Monitoring the effectiveness of bat compatible gates in the Silver Reef, East Reef and Tushar Mountain mining districts In Southwestern Utah

Principal Investigator
Dr. Kathryn W. Grandison

Project Supervisor
John Taylor

Project Leaders
Cameron Boyce
Nick Ervin
Keidy Rusk

Data Compilation
Cameron Boyce
Nick Erwin
Lindsey Heap
Oasee Malhotra
Rustin Pickett
Keidy Rusk

Cooperators
Utah Division of Oil, Gas, and Mining
Utah Division of Wildlife Resources, Southern Region
Bureau of Land Management, Arizona Strip Resource Area
Southern Utah University, Department of Biology

Field Observers
Southern Utah University undergraduate research students

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ABSTRACT

Populations of many bat species are believed to be declining due to a decrease in historical habitat. Recent studies have shown that abandoned mines are being used by numerous bat species. The Utah Department of Natural Resources, Division of Oil, Gas and Mining Abandoned Mine Reclamation Program is currently authorized to close abandoned mines to protect the public from potential hazards. Abandoned mines are surveyed prior to closure and those providing suitable habitat are sealed with bat-compatible gates. Few post-gate monitoring studies exist to document long-term effects of these techniques for conserving bat populations. This study is the initial step in this process. Long-term objectives include determining daily and seasonal use of mines by bats and evaluating species composition and relative numbers of bats utilizing the mines.

Two gated mines in the Silver Reef area, and one recently gated mine in the East Reef.

Eleven of Utah's 18 bat species have been netted or acoustically recorded at these mine entrances. *Myotis sp*. and Townsend's big-eared bats, *Corynorhinus townsendii pallescens*, were found in highest numbers in the Silver Reef (gated) and East Reef (recently gated). A combination of monitoring techniques, (infra red digital video recorders, night vision goggles, Anabat™ acoustic detection, and Trail Master™ event recorders), were used to collect bat behavior data. Infrared digital video provided a more accurate analysis of bat behavior and was the primary method for data collection. Bats circling before exiting the mine were more frequent at gated mines than at un-gated mines.

INTRODUCTION

Concern over bat populations has increased in recent years and many bat species appear to be declining (Stabbings 1980, McCracken 1988, Tudge 1994). Of the 43 United States bat species, five are listed by the USFWS as endangered and 19 are former candidates for listing (Code of Federal Regulations 1991).

Increased research of bats has resulted in many agencies recognizing them as a valuable species, worthy of inclusion in management decisions. Unfortunately, detailed data are lacking, and the present status of many bat species remains unknown (McCracken 1989). In addition, adequate funding is often unavailable to determine long-term trends in bat populations.

One of the primary causes of declining bat populations may be the loss of suitable habitat. However, in recent years, many cave dwelling bats have increasingly been found in abandoned mines (Pierson 1989, Brown and Berry 1991, Pierson and Brown 1992, Brown et al. 1993). This increase has largely been attributed to the dislocation of bats from caves due to increasing recreational caving, and the commercialization of many caves formerly identified as bat roosts (Tuttle, 1979, Brown and Berry 1991). Twenty-six of the 43 U.S. bat species are now known to roost regularly in abandoned mines (Pierson et al. 1991, Tuttle and Taylor 1994). Of the 18 Utah bat species (Hall 1981, Zeveloff 1988), 14 species regularly occur in mines. Ten Utah bat species are former Category 2 (C2) candidates for federal listing (Federal Register 1994), of which eight species inhabit mines during some time of the year. In recent years, Townsend's big-eared bat (*Corynorhinus townsendii),* a former Category 2 species and a state sensitive species, has been found almost exclusively in abandoned mines throughout the west (Brown and Berry, 1997).

Recent studies have shown abandoned mines throughout North America are being used for a variety of roosting needs including maternity, hibernation and day and night roosts (Tuttle & Taylor 1994), because of the stable internal microclimate. In particular, *C. townsendii* generally use mines with ambient temperatures around 15 °C as night roosts, 0°C to 11°C as hibernacula and 15°C or above as maternity roosts and day roosts (Humphrey and Kunz 1976). Mines offer not only a stable microclimate but may offer increased protection from predation

(Belwood and Welch 1991, Tuttle 1993).

In Utah and elsewhere in the West, abandoned mines are being sealed or fitted with bat compatible gates to protect an increasingly curious public. In the Silver Reef mining district, located in southwestern Utah, over 140 abandoned mine openings have been closed with bat compatible gates or grates on public lands administered by the Bureau of Land Management Dixie Resource Area, the Dixie National Forest and lands in private ownership within the Silver Reef Historic Mining District. Prior to the gating effort, a graduate student from Utah State University conducted a warm and cold season survey in an effort to identify bat species and general use patterns within these mines. The study found extensive bat use throughout the area, including a large maternity colony of *C. townsendii,* a Utah state-sensitive species (Lengas 1996).

Although gating mines offers a probable solution to protecting known bat habitat and decreasing human disturbance at roosts, few studies have been conducted regarding the long-term effect of bat gates on existing bat populations.

Despite the fact that much is being attempted to protect bats, it has been noted that bat gates may deter certain species from using mines (Tuttle 1977, White and Seginak 1987), may inadvertently inhibit bats currently using the mine (Ludlow & Gore, Burghardt, 1997), may change the internal microclimate such that bats no longer use mines for the same purpose (Richter, et. al. 1993), and may even offer a temporary "post" for snakes, feral cats or other small predators (Tuttle, 1997; Brack, as cited in Currie 2000). As more agencies adopt programs to protect bat populations, resource managers may have a negative impact on populations they are trying to protect, just through their presence or survey methods. Thomas (1995) found increased mortality after non-tactile disturbance in hibernating bats because of premature fat reserve depletion. Because bats in full flight, expend more energy per unit volume than any other mammal (Twente 1955), any additional energy expenditure, such as what might be required to maneuver a gate or avoid a potential predator (observer and/or natural) may have long-term impacts on bat populations.

The high concentration of abandoned mine closures and the existence of pre-closure survey data make Silver Reef an ideal site for evaluating the long-term effectiveness of bat compatible gates, further aiding land managers in making appropriate gate installation decisions. The Bat and Mines Project objectives included:

- Collection of baseline data to compare bat use of both gated and un-gated mines
- Documentation of seasonal, monthly, and daily bat activity patterns for a selected group of gated and un-gated mines
- Identification of bat species using this group of gated and un-gated mines and monitoring bat population trends in these mines
- Collection of internal and external temperature and relative humidity to determine if temperature affects bat populations and/or behavior
- Documentation of changes in bat behaviors associated with predator (human and/or natural) and bat gate avoidance.
- Evaluation of external monitoring techniques for assessing bat activity at the mine entrances

METHODS AND MATERIALS

Study Area

In 1997**,** two gated mines in Silver Reef, WH-48 and WH-180, and one un-gated mine, chosen in 1998, G4-HO7 in East Reef, were selected for monitoring based on known bat activity and accessibility (M. Mesch pers. com. and Lengas 1996, Silver Reef report 1999). G4-HO7's main entrance was subsequently gated in November 2000 and two of the other entrances to the mine were sealed off during gate installation. The Silver Reef and East Reef mine areas are located in the Mojave Desert eco-region at its transition to the Great Basin at approximately 3500 feet in elevation. These reefs are situated west and east of Leeds, Utah and consist of sedimentary rock layers.

Silver Reef gated mines WH-48 and WH-180 are large complex mines with multiple gated openings, over 1000 feet of drifts and multiple levels. The G4-HO7 mine in the East Reef has 120 feet of drift with one small side drift and one stope; the three portals are all located within 100 feet of each other. In November 2000, two of the three East Reef mine portals were backfilled during reclamation and a gate was placed on the center portal, however, a crack measuring 8 inches wide and 6 feet high above the gated portal was left open. Due to lack of bat activity, this mine was dropped from data collection for the 2003 season.

During 1999 to 2004 field seasons, a combination of visual, video, acoustic and trapping techniques were used at the Silver Reef gated mines beginning in May and ending in October. (Tables 1 and 2). Internal infrared data logger were installed and downloaded year-round at both Silver reef mines (WH-180 and WH-48).

Monitoring days were chosen as close to the new moon phase as possible to minimize possible effects of moonlight on bat behavior (Tables 1 and 2). In order to minimize the effects of weather on bat activity, simultaneous observations were made on gated and un-gated mines for three consecutive nights from approximately 8:30 p.m. to 11:30 p.m.

In 2003, bat activity and species composition were assessed at each mine by mist netting one night during the survey period (Tables 1 and 2). Capture data from 2000-02, suggest that the un-gated Rob Roy adit 1, 2 and 3 was used as a Long-legged myotis (*Myotis volans*) maternity colony (Table 1a and b). Consequently Rob Roy 1 was only netted after mid-July to avoid disturbance during critical reproductive time in June. The other mines were netted throughout the season (Table 2).

Several types of survey instruments were used to maximize observations of bat activity (Tables 1 and 2). During the surveys the Tushar Mountain mines had one to four observers present. A pair of night vision goggles, a laptop computer with Anabat™, an internal Trail Master® infrared data logger 10m inside gate, at least one max/min thermometer, and a Sony™ Hi-8 digital infrared camcorder. . All equipment was set up before 8:00 p.m. and camcorders were started at 8:30 p.m. and ended at 11:30 p.m. In September, survey time began at 8:00 p.m. and ended at 11:00 p.m. to match changes in earlier sunset times.

The following descriptions document techniques used:

Trail Master™ 1500 (TMs)

TMs (infrared data loggers) consisting of an infrared light transmitter and receiver/data logger were placed inside each gated mine for continuous monitoring of bat activity without the presence of observers. An event was recorded by the receiver/data-logger when an object, such as a flying bat, interrupted the vertical IR beam passing between the transmitter and receiver. Transmitters were suspended from the roof of the mines approximately 4 to 6 feet above the receiver, which was centered on the floor of the mine. These internal TM sets were installed (8-10 meters inside the mine entrance) in 1999 in all Silver Reef gated mines and had continued to be used through the 2003 season. For security purposes TMs were not installed at un-gated Tushar Mountain mines until the mines were gated in October 2002. Installation of TM's was identical to the Silver Reef Mines excepting the Prince mine which required the TM to be set horizontally due to water inside the mine and the presence of pack rats. TM's were downloaded monthly and batteries were replaced monthly to prevent data loss from power failure. Data collected by TM's were grouped in 15-minute periods using SAS (SAS Institute) for graphical and statistical analysis.

In 2003, Joel Diamond videotaped bat behavior at the TM event recorders addressing the effectiveness of TM event recorders as a reliable source of bat activity. This video data was regressed with Trail Master data. If a relationship can be modeled, long-term monitoring of the gated mines with Trail Masters will be not only cost effective but extremely informative. As of the date of publication, this information has not been released, though preliminary data suggests that TM's are a stable indicator of bat activity.

IR Digital Recordings

Sony™ Hi-8 digital infrared camcorders were used to permanently record survey data, providing a more complete analysis of bat behavior at entrances. Additional IR light sources were placed near the mine opening to improve image resolution recorded by the camera. The cameras and all light sources were placed on 20 cm tripods and nestled near a rock or mine sidewall, or were used in conjunction with a bullet camera and cabled 15 meters away from the mine to minimize the effect of camera presence. The camera were focused to include the entire mine entrance in the frame. Each Hi-8, 120-minute digital tape yielded approximately 1 hour of recorded data. Each tape was then transferred to VHS tape after the sampling sessions and analyzed for: recording time, bat entrances, exits, circling and flyby behavior event numbers. Taping began at 8:30 p.m. and ended at 11:30 p.m. on each survey night except in September when the time was adjusted to 8:00 p.m. until 11:00 p.m. due to earlier sunset times.

Bullet Cameras:

Small infrared surveillance cameras (VW-1000-WP, Eye Witness) were used in conjunction with the Sony Digital cameras to further minimize disturbance at the mine entrance. The added improvements over the Sony digital cameras allowed observers to avoid the mine entrance once recording began. The slightly fish-eyed lenses (4cm X 6cm cylinders) were placed on the ground, limiting the height and presence of equipment at the mine entrance. Bullet cameras were connected with 15-meter coaxial cables to Sony Hi-8 camcorders located at an observation site 12 to 18 meters from the mine. Video was then recorded on Hi-8 tapes using the Sony digital camcorders allowing researchers to monitor mine activity and image clarity remotely by viewing the Sony camcorder's LED screen. Electricity was supplied tot he camera/ light set up by either a small battery pack or a rechargeable battery containing a power inverter. The small battery packs did not emit any sound detectable by Anabat® detectors, however, the batteries that were outfitted with inverters emitted small amounts of noise due to a fan that cooled the inverter. When inverters were used they were placed approximately 15-meters from the mine entrance.

Supplemental Lighting for Camcorders

Video image clarity was greatly affected by the level of light. To reduce disturbance, only infrared lighting was used. Each mine was lit using 1-3 Sony ® IR LED (8VL-IRC) lights, placed on small 20 cm tripods. New to the 2003 field season were two IR Lamp 6 made by Wildlife Engineering. These small yet powerful IR lights took the place of 3 Sony LED lights greatly reducing set up time and enhanced picture quality. The number of light sources was dependent on the size of the mine opening.

Anabat™ Ultrasonic Bat Call Detectors

To aid in species identification, Anabat® ultrasonic detectors were positioned on tables or on the ground approximately 10 meters in front of, or to the side of a mine entrance, depending on the topography of the surrounding area. These microphone units pick up the ultrasonic calls of bats in the area, sending the signal to a Z-Cam. The Z-Cam unit digitized the analog signal from the Anabat. The digitized signal was then sent to a laptop computer were the calls could be viewed and recorded using Anabat software. All bat calls were recorded to document bat activity. In addition, calls were recorded when captured bats were released to add to the species identification library.

Mist Netting

Mist netting was used to identify bat species (Tables 1-3). Mist nets were set as close as possible to the mine face to capture bats entering and exiting mine. Captured bat measurements included weight, sex, reproductive status, body dimensions, and age to develop site-specific life history information.

Statistical Analysis

Daily bat activity recorded using TM's totaled in 15-minute intervals over a 24-hour period. To accommodate the large amount of data associated with the TM event recorders, pivot tables were created using Microsoft Excel which allowed us to analyze individual days, weeks, months and entire years at once. These data were then compared across all years of the study (1999-2004).

RESULTS

Typical daily bat activity pattern and Seasonal bat activity trends

Bat activity throughout the day, as well as seasonally, differed greatly between WH-48 and WH-180, but was consistent overall within these mines between years.

In WH 48, the typical daily bat activity pattern in a 7-day period during mid-June and Mid August was similar in all years (2000-2004). This pattern included an initial emergence activity spike, which occurred at similar times (2100 hrs) with a pronounced early morning spike (0500 hrs). The magnitude of early morning spikes was similar to the magnitude of the initial spikes in August but not in June (emergence spikes are 50% higher in June). Bat activity from the hours of midnight to 0600 hrs varied consistently between (50-300 TM events/15 minute period) and stopped abruptly at 0600 hrs. The magnitude, however, of the initial bat activity spikes in August ranged from 30-50% of June activity numbers, with a concomitant decrease in activity bounces after midnight. (Figure 1a and 1b)

Overall and Seasonal Activity Patterns

The total amount of bat activity varied greatly between years, but showed a similar pattern of use. The highest bat activity rates were recorded in 2000, and 2003. Extremely low bat activity rates were recorded in 2002 (<10%). Seasonal bat activity peak numbers of each mine were fairly consistent between years, though varying in TM event magnitude. WH-180 generally experienced the first peak of activity in mid-May, followed by a slight lull. Late June and July experienced often the largest activity peaks, followed again by a lull in activity through late July and early August. A final peak, though much lower than either the early or mid-season peaks, occurred in mid-September. Bat activity then stayed relatively constant until October where it slows to almost nothing (Figure 1a, b and c). Daily bat activity totals recorded by TM's in WH-180 were also much more variable than the totals in WH-48.

Bat activity in WH-180 typically started with a large initial emergence spike, at similar times between months but may vary between years (e.g., spikes at approximately 2130 hrs in mid-June, and 2045 hrs in mid-August, Figures 2a and b). In general, when bat activity peaks occurred early in the evening in June they also occurred early in August.

In 2001, the initial emergence spike occurred about an hour and a half earlier in June and August (1900 hrs) but only earlier in August of 2004. The magnitude of the initial emergence spike varied between years, but not within years except in August of 2004. After the initial spike, bat activity levels decreases by about 90% and continue at that level throughout the night until activity levels drop off to zero abruptly after 0600 hrs. After the initial emergence most years resulted in smaller peaks spaced approximately 90 minutes apart (Fig 2a and b).

In contrast, the average nightly bat activity of WH-48 was very low throughout the spring, peaking in June and July, and falling abruptly in August (Figure 2a). Like WH-180, bat activity in WH-48 generally began just after sunset, peaking after 21:00 hours. Bat activity then almost ceased except for a small peak of activity that occurred around 1:30 am. Beginning in June, this small peak of activity increased to a more constant activity level throughout the night following the initial emergence at 21:00 (Figure 2c), but this pattern was found only in July and August (Figures 2b-e).

Species Composition

Species composition has been generally consistent within mines, and between years. One species has been captured at WH-180, while at least three species have been captured at WH-48.

Only *C. townsendii* were captured at WH-180. Both males and females were captured, with more females except in 2001. Though number of bats caught per net hour has dropped since 1999, net hours have also decreased and the capture dates have been postponed to later dates in the season. For example, during the early project year of 1999, WH-180 and WH-48 mines were netted monthly from June through October, however, in 2004 both mines were netted only in August.

Each year, at least three different species (Townsend's Big Eared Bat (*C. townsendii*), Fringed-tailed Myotis (*M. thysanodes)*, and either Big brown bats (*Eptesicus fuscus*) or *Myotis* spp. were consistently netted at WH-48. (Table 3, Figure 8a and b). In 2002 , one bat, (*C. townsendii*) in late September was trapped at East Reef gated mine G4-HO7. TrailMaster® data also showed low bat activity throughout the year. No other bats have been captured at that mine, and the TrailMaster was removed in Fall of 2002.

To determine overall bat use of the Silver Reef area, a water site (Hidden Valley Pond) was mist netted in July and August of the 2002 field season. Although multiple species were captured in 2001, including species not captured at mines, only one bat (*Nyctinomops macrotis*) was captured in 2002 (Table 3). Other bats, flying in the area but effectively avoiding the nets, were seen by observers with night vision goggles. Bats may have been especially wary due to gusts of winds (>8 m.p.h.) which caused the nets to visibly move and the extremely low water level in the pond as a result of drought conditions.

Species Composition using Anabat® Ultrasonic Detectors

The number of bat calls from each species was compared with the total number of calls recorded throughout the field season to provide relative acoustic species composition. Anabat detectors recorded data at H-07 from May through September, WH-180 from May through August, and WH-48, which included April through October.

The three Silver Reef Mines showed similar trends in relative species composition throughout the 2002 field season. Western Pipestrelle (*Pipistellus hesperus*) calls were the most common at all times at WH-48 (33%), WH-180 (40%) and H-07 (69%). Seasonally, the frequency of *P. hesperus* calls gradually increased, peaking in August. In contrast, the frequency of *E. fusicus* calls was higher in May and late September and October, and declined to almost zero in June, July and August. Calls from *M. californicus, M. yumanensis, M. thysanodes, M. ciliolabrum, T. brasiliensis*, and *A. pallidus* bats were also recorded. The pattern of detection percentage of the *C. townsendii* trend was very similar to capture records and video data. *C. townsendii* calls were uncommon at WH-48 in April and May (<5%) but increased three fold in June and July before decreasing in August, September, and October (<10%). In contrast, *C. townsendii* calls at WH-180 peaked in May (23%) and declined in June and July (4%, 4%) before climbing again in August (14%). The frequency of *C. townsendii* calls at H-07 was lower than all other species (less than 2% all months).

Comparison of Bat Behavior at gated and un-gated mine entrances

Bat behavior consistently differs at gated mines when compared with un-gate mines in all years. Bats entering and exiting gated mine adits exhibited high proportions of circling behavior, with no obvious changes seasonally or between years. In gated mines at Silver Reef, circling behavior occurred > 90% of the time at WH-180, and >80% of the time at WH-48 (Figures 7a and b). Bat circling behavior in un-gated mines in the Tushar mountains near Beaver, Utah resulted in less than 30% of all video recorded sightings of bats. Once gated, these same mines showed and increase in circling behavior (>75%), similar to the Silver Reef mines.

Internal Survey

Internal mine surveys were conducted for the last time on August 2, 2002 at the gated mines WH-48, WH-180, and G4-HO7 to estimate bat population numbers and specific roost use areas. One observer and one mining engineer surveyed all mine workings and determined numbers and distribution of bats through direct observation and documentation with a 35mm camera and a Sony Nightshot™ camcorder. At the conclusion of these surveys, the Utah Oil, Gas and Mining safety engineer determined that these mines had become too unstable for any future surveys.

In the August internal surveys, the overall total number of bats found within the mines decreased from 2001, except in H-07, where no bat activity was evident.

The single roost within WH-48 is located in the main stope that lies between two of the main shaft openings. In 2002, only 88 *C. townsendii*, were counted, substantially fewer then the 150 *C. townsendii* found in 2001. *N*o new Ring-tailed cats (*Bassaricus astutus*) scat was found in 2002 inside WH-48.

WH-180, the known maternity colony for *C. townsendii*, contains four discrete roosting sites. There were 47 total number of bats located within these sites, a large increase from the 2001 survey count of only 6 bats. However, the location of the bats had changed in the 2002 summer survey. Additionally, there was no new ring-tailed cat scat found in 2002 near the maternity sites, but new scat was found deep in the mine where there are standing pools of water suitable for drinking.

Guano has also been collected from three known mine maternity sites through the use of plastic sheeting on the mine floor since 1999. In 2002 there was no change in the amounts of guano or the deposition patterns as compared with previous years, however, a new patch of guano was collected in a site never before used.

One roost used by the majority of the bats in WH-180 in 2001, was outfitted with three bullet cameras, internally linked to external video cameras. The subsequent disturbance to bats due to the presence of cameras may have been the cause of a shift in bats from their usual roosting site to the new site during the 2001 season. However, in 2002 there was a 15-fold increase in guano as compared with 2001, suggesting that the bats returned to that roost despite the camera presence.

DISCUSSION

Daily use patterns

The Silver Reef mines showed similar patterns of nightly bat use in all years, although the amount of bat activity differed substantially between years. These patterns can be used to identify the types of use by bats ((Humphrey and Kunz 1976).

The initial increase in bat activity after sundown suggests that WH-48 and WH-180 were used by bats for day-roosting. The additional and subsequent, smaller peaks of bat activity spaced approximately 90 minutes apart suggests that these mines were also used as night-roosts by foraging bat species.

Seasonal Bat Activity Patterns

Mines in these study areas are utilized for migration stops, maternity, hibernation, and day and night roosts. The type of bat use of the mines did not appear to be related to the presence or absence of gates.

Daily use patterns of newly gated mine G4-HO7 indicate that bats are using the mine primarily for both a day and night roost due to the sporadic use throughout the night. *C. townsendii* calls were recorded in the area, and some of the bats seen in video appear to be *C. townsendii*. In addition, *Myotis* spp. have been observed day roosting just inside the mine entrances, so it appears that at least one or two bats may be using G4-HO7 for a day roost. Seasonal bat activity is relatively higher for the early spring months and September suggesting the mine has also been used as a migratory stop over.

In contrast, daily use patterns of gated mines WH-48 and WH-180 indicated that bats use these mines primarily for day roosts, because bat activity peaked just after sunset and just before sunrise. Emergence times occur around sunset for many Myoti*s* species, according to Twente (1955) "Light is undoubtedly a factor" in emergence times. There was much lower activity at WH-180 throughout the nighttime hours, although the higher numbers of events recorded at WH-48 throughout the nighttime indicate some bats use it for a night roost.

Seasonal comparisons between mines suggest that WH-48 and WH-180 are being used throughout the year by bats, not just during the summer months. The peak in numbers in April suggested that WH-48 was used as an early season migratory stopover. In the pre-gating cold-season internal survey, Lengas (1996) found hibernating *C. townsendii* in WH-48. In March 2001, *C. townsendii* were also found hibernating during TM maintenance in WH-48 and WH-180.

Effect of Gates on Bat Activity

The occurrence of circling behavior inside and outside the gate was much greater at gated mines than un-gated mines. In July and August at the gated WH-48 (Silver Reef) video data reported a 10% increase in circling. July and August is also the time believed that WH-48 is being used to rear pups. Circling behaviors might reflect sub-adult difficulties in finding their way through the bars. Maternity colonies of Virginia big-eared bats showed bimodal activity around sunset and sunrise in summer until lactation when activity throughout the night increases (Lacki, 1994). As sub-adults become volant, circling may be a way of practicing flight maneuvers and not necessarily reflect gate effects. O'Shea (1977) suggested that adult bats fly close to their young to "coax" them to emerge.

In addition the increase in numbers of bats using the gates may physically impair their ability to navigate through the gate openings. Twente (1955) found that with larger numbers of bats emerging from a roost, they did not use echolocation because it is nearly "impossible". For example, his tests with Brazilian free-tailed bats (*Tadarida brasiliensis*) showed echolocation was not used during emergence events in large colonies. Furthermore, when Twente stood in front of the cave and turned on his head lamp the bats avoided him, but when he turned off his head lamp bats repeatedly flew into him. Similarly when he placed 1 to 3 layers of red cellophane over his head lamp bats steered clear of him. Finally, when he used 4 layers of red cellophane the bats behaved as if it were completely dark and again flew into him.

Bats in pre-gate observations at G4-HO7 circled only once for every entrance or exit, however, circling increased 10X after gating. Thus the newly installed gate appeared to increase circling behavior. Early in 2001 after gate installation, bats mostly entered and exited via the crack located above the gated portal, rather than the gate. Later, however, bats started to use the gated portal more than the crack. Furthermore, during the 2002 season, circling behavior for H-07 was low in comparison to the other Silver reef gated mines (<25% occurrence). This suggested that bats have possibly learned to negotiate the gate. The low number of bats that use this mine may explain the low occurrence of circling.

In this study, the dramatic increase in circling behavior by bats in gated mines indicated that gate presence, at least for some species, affects bat behavior. However, several researchers have suggested that since *C. townsendii* circle more than other bats before exiting their day roosts (P. Brown, R. Sherwin, and S. Altenbach, pers.comm.) this circling might reflect normal species behavior. Studies by Twente (1955) showed that *C. townsendii* sampled for light before exiting the roost by circling to the entrance then roosting on the cave wall and then returning to the entrance until it is dark. However, White and Seginak (1987) documented a significantly higher amount of circling, between gated and un-gated mines, by these bats before evening exits. Thus it appears that even in bats that are known to display circling, gates may increase the amount of circling.

Unfortunately, this increased circling has not been quantified for *C. townsendii* or any bat species. It is not clear if this circling represents a significant energy cost for these bats, based on constrained energy budget and warrants further study. In addition, the potential for added energy costs warrants caution in installing gates with an *a priori* assumption that it will benefit bats. Recent studies for other bat species in Florida and Indiana have identified bat species that are significantly compromised by gated entrances (Ludlow and Gore 2000). Gates may provide bats protection from disturbance thus reducing stress and increasing fat storage retention, but if this is negated by the effects of expending more energy to get through gates, the net benefit for bats is lost. In addition age specific and species-specific effects may actually affect recruitment rates for populations using these mines. Sub-adults learning to fly must negotiate the gate and thus larger energy costs may be required as they may spend more time circling before exiting the gate. Species such as the Townsend's big-eared bat may rely more on eyesight to exit gates. This may lead to an increase in circling to in-and-out ratios that other bat species may not experience. Echolocation frequency differences between species may also lead to differences in the amount of circling each species may exhibit in response to bat compatible gates. Certain bat species' echolocation frequencies may be better equipped to negotiate gates. Overall, this study shows no discernible pattern or trend in activity rates between years. Though circling behavior is consistently high at both WH-180 and WH-48, bat activity has not dropped significantly from year to year. The high bat activity numbers in both mines during 2000 and 2003 contrast sharply with the drastic reduction in numbers in 2002. This lack of pattern suggests that while gates may affect bat behavior, there is no evidence that these gates have affected population levels.

Species Composition

Species use of mines as determined by both trapping and Anabat™ recordings suggest consistent use by bat species between years, but that there is seasonal variation in types of bat species. Anabat™ recordings consistently picked up more species then were ever trapped at either mine. Some of these species may be using the area around the mines for foraging, while others may be more difficult to trap.

In this study the difference in levels of bat use may not be related to presence or absence of bat gates, but simply to the size and complexity of the mines. Large numbers of bats used the large and complex gated mines WH-48, WH-180, while less complex mines such as G4-H07 had much lower bat use. These mines were gated because of bat sign not necessarily because of mine size or potential bat use, so both gated and un-gated mines vary greatly in size and use. Overall more complex mines had higher bat use. For example, gated mines WH-48 and WH-180 are longer and more complex, with multiple openings and had high bat use (M.Mesch, pers. com., B. Lengas 1996, and internal survey 2001). In contrast, the gated mine G4-HO7, which had very little bat use, is shorter and less complex than WH-48 and WH-180 and has only one entrance. In addition mine complexity may increase use by overall numbers of bats as well as certain species. For example, *C. townsendii* select maternity roosts that are large-complex mines with multiple openings (Sherwin, 2000) like those found in WH-48 and WH-180.

Although it is apparent that mine complexity likely increases available habitat by providing a variety of suitable roost areas for a greater number of individuals as well as species, more complex mines also may have more suitable temperatures, relative humidity and airflow patterns. Tuttle (1994) suggested that airflow patterns, and temperature are important factors affecting bat's use of mines.

In general more complex mines offer a variety of temperature ranges for bats to take advantage of at different times of the day and season. Temperature needs may vary between species and individuals. Temperature preferences may be different in the spring than mid summer, and at night roosts versus day roosts. Bats choose different temperatures in maternity colonies than as sub-adults, non-breeding or hibernating adults. For example, Townsend's big-eared bats generally use mines with ambient temperatures around 15° C as night roosts, 0° C to 11° C as hibernation roosts and 15° C or above maternity roosts and day roosts (Humphrey and Kunz 1976). Bats may even select cool summer roosts to temporarily lower their metabolic rates (Hock, 1951). The ability to use temperature fluctuations within a mine to decrease energy expenditures would be advantageous to bats.

Bats also appear to move between mines at different times of the year. In July 2000, there was a spike of activity in WH-48 concomitant with the trapping of 9 sub-adult *C. townsendii*, and a sharp decrease in activity at WH-180 the *C. townsendii* maternity colony. In July 2001, there was a similar pattern of activity spike in WH-48, and a decrease in activity at WH-180. This same pattern of seasonal changes in bat activity between the two mines occurred again in the 2002 field season (Figures 1a & 2a).

The micro climate in WH-48 may be more hospitable to juveniles and sub-adults at the end of July and mid August. In addition in 2001, the ring-tail observations and scat distribution indicated that predation possibly occurred at the WH-180 maternity colony location (although no direct evidence of bat remains was found in the ring-tail scat). In 2002, no new ring-tailed scat was found in internal surveys of WH-180, however, the hypothesis that *C. townsendii* shifts roosts from WH-180 to WH-48 for either predation avoidance or to find a more suitable micro climate is still supported by the change in patterns of bat activity recorded in the two mines over the entire season. Other studies suggest that maternity colonies of *C. townsendii* and Virginia big-eared bats (*Corynorhinus townsendii virginianus*) tend to move between and throughout mines and cave complexes throughout the summer (Sherwin, 2000, Lacki, 1994), however, no confirmed shifts in roosting location were documented in either study.

On a landscape level, the network of mines at the Silver Reef, and East Reef mine sites may serve as interconnected habitat complex systems for several bat species in the same way bats move to a variety of locations within a large single cave based on the cave's environmental conditions (Sherwin pers. comm.). Bats may use different mines at different times of the year based on life history and environmental constraints. Long-term monitoring of these mines with the addition of internal cameras and bi-yearly internal surveys will continue to clarify these relationships.

Future Studies

There will be significant survey changes in 2005. Undergraduate researchers will video recording at Silver Reef and the recently gated mines in the Tushars. The focus will be on interaction of the bats with the new gates (e.g. circling, landing, etc.). This data will then be compared to video data of previous years to measure the effect the gates have on bat behavior as well as species composition.

Gabrielle Diamond will be taping the WH-48 and WH-180 mines in the Silver Reef area for entire nights. She will be analyzing the change in behavior of bats throughout the night, especially comparing dusk and dawn behavior, and evaluating the use and function of these particular mines (e.g. day, night, maternity, and bachelor roosts).

TrailMaster event recorders will be continually monitored in both the Silver Reef and Tushar mines as a way to record bat activity. HOBO temperature data loggers will also we used to record internal mine temperatures at all locations.

Video recordings will be scaled back to two consecutive nights at all four mines simultaneously. Two nights will be recorded in May, July and September. This data will continue to record the behavior of bats and any interactions they may be having with the gate.

Species composition will be determined by continued use of Anabat acoustical recording and mist netting. Anabat acoustical surveying will document species composition in the area in respect to the species we find within the mines through mist netting. Mist netting, however, will be done once in August. This late date will avoid the possible disturbance of maternity colonies.

ACKNOWLEDGEMENTS

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Mine #	Month	Date	IR goggle	Anabat	Deep TM	IR Video	HOBO	Min/Max	Net	Bullet Cam	IR Lights
SILVER REEF (gated)	April	04/12/02	*	*	*	*	*	*		*	*
WH-48	May	05/13/02		*	*	*	*	*		*	*
		05/14/02		*	*	*	*	*		*	*
		05/15/02		*	*	*	*	*		*	*
		05/21/02		*	*		*	*	*		
	June	06/10/02		*	*	*	*	*		*	*
		06/11/02		*	*	*	*	*		*	*
		06/12/02		*	*	*	*	*		*	*
		06/17/02		*	*		*	*	*		
	July	07/10/02		*	*	*	*	*		*	*
		07/11/02		*	*	*	*	*		*	*
		07/12/02		*	*	*	*	*		*	*
	August	08/07/02		*	*	*	*	*		*	*
		08/08/02		*	*	*	*	*		*	
		08/09/02		*	*	*	*	*		*	*
		08/14/02		*	*		*	*	*		
	September	09/04/02		*	*	*	*	*		*	*
		09/05/02		*	*	*	*	*		*	
		09/06/02	ɔ survey		*		*				
		09/19/02		*	*		*	*	*		
	October	10/08/02		*	*	*	*	*		*	*
	August	08/20/04		*	*	*	*	*		*	*

Table 1. List of equipment used at Mine WH-48 through 2004

Mine #	Month	Date	IR goggle	Anabat	Deep TM	IR Video	HOBO	Min/Max	Net	Bullet Cam	IR Lights
WH-180	April	04/12/02	*	*	*	*	*	*			*
	May	05/13/02		*	*	*	*	*		*	*
		05/14/02		*	*	*	*	*		*	*
		05/15/02		*	*	*	*	*		*	*
		05/21/02			*		*				
	June	06/10/02			*		*				
		06/11/02			*		*				
		06/12/02		*	*	*	*	*		*	*
		06/17/02			*		*				
	July	07/10/02			*		*				
		07/11/02		*	*	*	*	*		*	*
		07/12/02		*	*	*	*	*		*	*
	August	08/07/02			*		*				
		08/08/02			*		*				
		08/09/02			*		*				
		08/14/02		*	*		*	*	*		
	September	09/04/02			*		*				
		09/05/02		*	*	*	*	*		*	*
		09/06/02		*	*	*	*	*		*	*
		09/19/02			*		*				
	October	10/08/02			*		*				
	August	08/20/04		*	*	*	*	*		*	*

Table 2. List of equipment used at mine WH-180 through 2004

Table 3. Bats netted within the 1998-2002 field seasons in the Silver Reef Mining District.

Year	Date	Mine #	EPFU	COTO	MYTH	MYCI	MYCA	MYUN	MYEV	MYVO	MYLU^	TABR	NYMA	MYYU	PIHE	TOTALS	Net Hours
1998		**Silver Reef**															
	07/12/98	WH-48	2M	14F/7M				1M								24	1.5
	08/11/98	WH-48		1M	1F			1M								3	2.5
	07/21/98	WH-180		1M												1	1.5
	08/11/98	WH-180		3F/4M				3M							1M	11	3
	08/11/98	WH-178														0	2.25
	08/12/98	WH-50A														0	2.5
	1998 totals		**0F/2M**	**17F/13M**	**1F/0M**			**0F/4M**							**0F/1M**	**18F/20M**	**13.25**
1999		**WEST**															
	05/06/99	WH-48	1M		5F	1M	1M									8	2
	06/09/99	WH-48		1F												1	3
	07/09/99	WH-48	1M	2F/2M				1F/3M							1M	10	4
	08/11/99	WH-48	1F	2F/5M	1F											9	4
	09/15/99	WH-48	1F/1M	1M				1M								4	3
	10/14/99	WH-48			2M			1M							1F/2M	6	2
	09/15/99	WH-180		9F/2M												11	22
		EAST															
	05/06/99	G4-H07														0	2
	06/09/99	G4-H07														0	3
	07/09/99	G4-H07														0	4
	07/09/99	G3-H02													1F/1M	2	4
	08/11/99	G2-H05														0	4
	09/15/99	G2-H05														0	2
	1999 totals		**2F/3M**	**14F/10M**	**6F/2M**	**0F/1M**	**0F/1M**	**1F/5M**							**2F/4M**	**25F/26M**	**19**
2000		**WEST**															
	06/05/00	WH-48		1M												1	3.5
	07/10/00	WH-48	1M	5F/5M												11	3
	09/11/00	WH-48			2F/1M											3	5
	09/11/00	WH-180		1F/2M												3	4
		EAST															
	06/05/00	G4-H07														0	3
	07/10/00	G4-H07														0	3
	06/05/00	G2-H05														0	3
	07/10/00	G2-H05														0	3
	06/05/00	WH-1286	1M													1	3.75
	2000 Totals		**2F/3M**	**6F/8M**	**2F/1M**	**0F/1M**			**1F/0M**	**17F/7M/1U**	**1F/1M**					**29F/21M/1U**	**57.72**
2001		**WEST**															
	05/29/01	WH-48	1M	1F/1U												3	3
	08/30/01	WH-48		1M	2F		1M	1M								5	3.5
	10/09/01	WH-48			1F											1	3
	08/30/01	WH-180		2F												2	3.8
	06/06/01	Hidden Valley Irrigation Pond													1F	1	3.25
	07/27/01	Hidden Valley Irrigation Pond					3M					4M	1F			8	3.8
	06/06/01	Leeds Creek														0	3.5
	2001 Totals		**0F/1M**	**3F/1M/1U**	**3F/0M**		**0F/4M**	**0F/1M**				**0F/4M**	**1F/0M**		**1F/0M**	**8F/9M/1U**	**23.85**

Table 3. List of all bats captured at both Silver Reef mines

Table 3. (Continued)

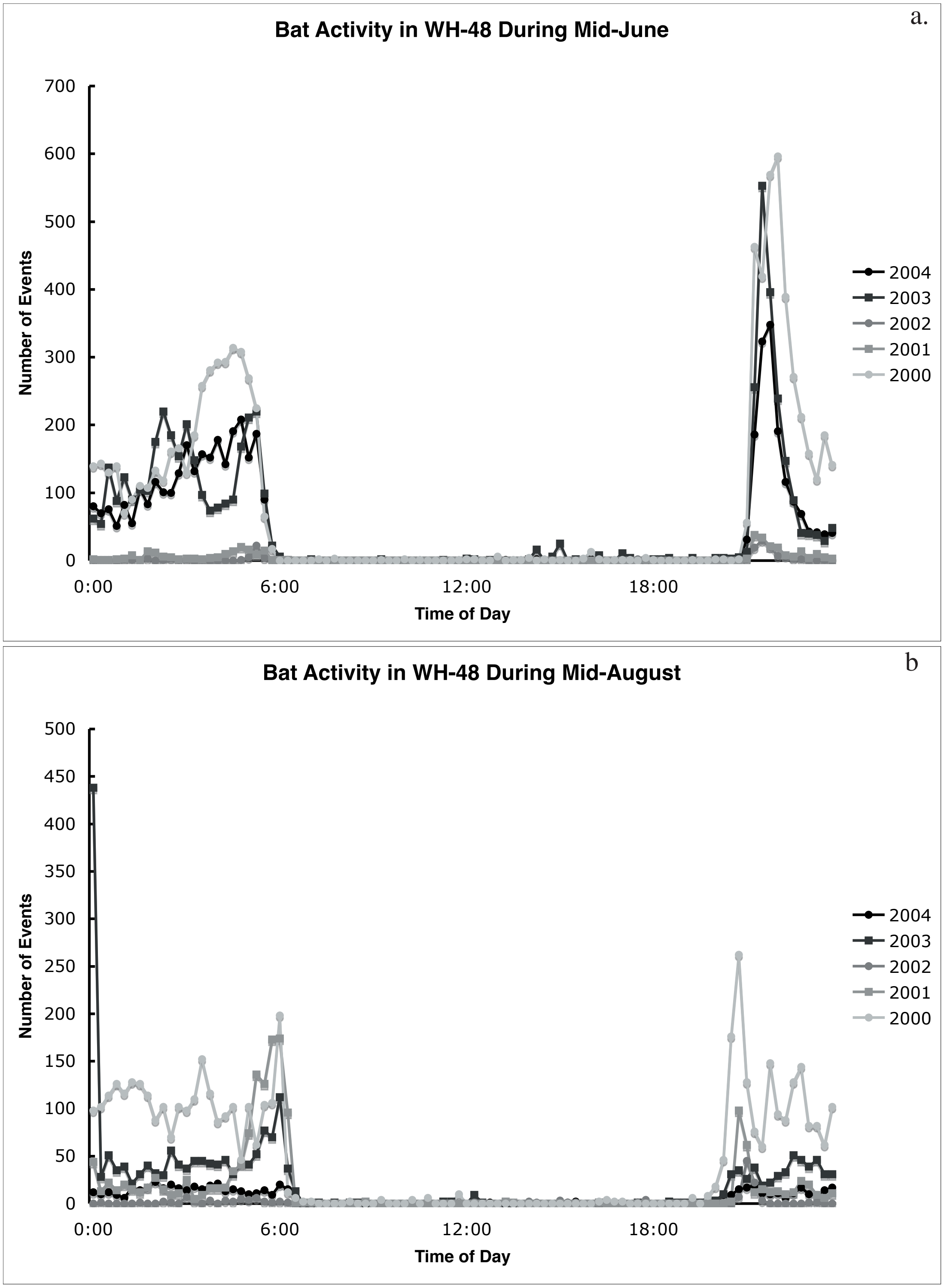
Year	Date	Mine #	EPFU	COTO	MYTH	MYCI	MYCA	MYUN	MYEV	MYVO	MYLU^	TABR	NYMA	MYYU	PIHE	TOTALS	Net Hours
2002		**SILVER REEF**															
	05/21/02	WH-48		1F	2F									1M		4	7
	08/14/02	WH-48		2F/1M	1F			1U								4	3.7
	09/19/02	WH-48			1M									1F		2	3
	08/14/02	WH-180		2F/2M												4	2.5
	09/19/02	HO7		1M												1	2.5
	07/17/02	Hidden Valley Irrigation Pond														0	12.5
	07/31/02	Hidden Valley Irrigation Pond											1F			1	3.5
	2002 Totals			**5F/4M**	**3F/1M**		**0F/0M**	**1U**					**1F/0M**	**1F/1M**		**10F/6M/1U**	**34.7**
2004		**TUSHARS**															
	08/20/04	WH-48														0	1.5
	08/20/04	WH-180														0	1.5
	2004 Totals																**3**

Species Codes:

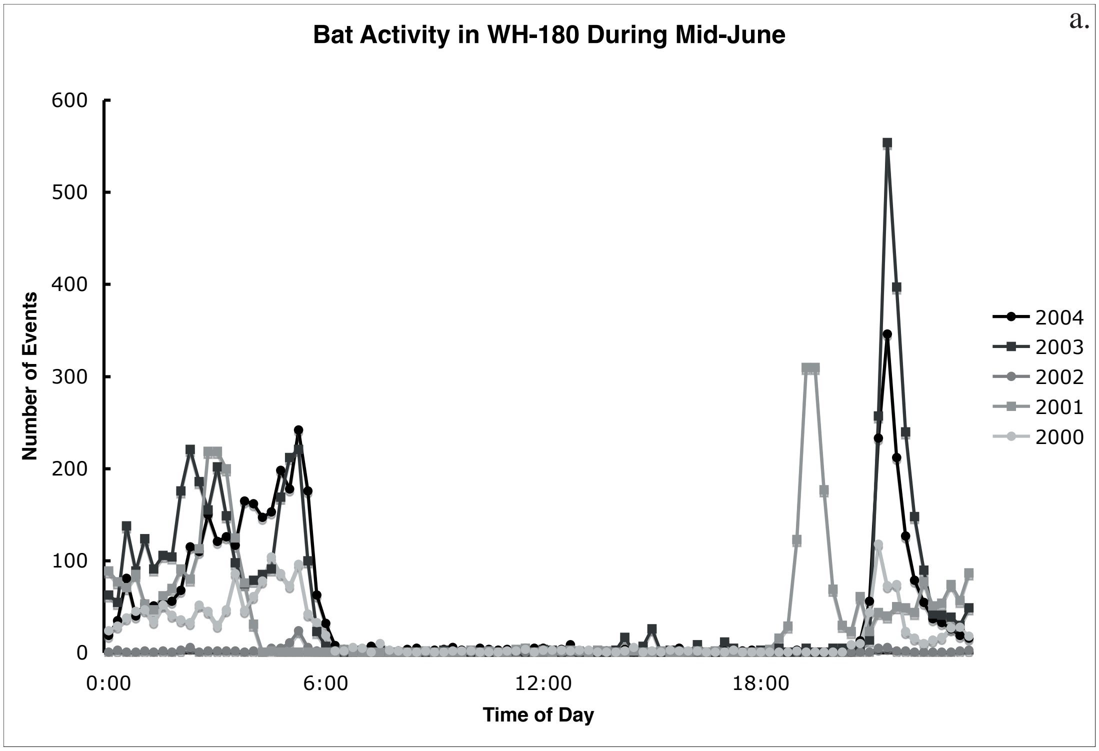
EPFU= Big brown bat (*Eptesicus fuscus*)
COTO=Townsend's big eared bat (*Cornyrhinus townsendii*)
MYTH=Fringed myotis (*Myotis thysanodes*)
MYCA=California myotis (*Myotis californicus*)
MYCI=Western small footed myotis (*Myotis ciliolabrum*)
MYUN=Unknown myotis either (*M.california* or *M.ciliolabrum*)
MYEV=Long eared myotis (*Myotis evotis*)

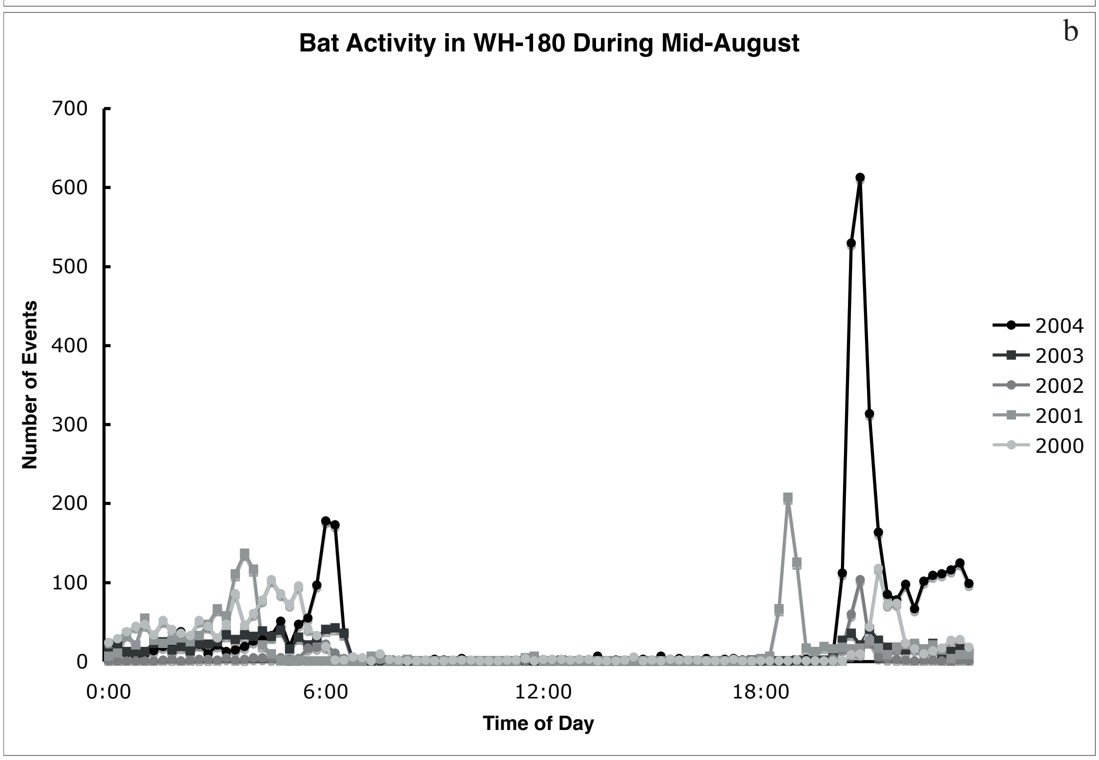
MYVO=Long legged myotis (*Myotis volans*)
MYLU=Little brown bat (*Myotis lucifugus*)
TABR= Brazilian free tailed bat (*Tadarida brasiliensis*)
NYMA= Big free tailed bat (*Nyctinomops macrotis*)
PIHE=Western pipistrelle (*Pipistrellus hesperus*)
MYYU= Yuma Bat (*Myotis yumanensis*)
^Possible species, still to be confirmed through Anabat call

Table 3. (Continued) List of all bats captured at both Silver Reef mines

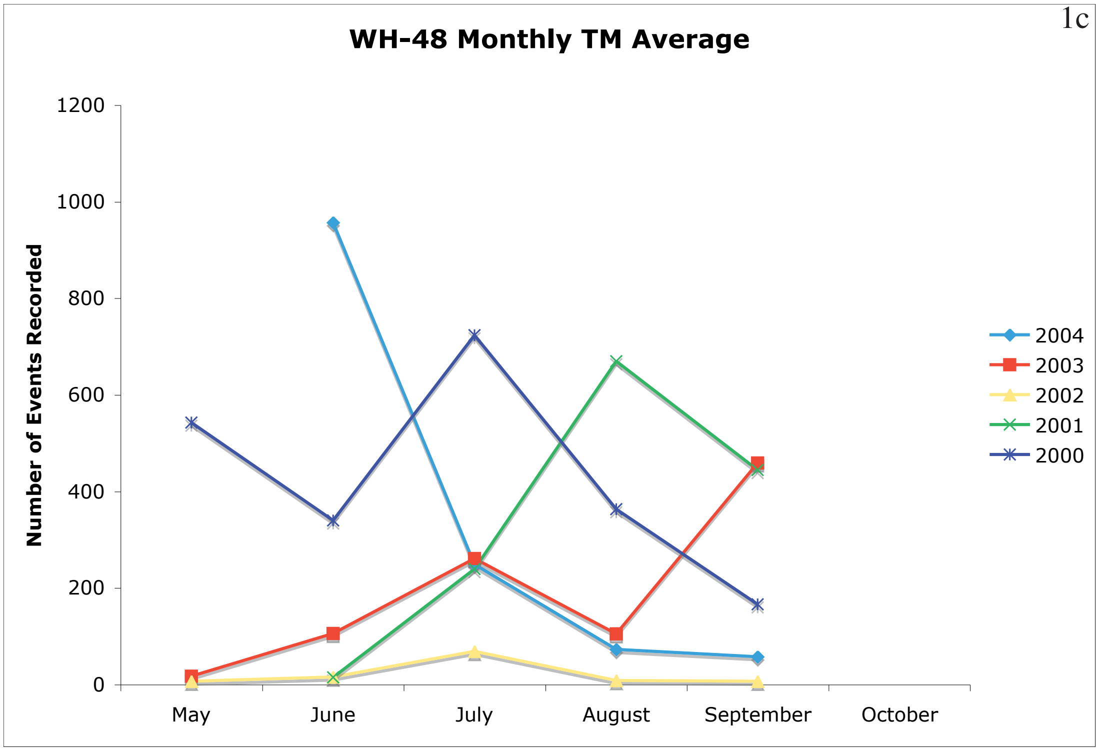


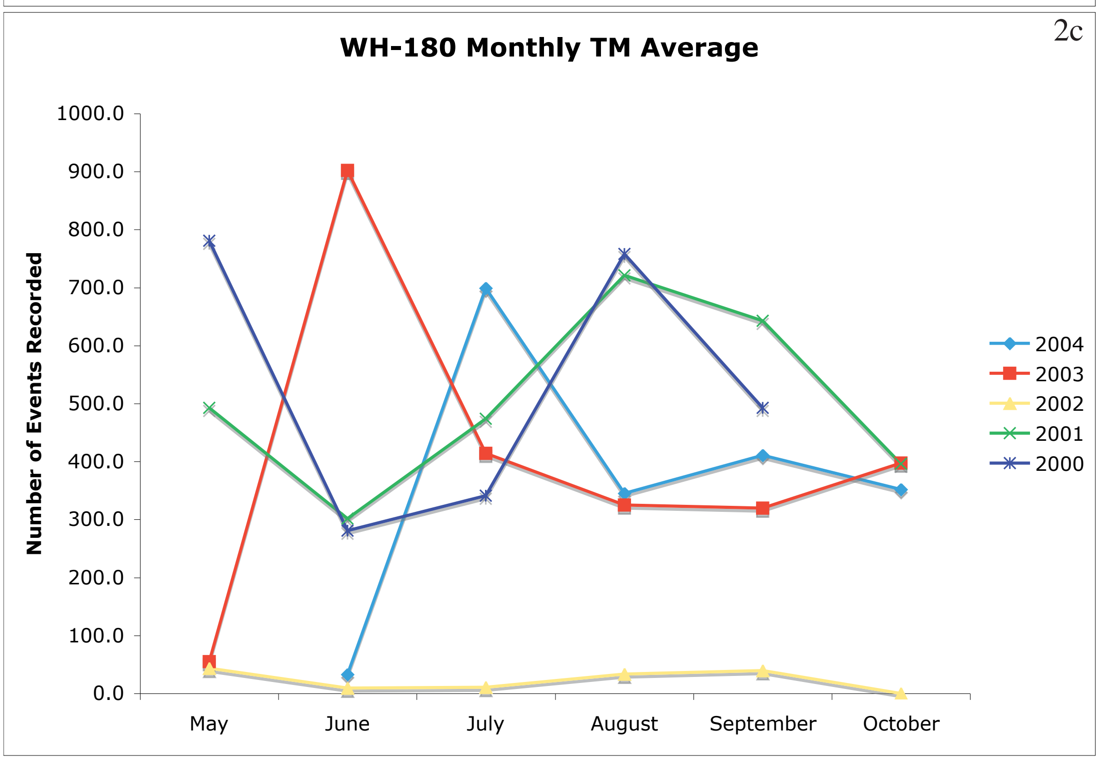
Figures 1a and 1b. Nighlty activity for mine WH-48 recorded using TM infrared event recorders. All data was grouped in 15-minute intervals



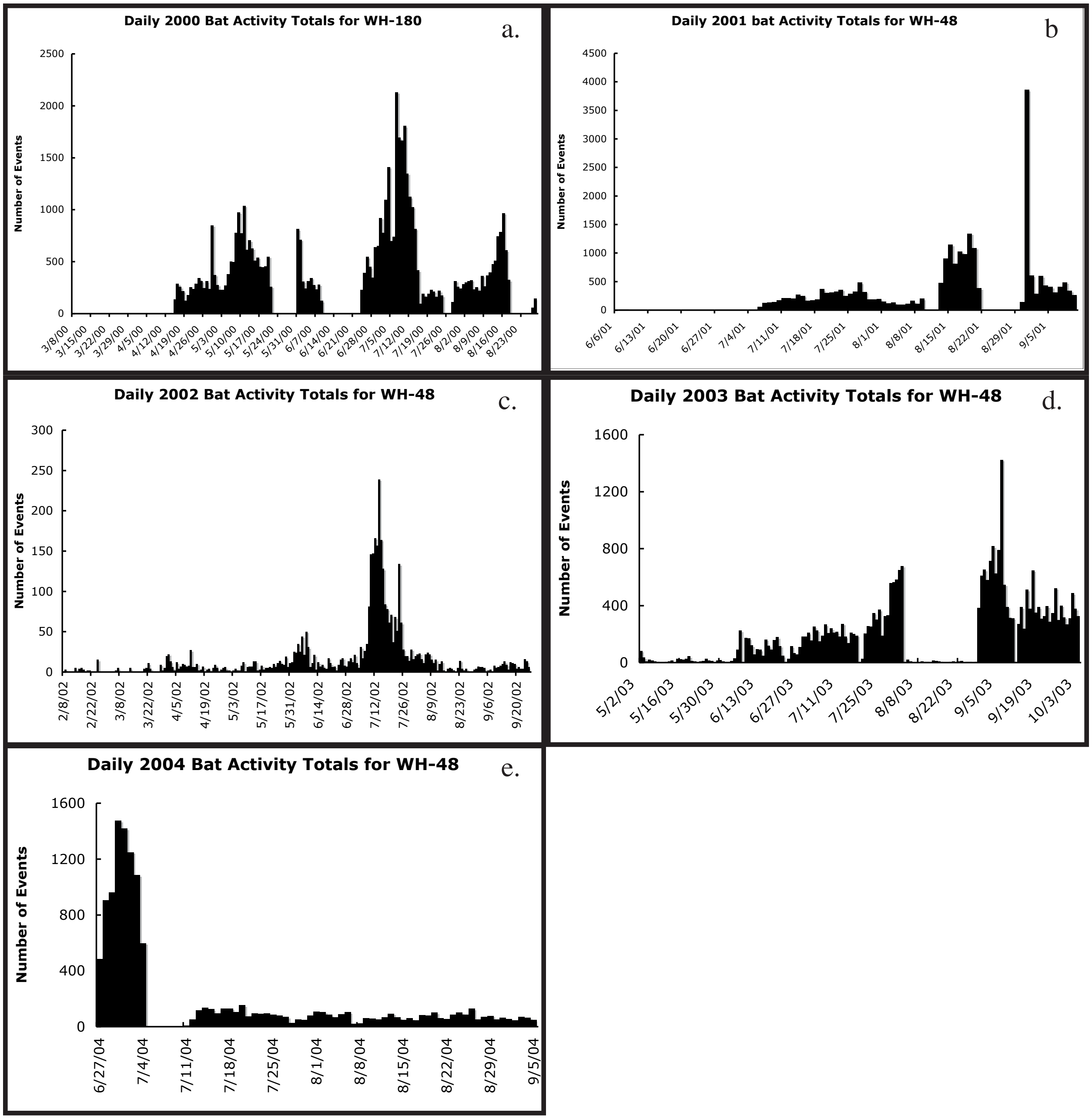


Figures 2a and 2b. Nightly activity for mine WH-180 recorded using TM infrared event recorders. All data was grouped in 15-minute intervals

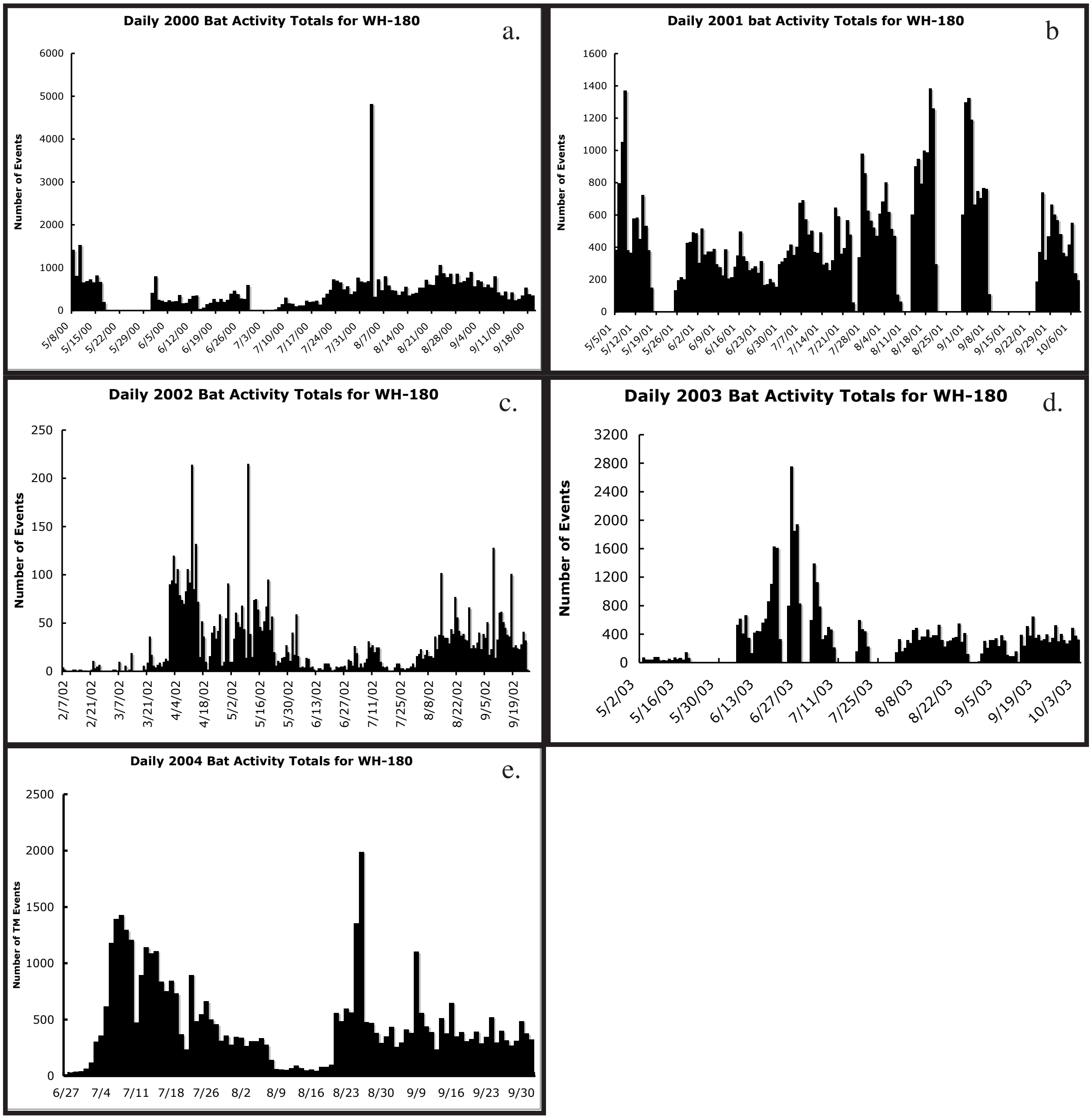




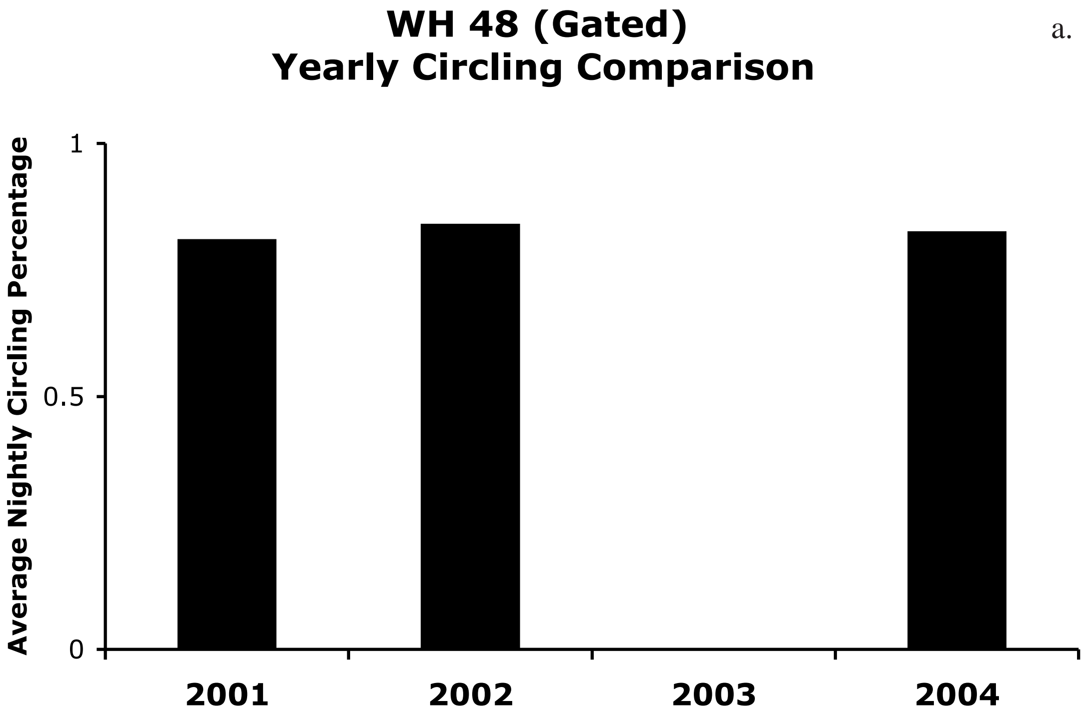
Figures 1c and 2c. Monthly averages of bat activity for all years as recorded by TM infrared event recorders.

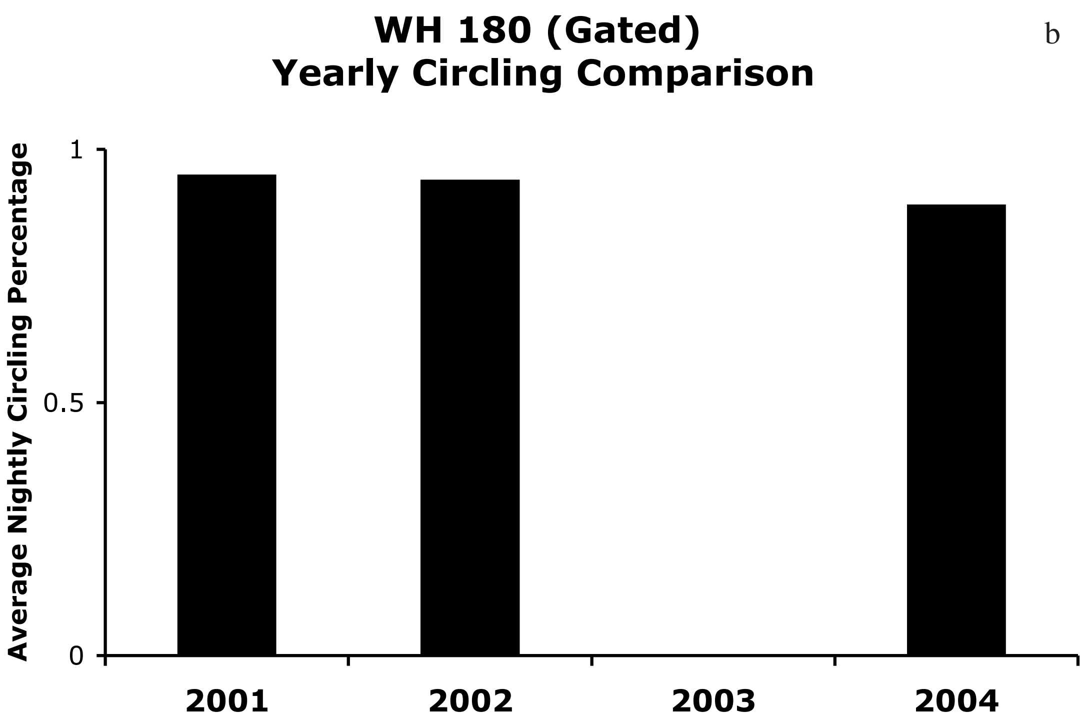


Figures 5a-e. Daily TM infrared event totals for all years. Days with left blank correspond to periods where no data were collected due to equipment failure.

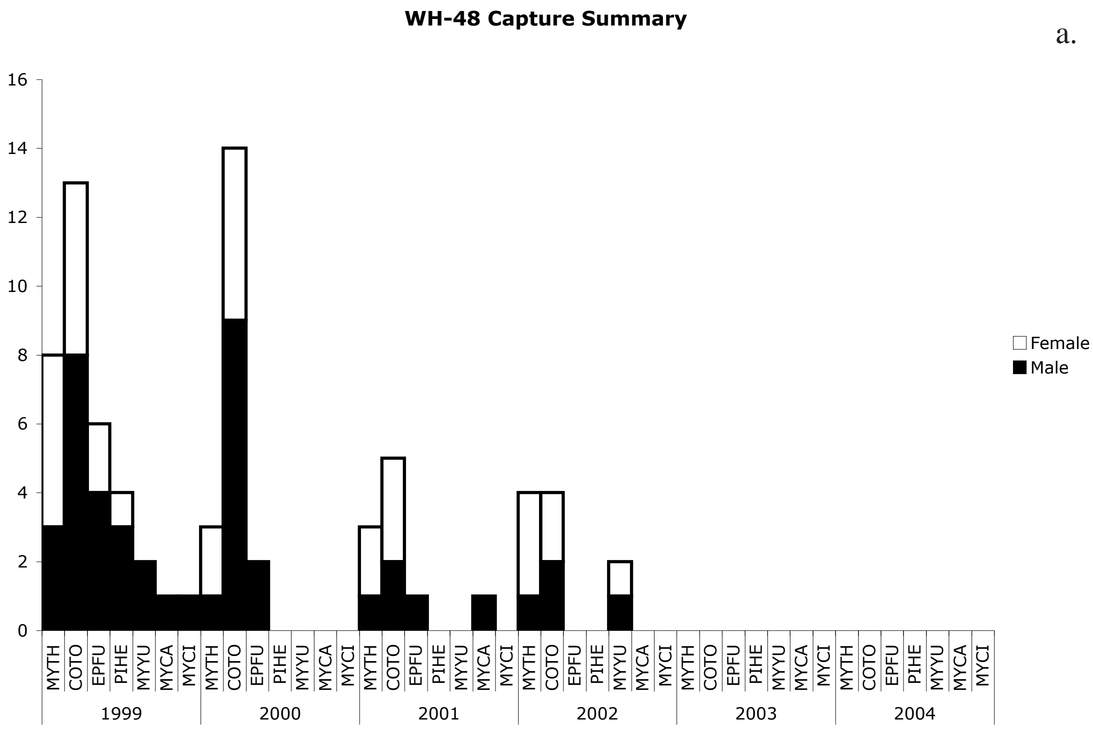


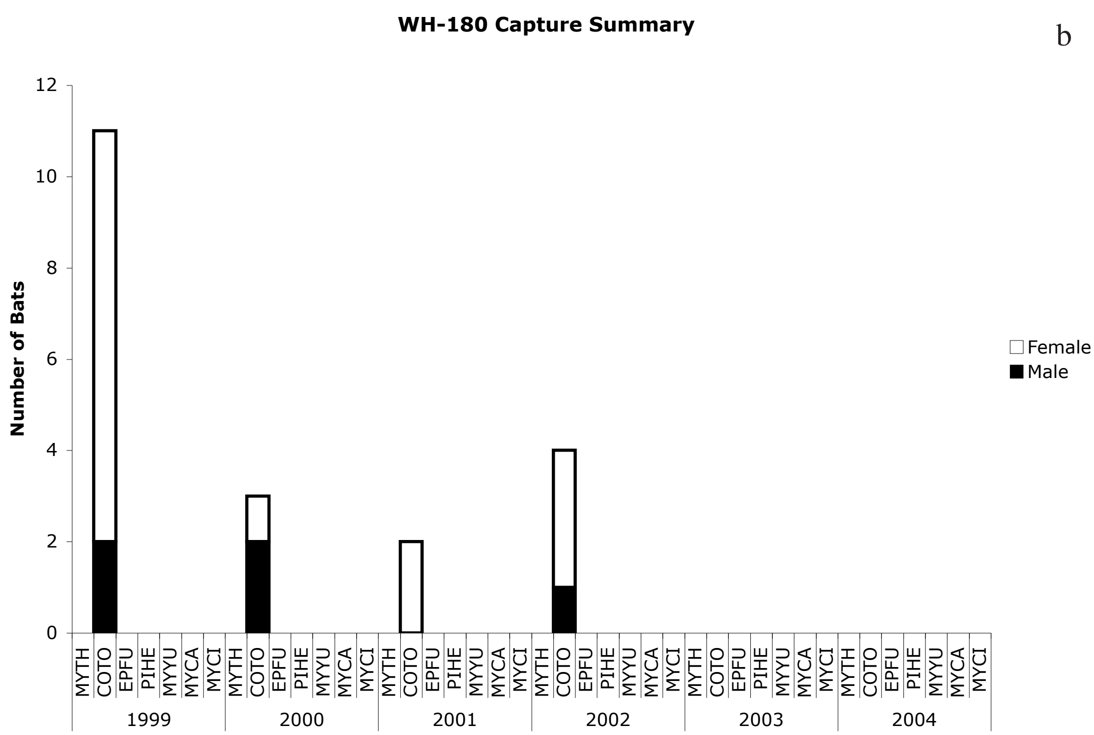
Figures 6a-e. Daily TM infrared event totals for all years. Days with left blank correspond to periods where no data were collected due to equipment failure.





Figures 7a and b. Yearly comparison of circling behavior per event recorded during video surveillance. Video data recorded during 2003 field season is part of graduate student's thesis and had not been released at the time of this publication.





Figures 8a and b. Yearly bat capture summary for both mines.