2-3 ft. Solutional domes found in Flat Room and Cleo's Dome.

Slope: Slightly downward.

Amount and timing of surface water entry: The cave is very damp throughout the year with water dripping from the ceiling. In Leprechaun's Ballroom puddles form and vary in size from season to season being largest in winter, driest in autumn. Flat Room is drier than the rest of the cave except near the back of the first portion where puddles found.

Air flow: Minimal. Single entrance, constrictions in cave passage, and breakdown impede airflow. Small size of entrance does not allow for great exchange of air, therefore temperature range within cave fairly stable.

Comments: Entrance passage supports largest wintering population of big brown bats encountered due to proximity to outside air and subsequent cold temperatures. Most of bats found in Big Room and Leprechaun's Ballroom. T<sub>a</sub> in Big Room ranged from 7-14°C and in Leprechaun's Ballroom

Bear Creek Cave (Continued)

Comments: 7-10.5°C.  $T_a$  in the Flat Room was 9-11°C  
(cont.) presumably too warm to support many bats  
although most of the pipistrelles were found in  
this room. Bats seem to prefer  $T_a$  and  $T_w$   
between 7-10°C.

Roger's Cave

Cave temperature range: Wall ( $\bar{x}$ ) = 7.0-10.0°C  
 Air ( $\bar{x}$ ) = 7.0-11.0°C

Entrance: Size = 5 ft x 4 ft  
 Number = 1  
 Position = S (Entrance sloped into entrance room.  
 Entrance located on top of knoll in  
 valley at base of bluff.

Passage size: Variable

Cave length: 720 ft (219.4 m)

Contour: Cave elongate with relatively uniform passage.  
 Rooms progress one into another. Two minor  
 branches. No significant widenings or large rooms.

Slope: Initially from entrance slopes down. Levels out  
 with first room and drops only slightly by the end  
 of the cave.

Amount and timing of  
 surface water entry: Surface runoff drained into the  
 entrance room making mud wet and  
 slippery. In April  $T_a = 9.8$  C in  
 entrance room possibly due to influence  
 of this surface runoff. Remainder of  
 cave appeared dry although sound of  
 dripping water could be heard without  
 apparent cause. Last room had small  
 puddle and floor was wet and slippery.

Air flow: Initial downward slope causes cold air to flow  
 in along floor and become trapped thus this cave  
 acts as cold air trap, therefore  $T_a$  and  $T_w$  are  
 cooler than Bear Creek Cave and Beeton Mine.  
 Constriction between first room and entrance  
 room favors low exchange of air. Upper passage  
 did not harbor any bats presumably because it  
 was warmer. Lack of another entrance and small  
 crawlway at the beginning of the cave also  
 restrict air exchange and flow.

Comments: Presumably smaller number of bats present  
 indicative of small cave size and lack of large  
 temperature range. Little brown bats found  
 between 8.0-10°C. Pipistrelles found at warmer  
 temperatures early in season but found at both  
 warmer and cooler temperature near end ( $T_a =$   
 5.0-9.0°C) January-April, Keen's myotis observed  
 often wedged into cracks.

Bogus Bluff Cave

Cave temperature range: Wall ( $\bar{x}$ ) = 7.0-14°C  
 Air ( $\bar{x}$ ) = 5.0-16°C

Entrance: Size = 3 ft x 4 ft (for all 3)  
 Number = 3  
 Position = S, E, W (Cave located atop bluff overlooking the Wisconsin River. Little vegetation blocking entrance in form of red cedar trees, otherwise open.)

Passage size: Fairly uniform throughout (4 ft wide with height variable.)

Cave length: 640 ft (195.1 m)

Contour: Passages connect all 3 entrances. Passage width uniform, but passage height variable usually low crawlspace. Approximately halfway through the cave is baffle provided by 1 ft high constriction.

Slope: Level

Amount and timing of surface water entry: Cave dry except in the last third which contains a few small puddles and in which the floor is often wet and slippery. Presumably water came in from percolating rain water.

Air flow: Three entrances, relatively even contoured walls, near absence of baffles, level slope, and position of cave on bluff contribute to flow of air quite noticeable to the touch.

Comments: Presumably airflow accounts for wide fluctuation in  $T_a$  and  $T_w$  and for lack of bats found. Strong airflow not only influences temperature but acts as a dessicant to hibernating animals. The bats that were found were found up in solutional pockets above the passageway where effects of airflow was minimal. Except for mines which have considerably larger passages and wider temperature fluctuations (except for Galena Level Mine) Bogus Bluff Cave represents the highest variability of microclimate in this study.

Pop's Cave

Cave temperature range: Wall ( $\bar{x}$ ) = 6.5-10°C  
 Air ( $\bar{x}$ ) = 6.0-12°C

Entrance: Size = 15 ft x 3 ft  
 Number = 1  
 Position = N (Sinkhole at top of hill. Surrounded by vegetation. Evergreen stand on north side and assorted shrubbery on east, west and south sides.)

Passage size: Variable (Wide in beginning, narrowing severely to crawlspace and then widening again.)

Cave length: 645 ft (196.6 m)

Contour: Entire floor of cave consists of breakdown. Approximately a third through the cave a small crawlway is encountered. Cave consists of uneven floors, ceilings and walls. Shape of cave generally a "Y".

Slope: Descending near entrance, rising near back of cave.

Amount and timing of surface water entry: Since Pop's Cave is situated atop a hill entry of surface water is from percolation and not from groundwater. The cave is damp and the floor and ceiling wet throughout the year. Some runoff enters the cave via the entrance but does not extend very far. Puddles found in rear portion of the cave.

Air flow: In front portion of cave decline from entrance is steep providing conditions favorable for a cold air trap. Small constriction separating front and back provides baffle to movement of air; rise in floor before reaching constriction also provides conditions favoring cooler temperatures in front portion.

Comments: Temperature data for November-March 1981 shows 1°C difference (at least) for  $T_a$  and  $T_w$ . April-October front and back portions  $T_a$  and  $T_w$  similar presumably because outside air mass coming into cave is warmer. Back portion consistently  $T_a$  = 9-11°C,  $T_w$  = 9-10°C. From October-December get shift of pipistrelles and little brown bats to back portion of cave or out of cave. December and January big brown bats found near entrance. In January 1981 no little brown bats found but October - December little brown bats were almost equal in numbers to pipistrelles.

Haines Cave

Cave temperature range: Wall ( $\bar{x}$ ) = 9.0-13°C  
 Air ( $\bar{x}$ ) = 10.0-14°C

Entrance: Size = 3 ft x 3 ft  
 Number = 1  
 Position = S (Not protected by vegetation.  
 Situated atop a hill in middle of low  
 pasture. Entrance to cave descends  
 steeply into sinkhole. Opening into  
 large room (2 ft x 2 ft).

Passage size: Initial passage 4 ft x 2 ft opening into  
 small room approximately 13 ft wide x 4 ft  
 high. Large room approximately 25 ft wide  
 x 25 ft high x 25 ft long.

Cave length: 825 ft (251.5 m)

Contour: Cave shaped like soup pan. Entrance passage  
 long and narrow opening to very large, deep room  
 with 3 pits.

Slope: Declining

Amount and timing of  
 surface water entry: Apparently little runoff drains into  
 the cave and most water is from  
 ceiling seepage. No puddles were  
 encountered but the cave was wet and  
 slippery throughout the year.

Airflow: Due to the structure of the cave one would expect  
 a cold air trap but this was overall the warmest  
 cave in the study. Presumably because the entrance  
 passage and entrance into the large room were  
 sufficiently small to restrict a flow of air that  
 would significantly alter the temperature of a  
 room of such large volume. Also as air traveled  
 down the entrance passage the small passage  
 dampened temperature fluctuation through the  
 increased cave-wall-surface-to-volume ratio.  
 Therefore the air was warmed before entering the  
 large room (Tuttle and Stevenson, 1977).

Comments: Perhaps because of narrowness of entrance passage,  
 body heat could have had an effect on temperature  
 reading. Because of high temperature throughout  
 the year, lack of temperature differences and  
 structural diversity, only 1 bat (little brown bat)  
 was ever observed on any visit and then only in  
 the early portion of the season (October-December).

Star Valley Cave

Cave temperature range: Wall ( $\bar{x}$ ) = 7.0-11°C  
 Air ( $\bar{x}$ ) = 8.0-12°C

Entrance: Size = 3 ft diameter  
 Number = 1  
 Position = Hole straight down (1-1.5 ft crawl  
 through leads into first room.  
 Entrance situated on top of hill.  
 Immediate vicinity clear of brush  
 but hilltop predominantly aspen.

Passage size: Variable

Cave length: 600 ft (183 m)

Contour: Uneven, walls of variable width. Floor of rooms  
 at times would drop several feet below level of  
 passage. Shape of cave is crude "Y". Right  
 branch with 2 large rooms connected by small  
 crawlway. Left branch rooms more or less connected.

Slope: Declining

Amount and timing of  
 surface water entry: The passage of this cave was very  
 wet with standing water up to 6 inches  
 deep at times. During a visit in  
 September 1980 the low, back portion  
 of the last room of the right branch  
 was completely flooded with water  
 rising into the main portion of the  
 room. During 1981 water in the back  
 portion of this room made traversing  
 it difficult but the water level of  
 1980 was never matched in 1981.  
 After spring rains and melts the cave  
 was very wet with alot of standing  
 water in puddles and stream in the  
 first passage. Last room of right  
 branch was often very wet. Left  
 branch typically drier than right.  
 Presumably left branch had less slope  
 and on higher ground therefore water  
 to flow towards deeper right branch  
 rooms.

Airflow: Restricted, particularly to right branch since  
 entry passage has several twists, and both right  
 branch rooms are preceded by crawlways.

Star Valley Cave (Continued)

Comments: Fluctuation of temperature within the cave was quite small and occurs throughout the cave rather than in one portion vs. another. Except for an occasional bat in the left branch and main passage bats were found mainly in the last room of the right branch, up high in a dome.

Eoscobel Bear Cave

Cave temperature range: Wall ( $\bar{x}$ ) = 7.5-10°C  
 Air ( $\bar{x}$ ) = 7.0-12°C

Entrance: Size = 10 ft x 5 ft  
 Number = 1  
 Position = SW (Large sinkhole at top of hill preceded by pasture. Very little vegetation other than sparse tree cover).

Passage size: Main room = 30 ft x 30 ft  
 Back passage = 3 ft x 12 ft

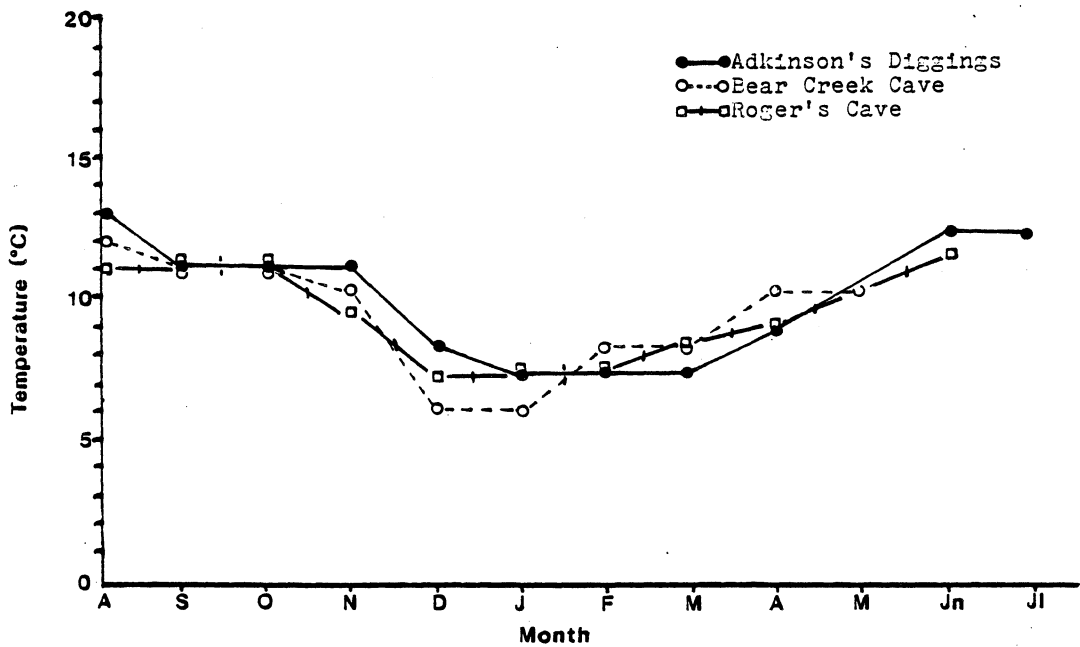
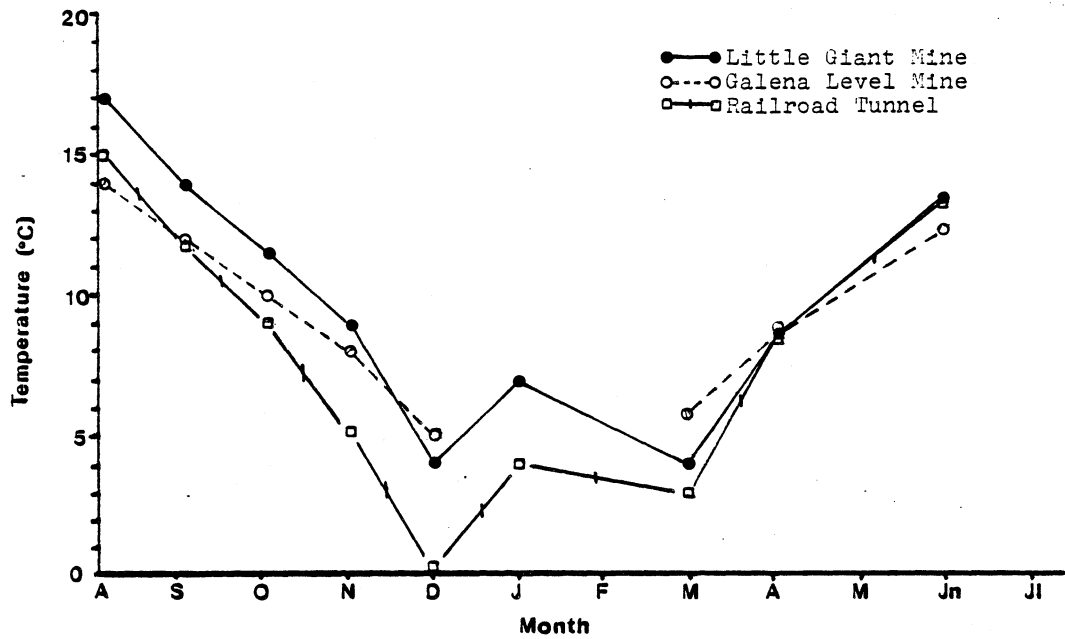
Cave length: 845 ft (258 m)

Contour: Descent into cave steep with side passage within 20 ft of entrance. Main room of cave very large containing large rock pieces. Shape of cave that of one long passage.

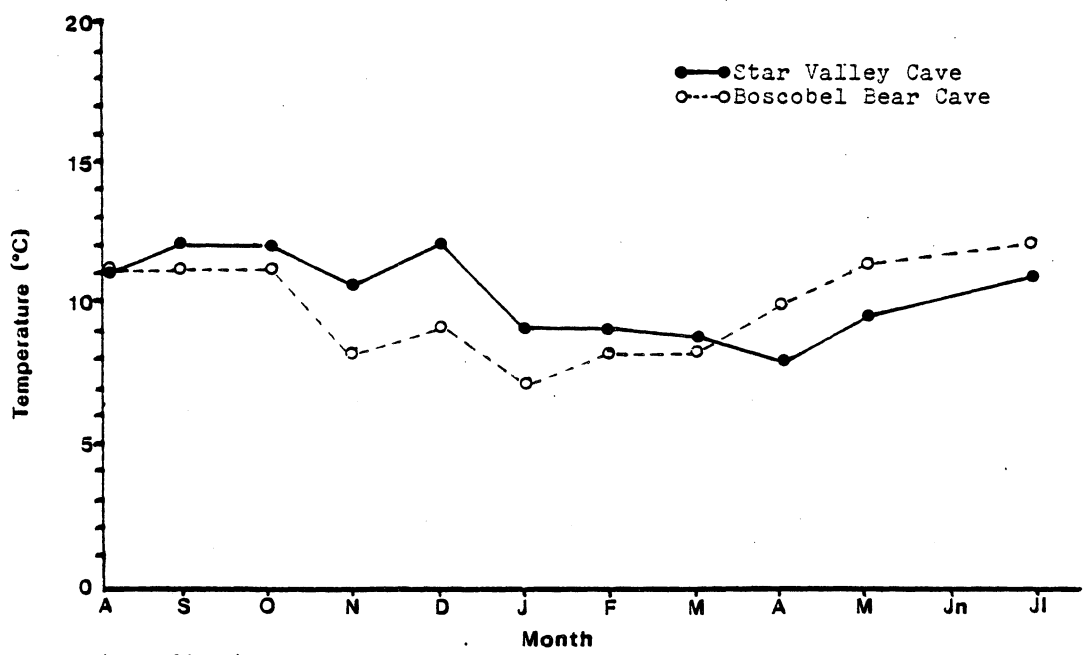
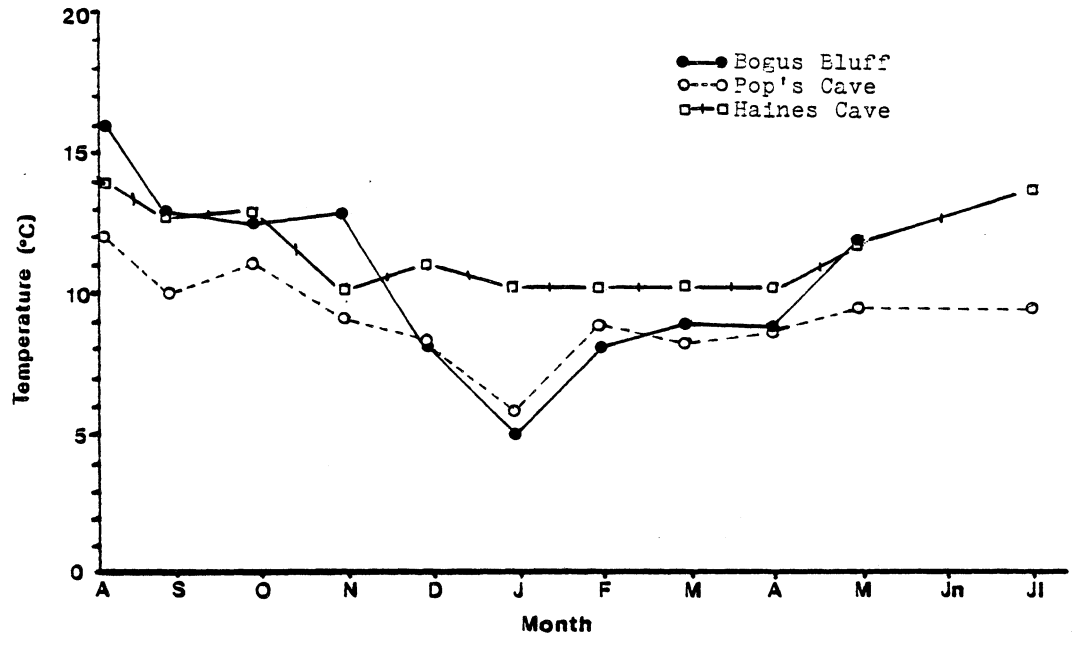
Slope: Declining into main room then rising to back passage where it remains level.

Amount and timing of surface water entry: Cave is supplied by ceiling seepage and is damp, slippery and muddy year round. Puddles found near rear of cave.

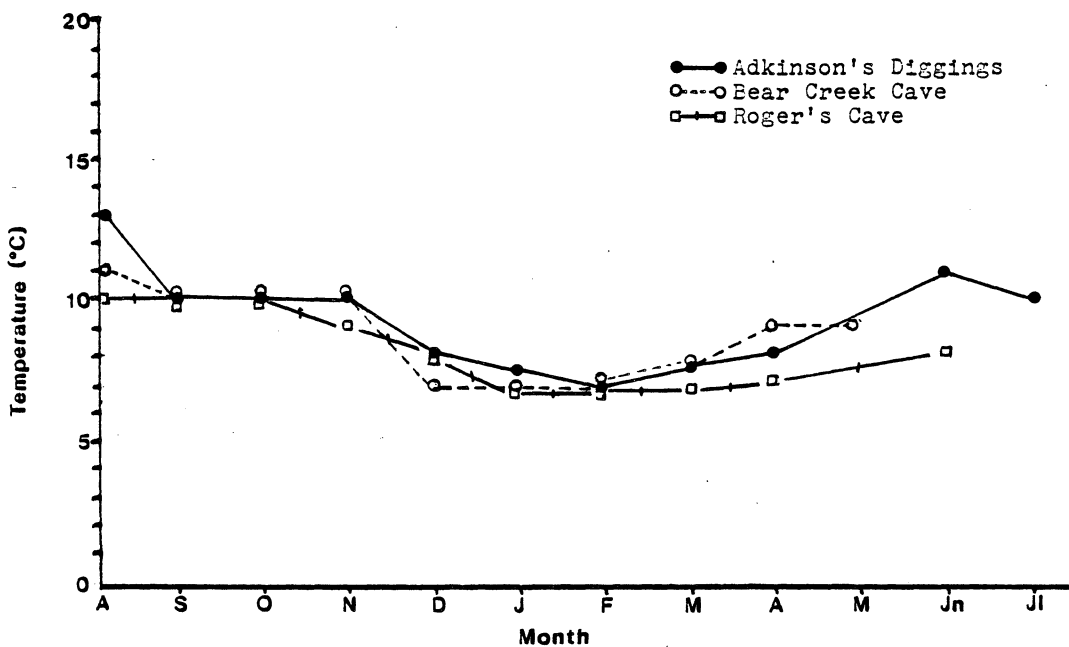
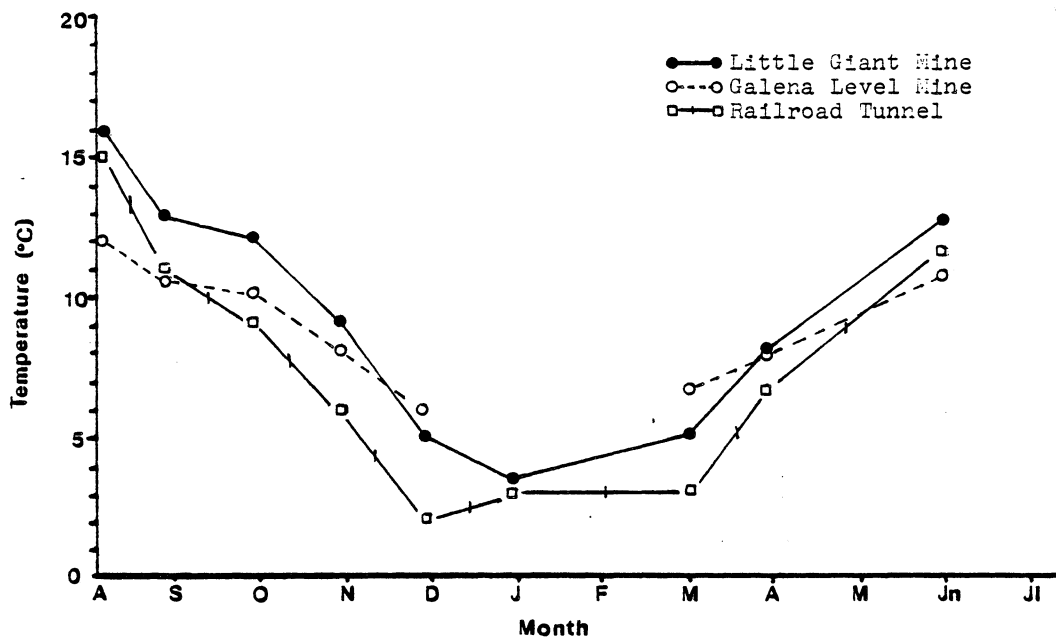
Airflow: Back passage airflow minimal due to small crawlways connecting it with the main room. Back passage  $T_a = 8.5-12^\circ\text{C}$  and  $T_w = 8.5-10.5^\circ\text{C}$ . Temperatures in the main room are typically 1-2.0°C cooler than the back passage indicating more airflow in the main room. Most temperature measurements taken near the floor of the main room where cold air collects. However most bats were found near the ceiling where temperatures could have been greater due to rising warm air. Few bats were found in the back passage presumably because temperatures there were too warm.



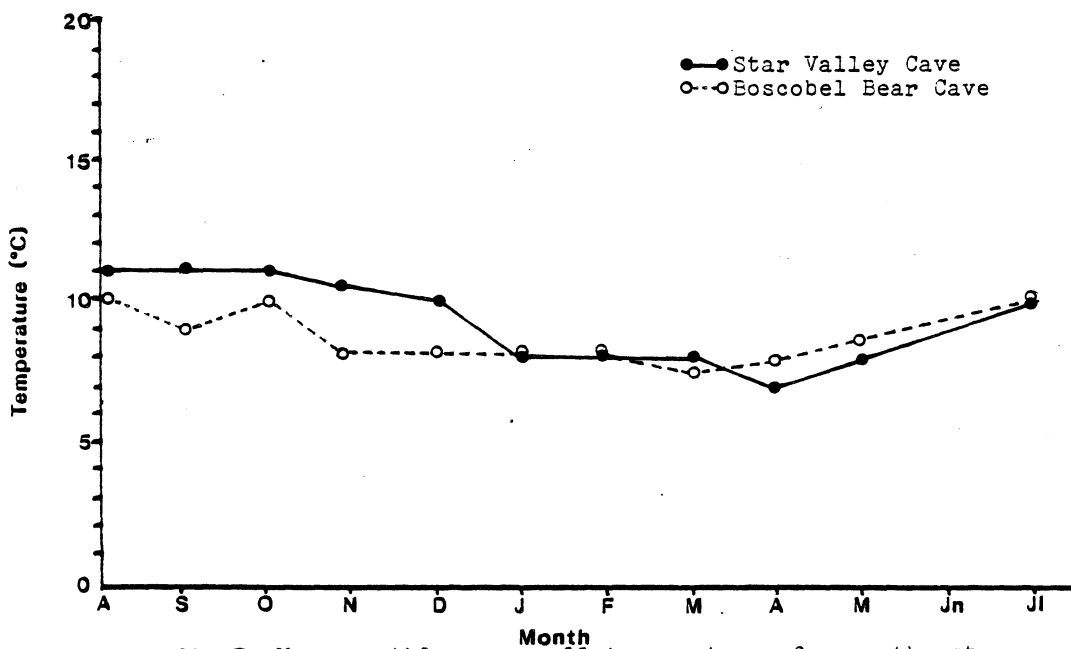
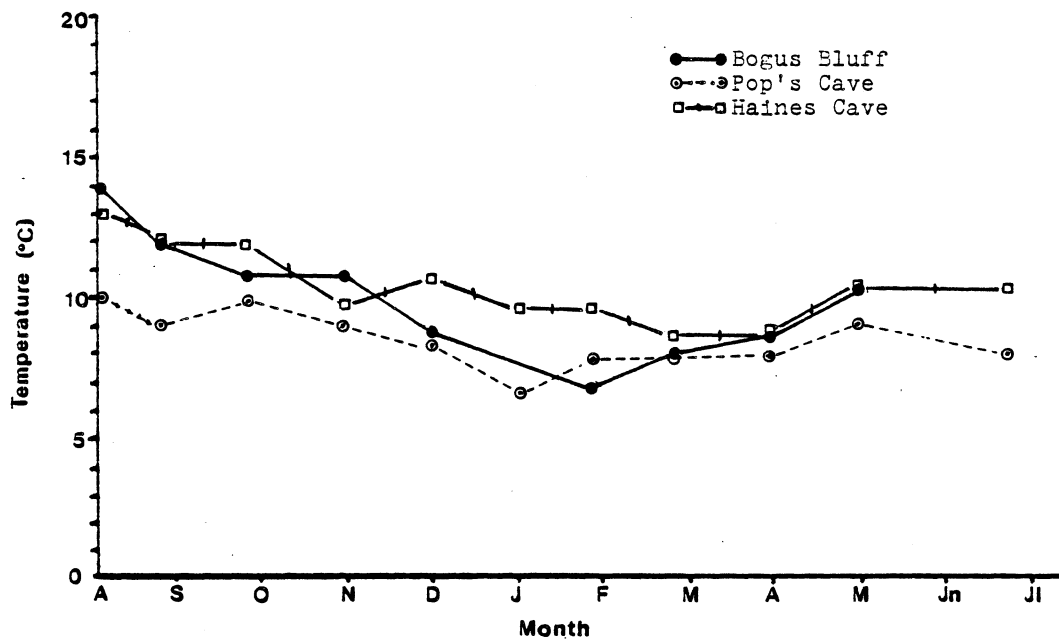
Appendix 4. Mean monthly cave air temperatures for southwestern Wisconsin caves and mines, 1981.



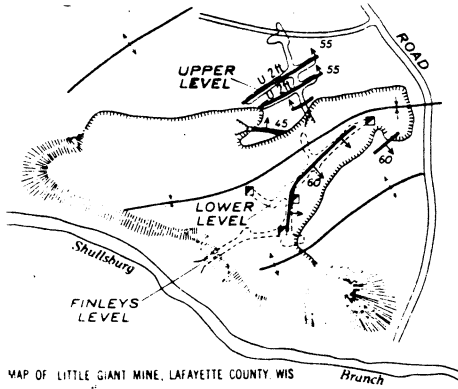
Appendix 5. Mean monthly cave air temperatures for southwestern Wisconsin caves and mines, 1981.



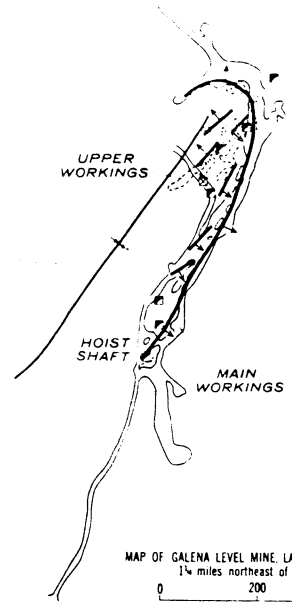
Appendix 6. Mean monthly cave wall temperatures for southwestern Wisconsin caves and mines, 1981.



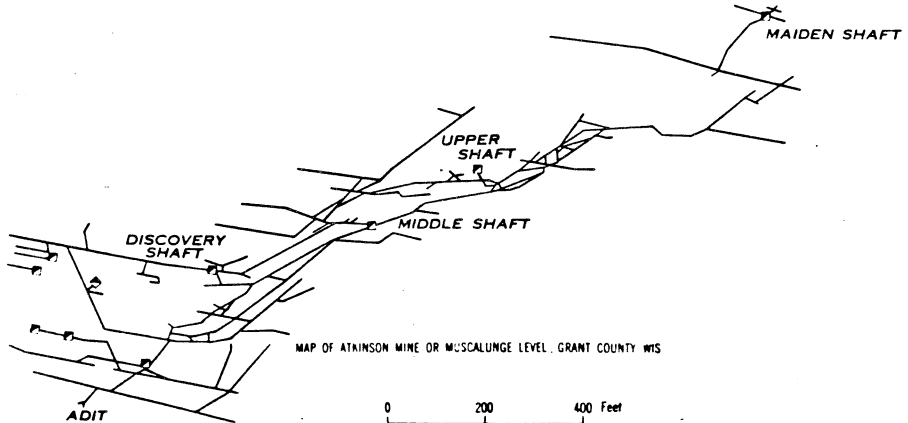
Appendix 7. Mean monthly cave wall temperatures for southwestern Wisconsin caves and mines, 1981.



MAP OF LITTLE GIANT MINE, LAFAYETTE COUNTY WIS



MAP OF GALENA LEVEL MINE, LAFAYETTE COUNTY WIS  
1 1/4 miles northeast of Shullsburg



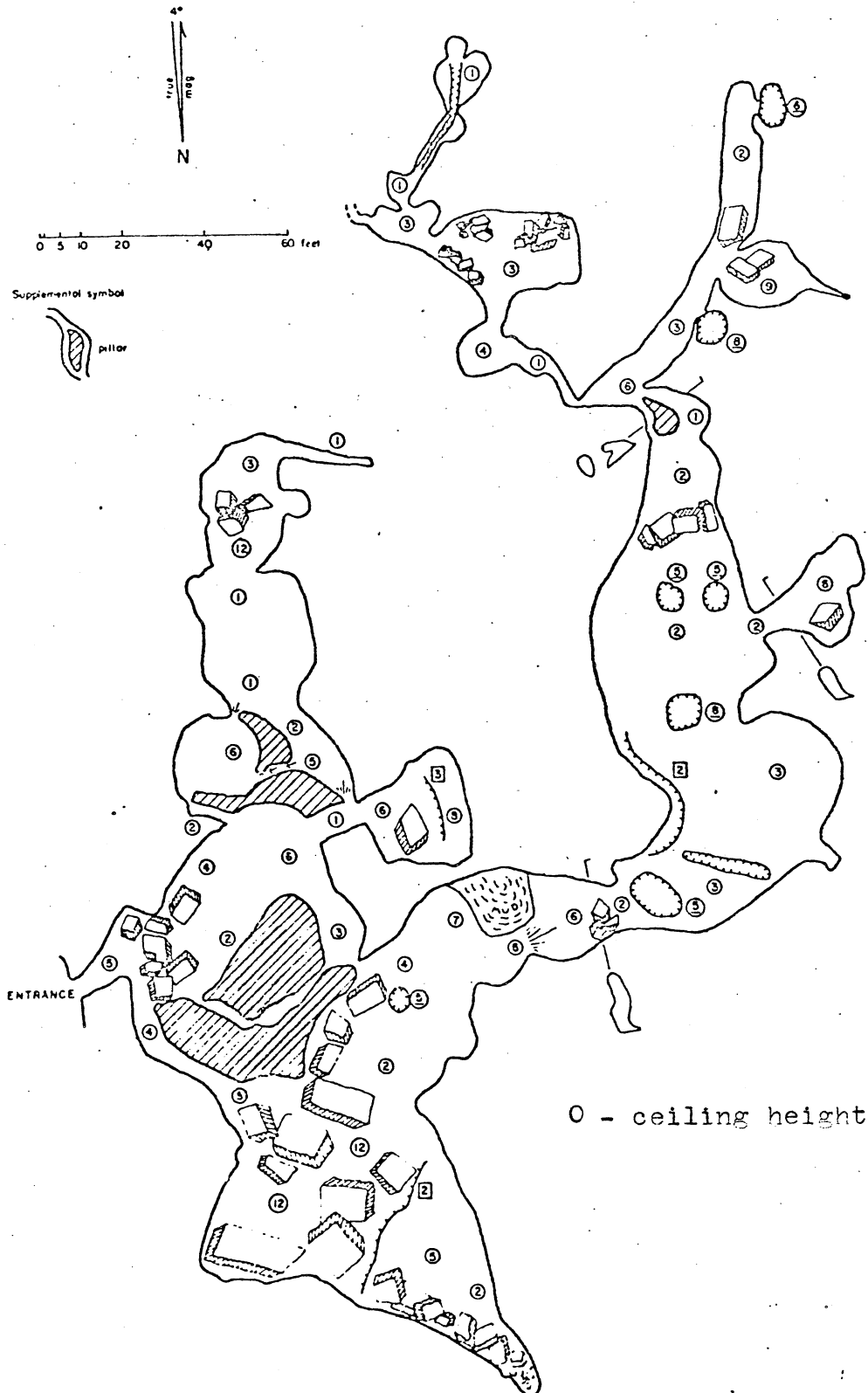
MAP OF ATKINSON MINE OR MUSCALUNGE LEVEL, GRANT COUNTY WIS

Appendix 8. Maps of 3 southwestern Wisconsin mines (Heyl et.al. 1959).

# BEAR CREEK (BRICE, QUARRY) CAVE

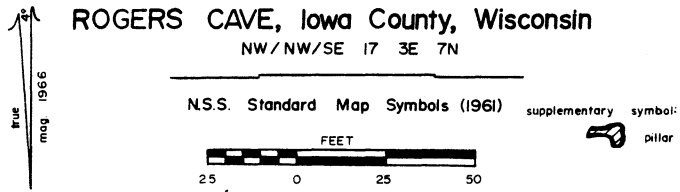
Sauk County, Wisconsin

ION 3E 3 SE/SW/NE

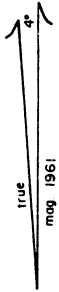


0 - ceiling height

Appendix 9. Wisconsin Speleological Society map of Bear Creek Cave.



Appendix 10. Wisconsin Speleological Society map of Rogers Cave.

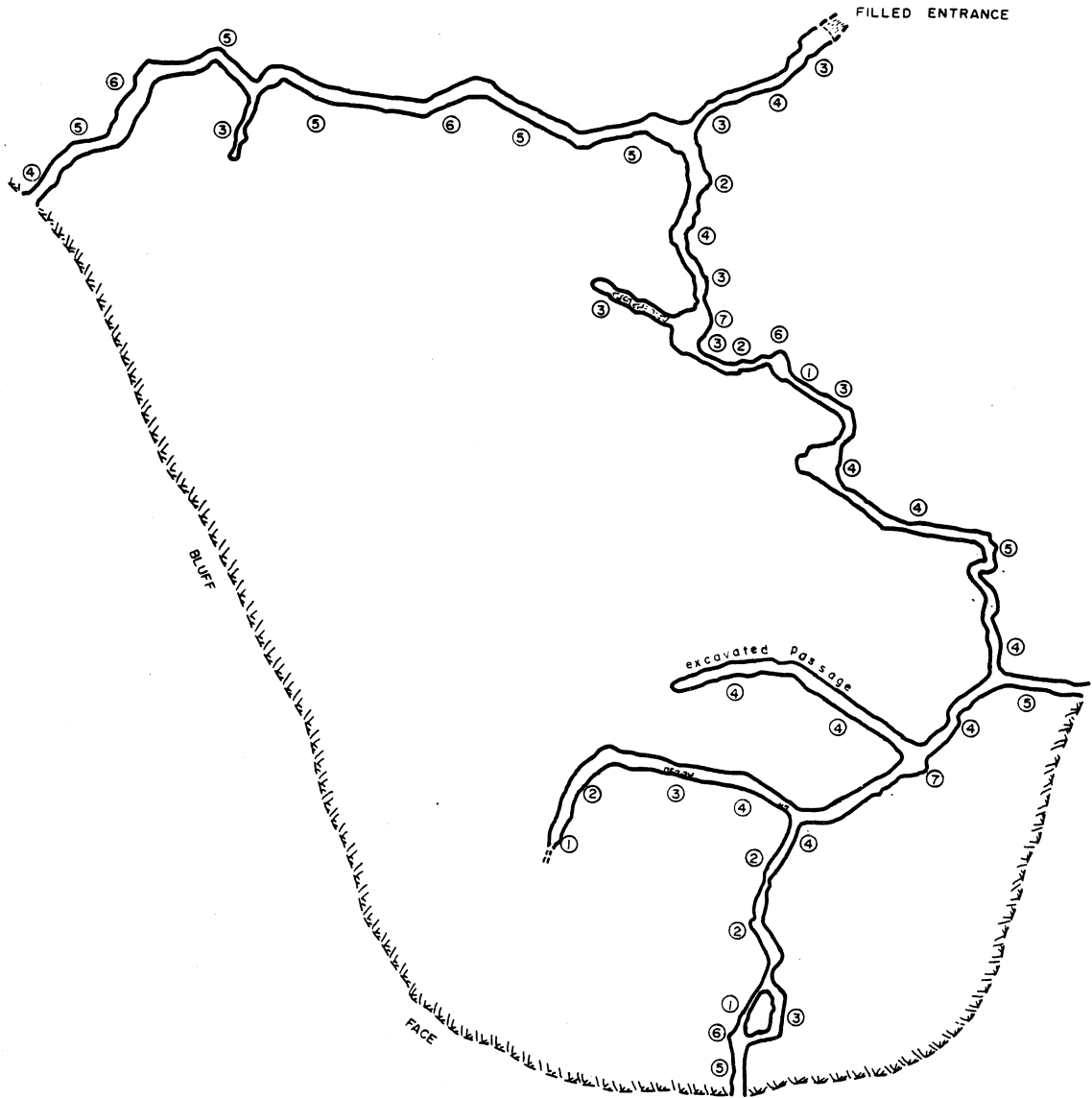
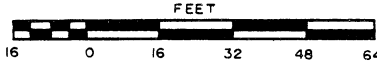


# BOGUS (Bogas, Bogus Bluff, Counterfeiter's) CAVE

## Richland County, Wisconsin

NE/SW & NW/SE 35 1E 9N

N. S. S. Standard Map Symbols (1961)

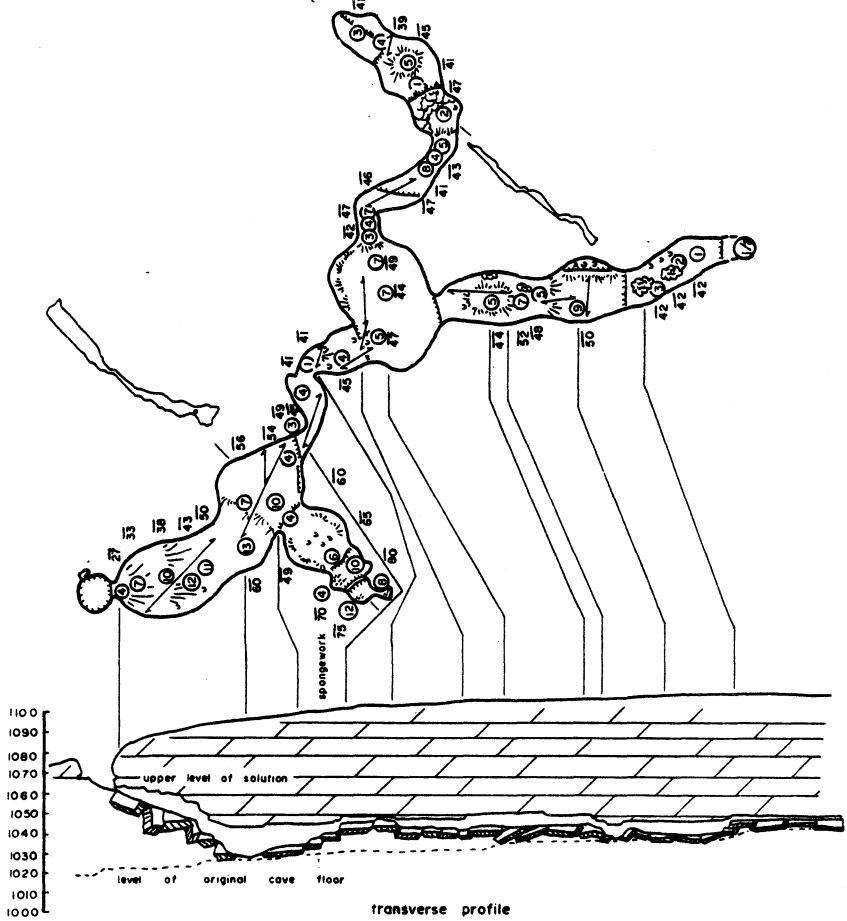


Appendix 11. Wisconsin Speleological Society map of Bogus Bluff Cave.

# POP'S (BIG BEAR) CAVE, Richland County, Wisconsin

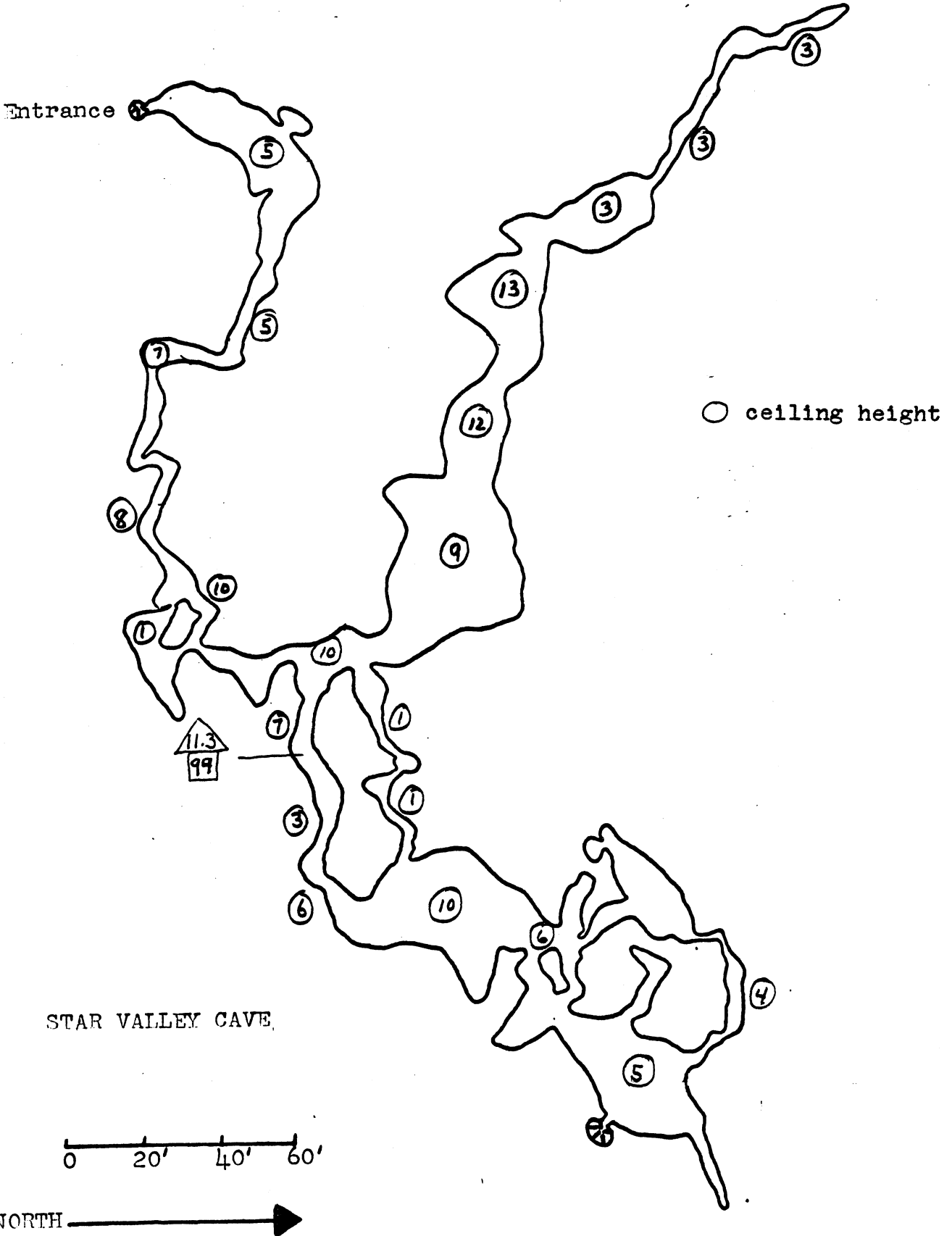
NE/SW/SE 34 2W 11N

N. S. Standard Map Symbols (1961)

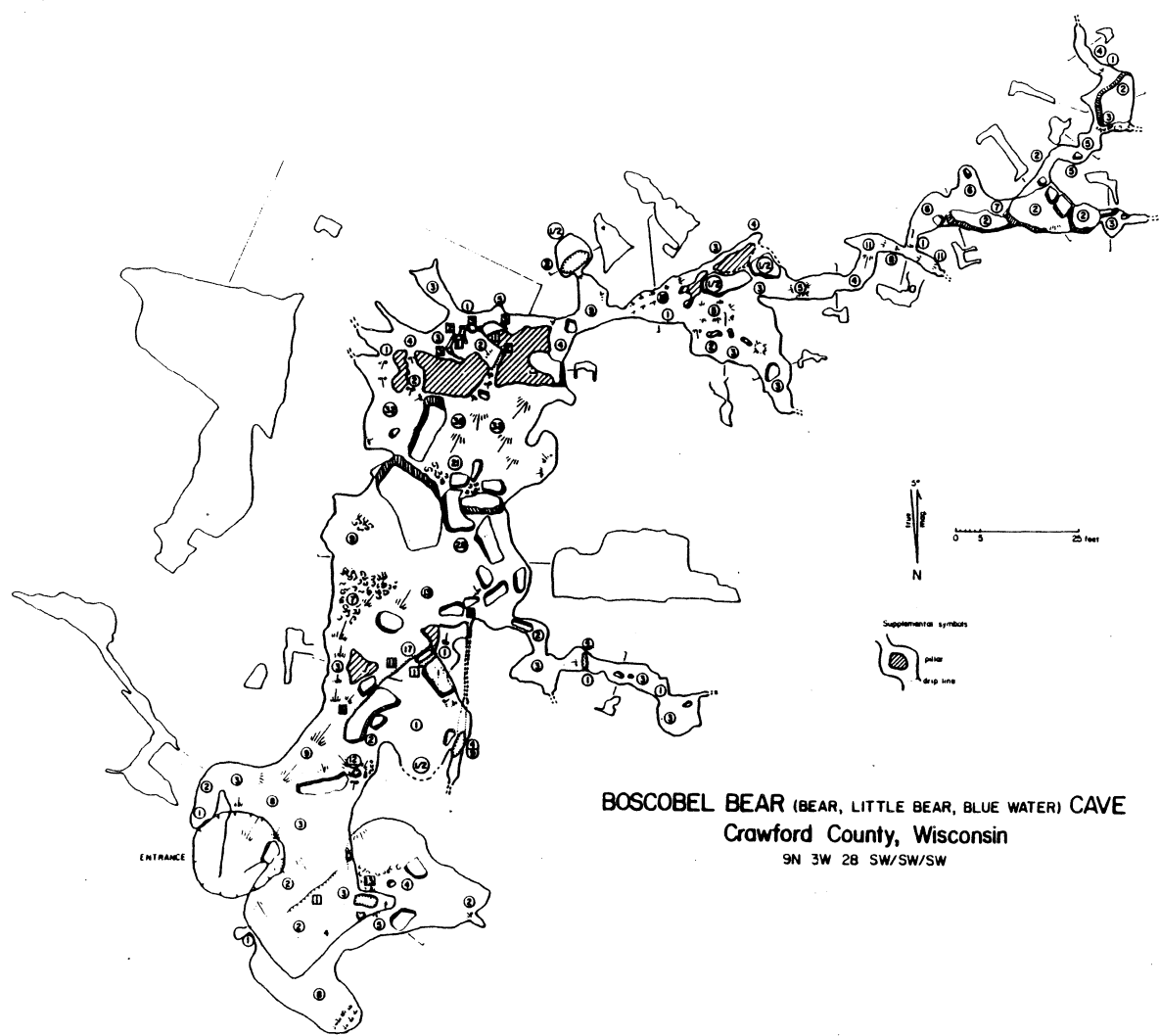


Appendix 12. Wisconsin Speleological Society map of Pop's Cave.





Appendix 14. Wisconsin Speleological Society map of Star Valley Cave.



Appendix 15. Wisconsin Speleological Society map of Boscobel Bear Cave.