BATS OF KARTCHNER CAVERNS STATE PARK, ARIZONA

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*Kartchner Caverns, in southeastern Arizona, is a summer maternity roost for approximately 1000-2000 cave myotis (*Myotis velifer*). The pregnant females first arrive at the cave in late April, give birth in June, and have left by mid- September. These bats are an important element in the cave ecosystem because their excrement introduces nutrients, which support a complex invertebrate cave fauna. Bat population densities and emergence behavior was monitored between 1988-1991. Other bat species seen using the entrance areas of the cave include* Corynorhinus townsendi *and* Choeronycteris mexicana.

*Because bats are easily disturbed by human intrusion into the roost, the baseline study was accomplished using low-disturbance techniques in an effort to provide the greatest amount of data with the least disturbance to the bat colony. These techniques included limited visual observations in the roost and netting bats only on the surface at a nearby water tank. During the baseline study, an episode of predation by a carnivore (*Bassariscus astutus*) caused the bats to abandon the site for a short time. Carbon-14 dating of guano from the Throne and Rotunda Rooms suggests that* Myotis velifer *used the Back Section of Kartchner Caverns 50-45 years Ka.*

The purpose of the Kartchner Caverns bat study was to obtain a biological inventory of the bats using the cave at baseline level prior to development of the cave. The inventory included identification of the bat species and population estimates of the bats that inhabit the cave in the summer. The acquisition of data before the bat population is potentially impacted by human disturbance, and during and after development, provides a method by which the effects of human activities on the bat population can be evaluated.

Kartchner Caverns is home to approximately 1000-2000 cave myotis (*Myotis velifer*), a species of insectivorous bat, from May to mid-September of each year. These bats, primarily pregnant females (Fig. 1), return each summer to Kartchner Caverns to give birth and rear their young. The bats are an integral part of the cave ecosystem. Bat excrement (guano) below bat roosts is the primary source of food for other organisms in the cave and is an unusually rich source of nutrients for obligate invertebrate residents (Welbourn 1999). The various cave-adapted organisms utilize the bat guano in different ways but all depend upon it for their survival (Harris 1970; Horst 1972; Poulson 1972). Loss of the roosting bats could cause a collapse of a healthy cave environment and the destruction of the entire cave ecosystem.

Some species of bats are extremely sensitive to human disturbance and will abandon a roost if human intrusion occurs (Brigham 1993; Harvey 1991; Mohr 1972; Williams & Brittingham 1997). Female bats choose a maternity roost, in part, for its high temperature and humidity to ensure the rapid growth of their young (Betts 1997; Kunz 1973; Tuttle & Stevenson 1982; Twente 1955). Females are highly loyal to their maternity roost and return year after year (Lewis 1995). A critical period during which the population may suffer reproductive loss due to disturbance is during parturition, (birth; Fig. 2). Immediately following parturition, it is essential that females have a time to imprint on the smell and sound of their own young (Altringham 1996). If disturbed prior to this bonding, the female may not recognize her offspring and therefore will not attempt to care for it. If disturbed following parturition, the female bats may attempt to move their pups to a safer location, either somewhere else in the cave, or to a different

Figure 1.

A pregnant female *Myotis velifer* netted at the water tank adjacent to the cave. Photo taken by Bob Buecher.

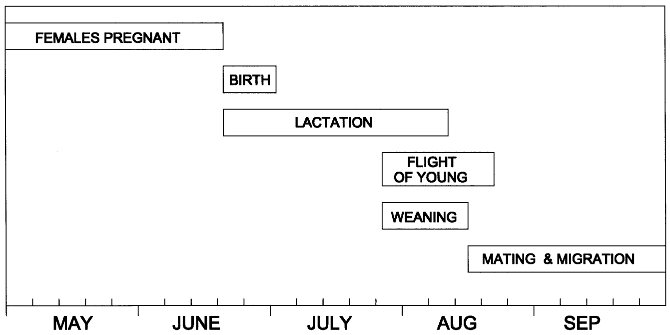


Figure 2. Maternity bat roost timetable for *Myotis velifer* at Kartchner Caverns.

site with sub-optimal conditions. During this process the females may drop their young, resulting in juvenile mortality (Fenton 1992). Forced displacement to another area of the cave (which may be cooler and drier), or total abandonment of the cave, may jeopardize the survival of the pups.

BASELINE STUDY

It was with these concerns in mind that we attempted to perform a baseline survey of the bat roost at Kartchner Caverns using low disturbance techniques utilized by bat biologists (Thomas & LaVal 1988). Because "baseline" conditions in a natural bat roost entail no human intrusion, we did as much work as possible to inventory the bat roost when the bats were not in residence. In addition, the baseline study team defined the need for a biologist specialized in the study of bats, and specifically contracted a project bat biologist (Sidner) who obtained the necessary permits from governing agencies. During the winter months when the bats were absent from the cave, we examined bone material and bat carcasses for species identification and stages of development. While a couple of solitary bats were removed from the wall of an isolated passageway and observed closely to determine species, sex and general health, we never netted bats in the cave because of the potential for disturbance within the roost. We netted bats away from the roost at a nearby water tank in order to record their measurements and other characteristics, such as events in the reproductive cycle. We placed bat bands with reflective tape on any captured *Myotis velifer.* We subsequently observed reflective bands on bats emerging from Kartchner during evening flights, confirming that these animals used the cave as a daytime roost.

In addition to *M. velifer*, we observed two other species of bats using Kartchner Caverns, but these bats were seen in only the entrance portions of the cave. *Corynorhinus townsendii* (Townsend's Big-eared Bat) was seen on occasion exiting during the middle of the *Myotis* flight, but there were never more than half a dozen of this species observed. *Choeronycteris mexicana* (Mexican Long-tongued Bat), a nectar feeding species, was also observed individually in the entrance area. Nine species of bats were netted or otherwise observed at Kartchner Caverns State Park during the summers of 1988-1991. Although *Myotis velifer* was the predominant species that utilized the cave, other bat species forage over the park or roost in small nearby caves (Table 1).

Table 1. Bat species netted or observed on the surface at Kartchner Caverns State Park.

Bat Species	Primary Food
Myotis velifer (Cave Myotis)	Insects
Myotis thysanodes (Fringed Myotis)	Insects
Myotis californicus (California Myotis)	Insects
Myotis ciliolabrum (Western Small-footed Myotis)	Insects
Eptesicus fuscus (Big Brown Bat)	Insects
Antrozous pallidus (Pallid Bat)	Insects
Corynorhinus townsendii (Townsend's Big-eared Bat)	Insects
Leptonycteris curasoae (Lesser Long-nosed Bat)	nectar/pollen
Choeronycteris mexicana (Mexican Long-tongued Bat)	nectar/pollen

METHODS OF OBERVATION

Once bats returned to Kartchner in the spring, we could estimate which areas of the cave were inhabited first due to fresh deposition of guano and a burst of invertebrate activity on the guano piles below each active roost. The bats often roosted in the general area of the Lunch Spot when they first arrived in the spring, but as the time of parturition approached, the bats moved to a "nursery roost" above Sharon's Saddle (Fig.3). Measurements taken in the maternity roost at Sharon's Saddle during the summer of 1990 indicate that the temperature reached 21.9°C (71.4°F) and the humidity 100% when the bats were in residence. This temperature is the highest recorded in the cave during the baseline studies, and suggests that the bats seek out the warmest section of the cave to rear their young.

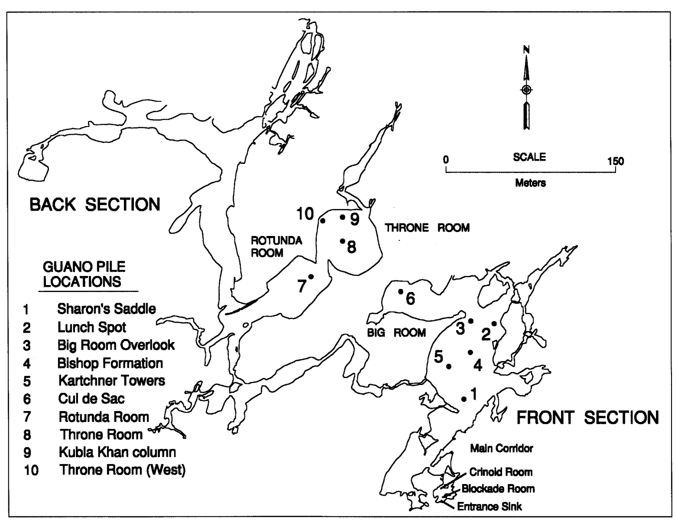


Figure 3. Outline map of Kartchner Caverns indicating significant guano piles below bat roosts.

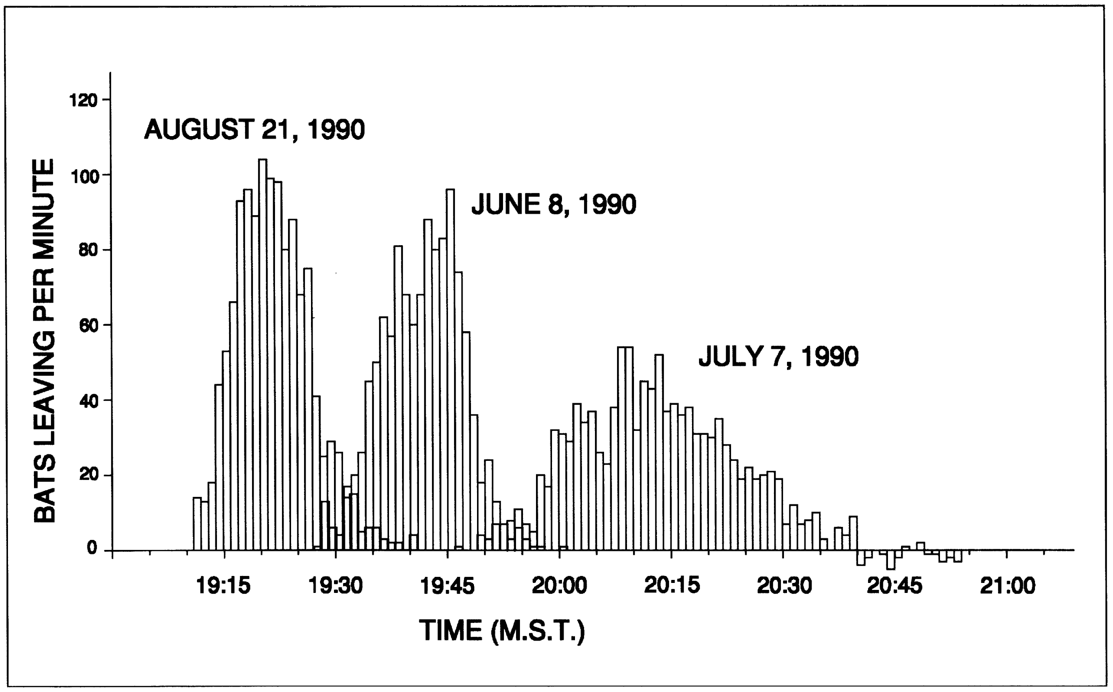


Figure 4.

Three representative plots of bat emergence flights during summer. Note change in flight characteristics during time of lactation in mid-summer.

Inventorying the deposition of fresh guano at different guano piles permitted us to monitor the bats' location in the cave without entering and disturbing the roost when bats were present. In order to do this we would quickly visit the Big Room after the evening exit flight. Fresh deposition of guano below a roost would indicate an active site. Sheets of material were laid over the existing guano piles so that new deposition could be easily monitored. These "guano sheets" were made of breathable material (fine nylon netting) so that invertebrates foraging on the guano piles did not suffocate. It was also necessary to avoid excess guano deposition on the sheets because removal of a guano sheet after a large buildup of guano could disturb the invertebrate community.

Once bats returned in the spring, trips into the cave for the baseline study were severely curtailed. If a need arose to traverse the Big Room when the bats were in residence, we used dim headlights covered with red filters and moved quickly into and out of the area. It has been our experience that filtered light causes slightly less disturbance to bats, as judged by fewer bats squeaking or taking flight during human intrusion. The presence and number of non-volant (non-flying) juvenile bats was determined by photographing (once per summer, usually during the first week of July) the juvenile cluster on the ceiling of the Big Room after the evening exit flight of adult bats. We were then able to count the total number of juveniles and roughly assess their ages by magnifying an enlarged photograph.

BAT POPULATIONS

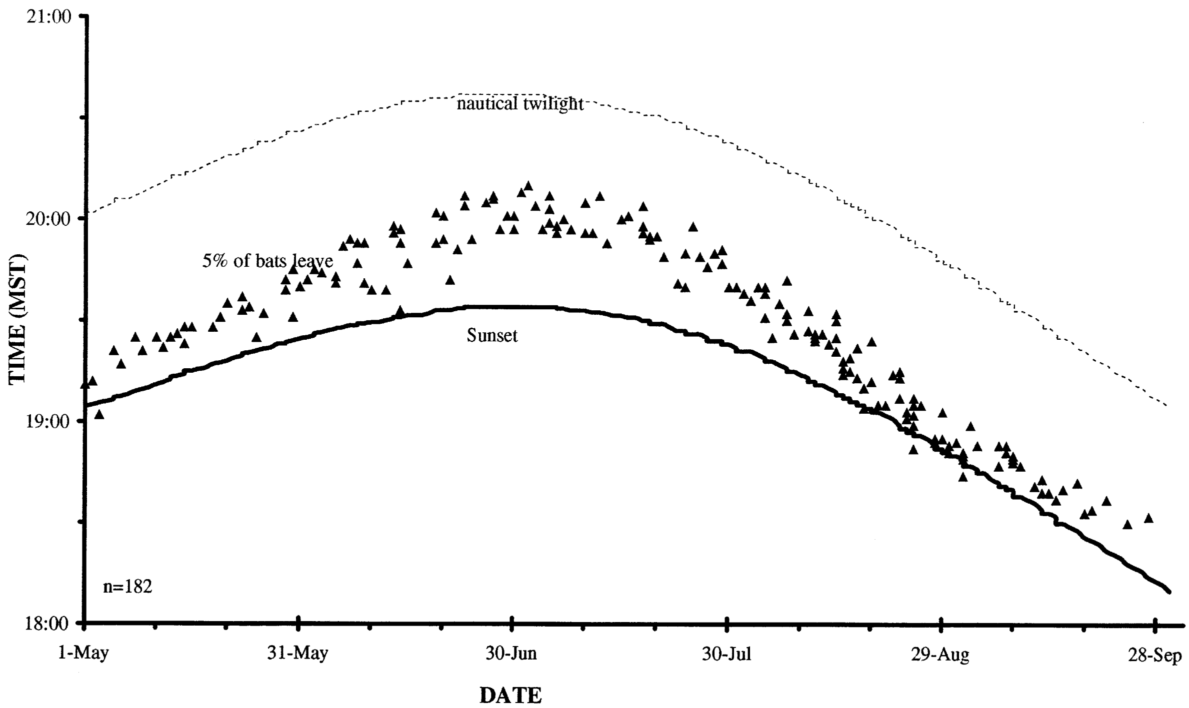
To estimate the number of bats using the cave, an unobtrusive human observer counted bats exiting during the evening flights. Due to the constricted passages in the front portion of the cave, bats are forced to leave the cave in small groups, so they can be easily counted visually by trained personnel. These counts of exiting bats provided the best estimate of the population size of bats using the interior cavern with the least disturbance to the colony. An observer sitting against the north wall of the entrance sinkhole, out of the direct path of exiting bats, had a good view of them silhouetted against the evening sky. Each individual bat exit was recorded to the nearest second on a lap-top computer. Bats that re-entered the sinkhole were subtracted from the total count. Time plots of exiting individuals reflected the overall pattern of bat activity during the evening emergence flight. During the three years of the baseline study, bat counts were conducted on a weekly basis throughout the summer months. In addition to these visual counts, during the 1990-1991 season an observer sat inside the Blockade Room using infrared-light goggles with an external source of infrared light to view the bats exiting through a small opening called the "bat window". This small window requires that the bats use the Crinoid Room as a staging area during the evening flight, because each bat must wait its turn to exit through the window. Because some errors in counting from within the sinkhole probably occurred during low-light conditions or during inclement weather, counts in the Blockade Room with infrared goggles act as a check on the accuracy of the sinkhole observations.

POPULATION ACTIVITY

Initiation of the evening bat flight correlated roughly with sunset. Bats began to leave the cave to forage for insects 15 to 20 minutes after sunset, but there was a definite shift in that

Figure 5.

***Myotis velifer* emergence flight pattern plotted against sunset and nautical twilight.**



pattern during the period when females were nursing their young (Fig. 4). The exit flight typically lasted one hour, with the majority of bats leaving during a 15-minute period within that hour. The pattern of bat flight activity varied during the summer. Exit flights in the spring and fall were of short duration, with most bats leaving fairly quickly. During mid-summer, however, when females were nursing their young, the exit flight lasted longer, with fewer bats leaving the cave at any one time (Fig. 5).

Each spring the bats of Kartchner Caverns began reappearing in small numbers, generally during the last week of April. The population of bats fluctuated throughout May, and then stabilized in the middle of June. Netting at the water tank adjacent to the cave indicated that female *M. velifer* were pregnant in mid-June. Netting in mid-July showed that female bats were lactating, and female bats netted in mid-August were in a post-lactating condition. It is suspected that the increase in the number of exiting bats from June/July to August is partially due to the presence of young bats beginning to fly (Table 2). Observers counting at the evening bat flights have reported erratic flight patterns in the emerging bats when the young would be just learning to fly. The consistently large increase in bats using the cave in August also suggests that Kartchner Caverns may be a roost used by migrating bats that have begun to move through southern Arizona in late summer. This pattern has been observed at other sites and may reflect the migratory behavior of bats late in the season.

The bats of Kartchner Caverns act as a natural insecticide for the area. A conservative estimate indicates that the bats roosting in Kartchner devour ~900 kg (0.5 ton) of insects every summer.

Table 2. Population numbers of *Myotis velifer* at Kartchner Caverns during baseline study.

Year	June/July Population	August Peak	# Increase	% Increase
1988	638	1245	607	95%
1989	1023	1804	781	76%
1990	1191	1469	278	23%
1991	634	1198	564	89%

EVIDENCE OF PREDATION

In spring 1991, we had a unique opportunity to observe non-human disturbance of the bat colony at Kartchner Caverns. Bats had arrived in late April and their numbers had begun to increase early in May as expected. However, in late May the exit flights became delayed, sporadic, and the total population size declined. On 4 June, the carcasses of 45 dead bats were found near the bat window. We removed these from the cave to determine the cause of death. Observers counting bats on the next two nights watched a ringtail (*Bassariscus astutus*) leave the cave. The following evening, we used a night vision scope and observed the ringtail sitting directly in the bat window. Apparently this animal was responsible for killing the bats. The ringtail was last seen in the cave on 6 June and no additional dead bats were found in the cave after that incident. However, the numbers of bats using the cave continued to decline, presumably due to the effect of the previous ringtail predation. The bat population reached a minimum on 14 June when only 49 bats were counted leaving the cave. In other years, a bat count at this time of year was ~1000 bats. The rapid decline in the number of bats using the cave illustrated how quickly the bat population can be impacted by an external disturbance. The number of bats slowly increased during the next six weeks as bats returned to the cave, and by the beginning of July, the population numbered 400. This increase in numbers despite the threat of predation may indicate that Kartchner Caverns is superior to other nearby roosts. The maximum number of bats counted during 1991 was the lowest of the four years of record.

PREHISTORIC BAT POPULATIONS

Skeletal material from *Myotis velifer* has been found in the back section of the cave, along with several piles of "old" guano. This bat guano has been severely eroded with drip water and has lost all resemblance to modern guano. The two largest guano piles are in the middle of the Throne Room, with smaller piles located along the western edge of the room. The Rotunda Room has one small guano pile located at the edge of a large breakdown slope (Fig 3, #7). Numerous other small cohesive clumps of guano are within the breakdown pile in the Rotunda Room, and the location of these clumps among the breakdown makes it difficult to envision how they would have been naturally deposited below a bat roost. There is also no evidence on the ceiling above this remnant guano to indicate that these areas were used as roosting sites by bats. One possible explanation is that these guano clumps are the remains of guano floated up onto the breakdown slope during past flooding of the cave (C. Welbourn, pers. com.). Similar clumps of desiccated guano can also be found in the Cul-de-sac area in the Front Section of the cave. Samples of this ancient bat guano were collected from the Throne and Rotunda Rooms and analyzed by the carbon-14 dating technique. Ages for this guano range from about 50-40 Ka (Table 3).

Table 3. Bat guano C-14 dates for the Back Section of Kartchner Caverns.

Kartchner Caverns Bat Guano Age Dates

Sample No.	Location	Age (years)	$\delta^{13}C_{PDB}$(%)
KC1	Throne Room	45,790	-21.0*
KC2	Throne Room	49,340	-20.8*
KC3	Rotunda Room	45,540	-18.1*
KC4	Rotunda Room	40,220	-17.3*

*Ages for these samples are near the limits of the Carbon-14 dating technique used and may represent samples that are much older than 50,000 years but contain small amounts of younger contaminants. Analysis performed by Owen Davis at the University of Arizona Dating Lab.

CONCLUSIONS

The predominant species of bat within Kartchner Caverns is the cave myotis (*Myotis velifer*). A small number of other bat species have been observed but are apparently represented by only a few individuals. *M. velifer* is presently known to use only the Front Section of the cave (entrance passages and Big Room area). The primary roosting sites are above Sharon's Saddle and near the Lunch Spot. Other locations in the Big Room are used occasionally and include the area around Kartchner Towers, near the Bishop Formation and the Overlook. Small accumulations of bat guano in numerous other locations within the Big Room indicate that the roosting sites favored by the bats can change through time.

Myotis velifer is present in the cave from late April to the middle of September each year. *M. velifer* begins to return to the cave as early as 20 April and generally leaves by 15 September. *M. velifer* uses the cave as a maternity site during the summer months when warm temperatures and high humidity within the cave appear to be ideal for a maternity bat roost. Apparently Kartchner Caverns is an important roost because bats returned to the cave in 1991, despite an incidence of severe predation by a carnivore at that time. A limiting factor on the use of the cave may be predation, which can occur in the small entrance passages. Mid-June to early August is a critical time period during which the female bats give birth and care for their young. If disturbed during this time, the females may be induced to abandon the site.

The number of bats found in the cave varies from year to year but averages ~ 1000 individuals. The numbers increase in August when the young begin to fly and may peak at close to 2000 bats. Peak estimates of the adult population and total usage show considerable year-to-year variation.

Evidence suggests that *Myotis velifer* inhabited the Throne Room and Rotunda Room 50-40 Ka. There is no indication that bats have used these areas in modern time. The prehistoric use of these areas by bats is an indication that the cave may have had, at one time, another entrance in the Back Section of the cave.

RECOMMENDATIONS

Bats occupy a vital niche in the healthy cave ecosystem of Kartchner Caverns. Not only do these flying mammals use the outside environment, but due to their capacity to echolocate by sonar, they can utilize areas of the cave inaccessible to other vertebrates. Bat guano provides the basic food source for invertebrates found in the cave. These obligate cave organisms are dependent upon the continued presence of the bats. Due to the importance of the bats to the entire cave ecosystem, the bat population should be carefully monitored every summer. Disturbance of the bat colony should be minimized and this is especially true when the pregnant females and the juvenile bats are in residence. Continued use of artificial optical devices (night vision equipment and infrared lights) should increase the accuracy of visual bat counts.

The bats are an important and exciting element of Kartchner Caverns State Park, and as such they make an ideal interpretive and educational tool. For example, bat guano can be used in discussions of biology, chemistry and physics when describing the flow of energy in the natural cave environment. The bats are a valuable resource for Kartchner Caverns and they should be as well protected as Kartchner's irreplaceable cave formations. Because so few maternity bat colonies are known in southern Arizona caves, the bat maternity colony is truly one of the elements that makes Kartchner Caverns important.

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