

January 2009

Cave myotis (*Myotis velifer incautus*) monitoring at Harrell's Cave, San Saba County, Texas during 2008

Charles E. Pekins

Follow this and additional works at: https://digitalcommons.usf.edu/kip_data

Recommended Citation

Pekins, Charles E., "Cave myotis (*Myotis velifer incautus*) monitoring at Harrell's Cave, San Saba County, Texas during 2008" (2009). *KIP Data Sets and Technical Reports*. 16.
https://digitalcommons.usf.edu/kip_data/16

This Text is brought to you for free and open access by the Karst Information Portal at Digital Commons @ University of South Florida. It has been accepted for inclusion in KIP Data Sets and Technical Reports by an authorized administrator of Digital Commons @ University of South Florida. For more information, please contact scholarcommons@usf.edu.

Cave myotis (*Myotis velifer incautus*) monitoring at Harrell's Cave, San Saba County, Texas during 2008.

Prepared on 27 Oct 08 by: Charles E. Pekins, Wildlife Biologist, Lampasas, Texas for Dennis M. Herbert, Conservation 1 Wildlife and Land Management Services, Salado, Texas.

Introduction

The cave myotis [Vespertilionidae: *Myotis velifer* (J. A. Allen 1890)] is the largest Texas myotis bat (100 mm total length) with long forearms (37-47 mm) and dark, dull brown pelage (Barbour and Davis 1969, Fitch *et al.* 1981, Schmidly 1991, 2004). The cave myotis' range includes most of the southwestern U.S., portions of south-central Kansas and western Oklahoma, and most of Mexico south to Honduras (Barbour and Davis 1969, Hayward 1970). In central Texas, *M. v. incautus* (hereafter velifer(s)) are abundant in the summer (Schmidly 1991, 2004), and rare in the winter (Davis *et al.* 1962). Because of anthropogenic caused population decline and disturbance, as well as inexplicable roost abandonment, velifers are on the "species of concern" (former category 2) list (USFWS 1994).

Velifer summer maternity roosts occur in warm sections of caves, mines, and crevices where daily temperature fluctuations seldom occur (Kunz 1973, Humphrey 1975). Velifers are highly colonial, and they form clusters consisting of a few individuals to several thousand, mostly in caves and mine tunnels that provide suitable temperature and humidity microclimates (Barbour and Davis 1969, Hayward 1970, Fitch *et al.* 1981). Winter and summer banding studies performed in northwest Texas (Tinkle and Patterson 1965), Kansas (Twente 1955a, 1955b; Dunnigan and Fitch 1967), and Arizona (Hayward 1970) demonstrate that velifers are loyal to cave cluster sites. Roosts that satisfy microclimate and metabolic needs are often occupied by generations of bats (Humphrey 1975) [*i.e.*, high site fidelity].

Anthropogenic roost disturbance and alteration are the greatest threats and causes for decline for most cave-dwelling bats (Mohr 1976, McCracken 1989). Large populations concentrated in a handful of caves, and bats' low reproductive potential (Barclay and Harder

2003), predispose velifers to rapid population decline should prolonged disturbance or destruction befall key roosts (such as maternity caves). Even though velifers are the most commonly encountered bat in Texas caves (Reddell 1994), several velifer caves have been abandoned due to human disturbance (Elliott 1994).

Harrell's is a single entrance cave 28.7 m deep and 152 m long with a huge room that contains several bat roosts and water pools (Fig. 1). Within the cave, bat roosts are easily distinguishable by dark ceiling stains and guano accumulation (Fig. 2 & Table 1). Although there are several bat roosts in the cave, it is likely that all are not occupied at once. That is, the bats may move amongst the roosts to satisfy body temperature needs (*i.e.*, metabolic regulation), life cycle needs (*e.g.*, nurseries), or to find a roosting surface without seeping water (especially during the rainy season). In this report, I summarize a cold season in-cave visit, and warm season population monitoring at a velifer maternity cave (Harrell's cave) in San Saba county, Texas. Additionally, I offer cave management recommendations to ensure a viable velifer population at the site.

Methods

Microclimate and Bat Roosts

During January 2008, I along with Jim Kennedy (Bat Conservation International biologist) and two cavers; mapped, measured, and photo documented the bat roosts inside of the cave. We defined a bat roost(s) as an obvious, darkened (also called stained), roughened area on the ceiling or wall with guano accumulation underneath (Fig. 2). Roughened areas on ceilings and walls provide a substrate to which bats can reliably cling during roosting. Darkened or stained areas result from the body oils of generations of roosting bats. I measured cave ceiling temperatures with a Raytek Raynger ST Pro infra red (IR) laser thermometer [Fluke Company].

Emergence Count

I placed 3 bedsheets in an "L" configuration on the south/southeast side (2 sheets) and the east side (1 sheet) of the entrance sink [west/southwest side is the sink headwall {no sheets needed}] (Fig. 3). I used the south/southeast bedsheets (long portion of the "L") as the counting screen to view emerging bats (bats flew between sheets and camera). Once bats emerged from

the entrance shaft, this configuration forced them to fly either in one direction (north/northwest toward a video camera), or continue their ascent above the sheets, out of camera field-of-view. Bedsheet height ranged from 1.6 m to 3 m and length ranged from 2.5 m (east side) to 5.5 m; all bedsheets made contact with the ground (prevented bats from flying underneath). I noticed that some bats collided with the sheets as they emerged. I observed no obvious harm to the bats, nor were any bats grounded due to sheet collision (*i.e.* the sheet absorbed the impact energy during collisions). Most bats redirected their flight path and left the viewing area; no bats stalled (*i.e.* lost lift) as a result of sheet collision.

I used two IRLamp6 [20° beam angle] infra-red illuminators (Wildlife Engineering Company) to illuminate the entrance. The lamps were placed approximately 5 m to the north (lamp 1) and northwest (lamp 2) of the entrance with the lamp axis oriented toward the bedsheets (Fig. 3). Once a month during May, July, and September, I recorded the emergence with a Sony Handycam DCR-HC96 video camera with 0 lux capabilities (Sony Electronics, Inc.), and I archived the footage onto DVD. I mounted the camera on an approximately 1 m high tripod, situated approximately 5 m north of the entrance. To ensure that I could readily identify and count only emerging bats, the camera field-of-view (FOV) contained only the sheets, the top of the entrance shaft, and the sink headwall. By creating a FOV in this manner, I reduced the potential to double count bats that lingered in the area.

I began my count 2-5 minutes after the first bat emerged from the cave. To count emerging bats, I replayed the footage in slow-motion for one minute (1 minute of real-time footage took 3 minutes to review in slow-motion). I counted bats for one minute, every three minutes, during a minimum of 42 minutes (July and September counts). This protocol resulted in fourteen 3-minute count intervals which accounted for early emergence, main emergence, and late emergence patterns (mathematically, 14 intervals spaced 3 minutes apart = 42 minutes). As long as bats continued to emerge, I counted past 42 minutes (May count = 66 minutes [see “diffuse” emergence in Results]). I classified an ***emerged bat*** as a bat(s) that flew from within the cave passage, then up the entrance shaft, and then exited the entrance into surface flight paths. By counting only ***emerged bats*** (*i.e.*, bats which flew *out* of the cave entrance), I greatly reduced the risk of double-counting bats that circled outside of the roost before they dispersed, and double-counting bats that re-entered the roost (Kunz *et al.* 1996). During counts, I carefully

identified an emerged bat *and* the shadow of the bat cast onto the sheets by the IR lamps. I advise caution when counting emerging bats using IR lights and sheets; one must ensure that a bat, not the shadow, is counted. Failure to identify bat *and* shadow may increase the risk of double-counting which may result in over-estimation. To avoid bat disturbance during emergence, I used a red LED lamp to illuminate data sheets and instruments.

I calculated parametric values (average and standard deviation) for the fourteen 3-minute count intervals (42 minute count). Next, I computed 95% confidence intervals [upper and lower limits] based on the *t*-distribution equation (Sokal and Rolf 2000). I rounded all computed population estimates either up or down to the nearest ones place (*e.g.* 47.8 bats = 48 bats). I plotted emergence data using SigmaPlot (SPSS Inc., 2002, Version 8.02).

I recorded the time when the *first* bat flew out of the cave (*i.e.*, emergence commencement). I then subtracted official sunset time from commencement time to document monthly emergence lag time patterns. At 5-15 minute intervals, I recorded surface wind speed/direction and air temperature 1.5 m above ground level using a Skymaster SM-28 handheld weather meter (Speedtech Instruments). During May and July counts, I recorded bat calls using a Pettersson Ultrasound Detector D-240X with time-expansion capabilities (Pettersson Elektronik AB) and an iRiver Rockbox H320 MP3 device (ReignCom). I viewed and analyzed call sonograms using SonoBat 2.6 for Windows (SonoBat, Arcata, Calif.).

Results

Microclimate and Bat Roosts

I observed 7 distinct roosts within the cave (Fig. 1); the roosts occupied 43.3 m² of ceiling surface. The largest roost was well-defined (*i.e.*, heavily stained ceiling and had deep guano accumulation underneath) and occupied 18.28 m²; the smallest roost was also well-defined and occupied 1 m² of ceiling surface (Table 1). I also observed ten small diameter, shallow ceiling pits with light staining and shallow guano accumulation underneath. The pits were scattered around the delineated roosts and each pit could accommodate approximately 10-15 bats. Using a roosting density of 1,700 velifers/m² (Twente 1955b, Barbour and Davis 1969, Fitch *et al.* 1981), I estimated that approximately 73,810 velifers (includes 200 additional bats from 10 ceiling pits) could occupy the cave (**note**: density is based on winter roosting when bats

may cluster tightly; summer roosting density may not be clustered tightly). I based my estimate on the assumption that *all* surfaces with staining and guano signs are occupied at once by velifers and that the bats do not move amongst the roosts. My assumption is likely not valid. I calculated the preceding estimate to define the *potential* carrying capacity of the cave, based solely on the premise that bats select a portion of the cave for roosting because optimal life cycle needs are met. In Harrell's cave, the bats likely occupy a roost surface for certain periods of time, then abandon that surface due to microclimate change/small-scale roosting surface changes (*e.g.*, seeping, meteoric water may force them to move); the bats may use certain portions of available roost space at a time (*e.g.*, for roost number 5, instead of occupying 18.48 m², only 9.5 m² of the roost is occupied); the bats may segregate by sex and age amongst the roost surfaces and shuffle around these roosts during social interactions; the bats may use a roost surface only for pups (*i.e.*, pups are "hung" in nursery clusters) and then abandon the surface once the pups are weaned; or the bats may use a roost surface only during spring and fall migration.

I observed one unidentified bat flying around the room; I observed no other bats in the cave. Eastern pipistrelle bats (*Perimyotis subflavus*) commonly hibernate in central Texas caves (personal obs.), so it is likely that the bat I observed was a pipistrelle. Warm temperatures inside of Harrell's cave likely prevented this bat from reaching deep torpor, thus it was easily disturbed. Additionally, warm temperatures may also preclude groups of bats from using this cave as hibernacula.

Cave ceiling temperatures remained in a narrow band of 21.8° - 23.2° C (71° - 73° F), which is within the range of optimal roost temperatures for velifer maternity caves. In gypsum caves in Kansas, velifers were active in roosts with temperatures ranging from 18° C in May to 29° C in June; one maternity cave with 15,000-20,000 bats remained between 15° C and 20° C during the summer (Twente 1955b). Another velifer nursery cave remained at 20° C during July, and a building maternal site fluctuated between 25° C and 35° C (Kunz 1973). Maternal sites for velifers in mines and caves in Arizona ranged between 21° C and 29.5° C (Hayward 1970). Spring/summer roost temperature in a velifer maternity cave on Fort Hood, Texas ranged from 16° - 26.1° C (Pekins 2007). Cave temperatures during the winter suggest that Harrell's remains warm throughout the year, and possibly increases during the spring/summer when the bats are present, perhaps increasing by as much as 5° - 10° C. Several factors contribute to the ability of

Harrell's cave temperature to remain warm and likely stable throughout the year: 1) the volume of the huge room buffers/resists short-term temperature fluctuations associated with surface seasonal changes, 2) the water pools keep cave humidity high, which contributes to temperature fluctuation buffering (mentioned in previous factor), 3) the gently-sloped cave ceiling [which has micro features such as shallow domes and recesses] traps and retains warm air, 4) the sloped cave floor with huge breakdown blocks (air dams) prevents cold, sinking air from infiltrating deep into the cave where the bats roost, 5) the ceiling restriction near the entrance shaft prevents warm air from drifting upslope and exiting through the entrance (refer to Fig. 1), 6) the small diameter vertical pit shaft minimizes air escape from the cave, and 7) the single entrance virtually eliminates the "chimney effect" air exchange with the surface (Tuttle and Stevenson 1978). Should Harrell's cave temperature decrease during January and February, velifers have the ability to increase roost temperature via clustering behavior. Clustering bats can modify roost temperature (Herreid 1963, Kunz 1973, 1974), especially if clustering occurs in a warm air trap [ceiling domes and recesses] (Bakken and Kunz 1988).

Emergence Count

I estimated that 2,907 bats (4,383 bats upper CI: 1,431 bats lower CI) occupied the cave in May; 5,922 bats (9,358 bats upper CI: 2,485 bats lower CI) occupied the cave in July; and 768 bats (1,110 bats upper CI: 426 bats lower CI) occupied the cave in September (Fig. 4). From May to July, the cave population nearly doubled, confirming that Harrell's cave is a maternity site. The population increase is the result of newly volant pups emerging from the cave, assuming that one female gives birth to one pup and the single pup survives to weaning. During all 3 months, the velifers emerged in a distinct pattern from the cave: pre-main emergence (low density for approximately 5 minutes); main emergence (high density for approximately 20 minutes); and post- main emergence (low density for up to 40 minutes) [Fig. 5]. The high density "spike" of bats during main emergence compared to the low density of bats during non-main emergence directly contributed to the wide confidence intervals observed in Fig. 4. The velifers emerged in groups of 5-15 bats. During main emergence, the temporal spacing between groups was shorter (groups of bats emerging in succession rapidly) than during non-main emergence. This is consistent with my observations for velifers at a maternity cave on Fort Hood, Texas (Twente 1955b, Kunz 1974, Pekins 2007).

Examination of Fig. 5 demonstrates that May emergence was more “diffuse” than July and September. That is, during May, the emergence was longer (*i.e.*, took more time for bats to emerge even though there were less bats than during July). Further, there were no large scale differences between main emergence and non-main emergence (*i.e.*, even though a “spike” occurred, bat emergence density more even across pre- and post-main emergence). In other words, during May, main emergence was 4 times greater than non-main emergence, whereas during July, main emergence was 7-14 times greater than non-main emergence. “Diffuse” emergence during May is another indication that Harrell’s is a maternity cave. Kunz (1973) observed that velifer parturition occurred in south-central Kansas during mid to late June. Because central Texas is located further south, parturition occurs approximately one month earlier than in Kansas (Schmidly 1991, 2004). During May in central Texas, parturition has already occurred for velifers, so the females must nurse their non-volant pups. The “diffuse” emergence I observed at Harrell’s in May resulted from the differential emergence related to nursing stage of the females. Parturition occurs at different times for different females. The result is that some velifers give birth *earlier* than others, and some give birth *later* than others. Differential birth rates result in differential nursing needs. As a consequence, some bats may be nursing neo-nates, other bats may be nursing older bats, and other bats may not have given birth yet. Rather than emerging *en masse* during the main emergence, some bats may delay emerging to nurse neo-nates because they (the nursing females) may be away from the cave for extended periods during foraging, whereas pregnant females may emerge earlier because they are not obligated to nursing duties. Kunz (1974) observed that pregnant velifers emerged significantly earlier than lactating velifers. Females that are nursing older pups may not have to nurse as long as those feeding neo-nates, thus the former can emerge sooner than the latter. By June and July, nursing duties have greatly subsided and the pups are volant, so the females are free to emerge whenever they choose (usually *en masse* during main emergence). My observations of population doubling, “diffuse” emergence during parturition periods, and main emergence “spikes” at Harrell’s cave are consistent with observations at a velifer maternity cave on Fort Hood, Texas (Pekins 2007) and in south-central Kansas and northwestern Oklahoma (Kunz 1974).

The velifers appear to use 2 main flight paths once they have emerged. The first path follows the north/northwest↔south/southeast axis over the entrance shaft (Fig. 1). This path

corresponds with the small grassland that extends north from the entrance sink to the secondary road, and the recently cleared pathway that extends south upslope from the entrance sink to the property line. After emerging, bats flew directly north or south or they flew in small, tight circles in the sink area before heading north or south. The second path is the area west of the sink headwall where Ashe juniper (*Juniperus ashei*) trees have been limb-cut from the ground level to ca. 2 m high (Fig. 1). Bats use this path, but it does not appear to be a major route. I rarely observed velifers using the east side, likely because of dense juniper trees and saplings.

The velifers began emergence approximately 20 minutes after sunset (Table 2), consistent with what others have observed (Twente 1955b, Barbour and Davis 1969, Kunz 1974, Pekins 2007). I recorded a total of 172 minutes of emergence (Table 2). I recorded numerous velifer calls and feeding buzzes, several Mexican free-tailed bat (*Tadarida brasiliensis mexicana*) calls, and a few calls suggestive of eastern red bats (*Lasiurus borealis*). I am uncertain if the free-tailed bats emerged from the cave. Red bats are tree-roosting species; thus they did not emerge from the cave. It is possible that other bat species fly overhead and are attracted to the area by the calls and feeding buzzes of the velifers (serves as a cue for potential food source), or it is possible that other bat species utilize the ponds and forests found on the ranch, or it is possible the ranch is in a flight path that leads to nearby Colorado River and its tributaries.

Management Recommendations

Bats occupy an important role in ecosystems by consuming invertebrates (including many crop-damaging and pest insects), pollinating plants (including important agricultural plants), and dispersing seeds in tropical regions. Contrary to misconceptions, bats: are not blind, are not dirty, do not become entangled in human hair, and seldom transmit disease to humans or other animals. Less than one-half of one percent of bats contract rabies, and these bats will bite only in self-defense. Only 3 out of 1,100 world-wide bat species consume blood for a meal. These 3 species are found in Latin America, and only one species consumes blood from a mammal. Any loss of bats and bat roosts contributes to the decline of ecosystems and biodiversity.

To ensure a viable velifer population at Harrell's cave in San Saba county, Texas, I recommend that the following actions occur:

- Restrict visits inside the cave to the winter (November-February) when the bats are not present
- Install a microclimate datalogger (*e.g.* HOBO or iButton) in the cave so that conditions can be recorded throughout the year
- Enter the cave once a year (in the winter) to record ceiling temperatures, monitor water pool levels, look for hibernating bats, and collect any other data as necessary. To avoid death or injury the cave should be entered: using proper vertical cave techniques, using rappelling equipment designed for cave use, using safety gear (pads, helmet, and lights), and following caving ethics (see The National Speleological Society website at www.caves.org). Local cavers can assist with this endeavor (Texas Speleological Association, Texas Speleological Survey, or Bat Conservation International)
- Visit the cave during July to count bats using the same or similar methodology described in this report. If this is not feasible, visit the cave during July to time the emergence (record the time when the bats begin emerging and record the time when the emergence ceases)
- Visit the cave site at least monthly (especially after spring/summer rainstorms) to ensure the entrance and entrance shaft is free from debris that may have become lodged. Care should be taken when approaching the cave entrance sink
- Visit the cave site during spring and summer to ensure woody and herbaceous vegetation remains below 1 foot tall in the area surrounding the cave entrance (the flight paths described in this report). Attention should be paid to the shrubs and greenbrier that may re-grow around the entrance shaft. Care should be taken when approaching the cave entrance sink
- Support bat and bat cave research that may be conducted by graduate students, research institutions, and non-profit organizations
- I DO NOT recommend that cave gates or any other gate device be installed over the cave entrance. The small diameter entrance shaft, vertical nature of the shaft, and the single

entrance to the cave makes this cave a poor candidate. If a gate is necessary, Bat Conservation International should be contacted so a proper gate can be recommended and designed

- If visits are made to the cave to enjoy the bat emergence, I recommend: 1) that viewing be conducted from the existing secondary road that passes north of the cave, 2) that white lights NOT be directed to the cave entrance (long duration light shine may cause the bats to retreat back into the cave), and 3) that flash photography be limited
- Pesticides, herbicides, and fertilizers should NOT be used within a 50 foot (15 m) perimeter around the cave entrance

Literature Cited

- Bakken, G. S., and T. H. Kunz. 1988. Microclimate methods. Pages 303-332 *in* Kunz, T. H. editor. Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington D. C., USA.
- Barbour, R. W., and W. H. Davis. 1969. *Myotis velifer* [Plate VI]. Pages 67-72 *in* Bats of America. University Press of Kentucky, Lexington, Kentucky, USA.
- Barclay, R. M. R., and L. D. Harder. 2003. Life histories of bats: life in the slow lane. Pages 209-253 *in* Kunz, T. H. and M. B. Fenton editors. Bat ecology. University of Chicago Press, Chicago, Illinois, USA.
- Davis, R. B., C. F. Herreid II, and H. L. Short. 1962. Mexican free-tailed bats in Texas. Ecological Monographs 32(4):311-346.
- Dunnigan, P. B., and J. H. Fitch. 1967. Seasonal movements and population fluctuations of the cave bat (*Myotis velifer*) in south-central Kansas. Transactions of the Kansas Academy of Science 70(2):210-218.
- Elliott, W. R. 1994. Conservation of Texas caves and karst. Pages 85-98 *in* Elliott, W. R., and G. Veni editors. The caves and karst of Texas 1994 NSS convention guidebook. National Speleological Society, Huntsville, Alabama, USA.
- Fitch, J. H., K. A. Shump Jr., and A. U. Shump. 1981. *Myotis velifer*. Mammalian Species 149:1-5. The American Society of Mammalogists, Lawrence, Kansas, USA.
- Hayward, B. J. 1970. The natural history of the cave bat *Myotis velifer*. Res. Sci., Western New Mexico University 1:1-74.
- Herreid, C. F., II. 1963. Temperature regulation of Mexican free-tailed bats in cave habitats. Journal of Mammalogy 44:560-573.
- Humphrey, S. R. 1975. Nursery roosts and community diversity of nearctic bats. Journal of Mammalogy 56(2):321-246.

- Kunz, T. H. 1973. Population studies of the cave bat (*Myotis velifer*): reproduction, growth, and development. Occasional Papers Museum of Natural History University of Kansas 15:1-43.
- _____. 1974. Feeding ecology of a temperate insectivorous bat *Myotis velifer*. Ecology 55(4):693-711.
- _____, D. W. Thomas, G. C. Richards, C. R. Tidemann, E. D. Pierson, and P. A. Racey. 1996. Observational techniques for bats. Pages 105-114 in Wilson, D. E., J. Nichols, R. Rudrin, R. Cole, and M. Foster editors. Measuring and monitoring biological diversity, standard methods for mammals. Smithsonian Institution Press, Washington, D. C., USA.
- McCracken, G. F. 1989. Cave conservation: special problems of bats. National Speleological Society Bulletin 51:49-51.
- Mohr, C. 1976. The protection of threatened cave bats. Pages 57-62 in National Cave Management Symposium Proceedings, Albuquerque, New Mexico. Speleobooks, Albuquerque, New Mexico, USA.
- Pekins, C. E. 2007. Cave myotis bat population and cave microclimate monitoring at a maternity site on Fort Hood, Texas during 2007. In Endangered species monitoring and management at Fort Hood, Texas: 2007 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
- Reddell, J. R. 1994. The cave fauna of Texas with special reference to the western Edwards Plateau. Pages 31-49 in Elliott, W. R., and G. Veni editors. The caves and karst of Texas 1994 NSS convention guidebook. National Speleological Society, Huntsville, Alabama, USA.
- Schmidly, D. J. 1991. Cave myotis (*Myotis velifer*). Pages 82-87 in The bats of Texas. First edition. Texas A & M University Press, College Station, Texas, USA.
- _____. 2004. Cave myotis (*Myotis velifer*). Pages 86-88 in The mammals of Texas. Sixth edition. University of Texas Press, Austin, Texas, USA.
- Sokal, R. R., and F. J. Rohlf. 2000. Biometry. Third edition. W. H. Freeman, New York, New York, USA.
- Tinkle, D. W., and I. G. Patterson. 1965. A study of hibernating populations of *Myotis velifer* in northwestern Texas. Journal of Mammalogy 46(4):612-633.
- Tuttle, M. D., and D. E. Stevenson. 1978. Variation in the cave environment and its biological implications. Pages 108-121 in Zuber, R., J. Chester, S. Gilbert, and D. Rhodes editors. National Cave Management Symposium Proceedings. Adobe Press, Albuquerque, New Mexico, USA.
- Twente, J. W., Jr. 1955a. Aspects of a population study of cavern dwelling bats. Journal of Mammalogy 36(3):379-390.
- _____. 1955b. Some aspects of habitat selection and other behavior of cavern dwelling bats. Ecology 36(4):706-732.
- U.S. Fish and Wildlife Service (USFWS). 1994. 50 CFR part 17. Endangered and threatened wildlife and plants: Animal candidate review for listing as endangered or threatened species: Federal Register 59: 58982-59028.

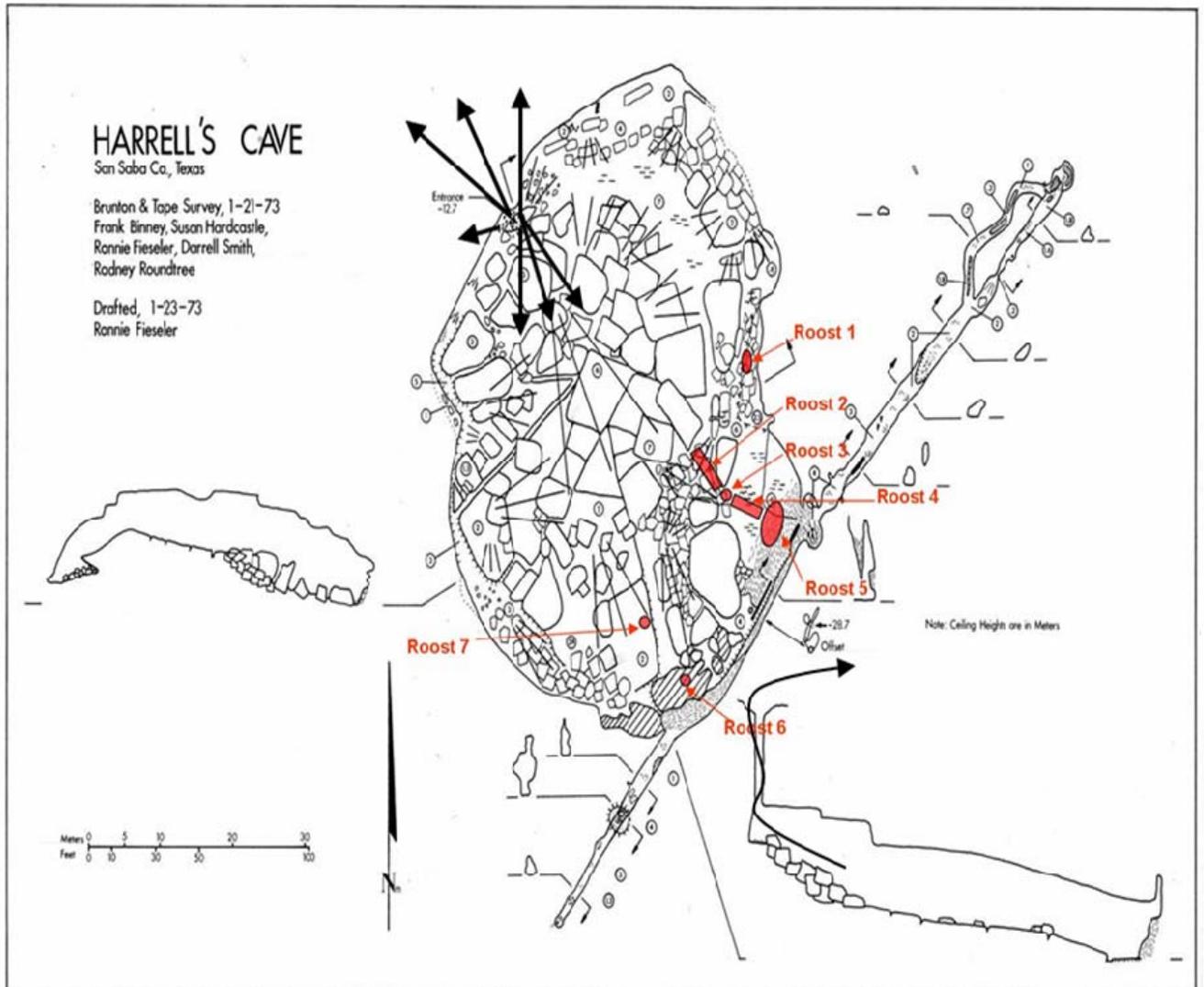


Figure 1. Harrell's cave map: plan (overhead) and profile (section) views, cave myotis maternity site San Saba county, Texas. Red polygons delineate 7 bat roost areas defined by stained ceilings with guano accumulation underneath (see also Table 1). Heavy black arrows indicate bat flight paths on the surface (upper middle) and within the entrance shaft (lower right). Ten small diameter, shallow, stained ceiling pits with shallow guano accumulation underneath (not delineated) surround the roosts; the pits can accommodate ~10-15 bats each. Note that roost 6 is over a pool.



Figure 2. Example of well defined bat roost (roost number 4 from Fig. 1 & Table 1) in Harrell's cave, San Saba county, Texas. Yellow circle delineates well stained (darkened) ceiling; red circle delineates deep guano accumulation. Photo by Jim Kennedy, Bat Conservation International.



Figure 3. Bedsheet screen and night vision equipment set-up at Harrell's cave, San Saba county, Texas. Photo is looking southeast across entrance shaft and entrance sink. Sink headwall is at image right. Sheets are placed in an "L" configuration; solid sheets are used as the counting screen and form the long portion of the "L"; striped sheet forms the short portion. IR lamps are at image lower left and lower right (black). 0 lux camera is at image lower center. Cleared, major flight path can be seen behind solid sheet. Second major flight path extends from cave and past the night vision equipment set-up. Refer to Fig. 1 for flight paths and cave cardinal directions. Photo by Charles E. Pekins.

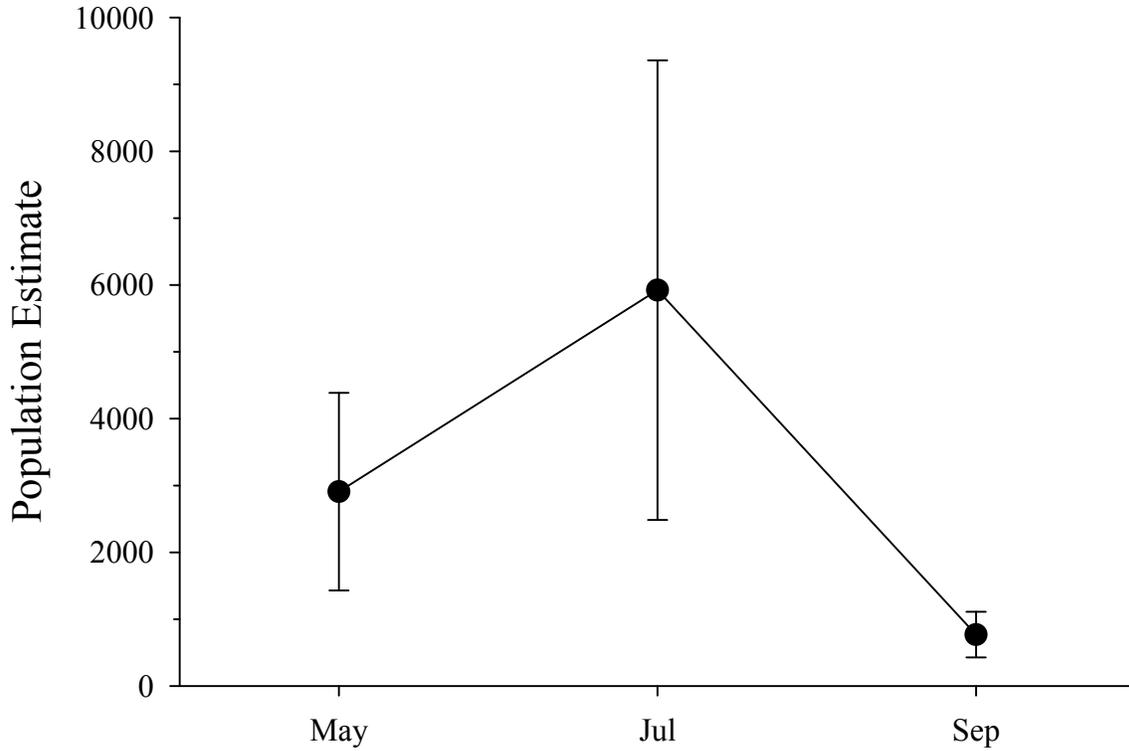


Figure 4. Monthly population estimate and occupation trend for cave myotis roosting in Harrell's cave, San Saba county, Texas during May, July, and September 2008. Each value and upper and lower 95 % limits were calculated based on the t distribution. July and September estimates are based on 42-minute emergence count period. Due to "diffuse" emergence (see Fig. 5), May estimate is based on 66-minute count period. Doubling of population from May to July suggests Harrell's is a maternity cave.

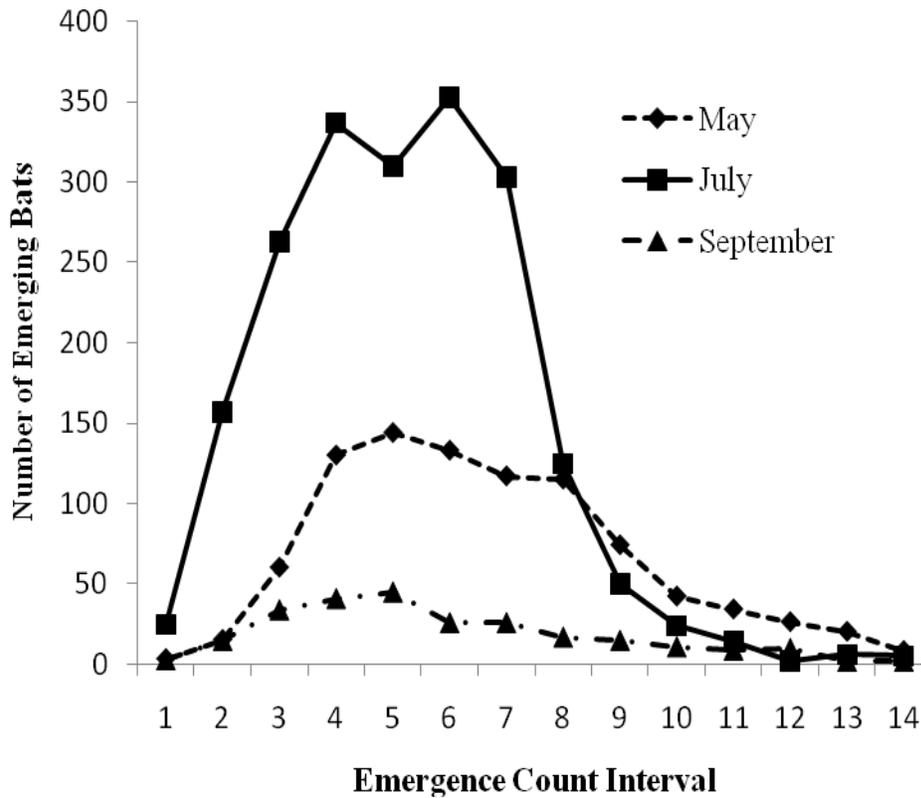


Figure 5. Emergence count interval between season variability observed at Harrell’s cave, San Saba county, Texas during 2008. Counts typically spike within 25 minutes, then approach 1. Emergence density doubling from May to July suggests Harrell’s is a maternity cave. Emergence progression (25 minute spike followed by drop in emergence density) contributes to wide confidence intervals observed in Fig. 4. May count is “diffuse” due to mix of lactating and pregnant females. When compared to July and September, May “diffuse” effects are observed in the higher number of emerging bats past count interval 9.

Table 1. Roost area measurements for cave myotis in Harrell's cave, San Saba county, Texas (refer to Fig. 1 for location). Stained category poor = very light staining, category well = heavy staining (see Fig. 2 for heavy). Ten satellite roosts (not delineated or reported below) occur in small diameter, shallow ceiling pits and can accommodate 10-15 bats each.

Roost number	Area (m²)	Stained category	Guano category
1	5.32	poor	shallow
2	12	well	deep
3	1	well	deep
4	4	well	deep
5	18.48	well	deep
6	1.5	well	unk (over pool)
7	1	poor	shallow

Table 2. Lag time between official sunset and cave myotis emergence commencement at Harrell's cave, San Saba county, Texas during 2008. Also shown is the length of filmed emergence.

Month	Sunset	First Bat Emerges	Difference	Footage Minutes
May	2026	2051	25 minutes	73 minutes
July	2034	2056	22 minutes	48 minutes
September	1921	1939	18 minutes	51 minutes
Mean			21.6 minutes	172 minutes (total)