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A STUDY OF BAT POPULATIONS AT
LOS ALAMOS NATIONAL LABORATORY
AND
BANDELIER NATIONAL MONUMENT,
JEMEZ MOUNTAINS, NEW MEXICO

By

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Abstract

Although previous work on bats has been conducted in the Jemez Mountains of New Mexico, the status and trends of bat populations there are not well known. In 1995, a three-year study was initiated to assess the current status of bat species of concern, elucidate distribution and relative abundance, and obtain information on roosting sites of bats. We captured and released 1532 bats of 15 species (*Myotis californicus, M. ciliolabrum, M. evotis, M. thysanodes, M. volans, M. yumanensis, Lasiurus cinereus, Lasionycteris noctivagans, Pipistrellus hesperus, Eptesicus fuscus, Euderma maculatum, Corynorhinus townsendii, Antrozous pallidus, Tadarida brasiliensis,* and *Nyctinomops macrotis*) and followed 32 bats of eight species (*M. evotis, M. thysanodes, M. volans, E. fuscus, E. maculatum, C. townsendii, A. pallidus,* and *N. macrotis*) to 51 active diurnal roosts. The most abundant species were *L. noctivagans, E. fuscus, L. cinereus, M. evotis, M. volans,* and *M. ciliolabrum.* Most of these species are typical inhabitants of ponderosa pine-mixed coniferous forests. The abundance of *L. noctivagans* is partly a function of their migration through the area. Captured males outnumbered females for many species; only 5 species (*M. californicus, M. thysanodes, M. yumanensis, E. fuscus,* and *C. townsendii*) were captured in about equal numbers of both sexes. Exact reasons for the observed distribution of sexes is unknown but climate, elevational influences, and sites chosen for netting may be involved. We netted eight bat species of concern in the Jemez. We frequently captured four of these species (*M. ciliolabrum, M. evotis, M. thysanodes,* and *M. volans*). We captured smaller numbers of the other four species of concern, for a variety of reasons, but we found or know reliably of moderate- to large-sized roosting aggregations of three of these: *M. yumanensis, Euderma maculatum,* and *Nyctinomops macrotis.* We captured only seven individuals of *C. townsendii,* lending credence to the possibility that this species is of concern in the area.

1.0 Introduction

It is generally believed that bat populations have declined in recent decades in the United States and elsewhere (Bogan et al. 1996). Several species are listed as endangered or threatened by the U.S. Fish and Wildlife Service (FWS), and additional species were listed as Category 1 and 2 Candidates for listing (e.g., 28 species or subspecies proposed; FWS 1994). In 1995, the FWS stopped maintaining a list of Category 2 Candidate Species to concentrate on higher-priority listing needs (memorandum, Director, FWS, July 1995). It is hoped that other entities, including U. S. Geological Survey (USGS), The Nature Conservancy, and individual states will assist in maintaining lists and acquiring information on these species of concern (former Category 2 Candidates) (Bogan et al. 1997).

Many states now protect bats and rank various species among taxa of special concern. The public has developed an increased interest in this diverse group of mammals, as exemplified by support for Bat Conservation International and bat societies in several states (e.g., Colorado). Federal land management agencies also have responsibilities relative to bat inventory, monitoring, and conservation, and carry out surveys in areas under their jurisdiction (see, for example, Bogan et al. 1996, Green et al. 1994, Lacki et al. 1993). Nonetheless, much remains to be learned of the distribution, abundance, natural history, and status and trends of bats in most areas.

The Jemez Mountains in north-central New Mexico support a diverse community of bats. Fifteen species are known, including eight species of concern (former Category 2 Candidate Species). Most of these species also are known from Bandelier National Monument (BAND) and Los Alamos National Laboratory (LANL). One additional species (*Myotis lucifugus*), known from elsewhere in northern New Mexico (Findley et al. 1975), may occur in the Jemez Mountains, at least at lower elevations. Previous work has been conducted on LANL and BAND by several investigators. Guthrie and Large (1980) used mist nets to sample several sites at BAND for bats, whereas both Arganbright (1987, 1991) and Judson (1990) concentrated on roosting colonies of *Tadarida brasiliensis* and *Myotis yumanensis* on BAND. Tyrell and Brack (1992) mistnetted three sites at LANL and one on BAND. Other investigators have netted bats on the Santa Fe National Forest (files and records, Museum of Southwestern Biology, University of New Mexico) or listened for the audible echolocation cries of *E. maculatum* (Cryan 1993).

In 1995, the Midcontinent Ecological Science Center (MESC), USGS, LANL, and BAND initiated a three-year project to determine the occurrence, distribution, and habitat use of bat species in the Jemez Mountains, New Mexico. We had seven major objectives: (1) compile and review available information on bats in the Jemez Mountains; (2) identify major information gaps for the area; (3) collect original field data on occurrence, distribution, roosting sites, and habitat use of bats in the Jemez; (4) provide samples of common bat species to assess impacts of potential environmental contamination; (5) analyze and synthesize all data gathered; (6) provide recommendations for maintaining bats as part of the Jemez Mountain ecosystem; and (7) provide a baseline that will serve as a foundation for future bat monitoring programs.

2.0 Methods

Bats were captured in mist nets and harp traps during the summers of 1995, 1996, and 1997 as they foraged over and drank from water sources and flew along cliff faces. We followed netting methods outlined by Kunz and Kurta (1988). Mist nets were deployed shortly after sunset and attended continuously until closure. Net closure varied for numerous reasons, such as inclement weather and radio-transmitter attachment and tracking, but most often netting persisted until bat activity diminished significantly (45 minutes after last bat captured). Harp traps similar to those described by Kunz and Kurta (1988) were deployed on a few nights in 1997. We removed bats upon capture and promptly processed them before release. Capture, handling, and radio-tagging of bats followed a written protocol approved by the MESC Animal Care and Use Committee. We recorded investigators' names, site location, date, number and size of nets, time that nets were set up and taken down, sky conditions, temperature at beginning and end of session, wind conditions, and a brief habitat description. We recorded the species, sex, age (adult or young-of-the-year based on epiphyseal fusion; Anthony 1988), reproductive condition (cauda epididymides visible in males, females pregnant, lactating, or postlactating), and time of capture for all bats mistnetted. Common and scientific names follow Jones et al. (1992), with the exception of *Corynorhinus townsendii* (Tumlinson and Douglas 1992). All data were recorded on standardized data sheets and later entered into a computer database; completed data sheets and computerized database are on file at the Albuquerque office of USGS-Biological Resources Division.

Selected individuals captured by mist net were marked with miniature radio transmitters (164MHz, Model LB2 & BD-2B, 0.5g & 0.6 g, Holohil Systems Ltd., Woodlawn, Ontario) for roosting studies. Radio tracking techniques followed the methods of Wilkinson and Bradbury (1988). Transmitters were attached to the interscapular region of the dorsal fur with a non-irritant medical adhesive (Skin Bond 8). Bats were held for about 30 minutes before release in order to insure secure adhesion. All instrumented bats were released at initial point of capture. On subsequent days, we monitored for signals on the ground and by air. In 1997 we made weekly flights in a Cessna 206 fixed-wing aircraft equipped with 2 wing-mounted, 2-element AH@ antennae (ATS, Advanced Telemetry Systems, Inc., Isanti, MN 55040) affixed to the wing struts and aligned with the wings. Antenna leads were run through a directional switch box and signals were monitored inside the airplane with a programmable scanning receiver (ATS R2000) set at an 8-second scan rate. We used headphones to hear signals on all flights. Once a signal was heard, we isolated the direction with the switch box and then circled in the plane until a general area was determined. Follow-up ground searches were conducted using both hand-held and truck-mounted, 3-element Yagi antennae and portable receivers (Model TRX 1000-S, Wildlife Materials, Carbondale, Illinois, 62901). Information on location, orientation, elevation, and general structure of each day roost was recorded. Roost locations were taken with global positioning system (GPS) receivers using UTM coordinates. Most roosts were also documented photographically. Roosts were observed during evening emergence to determine if the marked bat roosted alone or communally. We attempted to locate instrumented bats on a daily basis until radio contact was lost.

In addition to following radio tagged bats, we attempted to discover bat roosts during the day by systematically searching the bases of cliffs and shallow caves for droppings and by reflecting sunlight into likely crevices and cavities in cliff faces. Searches were conducted in the rugged terrain at cliff bases, and took about 90 minutes or more per kilometer of cliff face. In the interests of safety, no climbing was involved. Roosts were classified as diurnal retreats (occupied by bats during the daytime) or as night roosts (sheltered overhangs and grottos used by bats for resting or handling prey between foraging bouts). During 1996 and 1997 we searched for roosts while hiking along sections of the south-facing cliffs of Kwage Mesa (about 1.5-km search path), Otowi Mesa (about 2-km search path), and an unnamed mesa east of Otowi Ruins (about 2-km search path), all in Pueblo Canyon. We also searched the south-facing cliffs along lower Los Alamos Canyon above State Road 4 (about 1.5-km search path), and cliffs and boulders along both sides of a 3-km stretch of Cañon de Valle above State Road 4. Roost sites were categorized as currently active (occupied by bats), recent (fresh droppings indicating use in current season but bats not present) or old (droppings present but probably deposited prior to 1996). Freshness of droppings was judged subjectively based on darkness of color and apparent moisture content. When possible, droppings were also judged to be likely from pallid bats (large, often accompanied by culled insect parts in night roosts), big brown bats (large, no culled insect parts), *Myotis* species (small), or free-tailed bats (small to medium sized, about 3-6 mm long, sometimes accompanied by a distinctive odor at the roost).

We also documented the call signatures of bat species in the Jemez Mountains with an ANABAT ultrasonic detector and software (Appendix A) and developed protocols for sampling bats for contaminants (Appendix B). We analyzed capture data using SAS version 6.11 (SAS Institute, Inc., Cary, North Carolina) statistical analysis software. To evaluate the affect of elevation on sex ratio, we classified capture sites into three elevation ranges and tested for differences in the average proportion of males at capture sites between elevation ranges using analysis of variance (ANOVA). To determine if there were elevational differences between reproductive female and male bats, we used two-sample comparative tests (Satterthwaite or Mann-Whitney, depending on normality of data) on capture records from after the first of July, at which time female reproduction status can be accurately assessed. Species that were represented by less than ten captures were not used in elevational analyses. All statistical tests were evaluated at the 5% level of significance.

3.0 Results

We captured bats on 106 nights at 27 different locations in the Jemez Mountains during 1995, 1996, and 1997 (Tables 1 and 2, Appendix C). We captured a total of 1532 bats of 15 species (Table 3, Figure 1, Appendix D) including the first known records of *Euderma maculatum* and *Pipistrellus hesperus* for both BAND and LANL.

3.1 Los Alamos National Laboratory

We mistnetted for 56 nights at 16 sites on or adjacent to LANL (2 nights in 1995, 31 in 1996, and 23 in 1997). We captured 610 bats of 14 different species (Table 4, Figure 2). The most frequently captured species was *Lasionycteris noctivagans* (36% of LANL captures), followed by *Eptesicus fuscus* (17%), *Myotis ciliolabrum* (11%), *Antrozous pallidus* (9%), and *L. cinereus* (6%). Most bats captured at LANL were male (77%). The bat species with the most even sex ratios were *M. californicus* (50% male), *M. evotis* (50%), *M. thysanodes* (52%), and *E. fuscus* (39%). Female *L. cinereus, P. hesperus, C. townsendii,* and *T. brasiliensis* were not captured at LANL. Male *E. maculatum* and *M. yumanensis* have not been captured at LANL, although they are known to occur in the Jemez Mountains. The only species known from the Jemez Mountains that was not captured at LANL is *Nyctinomops macrotis.*

We captured an average of 11.3 bats per night at LANL (range 1-57). The greatest average numbers of bats captured per night were at Rendija Canyon ($\bar{x} = 22.0$), Icehouse pond ($\bar{x} = 20.3$), Los Alamos Canyon - Upper Puddle ($\bar{x}$ = 10.5), Pueblo Canyon Waste Facility ($\bar{x}$ = 10.4), and Pueblo Canyon Effluent Stream ($\bar{x}$ = 10.3). Many of these sites also showed the highest species diversity: Icehouse Pond, 10 species; Los Alamos Canyon - Upper Puddle, 10; Pueblo Canyon Waste Facility, 7; and Pueblo Canyon Effluent Stream, 7. *L. noctivagans* was captured at the greatest number of sites (n = 8), followed by *M. evotis* (7), *M. thysanodes* (6), *L. cinereus* (6), and *E. fuscus* (6). The species captured at only a single site were *M. yumanensis, E. maculatum,* and *T. brasiliensis.* Female *M. thysanodes* were captured at more sites than males at LANL, while female *M. californicus, M. evotis,* and *M. volans* were captured at the same number of sites as males (Table 5, Figure 3).

3.2 Bandelier National Monument

We netted for 50 nights at 9 sites on Bandelier and an additional 2 sites in the adjacent Santa Fe National Forest. We captured 925 bats of 14 species (Table 6, Figure 4). The most frequently captured species was *L. noctivagans* (57%), followed by *L. cinereus* (9%), *M. evotis* (7%), *Myotis volans* (6%), and *E. fuscus* (5%). Most bats captured at BAND were male (87%). The bat species with the most even observed sex ratios were *M. thysanodes* (43%), *M. volans* (56% male), *M. yumanensis* (58%), and *E. fuscus* (67%). Male *C. townsendii* and *N. macrotis* were not captured at BAND.

We captured an average of 18.8 bats per night at BAND sites (range 1-114). The greatest numbers of bats captured per night were at Meadow Pond ($\bar{x}$ = 32.9), Ski Pond ($\bar{x}$ = 23.1), and Dome Pond ($\bar{x}$ = 21.3). The most species were captured at Meadow Pond (12), Ski Pond (10), Frijoles Creek at the Visitor Center (9), and the East Fork of the Jemez River. *M. thysanodes, M. volans,* and *L. noctivagans* were captured at the greatest number of sites (n = 8), followed by *E. fuscus* and *M. evotis* (7). Male *M. californicus, M. ciliolabrum, M. evotis, M. volans, L. cinereus, L. noctivagans,* and *A. pallidus* were captured at more sites than females. Female *M. thysanodes* were captured at more BAND sites (n = 8) than females of any other species. There were more female than male *M. thysanodes* and *E. maculatum* capture sites on BAND. Female *M. californicus, C. townsendii,* and *A. pallidus* were each captured at single sites (Table 7, Figure 5).

3.3 Combined Sites and Years

We captured an average of 14.9 bats per night (range 1-114) in the Jemez Mountains over three years of study. The bats captured most frequently were *L. noctivagans, E. fuscus, L. cinereus, M. evotis, M. volans,* and *M. ciliolabrum* (Table 3, Figure 6). We rarely captured *M. californicus, P. hesperus, N. macrotis, E. maculatum, C. townsendii,* or *M. yumanensis*. The species captured at the most sites were *L. noctivagans, M. thysanodes, M. evotis, E. fuscus, L. cinereus,* and *M. volans,* while *P. hesperus, E. maculatum, C. townsendii,* and *N. macrotis* were captured at the fewest (Table 8, Figure 7). Males were captured at more sites than females for all species except *M. thysanodes, M. yumanensis, E. fuscus,* and *E. maculatum* (Figure 8). Females of *M. thysanodes, M. yumanensis,* and *E. maculatum* were captured at more sites than males. Males and females of *E. fuscus* were captured at the same number of sites. Eighty-three percent of all bats captured during the study period were male.

The number of individuals of each species that were captured varied across years (Figure 9), as did the average number of bats captured per night (Figure 10); most differences were small. The total and average numbers of *M. thysanodes* and *M. volans* that were captured were fairly consistent over three years. The only species we caught in consistently decreasing numbers each year was *M. evotis* (Figure 10); average numbers of both male and female *M. evotis* captured decreased each year (Figures 11 and 12). Females of *C. townsendii* were captured only during 1995, female *M. californicus* were only captured during 1996, and female *L. cinereus* were only captured during 1997. *P. hesperus* females have not been captured during the study.

Likewise, the number and proportion of females exhibiting observable signs of reproduction varied across species and years (Figures 13, 14, and 15). In 1995, we captured reproductive females of nine species; in 1996, seven species; and in 1997, 10 species. Among all species *L. noctivagans, L. cinereus, M. volans, M. yumanensis,* and *M. evotis* exhibited the lowest proportions of reproductive females (Tables 9, 10, and 11 and Figure 16). The species we captured that had higher ratios of reproductive to non-reproductive females were *M. californicus, M. ciliolabrum, E. fuscus, E. maculatum,* and *N. macrotis.* All female *C. townsendii, A. pallidus,* and *T. brasiliensis* captured appeared reproductive. Proportions of males that were reproductive varied by year. In 1995, 75% of all male bats captured were reproductive, 13% in 1996, and 8% in 1997. Some reasons for this variation are in the discussion.

We captured juvenile bats of *M. evotis* (1), *M. thysanodes* (2), *M. volans* (2), *M. yumanensis* (1), *E. fuscus* (2), *E. maculatum* (2), *A. pallidus* (2), and *T. brasiliensis* (1). The earliest date of juvenile bat capture was 7 July at the East Fork of the Jemez River. Multiple juveniles were caught at several sites; both juvenile *E. maculatum* were captured in Los Alamos Canyon, both *E. fuscus* at Pueblo Canyon Waste Facility, and both *M. thysanodes* were captured on Frijoles Creek near the Bandelier Visitor Center. However, no site yielded juveniles of more than one species. Sexes of the juveniles were *M. yumanensis* and *E. maculatum*, female; *M. evotis, M. thysanodes,* and *T. brasiliensis*, males; and juveniles of *Eptesicus fuscus, A. pallidus,* and *M. volans* exhibited even sex ratios.

The average elevations of capture for *A. pallidus, P. hesperus, M. californicus*, and *M. ciliolabrum* were lowest while *T. brasiliensis, L. noctivagans, M. evotis, N. macrotis, E. maculatum,* and *M. volans* were highest (Table 12, Figure 17). ANOVA results show no significant differences in the average proportion of males captured at sites between three elevational groups ($p = 0.11$; Table 13). Many species show differences in the average elevation of capture between reproductive females and males; a test for no difference in the average elevation of capture between reproductive female and male bats was significant at the 5% level for *E. fuscus* and *M. evotis* ($p < 0.001$ and 0.01, two-sample, unequal variance t-test; Table 14).

3.4 Radiotelemetry

We attached radio transmitters to 41 different bats; 32 of these bats were successfully tracked to 51 different diurnal retreats (Table 15). Bats were tracked for an average of 8.6 days (range 1-22). Bats moved varying distances from point of capture (0.1-18 km), and all but *M. evotis* and *C. townsendii* tended to choose roosts that were more than 10 m above the ground. Colony sizes varied from 1 to over 220 individuals (Table 16, Appendix E).

We followed two female and one male *M. evotis* to 10 day roosts. Each bat was followed for 8 days. This species used an average of 3.7 roosts (range 2-5) while we tracked them, with the male moving the most. All females roosted in rock crevices and the male moved between snags and rock crevices. On average, roosts faced southeast. These bats generally roosted near or on the ground ($\bar{x} = 2$ m, range 0-12). This species had the highest average roost elevation and among the lowest average distance traveled from point of capture to first roost. We suspect that most of these bats roosted alone or in small groups, as we never observed emergences of more than one bat from the same crevice. However, at three roosts we observed other presumed conspecifics roosting alone in rock crevices near the ground within a few meters of the instrumented bats.

Seven lactating female *M. thysanodes* led us to their daytime retreats (n = 8). Instrumented bats were followed an average of 9.7 days (range 3-18). All of these bats roosted in rock crevices and solution pits relatively high on cliff walls. This species had the third highest average roost height (15 m, range 9-23) of any species studied. These bats used an average of 1.7 roosts (range 1-2). However, these numbers may underestimate the amount of roost changing that actually occurs. Roosts were difficult to locate precisely because of the inaccessibility and abundance of cavities, and bats may have been moving among adjacent cavities within a small area. In other areas, reproductive females of this species are known to change roosts, yet remain within a small area on a daily basis (Cryan 1997). Roosts of this species had the lowest average elevation of any species studied. Fringed myotis moved less from point of capture to first roost than most other species and exhibited some of the shortest movements between roosts. Average colony size was 66 bats (range 4-162). On average, roosts faced southeast.

We successfully tracked two lactating and one pregnant female *M. volans* for an average of five days (range 4-7). A pregnant female tagged at the Pueblo Canyon Waste Facility in May 1997 was found roosting in houses in Los Alamos; the others used crevices in rock "hoodoos." This species traveled further from point of capture to first roost than all but two other species. Average roost height was 10 m (range 3-25). Roosts of this species had the second highest average elevation. This pregnant female was the only one to move (<100 m) between roosts while under our observation. The most accurate emergence count for this species was six bats, but up to 50 bats were seen flying from the general area of a roost in a "hoodoo." We found this species roosting elsewhere on LANL. Three bats were seen roosting beneath a strip of aluminum flashing on the roof edge of building 40-23 on 11 July 1997. The site was visited again on 16 July 1997, at which time 24 bats were seen in the same spot. One bat was removed from the roost; it was an adult, non-reproductive female *M. volans*.

The roosts of five female *E. fuscus* (two pregnant, two lactating, and one unknown reproductive status) were found by radio tracking. This species was tracked for an average of 9.3 days (range 3-22). During 1996 and 1997, we radio tagged different pregnant females at the Pueblo Canyon Waste Facility and followed them both to the same large ponderosa pine snag in upper Pueblo Canyon. Use of the same site over two years suggests site fidelity in this species. Another snag roost in Rendija Canyon was used by a female of unknown reproductive status, although we suspect she was pregnant. The two other instrumented females both roosted in the walls or attic of an apartment complex in Los Alamos, located just off a branch of lower Los Alamos Canyon. The average distance traveled by big brown bats from point of capture to first roost ranked fourth highest among species studied. Colony size averaged 39 bats (range 25-51).

We successfully tracked five *Euderma maculatum* to their roosts. Two lactating females, one male, and two juvenile females were followed for an average of 9.2 days (range 5-14) to an average of 1.6 roosts (range 1-2). All of these bats roosted in rock crevices high on cliff walls. Average height of known roosts was 16 m (range 7-21) and their orientation was southeast. It was difficult to locate some higher roosts, partly due to the occasional tendency of this species to emerge when light levels were inadequate to see, and the highest roosts are not included in this average. The average elevation of *E. maculatum* roosts was the third lowest of all species studied. Individuals of this species that were tagged on the Santa Fe National Forest traveled further from point of capture to first roost (13-17 km) than any other species except *N. macrotis*. One female engaged in nightly foraging bouts that we estimated covered at least 50 km roundtrip distance. Conservative emergence counts averaged six bats (range 1-30), but some colonies may have had greater numbers of bats.

At LANL, two juvenile spotted bats were captured in mist nets set along cliffs on the north side of Los Alamos Canyon. These bats roosted in south-facing rock crevices high in the same cliff, but always at separate locations in small groups of 4 to 12 individuals. The young changed roost locations frequently and roosts were frequently too high to count the numbers of exiting bats accurately. One roost location used on 25 August was only about 6 m above the ground and housed five individuals. We had the impression that there were other colonies of spotted bats along the canyon as several times we saw small, cohesive groups of spotted bats flying down-canyon towards the Rio Grande.

We tracked two male *C. townsendii* for an average of 10.5 days (range 6-15). Both bats roosted in cavities within rock walls close to the ground. These bats were captured in harp traps at night roosts in lower Los Alamos Canyon and both flew very short distances to their initial day roosts. However, one of these males later flew from lower Los Alamos Canyon to a roost in upper Pueblo Canyon, a distance of 1.4 km. Both males apparently roosted alone.

We followed two male and one lactating female *A. pallidus* for an average of 12.7 days (range 11-15). These bats roosted in crevices on cliff faces, except on one occasion when a male was found in the ceiling of a small cave. Pallid bats used an average of three roosts (range 2-4) while we followed them. Roosts averaged 13 m (range 1-20) in height and typically faced south. This species had the second lowest capture elevation and exhibited a narrower elevational range than any other species. Movements of *A. pallidus* from capture to first roost and movements between roosts were among the shortest. Colony sizes were small, ranging from 1 to 12 individuals. The tagged female roosted in a small group that appeared to be a nursery colony. An exit count at her main roosting area on 16 July numbered four bats, but on 30 July the count increased to 12, concordant with an increase that might be expected once young became volant.

We tracked four lactating female *N. macrotis* to presumed maternity roosts during the summer of 1997. In addition, we found another roost occupied by this species near one of the roosts used by a marked bat. The four females were tracked for an average of 5.3 days (range 1-8). All of these roosts were in crevices high on cliff faces and the roosts were higher, on average, than those of any other species studied. One such roost was located in a long narrow crevice high on a canyon wall. Using a clinometer we estimated that the crevice extended from 90 to 160 feet above the cliff base. The central rectangular part of the crevice, from which many of the bats exited, was 115 feet above the base of the cliff. Some of our observations at this roost are included here.

On 31 July there was continuous squeaking and chattering from the crevice from the time of our arrival at about 1940 h. The first bat took flight about 2023 h based on the rush of air ("zoom") while diving and may have emerged from a nearby unseen section of cliff. By 2025 a total of 46 had exited from the main crevice, several from the central rectangular part. This was followed by 9 bats seen exiting at 2026, 1 at 2027, 8 at 2028 (some could have appeared in flight from elsewhere), 3 at 2033, and 4 at 2039 (for a total of 71 visuals closely tied to the crevice; one week earlier we counted a minimum of 220 bats before it became to dark to continue). Most of the bats did not dive and create the "zoom" sound on emergence. Additional bats no doubt emerged from the crevice but were not counted as they were not well silhouetted against the sky. We had the impression that a large proportion of these bats were swooping near the cliff after emerging from the observed roost or from elsewhere along the cliff. On 31 July there may have been fewer bats than were present and emerging on 25 July. Such "local" decreases might be due to breakup of the large maternity colony with smaller numbers of bats using and emerging from crevices in various sections of the cliff up and down the canyon.

However, on both 25 and 31 July many bats apparently never emerged based on significant and nearly constant chatter from within the crevice even after the emergence of large numbers of bats. This chatter continued throughout the night on 31 July. These calls may represent communication calls between mothers and young. Often we heard bats vocalizing on the wing that were answered by bats from within the crevice. These were short, 4-5 syllable staccato bursts of sound (sometimes 2-3 syllables); calls outside seemed "tickier" and calls from inside seemed higher pitched. From about 2100 to 2120 h sound was continuous except for an occasional 5-10 seconds of quiet.

On 31 July, we tallied the amount of vocal activity by counting the number of these calls heard in 5-min intervals during early, middle, and late parts of the night. These are representative of the constant activity heard nearly all night. The rough counts are as follows: 2125-2130: 456 calls; 2155-2200: 378 calls; 2225-2230: 464 calls; 0125-0130: 497 calls; 0155-0200: 656 calls; 0225-0230: 518 calls; 0425-0430: 337 calls; 0455-0500: 572 calls; 0525-0530: 397 calls. Bats were also continuously in flight in the area throughout the night. This was best evidenced by the zoom sounds made while bats "stooped" in the area of the cliff. Over the 20-minute period from 0200-0220 h we counted 421 zoom sounds; from 0435-0455 283 zooms; and during a 15-min interval at 0510-0525 we heard 272 zooms. It is possible that some of these stooping dives could be from young as they are learning to fly. We could still hear the zooms at 0530 h but were unable to clearly count numbers of bats returning to the roost. However, we saw some bats fly directly into the crevice without landing outside first and then exit again (without diving zoom) with night vision equipment. By 0545 h no bats were in flight in the area but much twittering from within the crevice continued.

Roosts of *Nyctinomops macrotis* generally faced south and east. On one occasion, a marked bat changed roosts, but others apparently remained in the same locations during the time we followed them. These bats flew farther from initial point of capture to first roost than any other species studied. The average distance from point of capture to first roost was 18.2 km. The longest recorded distance of travel on a single night was 30 km, while the shortest distance was 11 km. Average colony size was 100 (range 6-220) bats, based on conservative counts.

3.5 Searches for Roosts

We found 14 diurnal bat roosts in the limited areas searched by walking cliff faces, but only one was active (Appendix F). The active roost was located on the south-facing cliffs of Kwage Mesa, and contained an estimated 540 Brazilian free-tailed bats (*Tadarida brasiliensis*). The bats were identified and counted in flight during their emergence on 29 August 1996, the date the colony was discovered. A follow-up visit to this roost on 3 September revealed no exit flight. No bats were captured from the roost and efforts were made to minimize disturbance. The crevice is around 40 m above the ground in a relatively smooth, vertical section of cliff. The roost was in two large dark, vertical, circular chutes that form almost a figure eight when viewed from below. The algae on the cliff face below the roost was a brighter green than on immediately adjacent surfaces, and a noticeable amount of guano was dispersed on the soil surface below the roost at the base of the cliff. Fresh droppings appeared below the crevice again between 13 May and 13 June 1997. In addition, we found another roost of Brazilian free-tailed bats while watching an emergence at a nearby roost occupied by an instrumented bat of a different species. This roost was located on the west wall of San Diego Canyon and was first discovered during late August and early September of 1997. Two visits to the site on 25 August and 1 September resulted in exit counts of between 200-250 *T. brasiliensis*. The bats roosted in an overhanging section of the cliff wall that forms an arch extending 9 m above the slope. This area of cliff was observed on several nights earlier in the summer and no emergences of this species were seen. It seems likely that both these roosts are only used by *T. brasiliensis* during migration.

Several other sites were also found that previously had colonies attributable to *T. brasiliensis* but they were unoccupied on the day discovered (Appendix F). These include two additional cliff crevices on Kwage Mesa, and one major and two minor sites elsewhere in Pueblo Canyon (two on Otowi Mesa and one on the unnamed mesa to the east of Otowi Ruins). These sites had notable accumulations of guano below vertical crevices. Typically healthy Jimsonweed (*Datura* spp.) plants occurred at the bases of cliffs below crevice openings, and two of the roost sites on Kwage Mesa had green-stained lichen streaks on the cliffs below their openings. A strong odor, typical of that associated with free-tailed bats, was notable at the major site on the cliffs of Otowi Mesa. None of the diurnal roosts provisionally attributed to free-tailed bats was in the numerous small caves formed as Indian ruins, except for one within an open overhang about 2 m above the cliff base in Pueblo Canyon.

Some vacant roosts, likely of other species, were located. Droppings suggestive of pallid bats were found beneath a large, lengthy vertical crevice on the south-facing cliffs of Los Alamos Canyon, and those suggestive of a species of *Myotis* were found beneath a small (about 10-cm diameter) round opening some 3 m high on a vertical cliff of Kwage Mesa. Other, minor amounts of droppings also were located sporadically during cliff searches, but these could not be attributed to obvious roost sites of any significance and were not recorded. No significant guano accumulations were found during the search of upper Cañon de Valle.

Night roosts were found in numerous small caves excavated by the original human inhabitants of the area. However, most of these sites had no significant accumulations of droppings. Scattered droppings of a wide range of sizes were located on cave floors, indicating that several species of bats used these excavations as night roosts. Particularly obvious were large-sized droppings accompanied by culled insect parts (e.g., wings of sphingid moths and elytra of beetles) in some of these roosts; such evidence is typical of pallid bats. Those situations that seemed most favorable as night roosts were small caves with smaller openings than neighboring unused sites, higher ceilings (about 2 m above the floor), and bowl-like depressions or small vertical chutes in ceilings. Droppings below some of the latter situations could also have been left by diurnally roosting bats. Current use of what were apparently favored night roosts in Los Alamos Canyon was verified on 26 August 1996, when a bat was observed exiting late at night as we walked past; on 27 August 1996, when a pallid bat was captured attempting to enter a cave blocked by a mist net; and on 23 July 1997, when a pallid bat carrying a radio transmitter was found roosting in a chute that projected upward from the ceiling of a small cave. Pallid bats also were netted at entrances to night roosts in Pueblo Canyon on three nights in 1997. Sections of cliff with night roosts that seemed to be most heavily and recently used were identified in Pueblo and lower Los Alamos canyons, and we obtained GPS fixes for some of these (Appendix F).

3.6 Sampling in Relation to Contaminants

A plan for analyzing bats for the presence of selected environmental contaminants was completed in 1997 (Appendix B). Following this plan, 13 male pallid bats were collected at lower Los Alamos Canyon during summer field work. Sampling required several nights of mist-netting and harp-trapping along the base of the canyon cliffs as well as over water on the canyon bottom. Two adult male big brown bats were also collected over the Pueblo Canyon sewage treatment plant ponds. These specimens are in storage at the freezer in ESH-20. Two large plastic jars of guano were collected from 1997 deposits at the free-tailed bat colony at BAND for radionuclide and metals analysis. All analyses are to be conducted in FY98. No bat or guano samples were collected for organochlorine analysis nor were bats collected for metals analysis in FY97. LANL must provide further guidance on numbers of samples that can be submitted in FY98 before additional collections will be made.

3.7 Technical Area 53 Monitoring

We monitored the large pond in Technical Area (TA) 53 (LANL) for bat activity on 7 August 1997 using a combination of mist nets and the Anabat II bat detector and echolocation recording device. We monitored for 2 h beginning at 2000 h and ending at approximately 2200 h. No bats were captured in mist nets. The TA-53 pond is a rectangular body of water with the southwest corner abutting Sandia Canyon. Anabat monitoring began in this southwest corner, and each corner was subsequently monitored for approximately 0.5 h each. A total of 11 bats was detected (11 bat passes), five in the southwest corner, one in the southeast corner, one in the northeast, and four in the northwest. No feeding buzzes were recorded. A total of seven species were detected based on distinctiveness of echolocation characteristics. Species detected in the southwest corner included (number of passes in parentheses): *Myotis volans* (1), *M. evotis* (1), *M. ciliolabrum* (2), and *Nyctinomops macrotis* (1). One *M. volans* was detected in the southeast corner. Both an *Eptesicus fuscus* (1) and a *Euderma maculatum* (1) were detected in the northeast corner, and finally, *Tadarida brasiliensis* (2), *M. evotis* (1), and *M. ciliolabrum* (1) were detected in the northwest corner. This single night of observation suggests that this contaminated pond is likely used as a drinking source by bats, including five species of concern.

4.0 Discussion

Many factors can affect year-to-year mistnetting results and should be considered in the interpretation of our data. Due to the late project start in 1995, the results from the first year are biased towards late-season captures and distributional patterns. At this time of year, most males are becoming reproductive (characterized by enlarged testes and cauda epididymides) and most females have ceased lactation (but often will exhibit bare patches around nipples). Additionally, most captures in 1995 were from sites on BAND that tended to be at higher elevations. In 1996 and 1997, the field work started earlier and more time was spent on LANL, where low-elevation sites were more frequently netted. Data from 1996 and 1997 contain more females in earlier stages of reproduction and males evince no signs of reproductive activity. We have not yet analyzed captures as a function of level of effort at different sites or times.

Although proportions of males and females and observed reproductive status of both males and females are important indices of general population status, several biases can affect our ability to discern or explain variation in such indices. Although females captured early in the season (May to mid-June 1996 and 1997) may have been in the early stages of pregnancy, we were unable to determine this in the field without sacrificing individuals, which we chose not to do. Thus, all females that were not obviously pregnant early in the season, or in some phase of lactation later in the summer, were designated as "non-reproductive." Likewise, early in the season, most males appeared (and likely were) non-reproductive. Thus, our data at this time of year may appear to reflect a preponderance of non-reproducing individuals, especially for females, when such may not be the case. Bats captured early in the season are not distinguished from those captured later in figures and tables of this report. The date of earliest reproductive female capture varies from species to species and year to year; any bias associated with these results is included in the discussion and individual species accounts (Appendix D). As noted in results, numbers of males and females varied across all sites (Figure 8).

Seasonal or yearly climatic fluctuations also influenced our capture data. Bat activity over a given water source seems to be directly proportional to the amount of water dispersed across the landscape (Findley 1993, K. Geluso, pers. comm.); that is, the more water there is, the less concentrated the bat activity will be over a site. For example, in the first half of 1996 much of New Mexico, including the Jemez Mountains, experienced drought conditions (Appendix G). Many of the water sources in the mountains where we captured bats in 1995 and 1997 were dry and were not netted. There appeared to be some concentration of activity over the remaining water sources. This situation reversed itself in a remarkably short period in late June of 1996 when early monsoonal rains began to fall. Following the commencement of summer rains, water sources were abundant and an apparent dispersal of bats across the landscape occurred. Both precipitation and its converse, drought severity, have varied considerably over the last four years (Appendix G). Also, conditions on any given night may influence bat activity and hence our ability to capture bats. Wind, rain, cool temperatures, and full moon are probably the most significant factors affecting our ability to capture bats in mistnets.

Climate also affects mistnetting success through its effects on insects, upon which bats in the Jemez Mountains feed. During the breeding season, temperature and precipitation determine whether individuals forage or not (Grindal et al. 1992, Holroyd et al. 1994, Rydell 1989).

Furthermore, most north-temperate female bats remain homeothermic during pregnancy and lactation and may not be able to maintain homeothermy if regular feeding is not possible (Findley 1993). In addition, females may not breed in some years (Holroyd et al. 1994), or may resorb or abort embryos during times of stress (Grindal et al. 1992). In the drought conditions of late 1995 and early 1996 we believe there is the possibility that all these phenomena may have occurred.

Our work in the Jemez Mountains has added to the knowledge of bat abundance and distribution there. Species added to the known fauna of LANL or BAND since Findley et al. (1975) summarized mammal distributions in New Mexico include *M. californicus, M. ciliolabrum, P. hesperus, E. maculatum, C. townsendii, N. macrotis*, and *T. brasiliensis* (Arganbright 1987, Judson 1990, Guthrie and Large 1980, Tyrell and Brack 1992, this study). Refinements in our understanding almost certainly are the result of increased research effort rather than distributional changes in any of the bat species.

Most species captured during this study are typical associates of ponderosa pine-mixed conifer forests (Findley et al. 1975). The average elevation of capture (Table 12, Figure 17) generally reflects what is known about the elevational distributions of these species, although most species have greater elevational ranges (Mollhagen and Bogan 1997) than our data indicate, a consequence of where we were able to net. *Euderma maculatum*, along with *M. evotis, M. volans, L. cinereus* and *L. noctivagans* are commonly captured in mixed conifer-ponderosa pine forests. Species captured in ponderosa pine forest that also typically range down to lower elevations are *E. fuscus, M. ciliolabrum, M. thysanodes, M. yumanensis*, and *C. townsendii*. Bats most characteristic of lower elevations include *M. californicus, P. hesperus*, and *A. pallidus*. All the species likely occur at low elevations on a seasonal basis (Mollhagen and Bogan 1997). *T. brasiliensis* was captured over a wide elevational range but had a high average capture elevation, as did *N. macrotis* (Table 12).

The average elevation of sites at BAND was higher ($\bar{x} = 2410$ m) than those on LANL ($\bar{x} =$ 2039 m), and the captures from each area reflect these differences to some extent. The four most commonly captured species at BAND were *L. noctivagans, L. cinereus, M. evotis,* and *M. volans*. At LANL, the four most commonly captured species were *L. noctivagans, E. fuscus, M. ciliolabrum*, and *A. pallidus*. Captures of *L. noctivagans* and *L. cinereus* at any elevation are biased by migratory waves of these species passing through the area in late spring and early summer. Captures of *M. ciliolabrum, E. fuscus*, and (certainly) *A. pallidus* are a product of the lower-elevation sites where we worked at LANL.

Common low-elevation species in New Mexico are *M. californicus, P. hesperus, A. pallidus*, and *T. brasiliensis*. We captured 10 *P. hesperus* and 67 *A. pallidus* during the study, all at sites lower than 2100 m. The earliest, and only other, record of *P. hesperus* from the Jemez Mountains is an individual reported by Bailey (1931) from "Jemez Canyon." Captures of *P. hesperus* and more *A. pallidus* in 1996 and 1997 than in 1995 reflect the increased effort at lower elevation sites (LANL). Captures of *M. californicus* were from a greater range (1753-2729 m; Table 12) but some of these records may be confounded by our occasional inability to distinguish *californicus* from *ciliolabrum* (e.g., Bogan 1975).

Overall frequency and distribution of species capture for all years reflects the preponderance of sites in ponderosa pine-mixed conifer forest. The species that we captured most frequently were *L. noctivagans, M. volans, E. fuscus, M. evotis, M. thysanodes, M. ciliolabrum*, and *L. cinereus* (Table 8). These same species (in slightly different rank order; Table 8) were also captured at more sites than other species, again likely reflecting the forest composition at a majority of the sites. The lack of capture data for certain species may be the result of mistnetting bias rather than absence of the species in the area. For example, the distinct, audible calls of *E. maculatum* or *N. macrotis* were heard at nearly every site during the study period, yet they were captured at only 4 and 6 sites, respectively. It is also interesting to note the small number of *T. brasiliensis* captured during the three years of study, considering the presence of several large roosts within the study areas, at least seasonally. *Tadarida* may be leaving their roosts and foraging and drinking in the valley of the Rio Grande. These same comments likely apply to *M. yumanensis* as well.

Bats are long-lived, slow-breeding mammals with relatively low mortality rates (Findley 1993) and undisturbed populations are not known to fluctuate greatly over short periods of time, although movements of bats among roosts may obscure our ability to track population-level changes. Despite the increased netting effort during 1996 and 1997, more *M. evotis, M. thysanodes, M. volans, M. yumanensis,* and *T. brasiliensis* were captured per night during 1995 than in 1996 and 1997 (Figure 10). The reason for this is unknown, but probably reflects the biases of current sampling techniques rather than actual population trends.

The ratios of reproductive to non-reproductive females over the past three years (Figures 13, 14, and 15) reveal that during 1996 and 1997 we observed increasingly greater percentages of reproductive females to non-reproductive females than in 1995. If indeed reproductive females of some species are prone to inhabit lower elevations (Table 12, Figure 17; Cryan 1997), the greater total percentage of reproductive females captured in 1996 and 1997 may be a consequence of netting more low elevation sites. Overall, nine out of 14 species exhibited more reproductive than non-reproductive females.

More non-reproductive than reproductive females were captured of *M. evotis, M. volans, M. yumanensis, L. cinereus,* and *L. noctivagans.* In general, only male *L. noctivagans* (this study) and *L. cinereus* (Findley and Jones 1964) occur in the Jemez Mountains during summer, as females are elsewhere. All of the non-reproductive *M. yumanensis* were captured late in the season (mid-July through August) and it is unlikely that signs of reproduction at this time would go undetected. The greater percentage of reproductive males captured in 1995 most likely is a result of a delayed study period (late summer), during which time reproductive males are more frequently encountered.

There are several possible explanations for the male-biased, overall sex ratio in the capture data. Only 11 (1.5%) of the most frequently captured (and presumed migratory) species *(L. noctivagans)* were female. None of these females were grossly diagnosed as reproductive; all were captured between 23 April and 29 May 1996, and 30 May and 17 June 1997, probably as they were migrating through the area en route to the north and east. Males and females of this species and *L. cinereus* are known to segregate during the breeding season and most reproductive females are found elsewhere in these species' ranges (Findley and Jones 1964, Kunz 1982). There were exceptions to the male-biased sex ratios. For example, all *N. macrotis* we captured were female. This species presumably makes long-distance migrations, but we know too little about the seasonal movement and distribution of the sexes to speculate on reasons for the capture of only females in the Jemez Mountains.

In Europe, Kronwitter (1988) and other researchers report sexual segregation of bat populations on a local scale affecting capture results (Sluiter and van Heerdt 1966, Gaisler et al. 1979). They found no female bats of the species they were studying (*Nyctalus noctula*) in their study area, despite three years of intensive survey, while colleagues in neighboring regions of Europe reported predominantly female populations.

Across North America, females demonstrate a tendency to form maternity colonies. Temperature plays an important role in the reproductive physiology of bats (Studier and O'Farrell 1972), and females may be selecting lower elevation, warmer sites to comply with thermoregulatory needs during the relatively short birthing season. This may tend to concentrate their distribution locally and make them relatively more difficult to capture. If netting sites do not occur near maternity colonies, then reproductive females may not be captured. Conversely, males, which have different thermoregulatory needs more attuned to energy storage and conservation, usually enter torpor during the day. Roosts for males may be widespread across the landscape, and males may show less fidelity to them by moving often, thus making males more amenable to capture. The elevational segregation of males and reproductive females (females being captured at lower elevations) has been shown in other areas (Cryan and Bogan

1995, Cryan 1997). Future research should incorporate more low elevation capture sites to determine if females are selecting these areas.

Our studies have added considerably to knowledge of the roosting habits of eight species: *M. evotis, M. thysanodes, M. volans, E. fuscus, E. maculatum, C. townsendii, A. pallidus,* and *N. macrotis.* Roosts of *M. evotis* are known from a variety of structures including buildings, trees, rock crevices, caves, and mines (Manning and Jones 1989). In the Jemez, this species roosted alone, or possibly in small groups, and changed roosts fairly frequently. Tagged bats typically roosted in rock crevices close to the ground and exhibited little fidelity to a specific roost, although they generally remained within the same general area. One male moved between snags and rock crevices, indicating some flexibility in its roosting habits. We only followed one known reproductive female to her roost and thus the specific maternity roost needs of this species merit further study.

In general, the roosting habits of *M. thysanodes* were similar to observations made elsewhere in its range (Cryan 1997). Female *M. thysanodes* roosted in cavities on south- and east-facing cliffs that we presume provided warm microclimates for females needing to maintain homeothermy. Additionally, they appeared to move roosts daily but within short distances, consistent with observations in the Black Hills (Cryan 1997). Lewis (1995) discusses several reasons why bats would move frequently among roosts, and such lability is characteristic of bats that occupy roosts that are abundant in the landscape, as the pits in the Bandelier tuff appear to be. Male bats tend to remain heterothermic even in summer, and the choice of a north-facing cliff as a roosting site by male *M. thysanodes* is consistent with this themoregulatory strategy.

In other regions, maternity colonies of *M. volans* have been found in buildings, trees (Jones et al. 1973), and rock crevices (Quay 1948). In the Jemez, we found reproductive females at maternity colonies within buildings in Los Alamos and in rock crevices in remote canyons. We also opportunistically found small numbers of non-reproductive *M. volans* in buildings on LANL.

We found this species to be one of the most difficult to locate once an animal was tagged, and some of those we found traveled farther (4-9 km) than we had expected.

Eptesicus fuscus is known to form maternity roosts in a variety of structures, including trees and buildings. We found three female *E. fuscus* roosting in large ponderosa pine snags. Two of these bats used the same snag roost; one in 1996, the other in 1997. Trees in forests that are used by reproductive females tend to be large, old, and often dead snags (Barclay and Brigham 1996). Furthermore, such roost trees are often in clearings and well insolated. Use of such trees by homeothermic females would be predicted. The apartment complex that was used by two reproductive female big brown bats was also structurally conducive to warm internal temperatures. The bats roosted within the wooden walls of the building, but adjacent to a brick wall that likely retains solar energy during the day and radiates it at night. This species is commonly associated with buildings and is considered a hardy bat with flexible roosting habits. All observed colonies contained over 25 individuals that we presume were conspecifics.

Spotted bats are known to roost primarily within crevices high in cliffs (Easterla 1970; Watkins 1977; Leonard and Fenton 1983). Prior to this study no roosts of this species were known in New Mexico. The roosts we found appear safe from intrusion or vandalism due to their remoteness and height above the ground. Exit counts at maternity roosts ranged up to 30 individuals and this appears to be one of the first accounts of communal roosting in this species (W. Rainey, personal communication). Our captures of young-of-the-year spotted bats, apparently flying with an adult bat relatively close to the ground in lower Los Alamos Canyon, suggest they were exploring the many small caves and grottos in this area. Spotted bats in lower Los Alamos Canyon appeared to be flying towards the Rio Grande whereas those in San Diego Canyon appeared to be foraging in that general vicinity and south to Jemez Pueblo and San Ysidro, making roundtrip flights of up to 50 km. One spotted bat that we tracked appeared to fly all night, a phenomenon reported by Wai-Ping and Fenton (1989). This species also flies at some height above the ground (est. 50 m, Wai-Ping and Fenton 1989), limiting our ability to capture them in mist nets, although their calls are clearly audible throughout the area at night.

During the warmer months, Townsend's big-eared bats are known to roost in caves, mines, and buildings (Kunz and Martin 1982). Our observations of roosts of this species only involved male bats, which roosted alone in sites that were less confined and more exposed than those used by the other rock-roosting species we followed. On 19 July 1997 we followed one of the instrumented males to a small cave in the east wall of lower Los Alamos Canyon near where it was trapped. The bat roosted on the sloping ceiling of the cave and was visible from the slope below (approx. 2 m). Other roosts used by these bats were in rock substrate that had numerous inner cavities and, although we could not observe them within the roost, we suspect they were in open chambers rather than crevices. Roosting in open, non-confined spaces is characteristic of this species (Barbour and Davis 1969). The agile flight behavior of *C. townsendii* may limit our ability to capture them in mist nets, but the presence of only males among those captured suggests that females may be absent from the area. In other areas, evidence suggests that reproductive females that hibernate in the mountains during the summer may move to lower elevations to form maternity colonies (Cryan 1997). In addition, *C. townsendii* in maternity colonies are known to be extremely susceptible to disturbance, often abandoning a roost after disturbance (Kunz and Martin 1982). It is possible that this sensitivity to disturbance, coupled with their need for open, non-confined roosts may limit their use of the low-elevation areas surveyed. We are uncertain what the levels of possible disturbance might be in this canyon; we frequently found evidence that humans had visited the small caves here.

Pallid bats are usually associated with arid lands near rocky outcrops, and seem to be less abundant in forested life zones (Jones 1965). Most of the pallid bats we captured were males, and this is consistent with studies in Arizona that showed a possible tendency of males of this species to be found at higher elevations and females to form maternity colonies in warmer, lower-elevation sites (O'Shea and Vaughan 1977). In the Jemez Mountains, solitary males, or possibly small groups, roosted in rock crevices and shifted roost locations within a small area. Captures of juveniles and the tracking of a single radio-tagged female provided evidence that pallid bats form small maternity colonies at LANL. The female roosted in small, partly horizontal solution cavities on the south side of lower Los Alamos Canyon, first in a group of about four to six bats (based on exit counts in mid-July) and later about 12 in late July. This may reflect the appearance of volant young, because pallid bats typically have about two offspring per litter (Hermanson and O'Shea 1983). Behavior at emergence was typical of observations of pallid bat maternity roosts elsewhere, and included bats circling at the cliff face near the roost entrance giving audible communication calls, as if females were "coaxing" the emergence of young (Vaughan and O'Shea 1976, O'Shea and Vaughan 1977). Pallid bats also commonly use night roosts to consume prey and to gather in clusters for thermoregulation. The grottos in lower Los Alamos Canyon are regularly used as night roosts by pallid bats, based on our observations of droppings and culled insect parts typical of pallid bat prey. Most of the observations reported in the literature of night-roosting behavior of pallid bats involve females and young, who locate each other through audible "directive" calls (Brown 1976, Orr 1954, O'Shea and Vaughan 1977). On several occasions we captured single adult male pallid bats entering or exiting night roosts in lower Los Alamos Canyon and heard them give audible directive calls as they did so. This verifies that night roosting behavior of male pallid bats shares some characteristics with females.

Very little is known of the roosting habits of *N. macrotis* and prior to this study only two such roosts were known in New Mexico, one near Los Lunas in Valencia County and one near the Rio de los Pinos in San Juan County (Findley et al. 1975). We found five roosts (including one opportunistic find) of this species in the Jemez Mountains, both on BAND and Santa Fe National Forest. We believe all of these were maternity colonies.

The presence of suitable nursery roosts is believed to be the most important factor governing the distribution of temperate bats (Humphrey 1975). Typically, areas with the most topographic diversity also demonstrate the greatest bat species diversity. We believe that presence of maternity roosts that meet narrow thermal tolerances is the most critical habitat need for bats in the Jemez and should be the primary focus of research and management activities. Females often demonstrate high fidelity to such roosts, and maternity roosts often are characterized by their relative permanency and low availability (Lewis 1995). Non-reproductive females and males typically occupy multiple solitary roosts and often demonstrate low fidelity to such widespread roosts (Lewis 1995). There may be less need to protect roosts used by solitary bats, given their presumed widespread availability. Secondarily, we agree with Mollhagen and Bogan (1997) on the need to protect, and provide continuity of, water sources for bats.

We netted all eight bat species of concern in the Jemez and a majority of females of these species were reproductive. Four of these species (*M. ciliolabrum, M. evotis, M. thysanodes,* and *M. volans*) were captured frequently and a fifth (*Euderma*) was captured occasionally and heard frequently. Roosts of long-eared myotis that are close to the ground are susceptible to disturbance, although all such roosts found by us were in relatively remote areas in dense vegetation away from humans; logging or road building might disturb such roosts. The roosts of fringed myotis, long-legged myotis, and spotted bats seem secure from disturbance, and there appears to be an abundance of such roosts in the mountains. Roosts in houses (*M. volans*) are susceptible to disturbance. We captured only seven *C. townsendii*, two females and five males. These bats are agile fliers, and their capture numbers may reflect netting bias rather than relative abundance. *Corynorhinus* also may be patchily distributed in this area and only locally common. Nonetheless, there is widespread concern over the status of *C. townsendii* in the West. This species often roosts in exposed places, such as where we found them, and are thus exposed to disturbance and vandalism. More information should be gathered on this species on an opportunistic basis, but extreme care should be exercised near maternity roosts. There is a maternity colony of *M. yumanensis* at BAND (Guthrie and Large 1980, Judson 1990), and it is a common species in the Rio Grande corridor of New Mexico (E. Valdez, unpubl.). This species tends to occur at elevations lower than where we netted; we suspect it is relatively secure. Assessing the local status of *M. yumanensis* could best be done by monitoring the roosts at BAND. Females of the last species of concern, *N. macrotis*, were netted in low numbers both at BAND and on the Santa Fe National Forest, but sizable maternity roosts of this species were found in the area. Like several of the other cliff-dwelling species, the roosts of *Nyctinomops* seem secure.

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Table 1. Dates bats were mistnetted in the Jemez Mountains during the study period. LANL = Los Alamos National Laboratory and BAND = Bandelier National Monument.

LANL DATES	LANL DATES (cont.)	BAND DATES	BAND DATES (cont.)
09/05/95	08/14/96	07/18/95	08/09/96
09/06/95	08/28/96	07/19/95	08/12/96
04/24/96	09/04/96	07/20/95	8/27/1996
04/25/96	09/05/96	07/26/95	08/28/96
05/21/96	09/10/96	07/27/95	09/06/96
05/22/96	05/27/97	07/31/95	9/11/1996
05/23/96	05/29/97	08/01/95	05/28/97
05/29/96	05/31/97	08/02/95	05/30/97
05/30/96	06/09/97	08/03/95	06/06/97
06/01/96	06/11/97	08/07/95	06/17/97
06/02/96	06/12/97	08/08/95	06/23/97
06/05/96	06/16/97	08/09/95	06/30/97
06/18/96	06/18/97	08/10/95	07/01/97
06/25/96	06/19/97	08/14/95	07/12/97
06/27/96	06/27/97	08/16/95	07/15/97
06/28/96	07/04/97	08/17/95	07/18/97
07/02/96	07/05/97	05/15/96	07/19/97
07/09/96	07/09/97	05/20/96	07/23/97
07/10/96	07/09/97	05/31/96	07/24/97
07/11/96	07/13/97	06/06/96	07/27/97
07/17/96	07/14/97	06/10/96	08/15/97
07/18/96	07/17/97	06/24/96	08/19/97
07/22/96	07/29/97	07/15/96	*
07/23/96	08/09/97	07/16/96	*
07/24/96	08/11/97	07/21/96	*
07/30/96	08/16/97	07/29/96	*
08/06/96	08/21/97	07/31/96	*
08/13/96	08/22/97	08/08/96	*
	56 Nights		50 Nights

Table 2. Sites netted in the Jemez Mountains during of 1995, 1996, and 1997.

1995	1996	1997
Site	Site	Site
Dome Pond (P 2)	East Fork of Jemez River	Dome Pond (P 2)
Frijoles Creek @ R.H. Crossing	Frijoles Creek @ R.H. Crossing	East Fork of Jemez River
Frijoles Creek @ Visitor Center	Icehouse Pond	Frijoles Creek @ R.H. Crossing
Icehouse Pond	Los Alamos Canyon - Otowi Well 4	Frijoles Creek @ Visitor Center
Los Alamos Canyon Resevoir	Los Alamos Canyon - Upper Puddle	Guaje Canyon
Los Alamos Canyon - Lower	Los Alamos Canyon - Cliffs	Icehouse Pond
Lower Pond (P 4)	Los Alamos Canyon CLF	Los Alamos Canyon - Cliff Face
Meadow Pond (P 1)	Los Alamos Canyon Resevoir	Los Alamos Canyon - Lower
Mortandad Canyon	Meadow Pond (P1)	Las Conchas
North Upper Pond (P 7)	Pueblo Canyon Effluent	Meadow Pond (P1)
Pajarito Wetland	Pueblo Canyon Waste Facility	Pueblo Canyon Effluent
Sewage Lagoons (L 1-3)	Ski Pond (P5)	Pueblo Canyon Waste Facility
Ski Pond (P 5)	Tech. Area 15 Cement Pond	Rendija Canyon
Upper Pond (P 3)		Tech. Area 53 Lagoon
		Ski Pond (P5)
		Water Canyon
		White Rock Sewage Lagoons
14 Sites	13 Sites	17 Sites

Table 3. Number and species of bats captured in the Jemez Mountains. F = female; M = male; Sub = subtotal captured each year. Asterisks denote federal Species of Concern. E = state endangered.

	Species	F'95	M'95	Sub. '95	F'96	M'96	Sub. '96	F'97	M'97	Sub. '97	Total F	Total M	TOTAL
	M. californicus	0	2	2	5	4	9	0	0	0	5	6	11
*	*M. ciliolabrum*	2	4	6	7	30	37	9	34	43	18	68	86
*	*M. evotis*	4	40	44	11	24	35	8	19	27	23	83	106
*	*M. thysanodes*	8	8	16	13	13	26	16	11	27	37	32	69
*	*M. volans*	5	18	23	12	29	41	25	12	37	42	59	101
*	*M. yumanensis*	3	5	8	2	0	2	1	2	3	6	7	13
	L. cinereus	0	2	2	0	19	19	7	92	99	7	113	120
	L. noctivagns	0	91	91	6	314	320	5	329	334	11	734	745
	P. hesperus	0	0	0	0	3	3	0	7	7	0	10	10
	E. fuscus	2	5	7	33	34	67	45	37	82	80	76	156
*(E)	*E. maculatum*	3	0	3	2	0	2	4	3	7	9	3	12
*	*C. townsendii*	2	0	2	0	2	2	0	3	3	2	5	7
	A. pallidus	1	1	2	0	45	45	2	18	20	3	64	67
	T. brasiliensis	1	4	5	0	1	1	1	7	8	2	12	14
*	*N. macrotis*	0	0	0	7	0	7	8	0	8	15	0	15
	TOTALS	31	180	211	98	518	616	131	574	705	260	1272	1532

Table 4. Bats netted at LANL during the study. Asterisks denote Species of Concern.

	Species	Male	Female	Total	% Male	% Frequency
	M. californicus	4	4	8	50	1.31
*	*M. ciliolabrum*	51	16	67	76	10.98
*	*M. evotis*	19	19	38	50	6.23
*	*M. thysanodes*	13	12	25	52	4.10
*	*M. volans*	26	16	42	62	6.89
*	*M. yumanensis*	0	1	1	0	0.16
	L. cinereus	34	0	34	100	5.57
	L. noctivagans	216	5	221	98	36.23
	P. hesperus	10	0	10	100	1.64
	E. fuscus	40	62	102	39	16.72
*	*E. maculatum*	0	2	2	0	0.33
*	*C. townsendii*	5	0	5	100	0.82
	A. pallidus	52	2	54	96	8.85
*	*T. brasiliensis*	1	0	1	100	0.16
	N. macrotis	0	0	0	0	0.00
	TOTAL	471	139	610	77	100

Table 5. Number of capture sites for male and female bats of each species at LANL. Asterisks denote Species of Concern.

	LANL Species	Female	Male
	M. californicus	2	2
*	*M. ciliolabrum*	4	5
*	*M. evotis*	4	4
*	*M. thysanodes*	6	4
*	*M. volans*	3	3
*	*M. yumanensis*	1	0
	L. cinereus	0	6
	L. noctivagans	2	8
	P. hesperus	0	3
	E. fuscus	4	6
*	*E. maculatum*	1	0
*	*C. townsendii*	0	3
	A. pallidus	2	5
	T. brasiliensis	0	1
*	*N. macrotis*	0	0

Table 6. Bats netted at BAND sites during the study. Asterisks denote Species of Concern.

	Species	Male	Female	Total	% Male	Frequency
	M. californicus	2	1	3	67	0.32
*	*M. ciliolabrum*	19	2	21	90	2.27
*	*M. evotis*	65	4	69	94	7.46
*	*M. thysanodes*	19	25	44	43	4.76
*	*M. volans*	33	26	59	56	6.38
*	*M. yumanensis*	7	5	12	58	1.30
	L. cinereus	79	7	86	92	9.30
	L. noctivagans	518	6	524	99	56.65
	P. hesperus	0	0	0	0	0.00
	E. fuscus	36	18	54	67	5.84
*	*E. maculatum*	3	7	10	30	1.08
*	*C. townsendii*	0	2	2	0	0.22
	A. pallidus	12	1	13	92	1.41
	T. brasiliensis	11	2	13	85	1.41
*	*N. macrotis*	0	15	15	0	1.62
	TOTAL	804	121	925	87	100

Table 7. Number of capture sites for male and female bats of each species at BAND. Asterisks denote Species of Concern.

	BAND Species	Female	Male
	M. californicus	1	2
*	*M. ciliolabrum*	2	4
*	*M. evotis*	2	6
*	*M. thysanodes*	8	6
*	*M. volans*	6	7
*	*M. yumanensis*	3	3
	L. cinereus	3	7
	L. noctivagans	2	8
	P. hesperus	0	0
	E. fuscus	4	6
*	*E. maculatum*	3	1
*	*C. townsendii*	1	0
	A. pallidus	1	2
	T. brasiliensis	2	0
*	*N. macrotis*	2	0

Table 8. Number of sites at which each species was captured and number of nights each species was captured during the study period.

Species	# Sites	# Nights
M. californicus	5	7
M. ciliolabrum	10	35
M. evotis	14	41
M. thysanodes	14	41
M. volans	12	46
M. yumanensis	6	8
L. cinereus	13	33
L. noctivagans	15	57
P. hesperus	3	5
E. fuscus	13	44
E. maculatum	4	5
C. townsendii	4	4
A. pallidus	8	18
T. brasiliensis	6	10
N. macrotis	2	5

Table 9. Reproductive status of bats captured at LANL and BAND during 1995. NR = non-reproductive; S = scrotal; J = juvenile; P = pregnant; L = lactating; PL = postlactating.

1995	FEMALE					MALE		
Species	NR	P	L	PL	J	NR	S	J
M. californicus	0	0	0	0	0	1	1	0
M. ciliolabrum	0	0	0	2	0	2	2	0
M. evotis	3	0	0	1	0	14	26	0
M. thysanodes	2	0	2	4	0	3	3	2
M. volans	4	0	0	0	0	5	13	1
M. yumanensis	2	0	0	1	0	1	4	0
L. cinereus	0	0	0	0	0	2	0	0
L. noctivagans	0	0	0	0	0	12	79	0
E. fuscus	1	0	0	1	0	1	4	0
E. maculatum	0	0	2	1	0	0	0	0
C. townsendii	0	0	2	0	0	0	0	0
A. pallidus	0	0	0	1	0	0	1	0
T. brasiliensis	0	0	0	1	0	3	0	1
TOTAL	12	0	6	12	0	44	133	4

Table 10. Reproductive status of bats captured at LANL and BAND during 1996. NR = non-reproductive; S = scrotal; J = juvenile; P = pregnant; L = Lactating; PL = postlactating.

1996	FEMALE					MALE		
Species	NR	P	L	PL	J	NR	S	J
M. californicus	1	1	2	0	0	1	3	0
M. ciliolabrum	2	3	2	0	0	23	7	0
M. evotis	5	4	2	0	0	22	2	0
M. thysanodes	7	1	5	0	0	12	1	0
M. volans	10	0	2	0	0	28	1	0
M. yumanensis	2	0	0	0	0	0	0	0
L. cinereus	0	0	0	0	0	19	0	0
L. noctivagans	6	0	0	0	0	306	8	0
P. hesperus	0	0	0	0	0	1	2	0
E. fuscus	13	15	4	0	1	32	1	1
E. maculatum	2	0	0	0	0	0	0	0
C. townsendii	0	0	0	0	0	2	0	0
A. pallidus	0	0	0	0	0	4	41	0
N. macrotis	2	0	5	0	0	0	0	0
TOTAL	50	24	22	0	1	450	66	1

Table 11. Reproductive status of bats captured at LANL and BAND during 1997. NR = non-reproductive; S = scrotal; J = juvenile; P = pregnant; L = Lactating; PL = postlactating.

1997	FEMALE					MALE		
Species	NR	P	L	PL	J	NR	S	J
M. californicus	0	0	0	0	0	0	0	0
M. ciliolabrum	2	1	4	2	0	30	4	0
M. evotis	5	1	2	0	0	16	2	1
M. thysanodes	7	4	3	2	0	11	0	0
M. volans	12	2	10	1	0	10	1	1
M. yumanensis	0	0	0	0	1	2	0	0
L. cinereus	6	1	0	0	0	91	1	0
L. noctivagans	5	0	0	0	0	304	26	0
P. hesperus	0	0	0	0	0	6	1	0
E. fuscus	6	8	26	5	0	34	3	0
E. maculatum	0	0	2	0	2	1	2	0
C. townsendii	0	0	0	0	0	3	0	0
A. pallidus	0	0	1	0	1	12	5	1
T. brasiliensis	0	0	1	0	0	7	0	0
N. macrotis	1	0	7	0	0	0	0	0
TOTAL	44	17	56	10	4	527	45	3

Table 12. Mean elevation (meters), standard deviation, and range of capture for bat species in the Jemez Mountains.

Species	Mean Elevation (m)	Standard Dev.	Range (m)
A. pallidus	1903	91	1738-2012
P. hesperus	1952	85	1829-2006
M. californicus	2057	302	1753-2729
M. ciliolabrum	2059	295	1753-2729
C. townsendii	2161	470	1753-2774
M. thysanodes	2217	402	1753-2774
E. fuscus	2233	316	1753-2729
L. cinereus	2404	373	1753-2729
M. yumanensis	2422	400	1835-2729
M. volans	2438	305	1753-2774
E. maculatum	2450	324	1829-2729
N. macrotis	2504	140	2423-2729
M. evotis	2542	265	1753-2774
L. noctivagans	2543	268	1753-2729
T. brasiliensis	2580	294	1854-2729

Table 13. Results of an analysis of variance test for differences in the mean percentage of male captures at sites within three elevation ranges.

Anova: Single Factor

SUMMARY

Elevation Groups	*Sites*	*M. % Male*	*Variance*
5500-6500 feet	6	80.39	267.59
6500-7500 feet	6	54.41	1657.15
7500-9000 feet	6	86.31	59.93

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3454.36	2	1727.18	2.61	0.11	3.68
Within Groups	9923.31	15	661.55			
Total	13377.67	17				

Table 14. P-values from a two-sample, two-tailed, unequal-variance t-test for no difference in mean capture elevation between reproductive females and males of each species, for which adequate data exists.

Species	p-value
M. californicus	0.61
M. ciliolabrum	0.27
M. evotis	0.01*
M. thysanodes	0.38
M. volans	0.33
E. fuscus	< 0.001*

Table 15. Summary statistics of radiotracked bats. PRG = pregnant; LAC = lactating; UNK = unknown reproductive status; NSC = non scrotal. Weights are in grams.

Date	Frequency	Species	Sex	Repro	Weight	Days Followed	# Roosts	Roost Type
06/18/96	164	*M. evotis*	F	PRG	*	0	*	*
06/09/97	081	*M. evotis*	M	NSC	7.0	8	5	snag/rock crevice
06/09/97	106	*M. evotis*	F	UNK	11.0	8	4	rock crevice
06/29/97	209	*M. evotis*	F	*	8.5	0	*	*
07/04/97	331	*M. evotis*	F	LAC	*	8	2	rock crevice
06/10/96	237	*M. thysanodes*	M	NSCC	*	9	1	rock crevice
07/18/96	100	*M. thysanodes*	F	LAC	*	18	2	rock crevice
07/18/96	253	*M. thysanodes*	F	LAC	*	3	2	rock crevice
07/19/96	278	*M. thysanodes*	F	LAC	*	17	1	rock crevice
06/23/97	019	*M. thysanodes*	F	*	9.0	0	*	*
06/30/97	031	*M. thysanodes*	F	LAC	8.5	12	1	rock crevice
06/30/97	257	*M. thysanodes*	F	LAC	9.5	10	2	rock crevice
07/15/97	720	*M. thysanodes*	F	LAC	8.5	7	2	rock crevice
05/13/97	169	*M. volans*	F	UNK	9.5	0	*	*
05/13/97	610	*M. volans*	F	PRG	7.5	7	2	buildings
06/23/97	040	*M. volans*	F	*	8.5	0	*	*
07/01/97	278	*M. volans*	F	LAC	9.0	0	*	*
07/15/97	709	*M. volans*	F	LAC	7.5	0	*	*
07/19/97	887	*M. volans*	F	LAC	7.5	4	1	rock crevice
07/23/97	913	*M. volans*	F	LAC	7.5	4	1	rock crevice
07/24/96	637	*E. fuscus*	F	PRG	*	12	1	snag
08/19/96	663	*E. fuscus*	F	LAC	*	0	*	*
06/19/97	061	*E. fuscus*	F	UNK	17.0	22	1	snag
07/04/97	167	*E. fuscus*	F	PRG	*	6	1	building
07/14/97	583	*E. fuscus*	F	LAC	18.0	3	1	snag
07/14/97	230	*E. fuscus*	F	LAC	*	6	1	building

Table 15. Continued

Date	Frequency	Species	Sex	Repro	Weight	Days Followed	# Roosts	Roost Type
07/24/97	964	*E. maculatum*	F	LAC	15.0	14	1	rock crevice
07/24/97	929	*E. maculatum*	F	LAC	17.5	8	2	rock crevice
07/24/97	992	*E. maculatum*	M	NSC	15.0	5	1	rock crevice
08/23/97	949	*E. maculatum*	F	JUV	16.0	7	2	rock crevice
08/23/97	658	*E. maculatum*	F	JUV	14.0	12	2	rock crevice
07/17/97	779	*C. townsendii*	M	NSC	9.0	6	1	rock cavettes
07/17/97	742	*C. townsendii*	M	NSC	9.0	15	2	rock cavettes
05/13/97	487	*A. pallidus*	M	NSC	15.0	15	3	rock crevice
07/14/97	433	*A. pallidus*	F	LAC	*	12	2	rock crevice
07/14/97	534	*A. pallidus*	M	NSC	*	11	4	rock crevice
07/12/97	354	*N. macrotis*	F	LAC	*	0	*	*
07/15/97	559	*N. macrotis*	F	LAC	*	7	1	rock crevice
07/15/97	484	*N. macrotis*	F	LAC	*	8	1	rock crevice
07/15/97	609	*N. macrotis*	F	LAC	*	1	1	rock crevice
07/24/97	799	*N. macrotis*	F	LAC	*	5	*	rock crevice

Table 16. Summary statistics for bat roosts found in the Jemez Mountains. N = number of roosts found; Elevations = mean roost elevation (range in parentheses); Dist. Capt. = mean distance from point of capture to first roost; Dist. Prev. = mean distance from previous roost; Height = height of roost above ground; Orient. = orientation of roost in degrees.

Species	N	Elevation (m)	Dist. Capt. (km)	Dist. Prev. (km)	Height (m)	Colony Size	Orient. (deg)
M. evotis	10	2371 (1585-2542)	0.6 (0.3-1.0)	2.0 (0.1-15.2)	2 (0-12)	1	124
M. thysanodes	8	2010 (1835-2439)	1.9 (0.3-6.9)	0.2 (0.1-0.2)	15 (9-23)	66 (4-162)	140
M. volans	4	2270 (2195-2378)	7.0 (4.5-9.3)	0.1	10 (3-25)	6	133
E. fuscus	4	2148 (2095-2201)	3.0 (1.0-4.8)	-	10 (4-15)	39 (25-51)	175
E. maculatum	8	2098 (2005-2287)	8.0 (0.01-17.6)	0.4 (0.1-0.8)	16 (7-21)	6 (1-30)	152
C. townsendii	3	2078 (2016-2175)	0.6 (0.1-1.0)	1.4	2 (0-4)	1	240
A. pallidus	9	2068 (2012-2165)	0.6 (0.2-1.0)	0.3 (0.1-0.7)	13 (1-20)	3 (1-6)	181
N. macrotis	5	2149 (1921-2311)	18.2 (11-30)	0.5	20 (9-35)	100 (6->220)	151

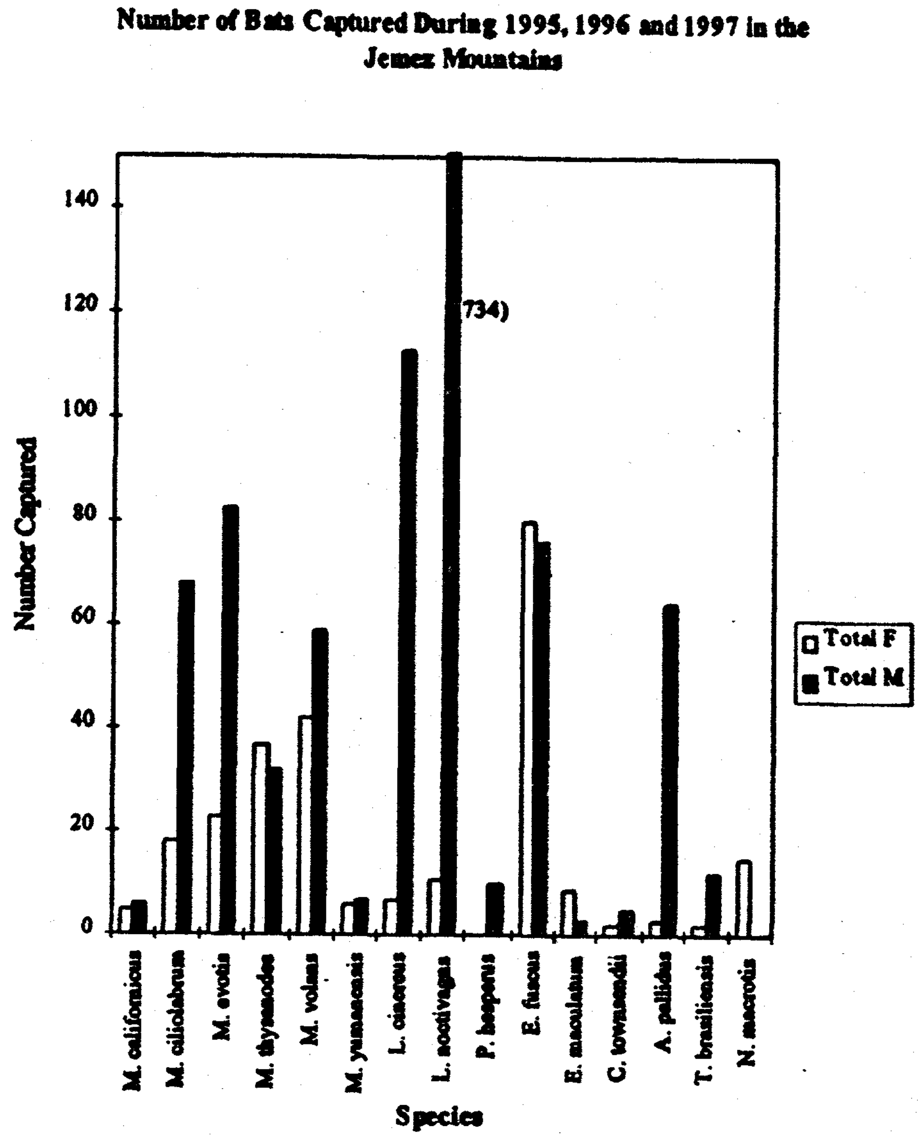


Figure 1. Total number of bats captured during the study in the Jemez Mountains.

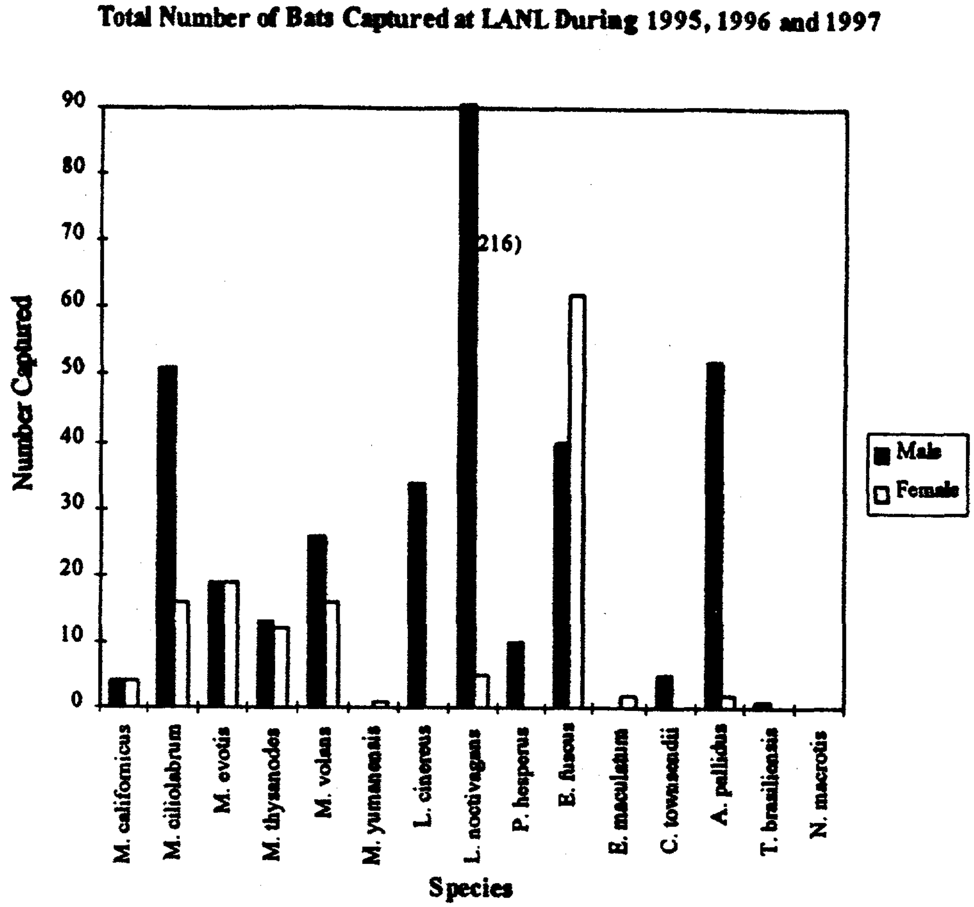


Figure 2. Total number of bats captured at LANL during the study.

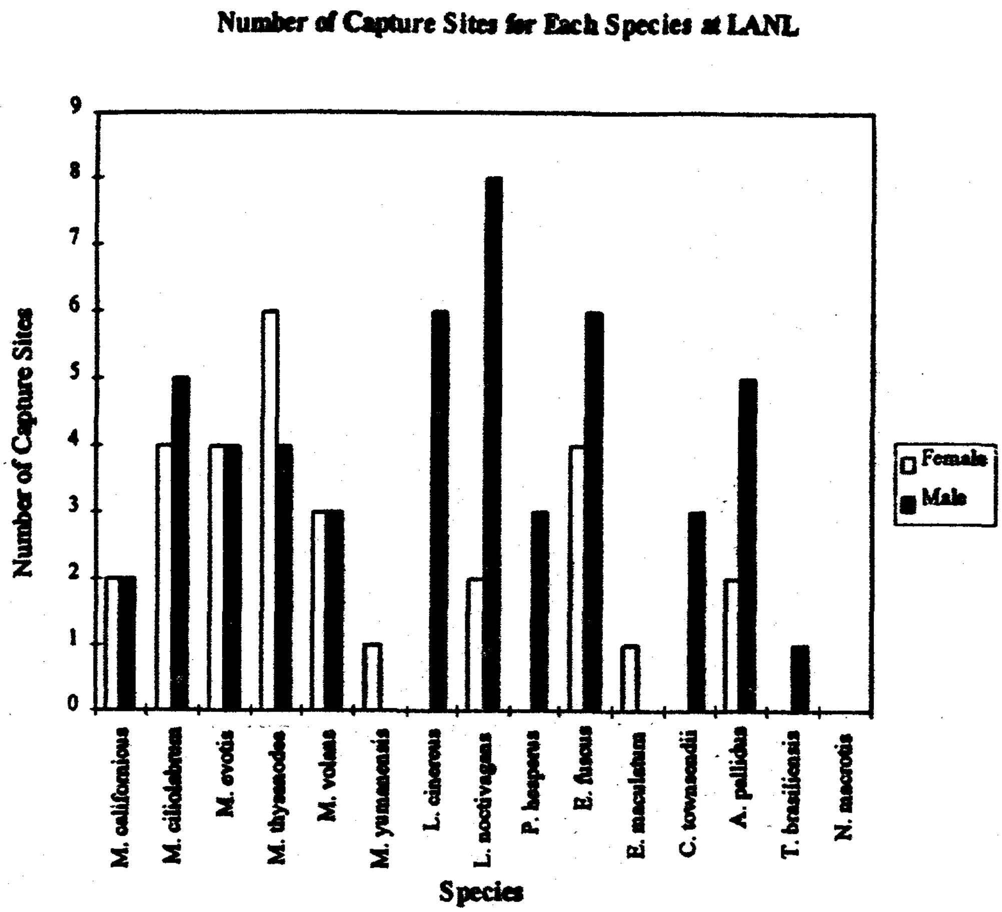


Figure 3. Number of capture sites for bat species at LANL.

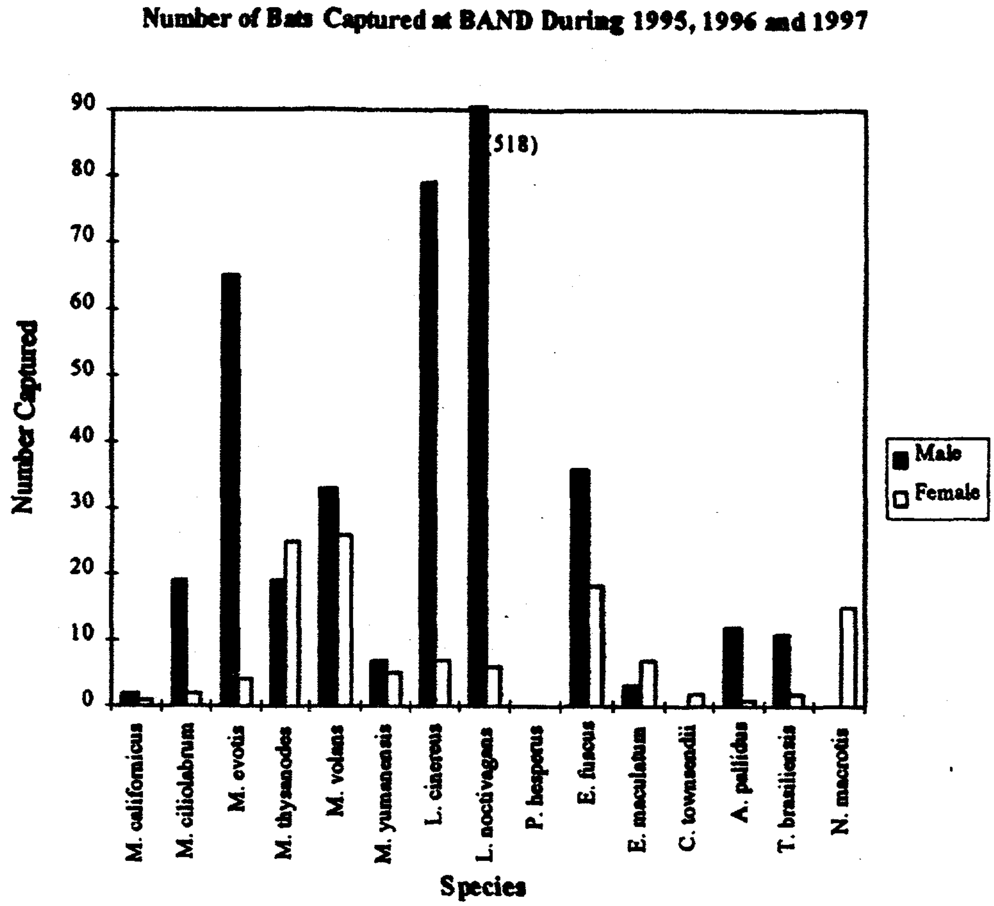


Figure 4. Total number of bats captured at BAND during the study.

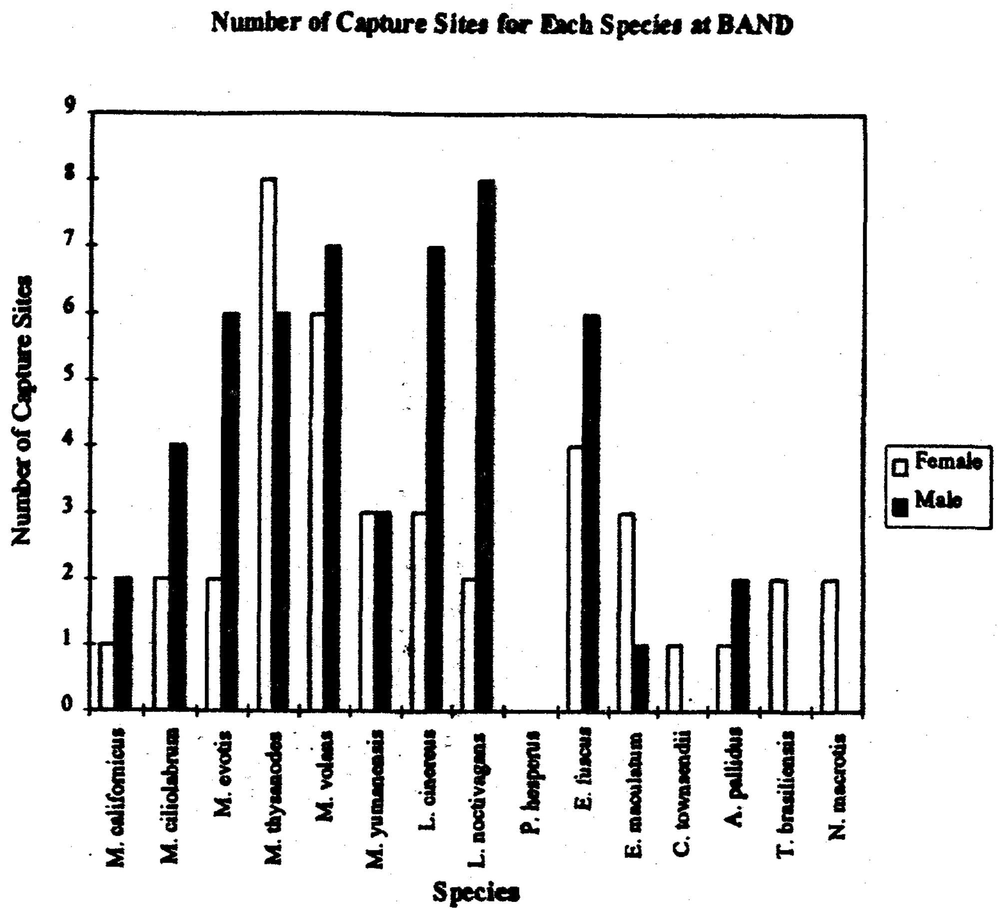


Figure 5. Number of capture sites for bat species at BAND.

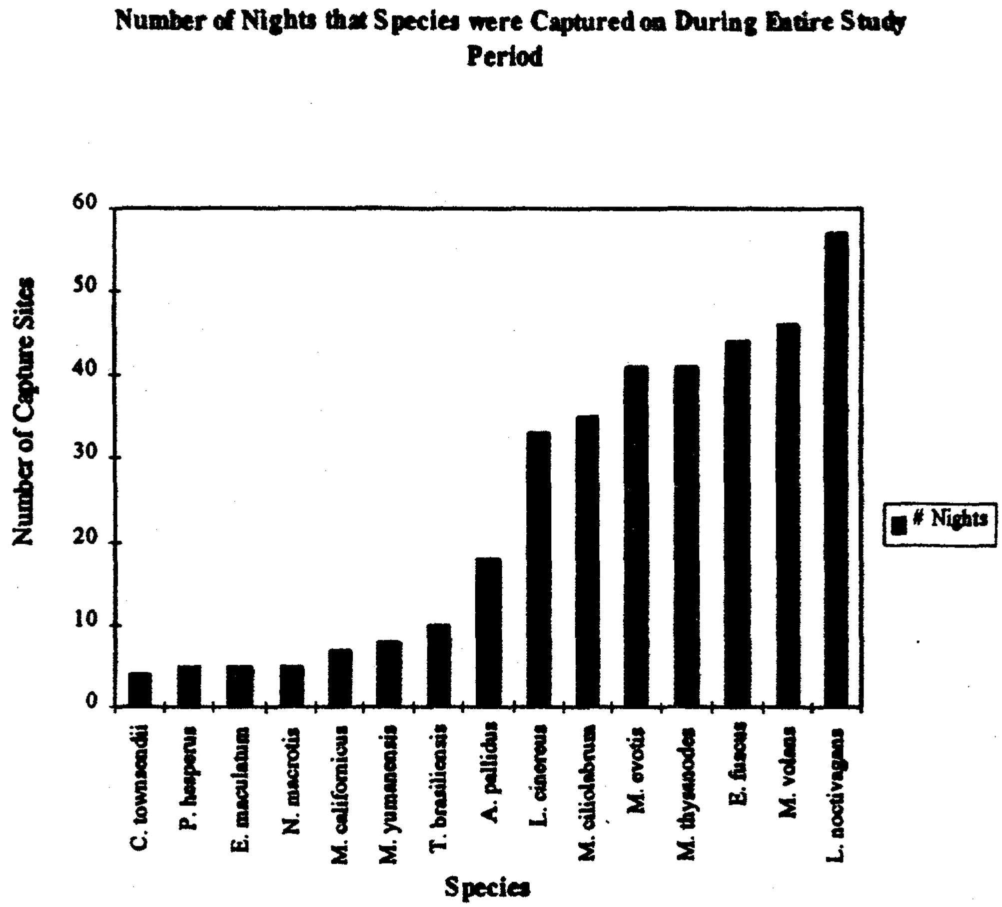


Figure 6. Number of nights species were captured at all sites in the Jemez Mountains.

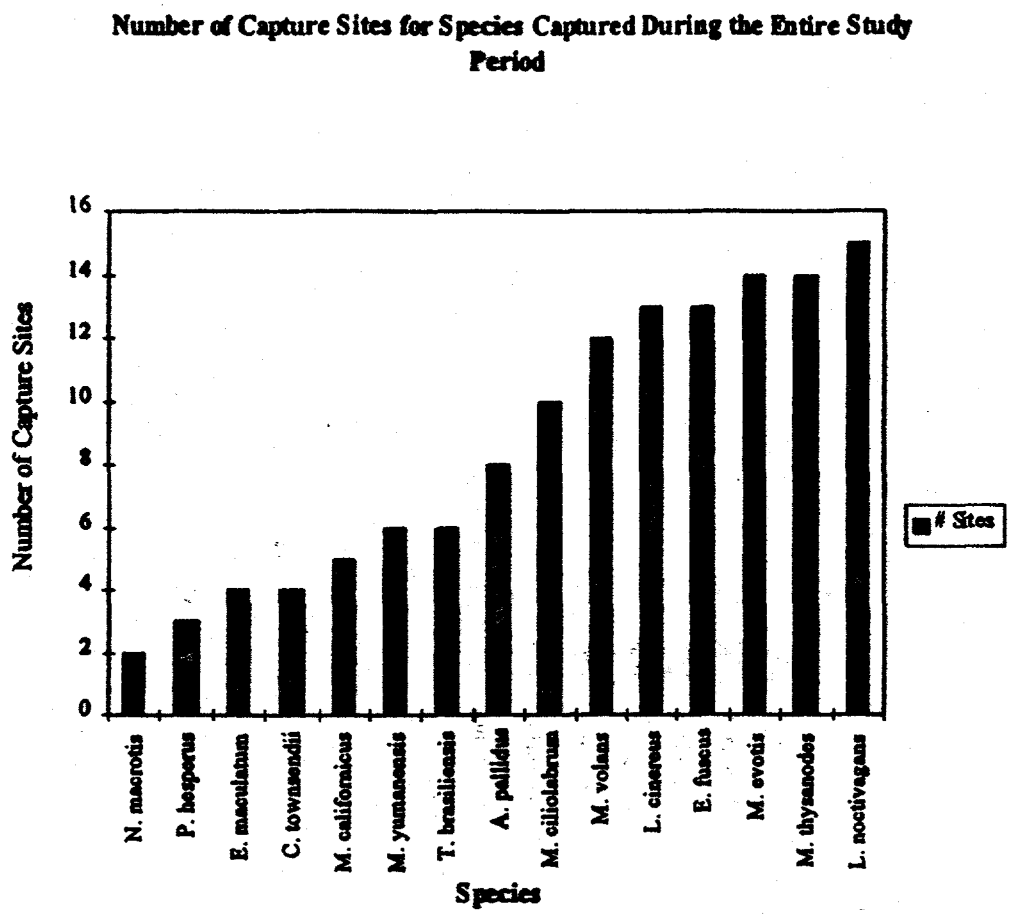


Figure 7. Number of capture sites for bat species in the Jemez Mountains.

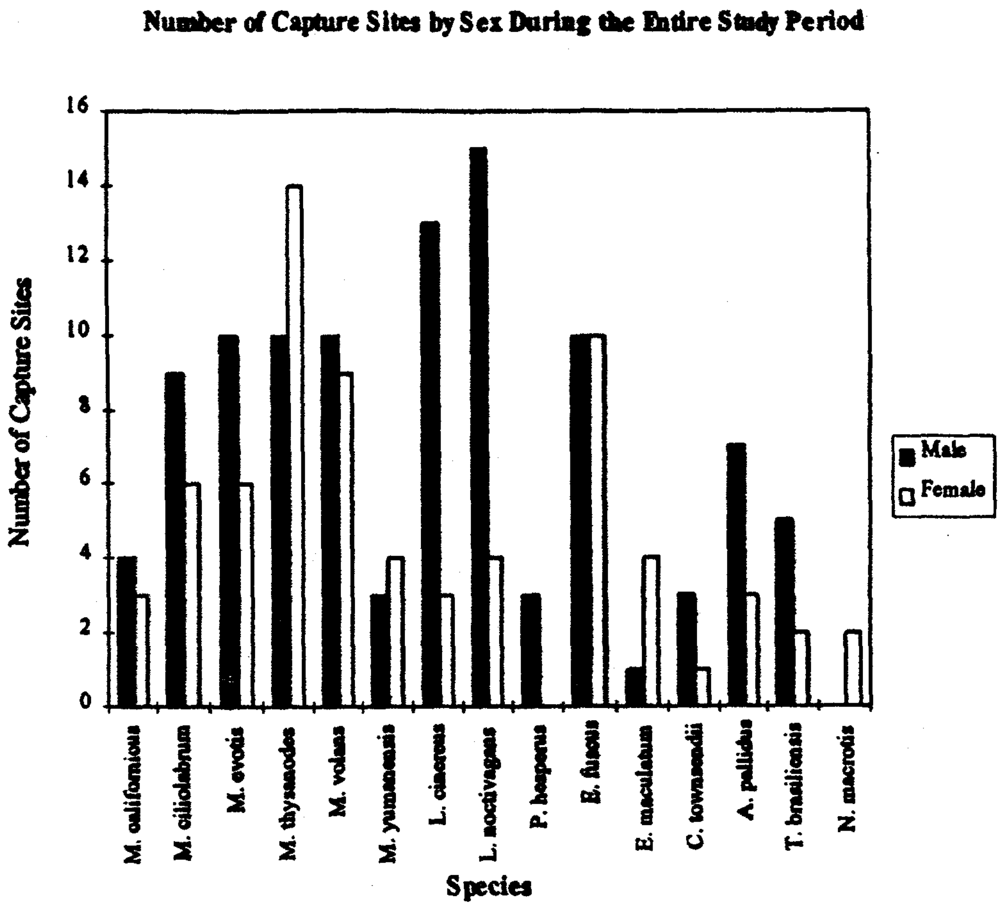


Figure 8. Number of capture sites for males and females in the Jemez Mountains.

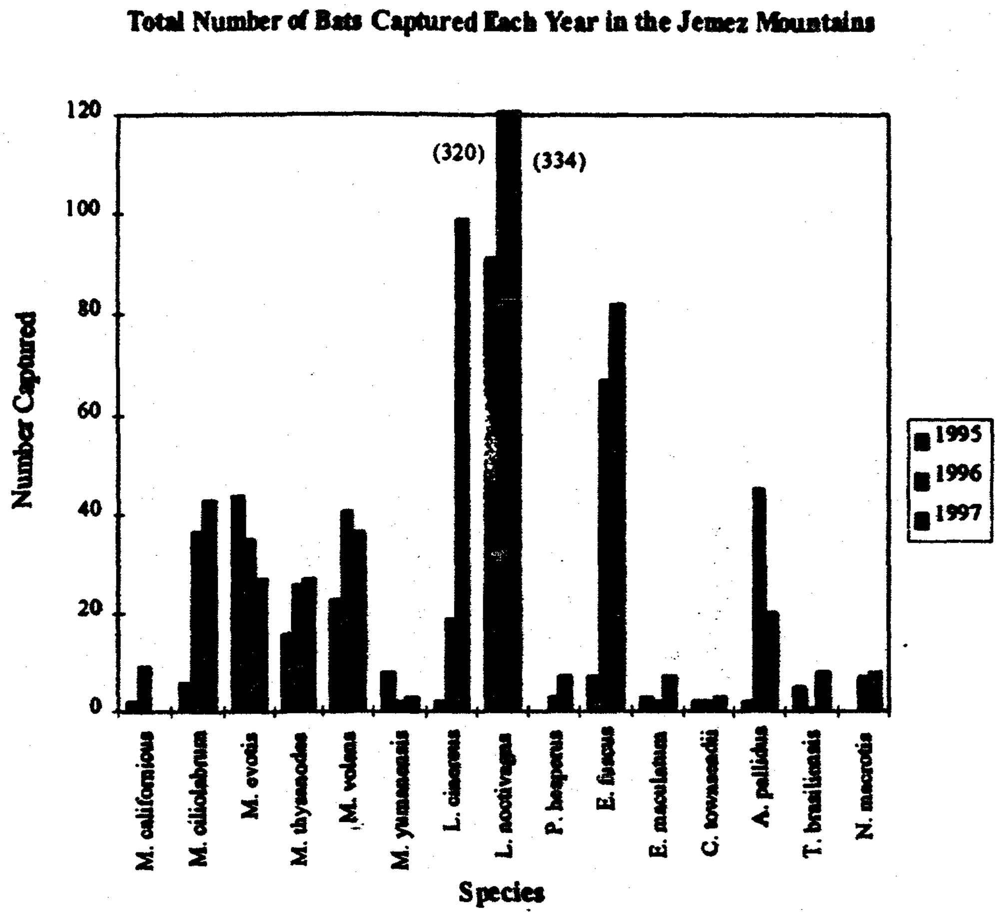


Figure 9. Total number of bats captured each year at all sites.

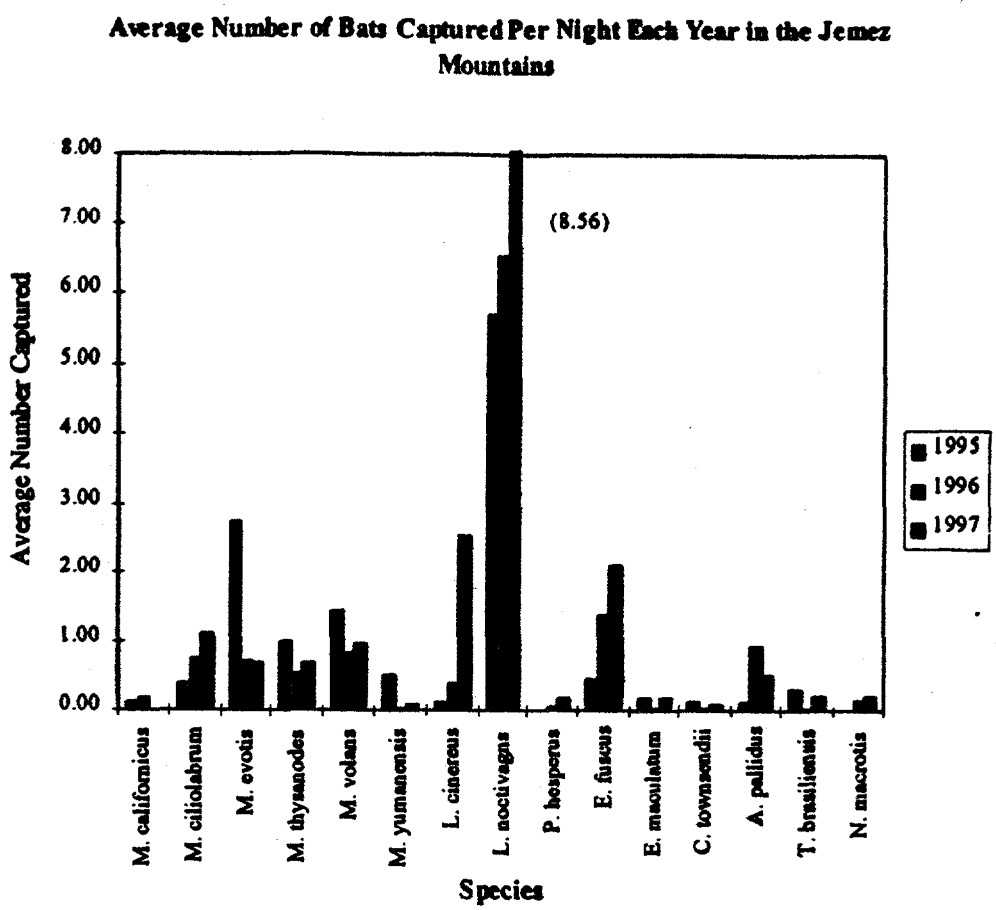


Figure 10. Average number of bats captured per night each year at all sites.

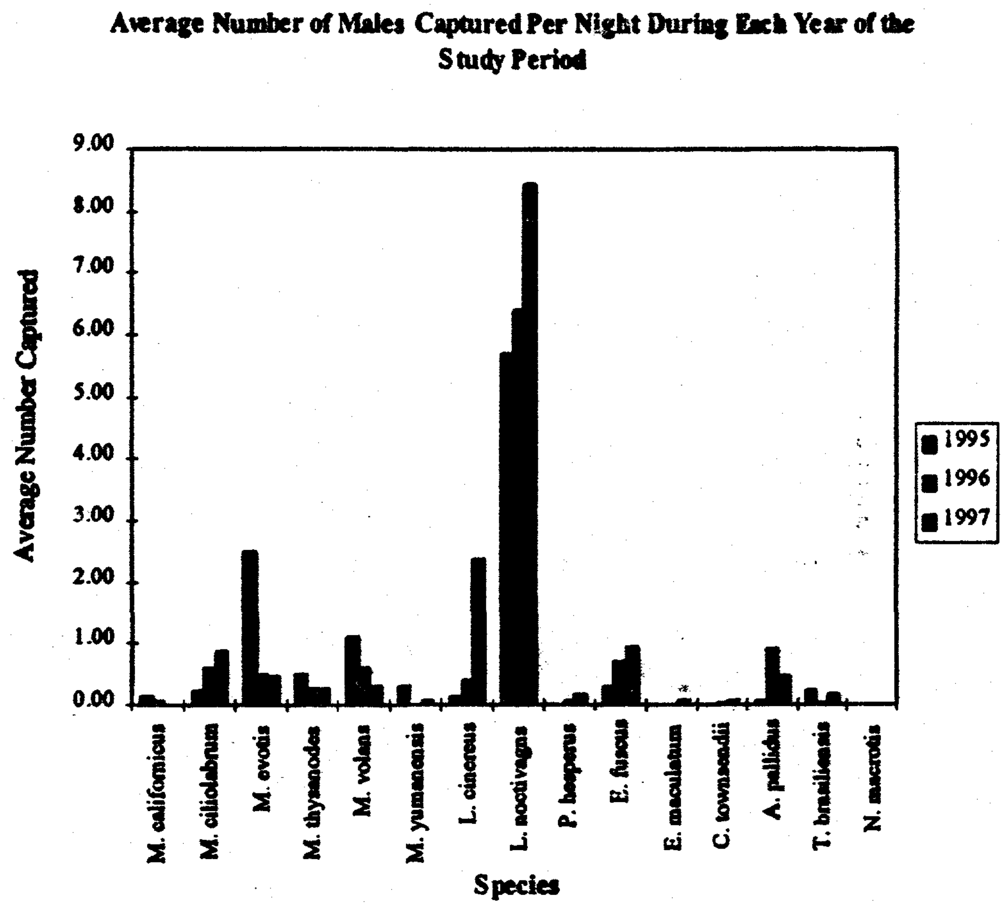


Figure 11. Mean number of male bats captured per night each year at all sites.

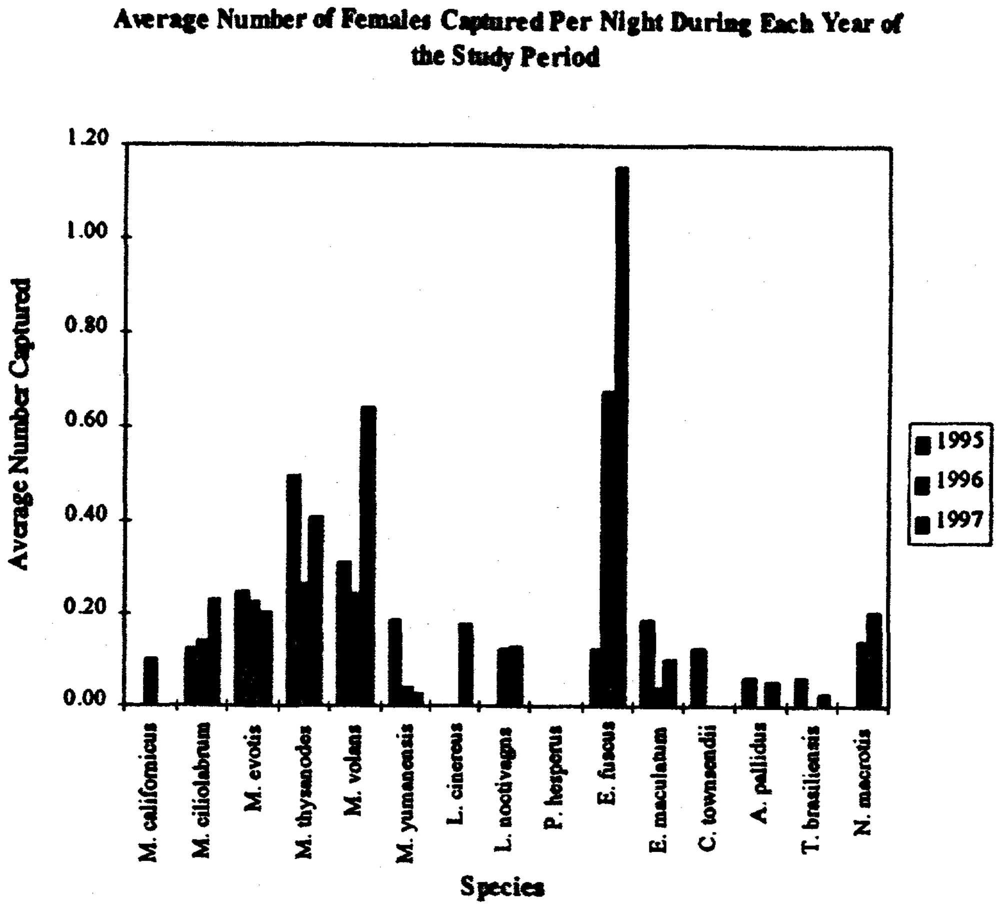


Figure 12. Mean number of female bats captured per night each year at all sites.

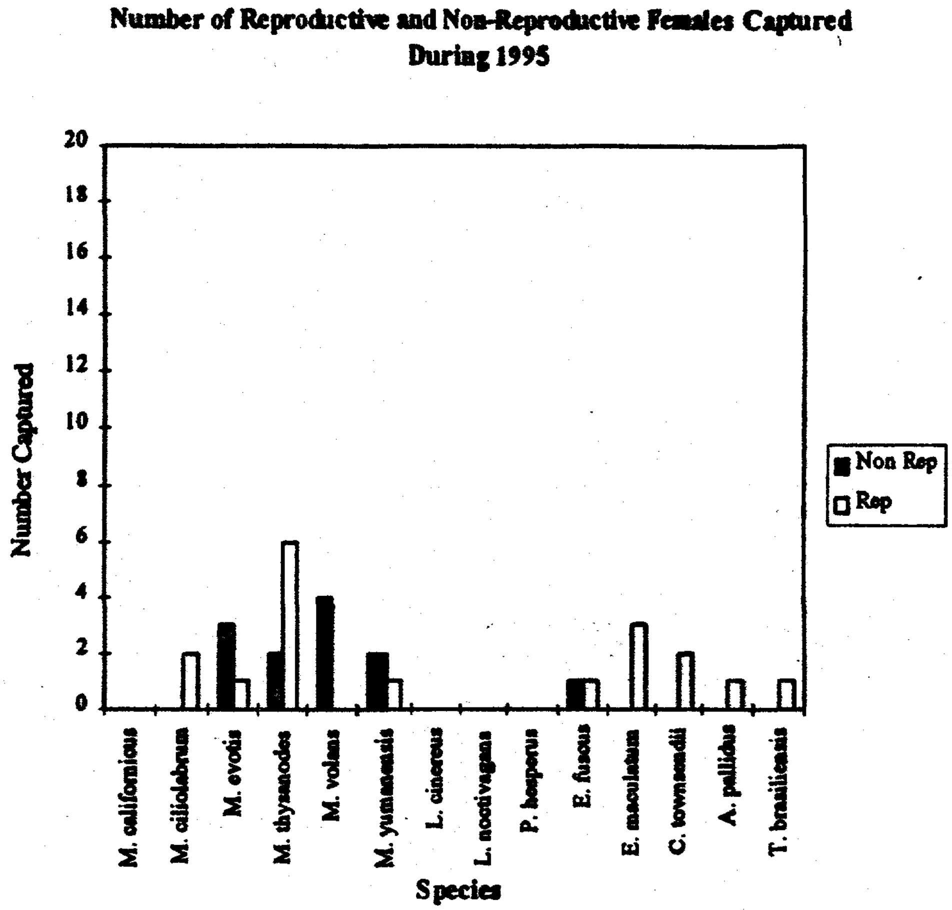


Figure 13. Number of reproductive and non-reproductive bats captured at all sites during 1995.

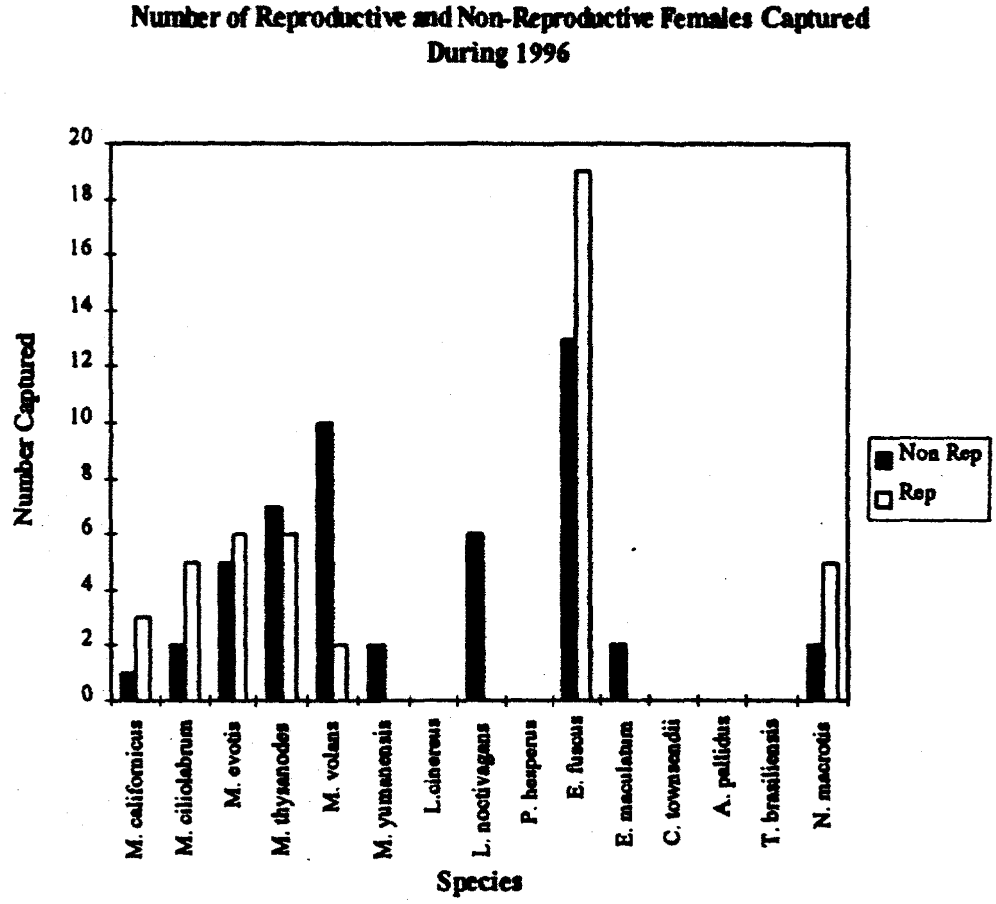


Figure 14. Number of reproductive and non-reproductive bats captured at all sites during 1996.

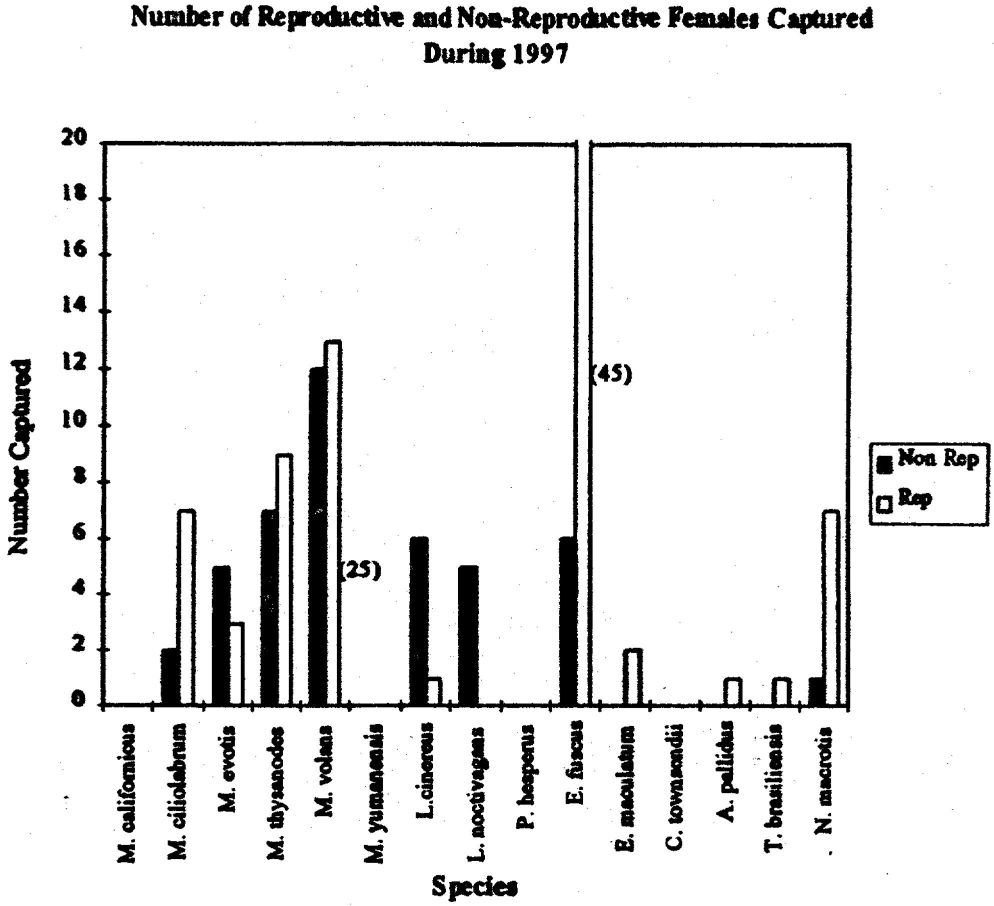


Figure 15. Number of reproductive and non-reproductive bats captured at all sites during 1997.

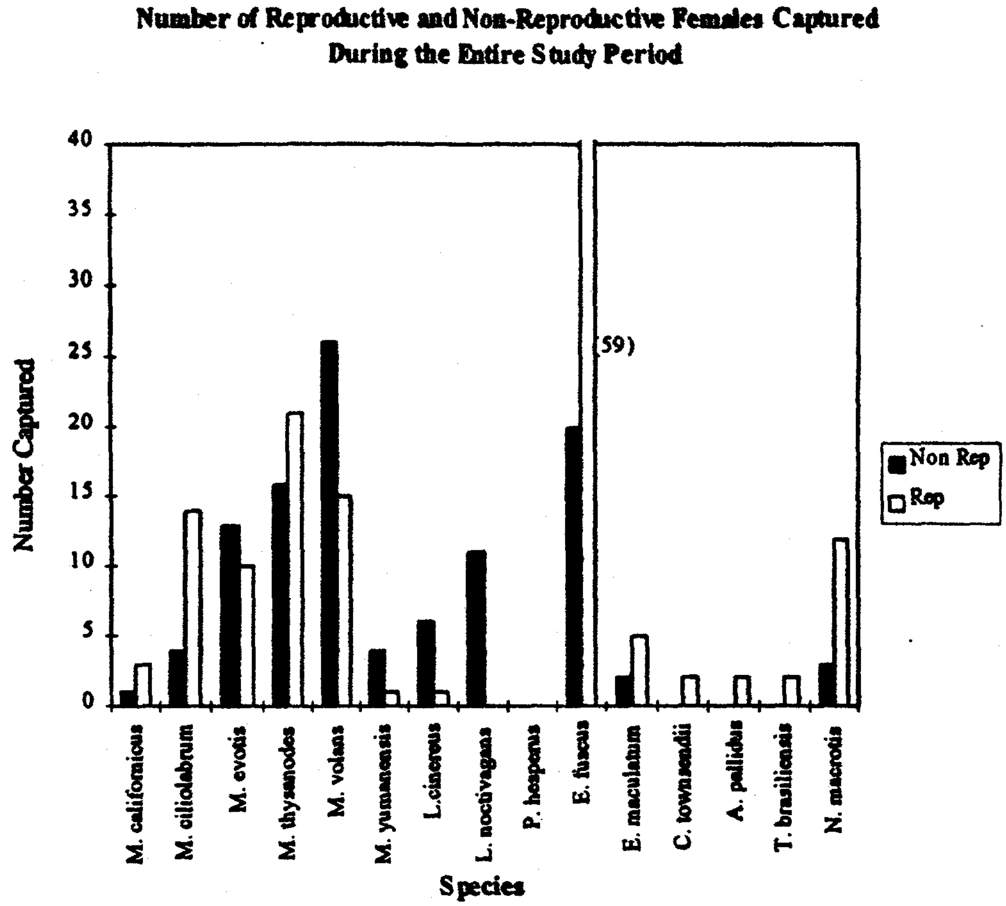


Figure 16. Number of reproductive and non-reproductive females captured at all sites during the entire study period.

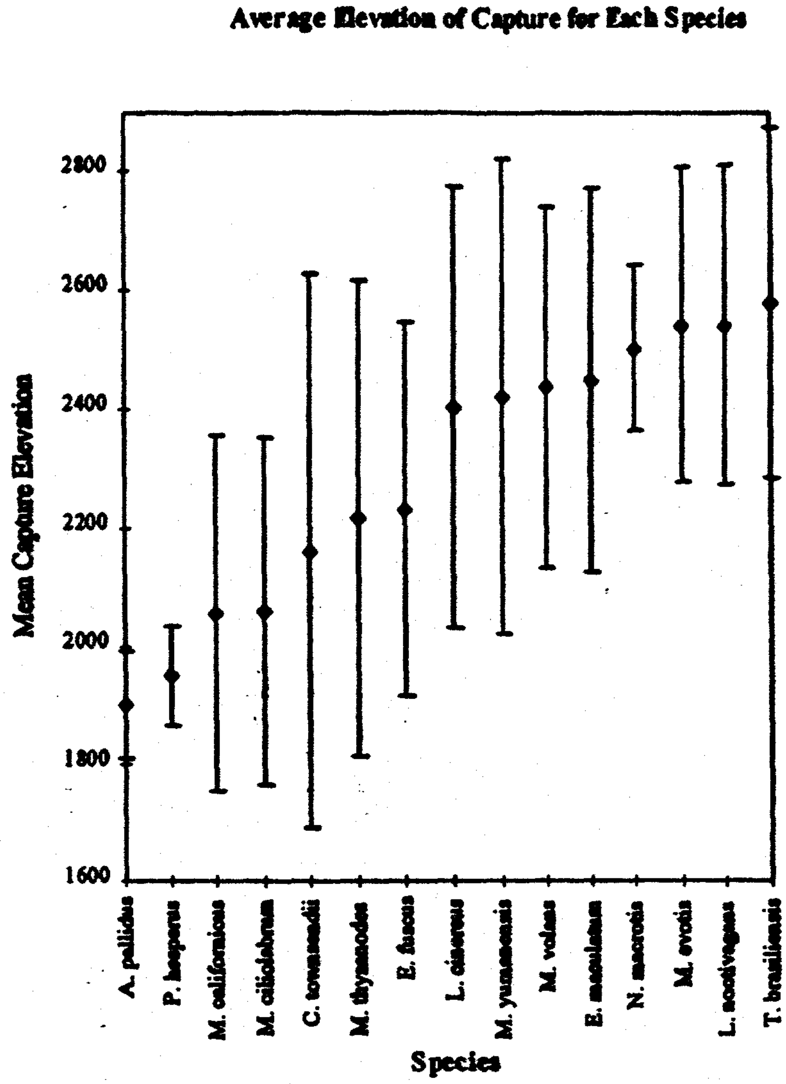


Figure 17. Average elevation of capture for bat species in the Jemez Mountains. Bars represent one standard deviation.

APPENDIX A. Summary of results of ultrasonic surveys for bats at BAND/LANL.

INTRODUCTION

Studies of bats using ultrasonic recording devices have become more common, as recording technology has developed and become less expensive (e.g., Fenton 1988). Bat surveys using ultrasonic recording devices have the potential to provide valuable information on the distribution, abundance, and ecology of bat species that complements the information gained through trapping and roost surveys. In particular, such surveys are not restricted to roost areas or the vicinity of water. They can be used to survey broad areas and a variety of habitats, and offer more complete information about overall distribution and habitats used by bats (Fenton 1988). Ultrasonic surveys are still in the development phase, however, and they have limitations. More work is needed in evaluating calls to determine whether species can be safely distinguished by their vocalizations.

I conducted surveys for bats in Bandelier National Monument (BAND) and Los Alamos National Laboratory (LANL) using ultrasonic detectors during the summer of 1996. My primary goals were to assess the utility of AnaBat detectors and point transect methodology for estimating bat activity, diversity, and habitat use and to develop a reference library of echolocation calls of known species from the Jemez Mountains. A secondary goal was to determine whether a density or volume of foraging bats could be estimated with the use of DISTANCE sampling theory in three dimensions.

METHODS

I used the AnaBat II bat detector, a unit designed specifically for identifying microchiropteran bats by their echolocation calls. AnaBat II detects the inaudible, high frequency sounds of bats and produces from them sounds that are audible to the unaided human ear. I interfaced the bat detector with a laptop computer in the field which enabled me to view the true frequency-time structure of echolocating bats at the time of detection. I could also record the vocalizations of bats directly onto the hard drive of the laptop with file header information such as date, location, species, and pertinent comments.

I developed the echolocation reference library by recording vocalizations from hand-released bats at 10 mist netting sites around BAND/LANL. A 500,000 candle-power spotlight was used to follow the bat as it flew from the hand. Approximately 2 recordings were made from every hand-released bat.

In conjunction with developing a call reference library, I also conducted 17 pilot transect surveys in 4 major habitat types in BAND/LANL: Reparian/Canyon bottom, Mixed Coniferous Forest, Pinyon-Juniper Woodland, and the 1977 La Mesa fire area. Encounter rates (number of "bat passes" detected/number of points along the transect) were calculated for each habitat type. A "bat pass" was defined as a continuous sequence of calls given by a single bat from when it is first detected until it travels beyond the range of detection. A bat pass usually lasts from 2-12 seconds.

RESULTS

Echolocation library: Eleven species of bats were recorded from hand releases (common name and number of recordings in parentheses): *Myotis evotis* (long-eared myotis, 23), *M. volans* (long-legged myotis, 27), *M. ciliolabrum* (western small-footed myotis, 190), *M. thysanodes* (fringed myotis, 6), *M. Californicus* (California myotis, 2), *Eptesicus fuscus* (big brown bat, 53), *Antrozous pallidus* (pallid bat, 31), *Corynorhinus townsendii* (Townsend's big-eared bat, 1), *Lasionycteris noctivagans* (Silver-haired bat, 24), *Lasiurus cinereus* (hoary bat, 8), and *Nyctinomops macrotis* (big free-tailed bat, 2). We made additional recordings of free-flying *Myotis yumanensis* (Yuma myotis), *Euderma maculatum* (spotted bat), *Pipistrellus hesperus* (western pipistrelle), and *Tadaruda brasiliensis* (Brazilian free-tailed bat). Representative calls for 14 species in the Jemez Mountains are included in Figures 1-14.

Point transects: Encounter rates varied dramatically among the four habitat types. Points with the highest average encounter rate were found along Riparian/Canyon bottom habitats. Mixed coniferous forest averaged 2.7 passes/point. Due to the difficulty of estimating a distance to an individual foraging bat, I was not able to use DISTANCE sampling theory to determine foraging densities or volumes during the 1996 surveys.

LIST OF FIGURES

LITERATURE CITED

Fenton 1988: M. B. Fenton, "Detecting, Recording, and Analyzing Vocalizations of Bats," in *Ecological and Behavioral Methods for the Study of Bats*, H. H. Kunz (ed.), Smithsonian Institution Press, Washington, D. C., pp. 91–104.

Figure 1 a

TAPE: computer DATE: 07 18/96 LOC: Frijoles Canyon
SP: Myotis californicus SPEC: female
NOTES: lactating; 4 grams

Compressed 0 to 80 kHz Div = 16 Cal = 40000 67182327.30#
DUR = 3.55 ms TBC = 157 ms FRE = 49.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 110 Buff = 0 % F 7

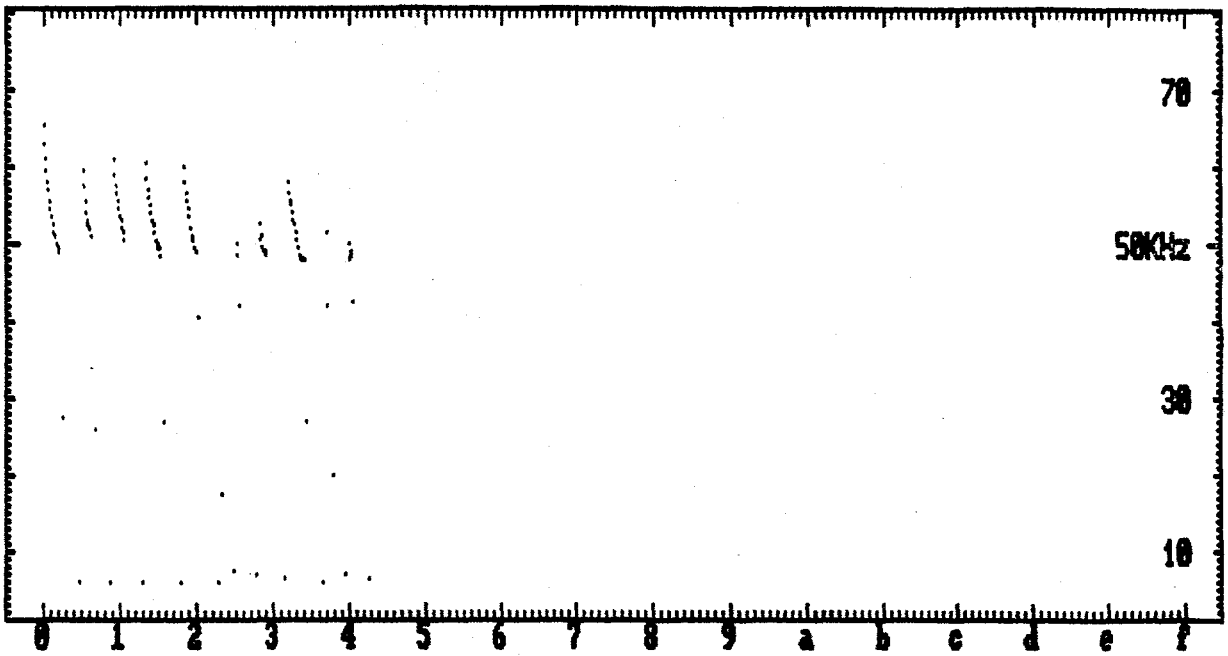


Figure 1 b

TAPE: computer DATE: 07/18/96 LOC: Frijoles Canyon
SP: Myotis californicus SPEC:
NOTES: Hand release; female; 4 grams; still in hand, not flying.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 67182327.27#
DUR = 3.77 ms TBC = 92.4 ms FRE = 35.5 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 301 Buff = 3 % F 7

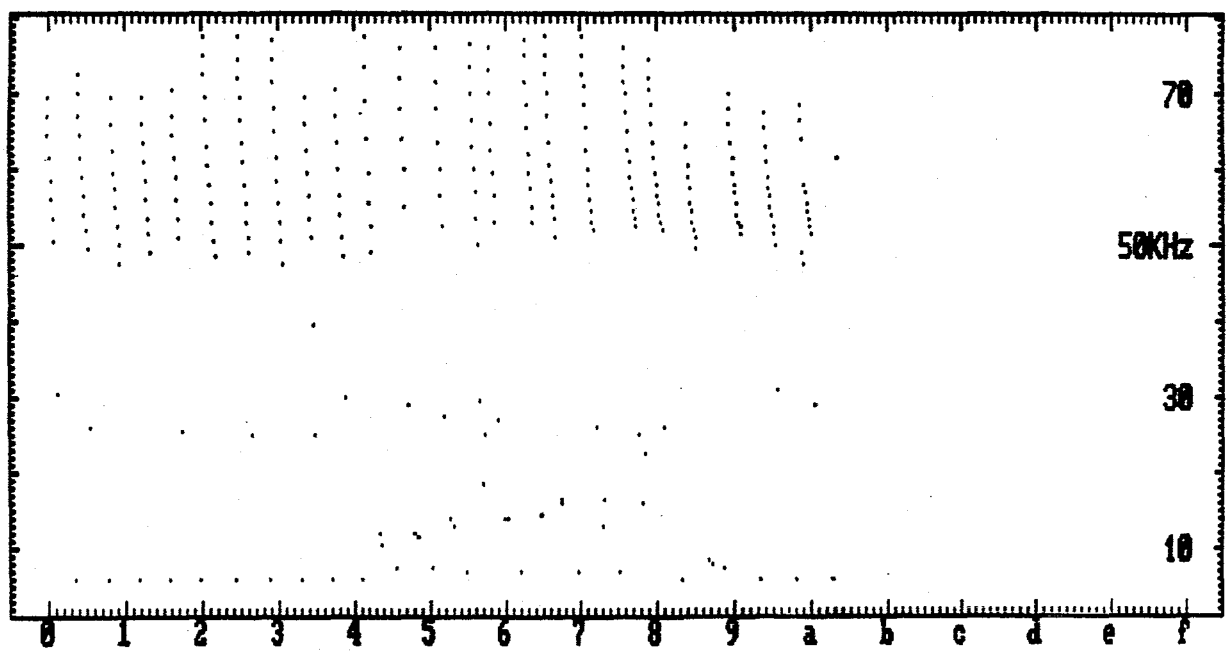


Figure 2 a

TAPE: Computer DATE: 05/21/96 LOC: Pueblo Canyon Effluent Area
SP: Myotis ciliolabrum SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65210944.16#
DUR = 4.88 ms TBC = 166 ms FRE = 42.5 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 250 Buff = 1 % F 7

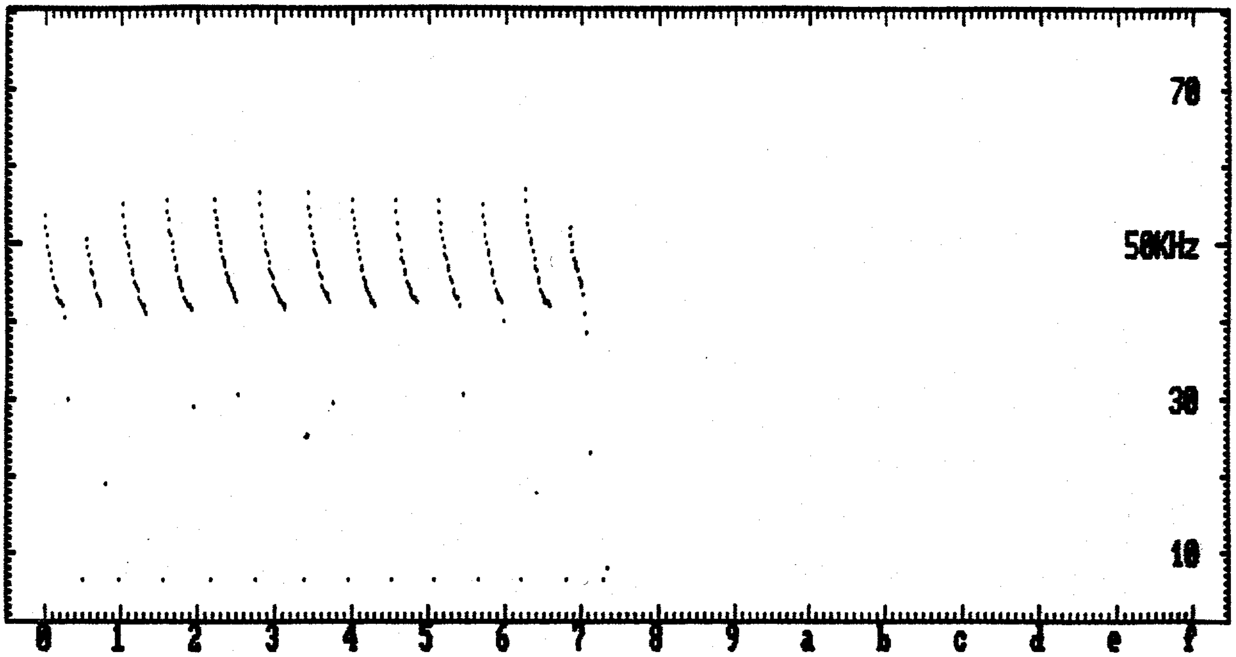


Figure 2 b

TAPE: Computer DATE: 05/21/96 LOC: Pueblo Canyon Effluent Area
SP: Myotis ciliolabrum SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65211149.27#
DUR = 5.07 ms TBC = 112 ms FRE = 41.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 274 Buff = 1 % F 7

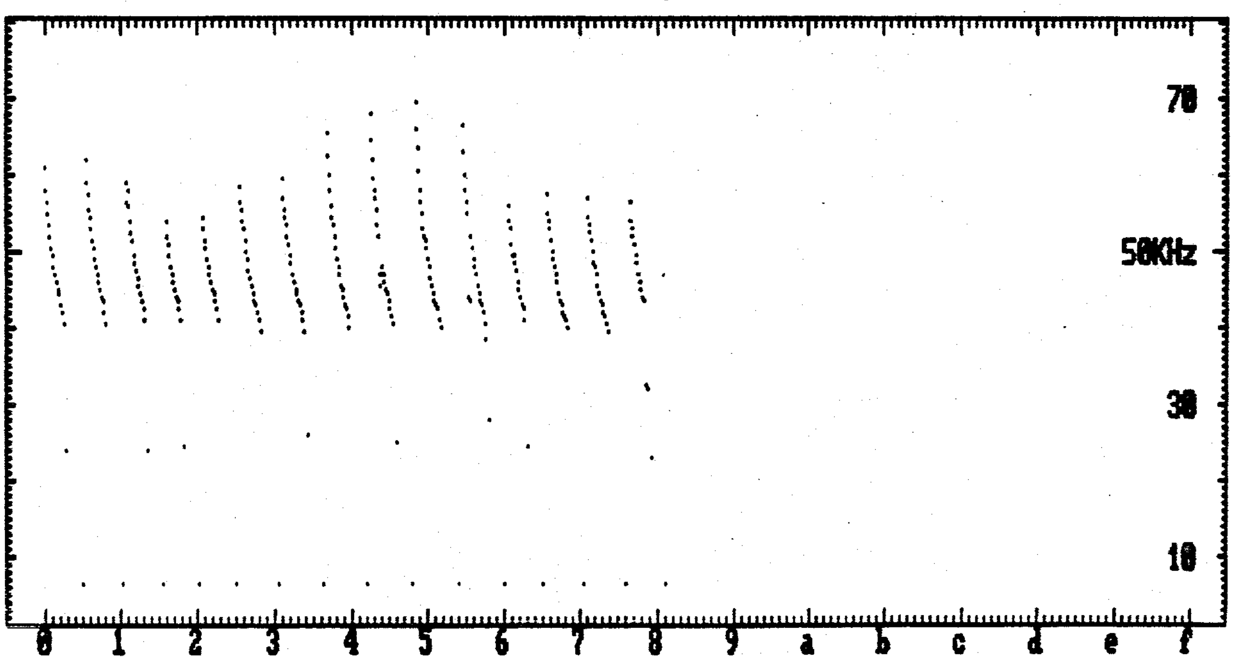


Figure 3 a

TAPE: computer DATE: 06/25/96 LOC: Icehouse Pond, LANL, Los Alamos Co. NM
SP: Myotis evotis SPEC:
NOTES: Hand release; female.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 66251141.43#
DUR = 3.72 ms TBC = 156 ms FRE = 29.5 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 109 Buff = 0 % F 7

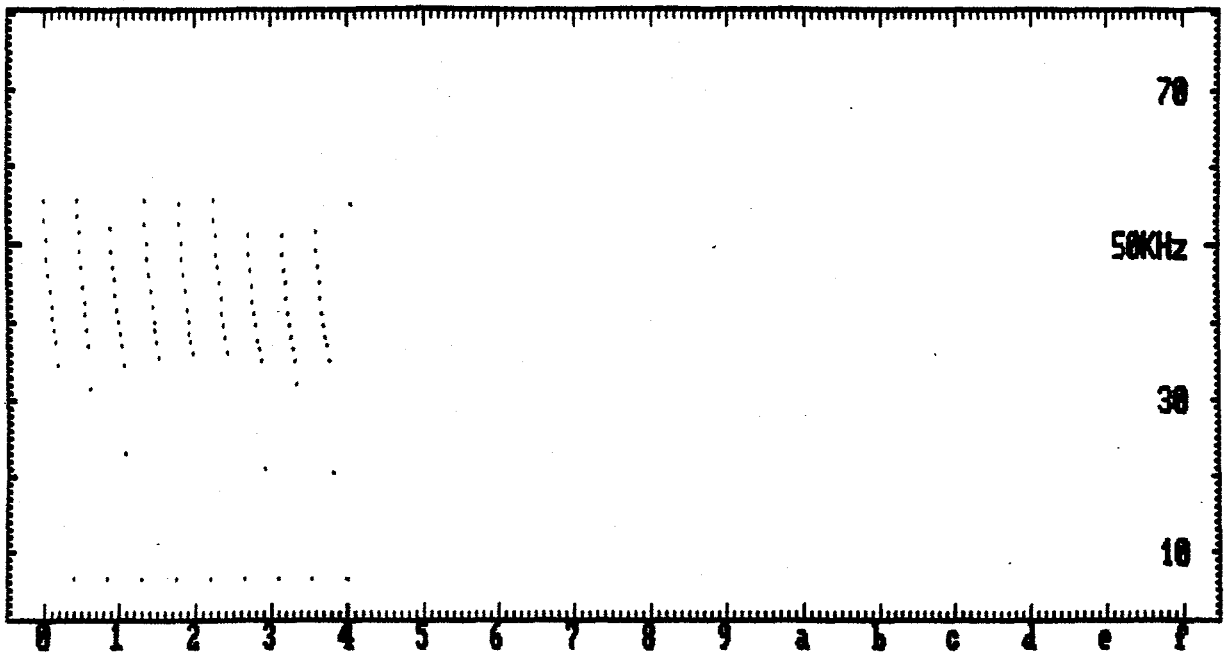


Figure 3 b

TAPE: computer DATE: 06/03/96 LOC: Pajarito Wetland, 6200 ft., Biomonitsite
SP: Myotis evotis SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 66032156.24#
DUR = 3.43 ms TBC = 744 ms FRE = 33.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 65 Buff = 0 % F 7

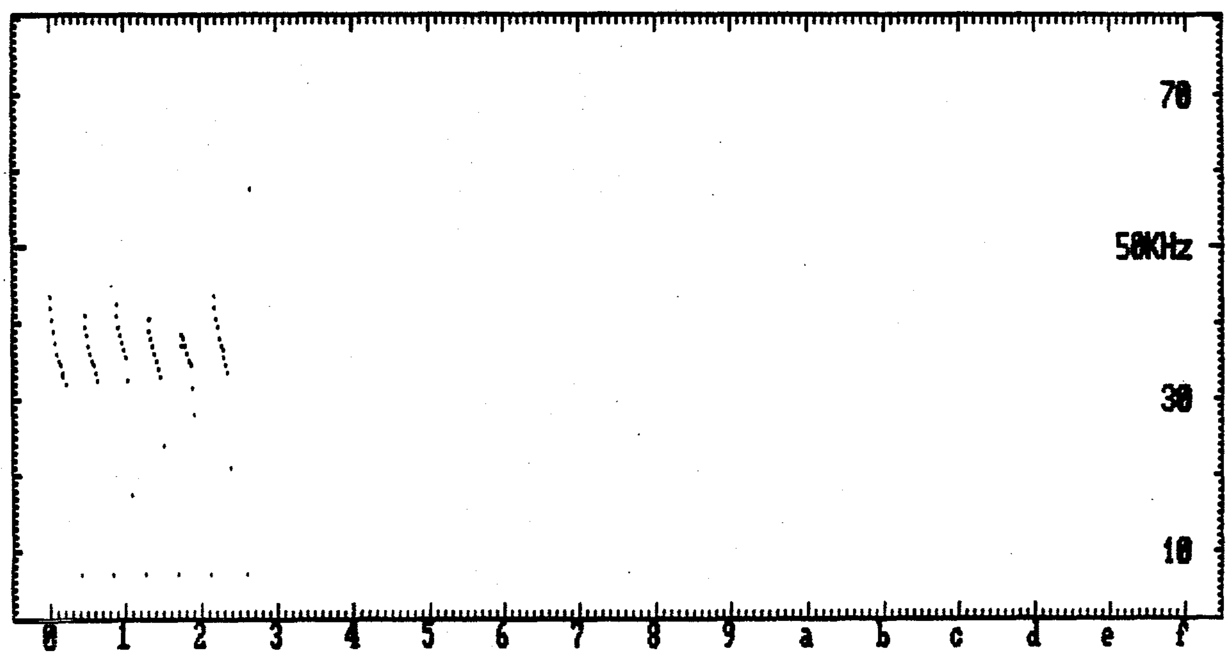


Figure 3 c

TAPE: computer DATE: 06/03/96 LOC: Pajarito Wetland, 6200 ft., Biomonitsite
SP: Myotis evotis SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 66032156.19#
DUR = 3.80 ms TBC = 191 ms FRE = 34.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 99 Buff = 1 % F 7

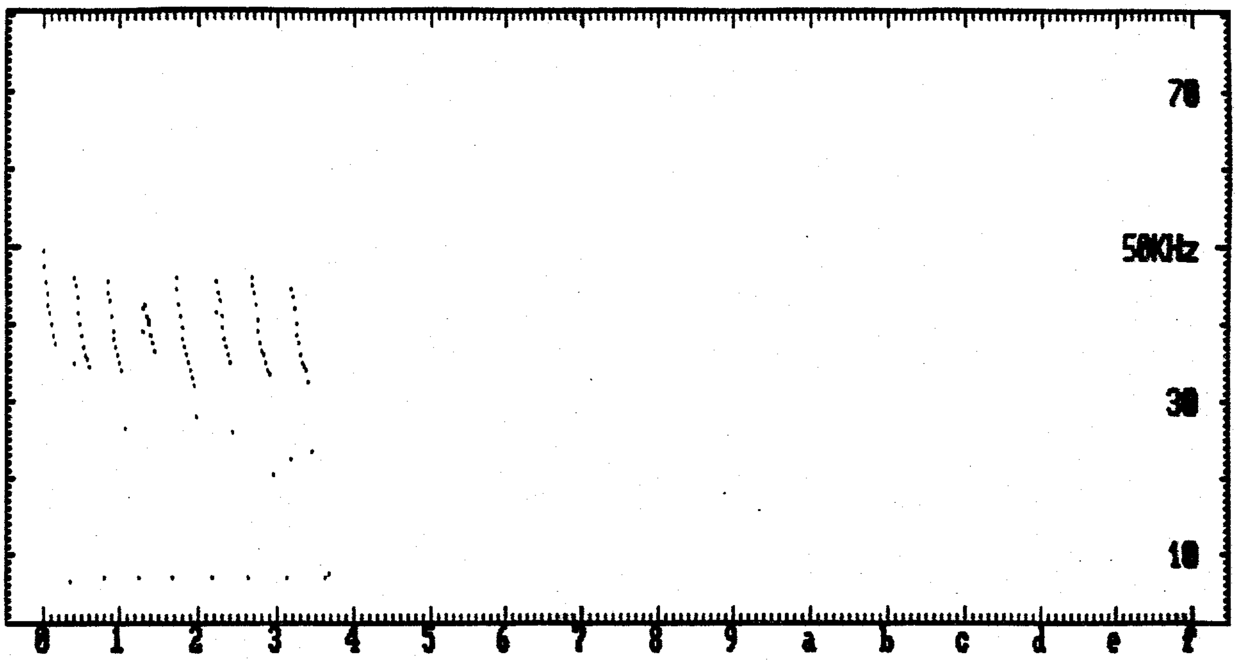


Figure 3 d

TAPE: computer DATE: 07/15/96 LOC: stockpond@ski trailhead; 8930'; P.5
SP: Myotis evotis SPEC:
NOTES: male; hand realease

Compressed 0 to 80 kHz Div = 16 Cal = 40000 67150912.48#
DUR = 4.22 ms TBC = 188 ms FRE = 33.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 171 Buff = 1 % F 7

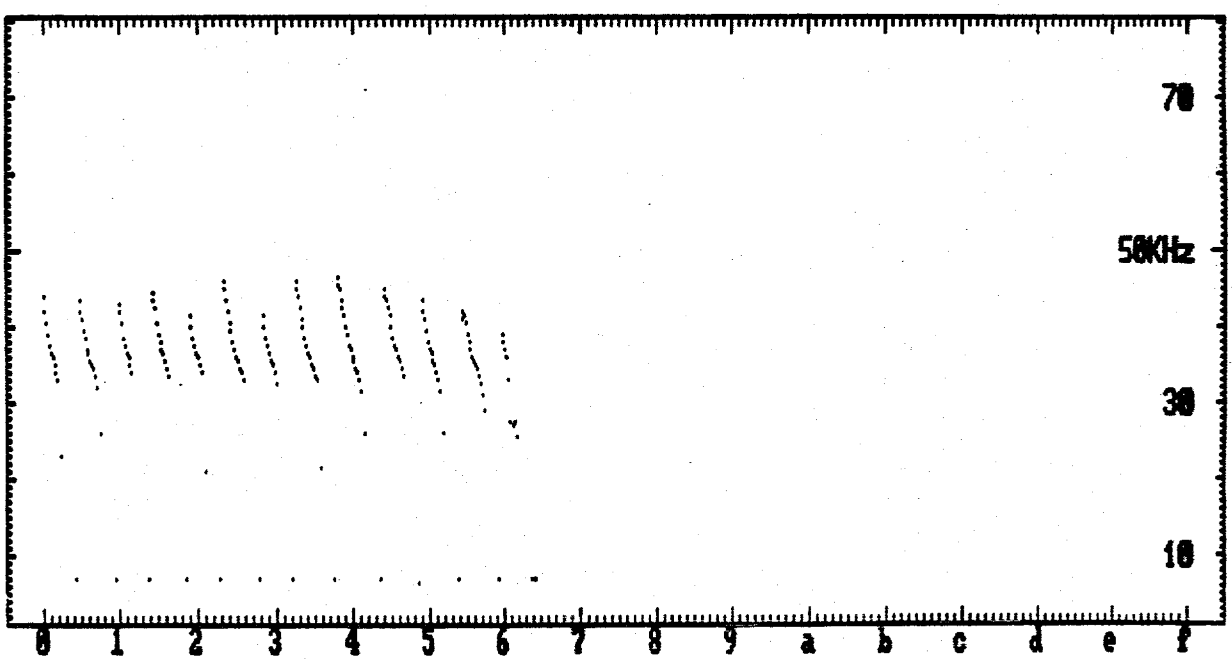


Figure 4 a

TAPE: Computer DATE: 05/21/96 LOC: Pueblo Canyon Effluent Area
SP: Myotis thysanodes SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65211010.23#
DUR = 5.14 ms TBC = 104 ms FRE = 23.5 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 358 Buff = 2 % F 7

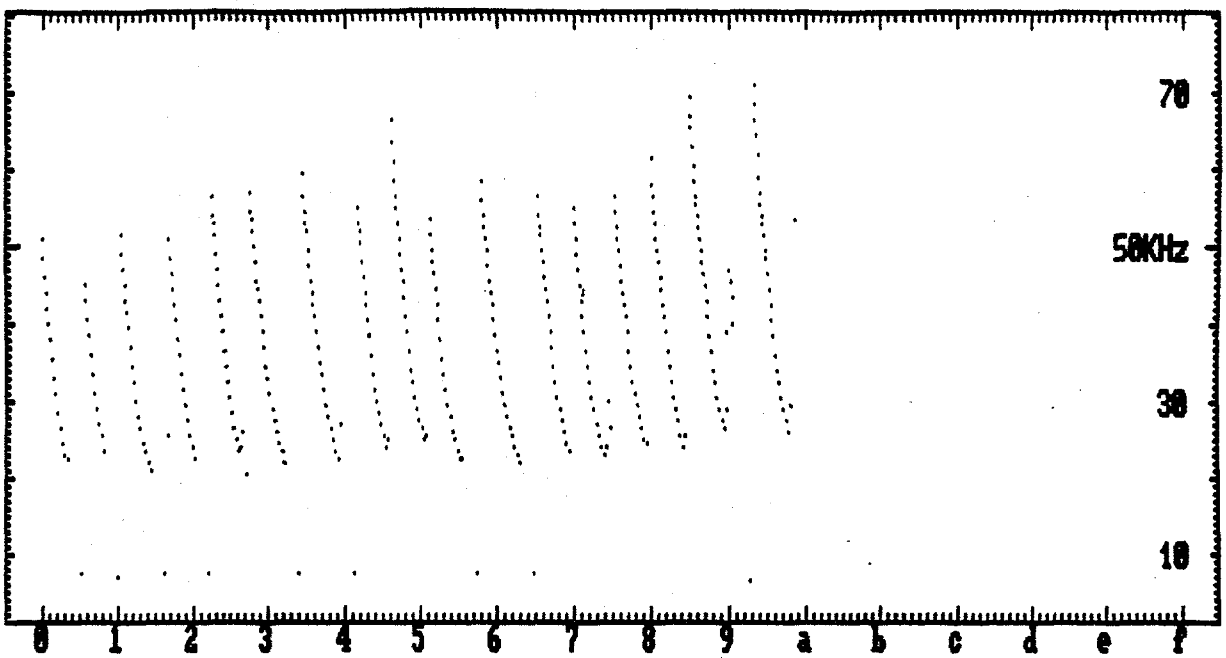


Figure 4 b

TAPE: Computer DATE: 05/21/96 LOC: Pueblo Canyon Effluent Area
SP: Myotis thysanodes SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65210919.46#
DUR = 3.41 ms TBC = 502 ms FRE = 24.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 297 Buff = 2 % F 7

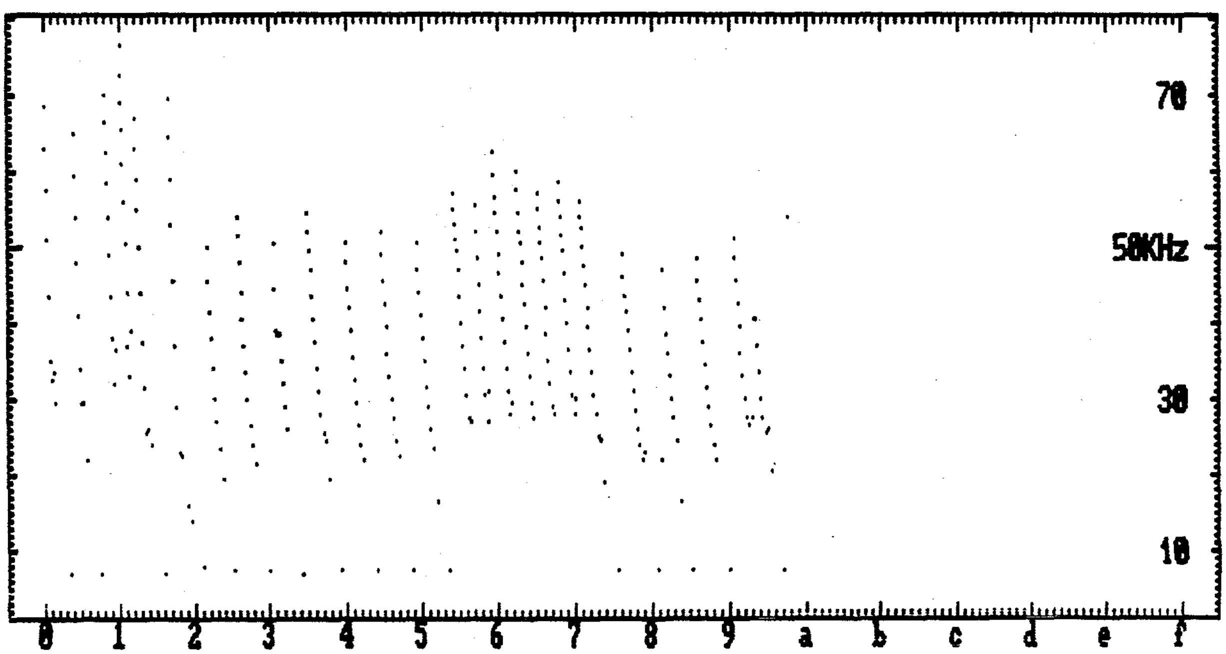


Figure 4 c

TAPE: Computer DATE: 05/21/96 LOC: Pueblo Canyon Effluent Area
SP: Myotis thysanodes SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65211010.26#
DUR = 6.49 ms TBC = 132 ms FRE = 23.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 445 Buff = 2 % F 7

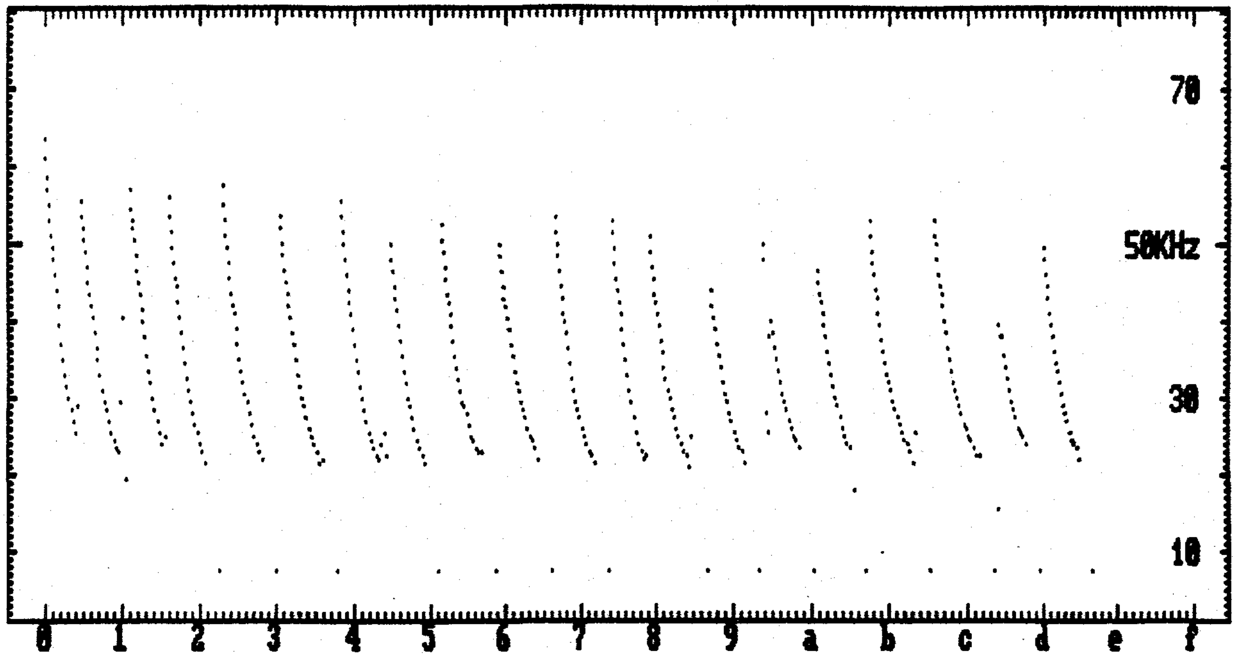


Figure 4 d

TAPE: Computer DATE: 05/21/96 LOC: Pueblo Canyon Effluent Area
SP: Myotis thysanodes SPEC:
NOTES: Hand release; Low?

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65211010.28#
DUR = 5.70 ms TBC = 146 ms FRE = 21.5 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 200 Buff = 1 % F 7

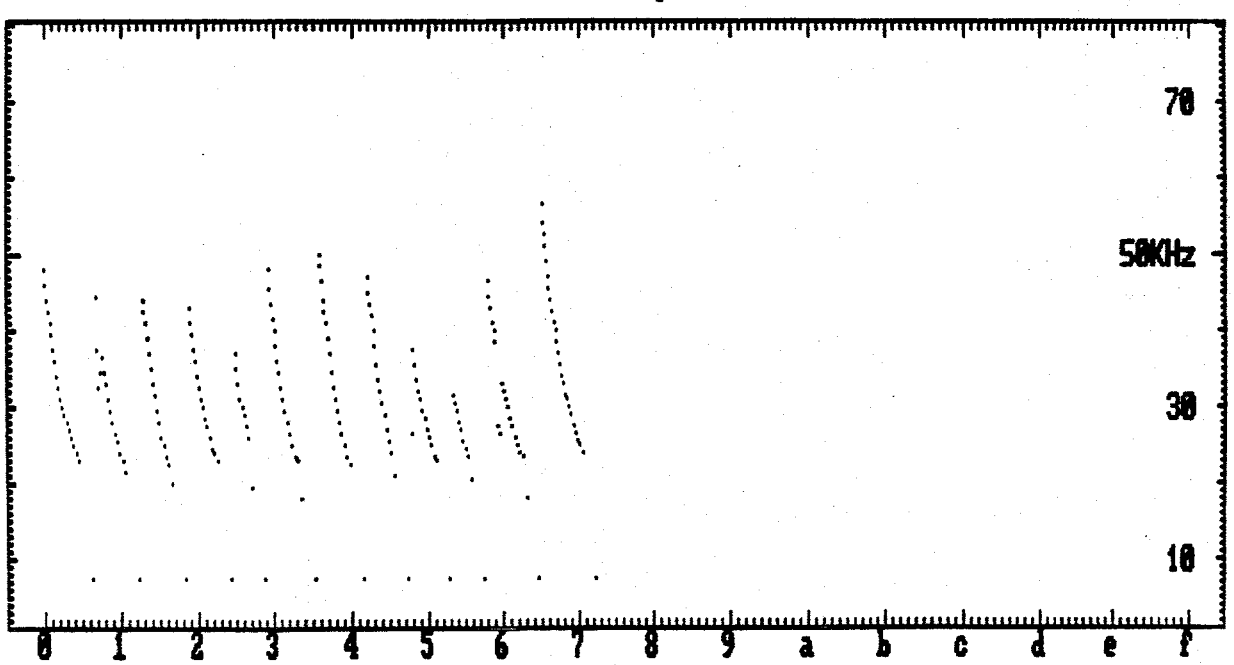


Figure 5 a

TAPE: computer DATE: 08/12/96 LOC: Frijoles Canyon below VC across creek
SP: Myotis volans SPEC:
NOTES: Hand release; interference with EPFU? first part of call is a EPFU, then MYVO last part; male adult.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 68122233.06#
DUR = 5.43 ms TBC = 136 ms FRE = 40.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 392 Buff = 12 % F 7

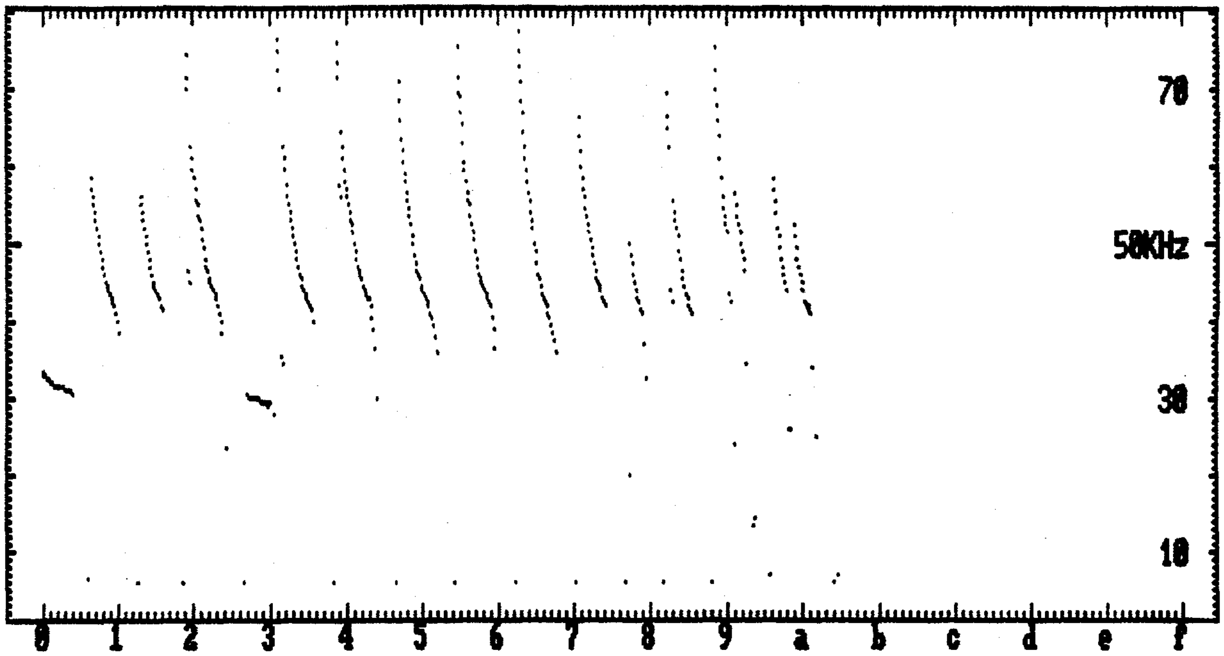


Figure 5 b

TAPE: computer DATE: 07/24/96 LOC: Pueblo Cyn Sewage Trtment facility
SP: Myotis volans SPEC: male
NOTES: 7 grams; hand release

Compressed 0 to 80 kHz Div = 16 Cal = 40000 67242255.56#
DUR = 4.42 ms TBC = 76.6 ms FRE = 32.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 573 Buff = 9 % F 7

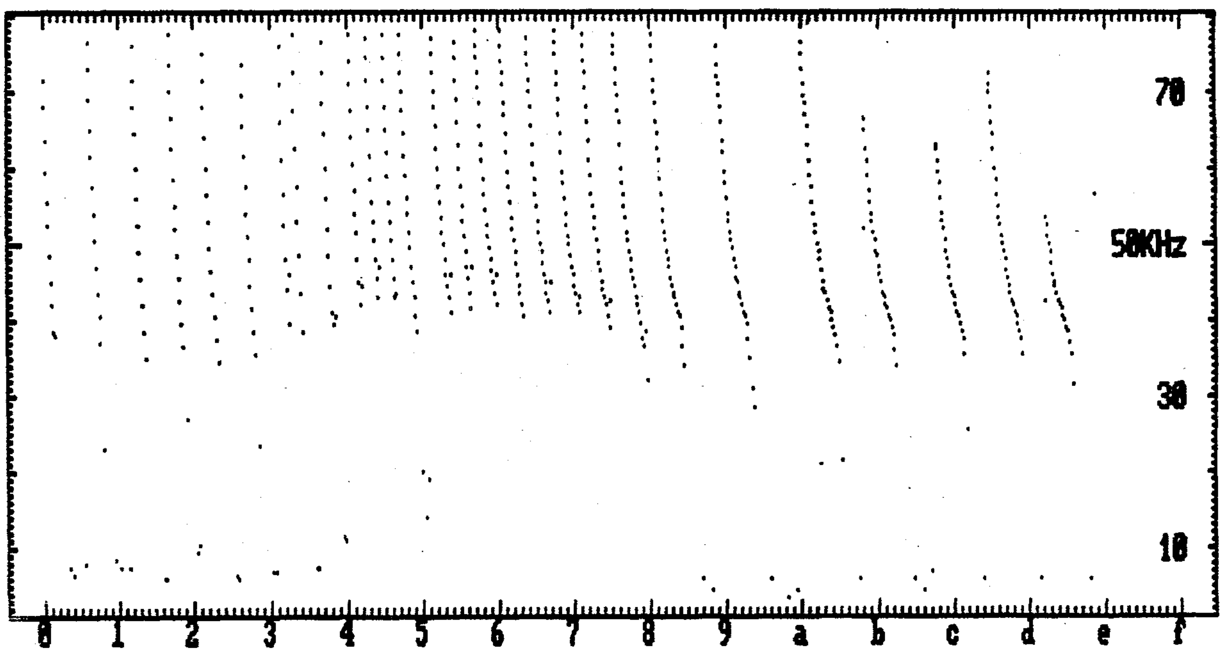


Figure 6

TAPE: Computer DATE: 05/20/96 LOC: Stock Pond at Ski Trailhead, 8,930 ft
SP: Lasiurus cinereus SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65202133.27#
DUR = 6.60 ms TBC = 748 ms FRE = 24.5 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 219 Buff = 1 % F 7

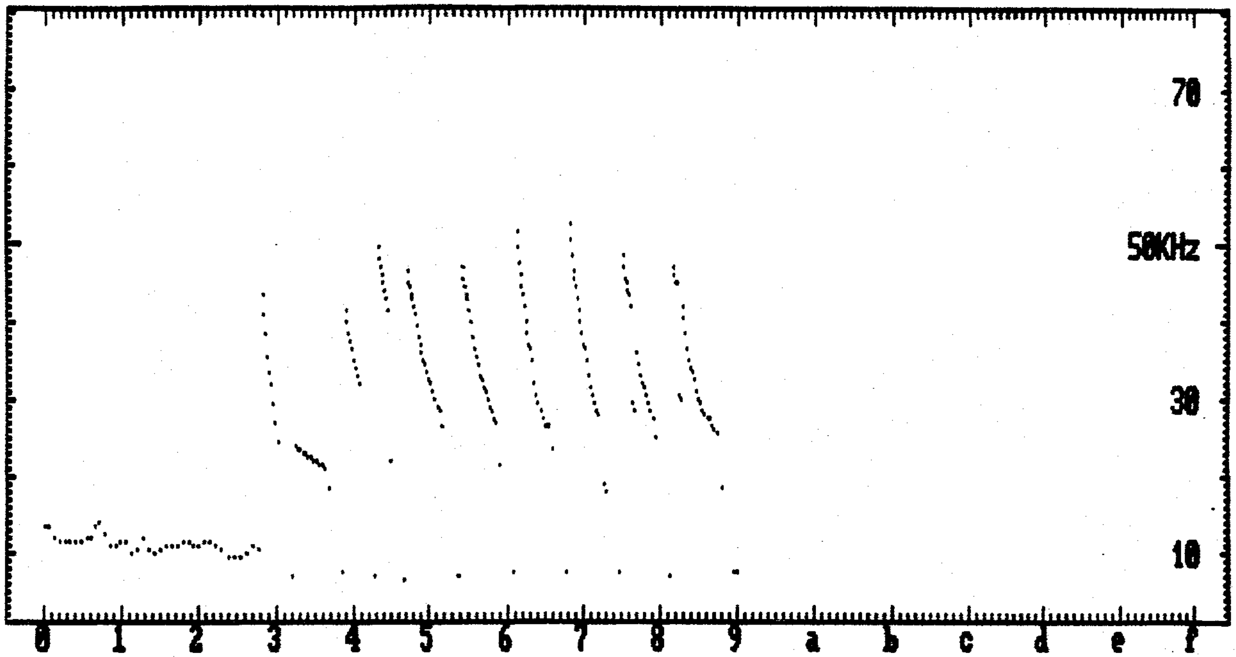
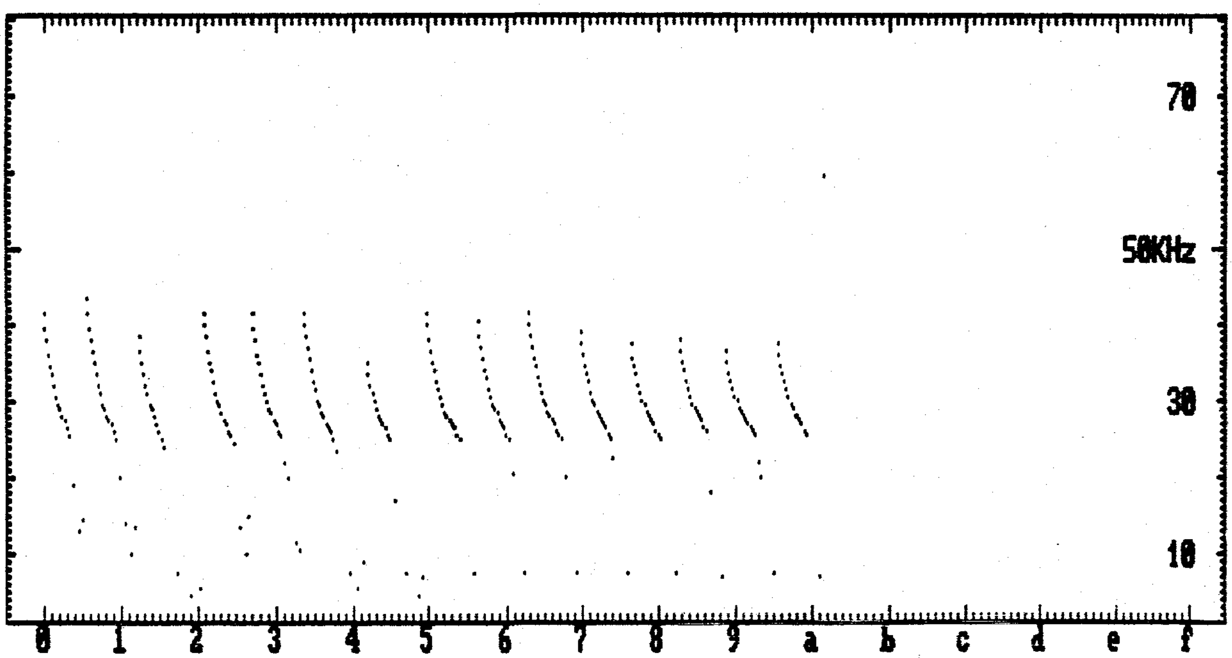


Figure 7 a

TAPE: computer DATE: 05/31/96 LOC: Stock Pond @ Ski Trailhead, 8930',P.5
SP: Lasionycteris noctivagans SPEC:
NOTES: male; hand release

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65310906.08#
DUR = 6.01 ms TBC = 135 ms FRE = 25.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 268 Buff = 2 % F 7



TAPE: Computer DATE: [illegible] LOC: [illegible] Wetland, [illegible]
SP: Lasionycteris noctivagans SPEC:
NOTES: Not a hand release; bat foraging around during mist net set-up.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 66032052.49#
DUR = 11.3 ms TBC = 243 ms FRE = 26.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 450 Buff = 3 % F 7

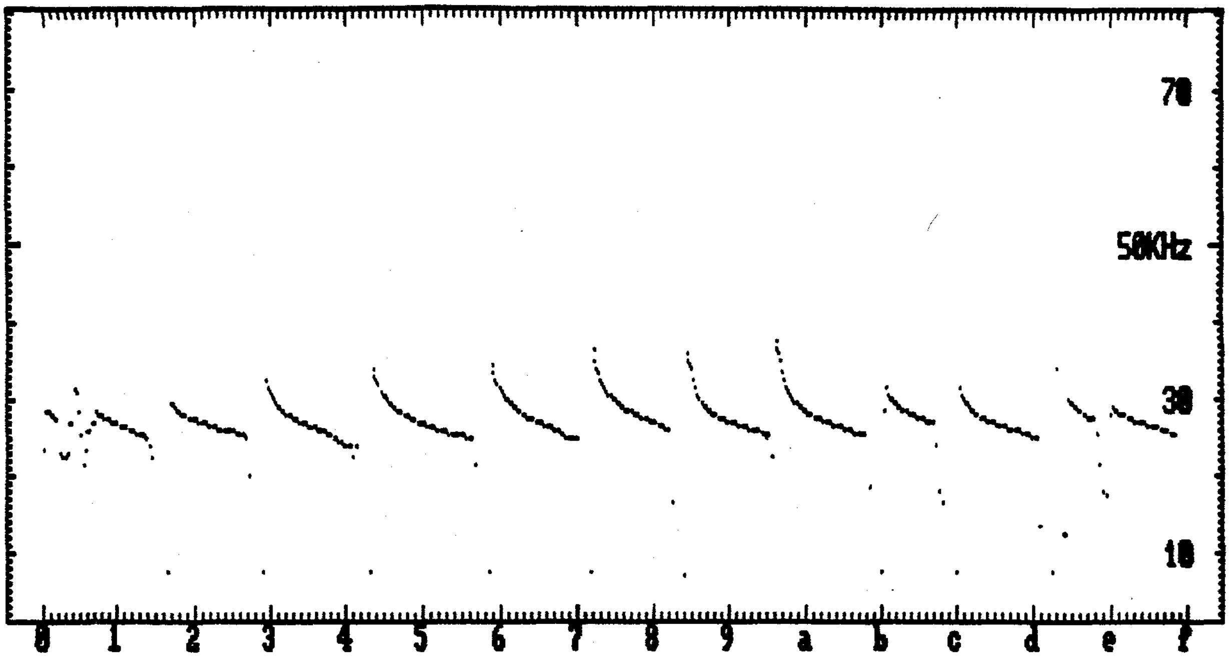


Figure 7 c

TAPE: Computer DATE: 05/20/96 LOC: Stock Pond at Ski Trailhead, 8,930 ft.
SP: Lasionycteris noctivagans SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65202127.01#
DUR = 12.0 ms TBC = 284 ms FRE = 28.5 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 206 Buff = 1 % F 7

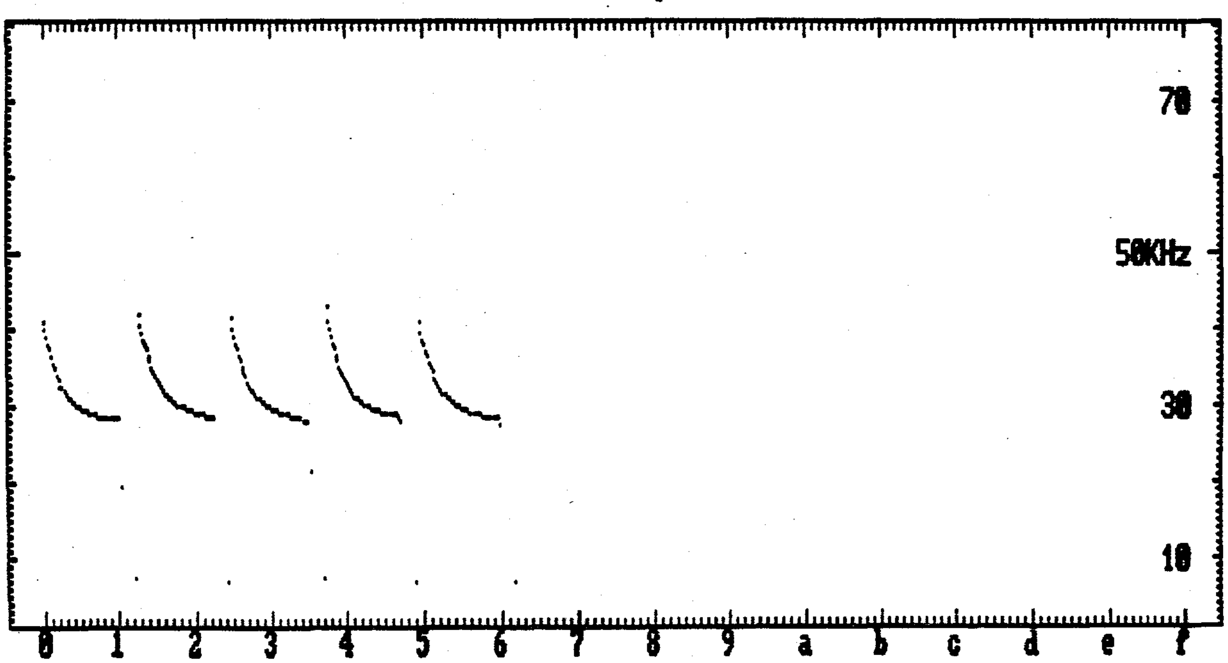


Figure 8 a

TAPE: computer DATE: 05/23/96 LOC: Pueblo Canyon Sewage Plant
SP: Eptesicus fuscus SPEC:
NOTES: Hand release; female.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65232114.38#
DUR = 7.21 ms TBC = 120 ms FRE = 27.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 368 Buff = 2 % F 7

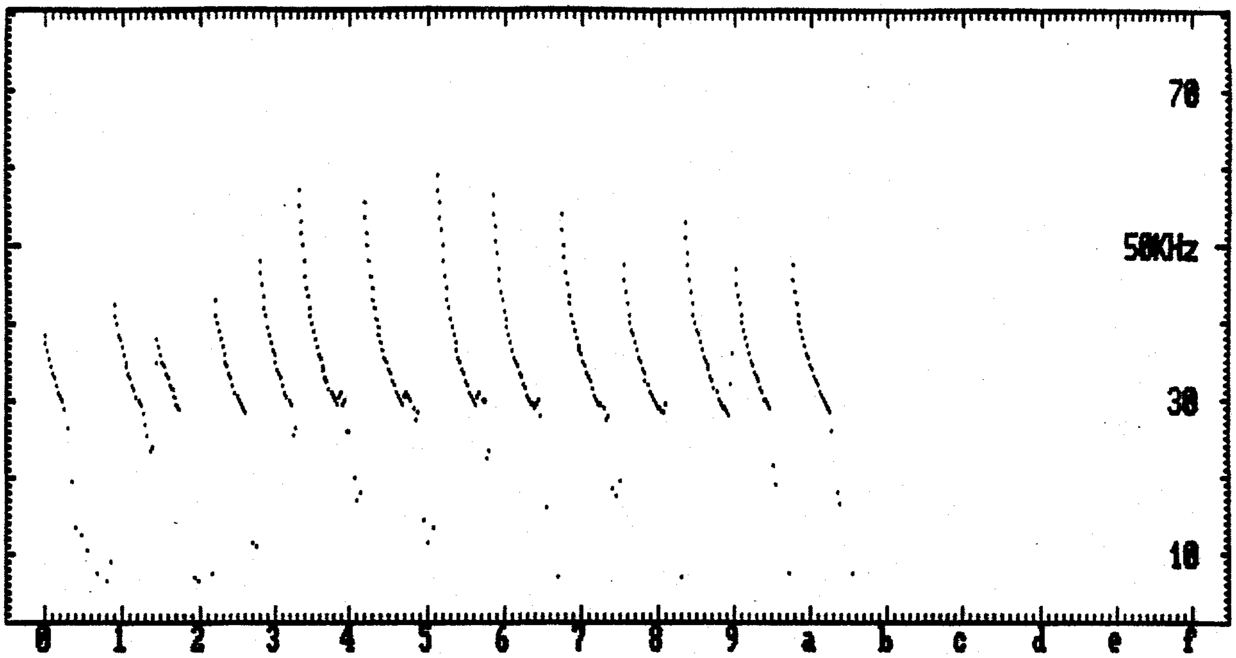


Figure 8 b

TAPE: computer DATE: 05/23/96 LOC: Pueblo Canyon Sewage Plant
SP: Eptesicus fuscus SPEC:
NOTES: Hand release; female.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65232114.40#
DUR = 7.24 ms TBC = 124 ms FRE = 28.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 432 Buff = 2 % F 7

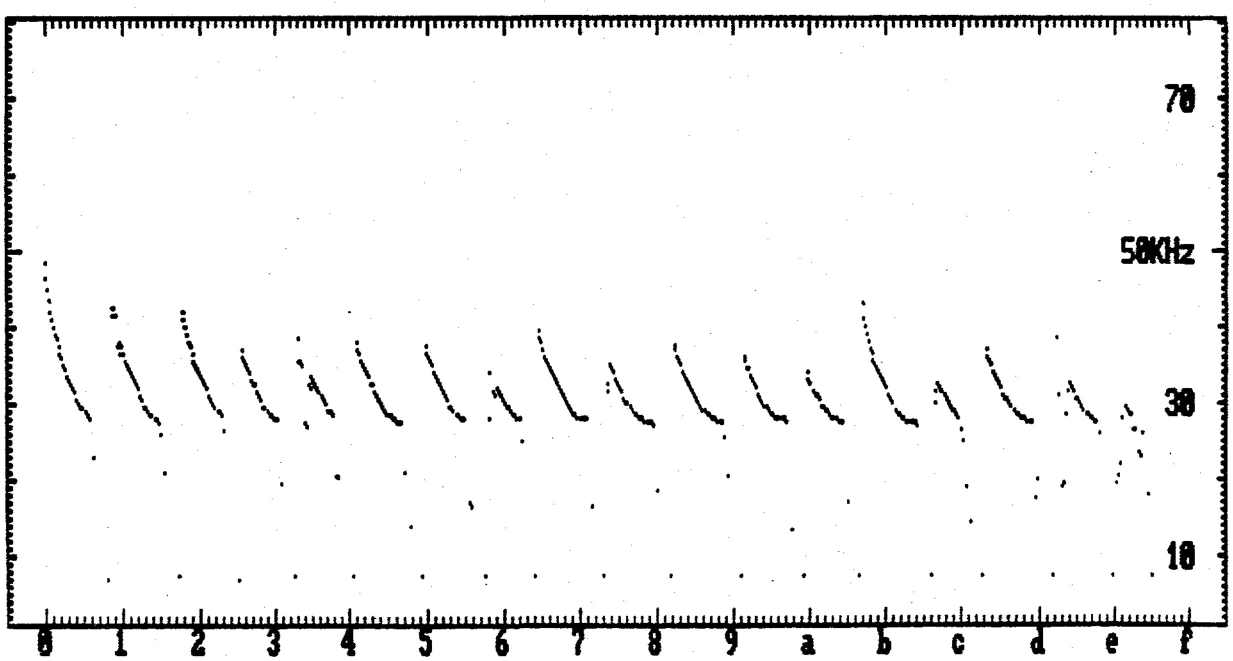


Figure 8 c

TAPE: computer DATE: 05/31/96 LOC: Stock Pond @ Ski Trailhead, 8930',P.5
SP: Eptesicus fuscus SPEC:
NOTES: hand release

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65310950.15#
DUR = 5.51 ms TBC = 159 ms FRE = 32.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 591 Buff = 15 % F 7

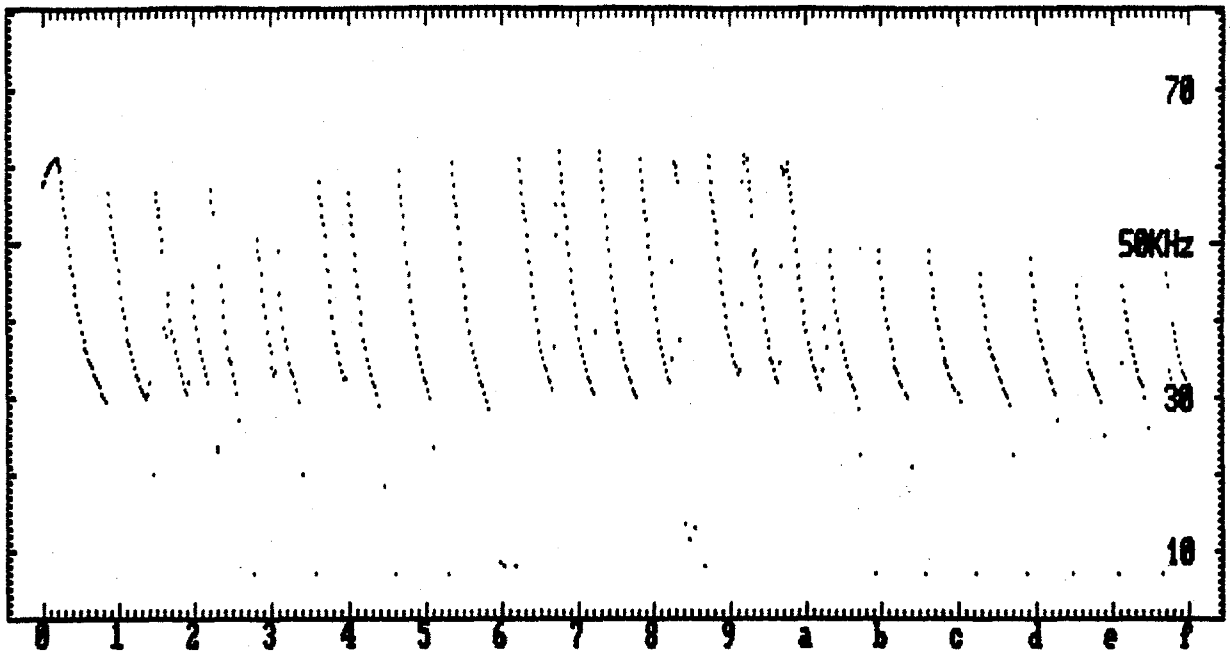


Figure 8 d

TAPE: computer DATE: 05/31/96 LOC: Stock Pond @ Ski Trailhead, 8930',P.5
SP: Eptesicus fuscus SPEC:
NOTES: hand release

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65310950.24#
DUR = 10.8 ms TBC = 268 ms FRE = 28.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 427 Buff = 2 % F 7

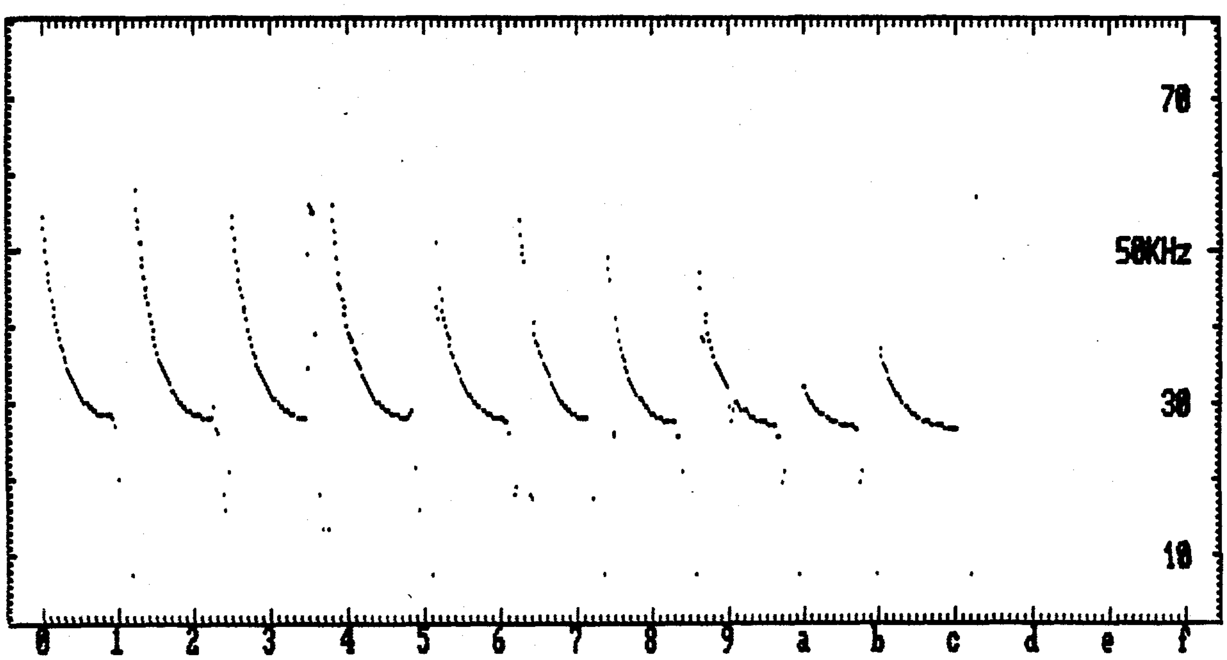


Figure 9 a

TAPE: computer DATE: 07/30/96 LOC: Lower Falls Trail Transect (pilot)
SP: Euderma maculatum SPEC:
NOTES: Recording of a free-flying foraging Euderma near the Rio Grande River.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 67302138.22#
DUR = 14.3 ms TBC = 188 ms FRE = 12.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 67 Buff = 0 % F 7

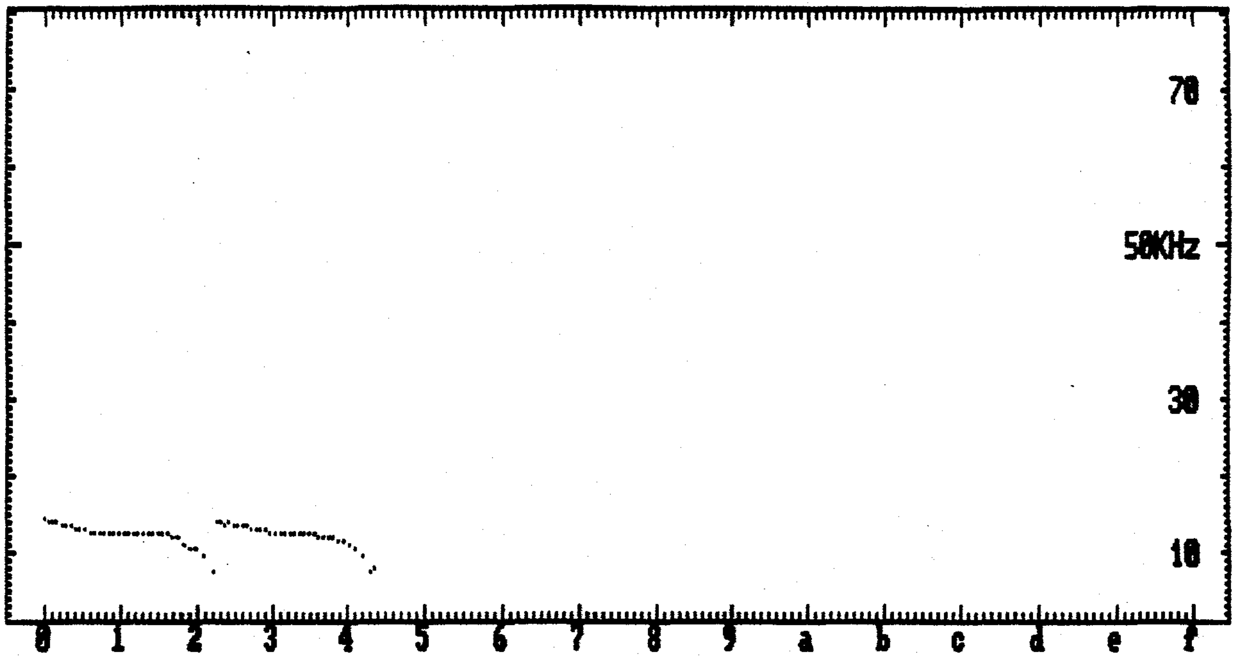


Figure 9 b

TAPE: computer DATE: 07/30/96 LOC: Lower Falls Trail Transect (pilot)
SP: Euderma maculatum SPEC:
NOTES: Recording of a free-flying foraging Euderma near the Rio Grande River.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 67302138.33#
DUR = 17.6 ms TBC = 70.2 ms FRE = 10.5 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 100 Buff = 0 % F 7

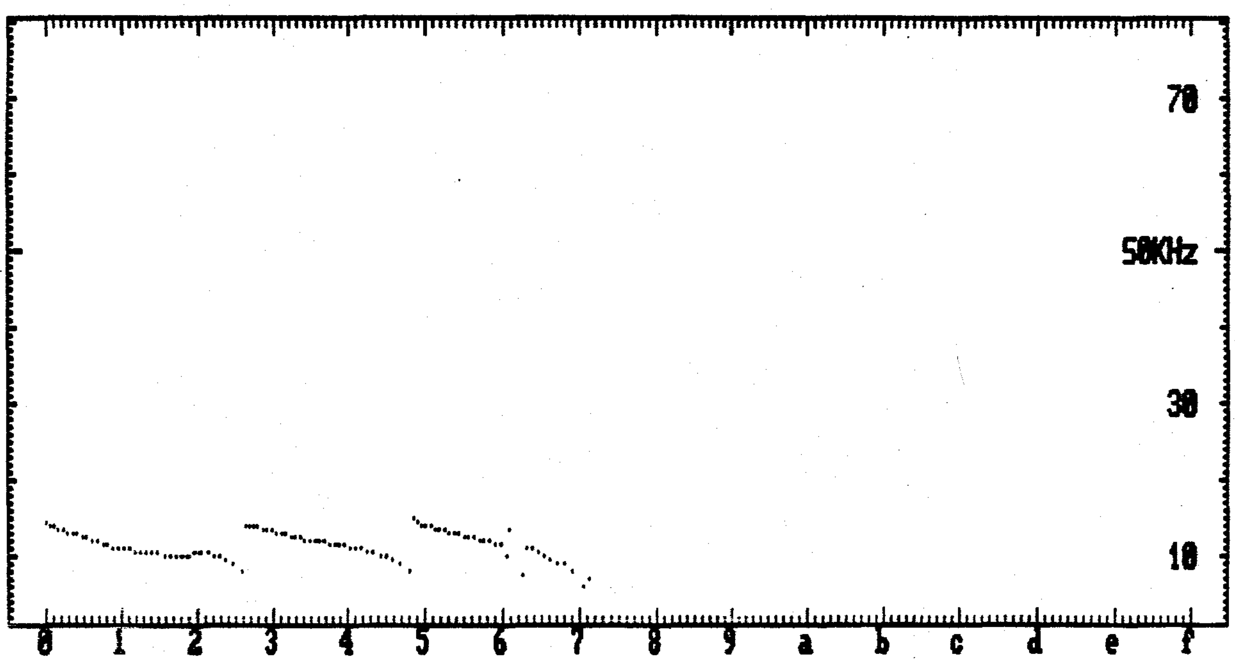


Figure 10

TAPE: Computer DATE: 05/20/96 LOC: Stock Pond at Ski Trailhead [illegible]
SP: Corynorhinus townsendii SPEC:
NOTES: Hand release; distress calls from the hand.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65202043.54#
DUR = 6.62 ms TBC = 175 ms FRE = 28.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 510 Buff = 12 % F 7

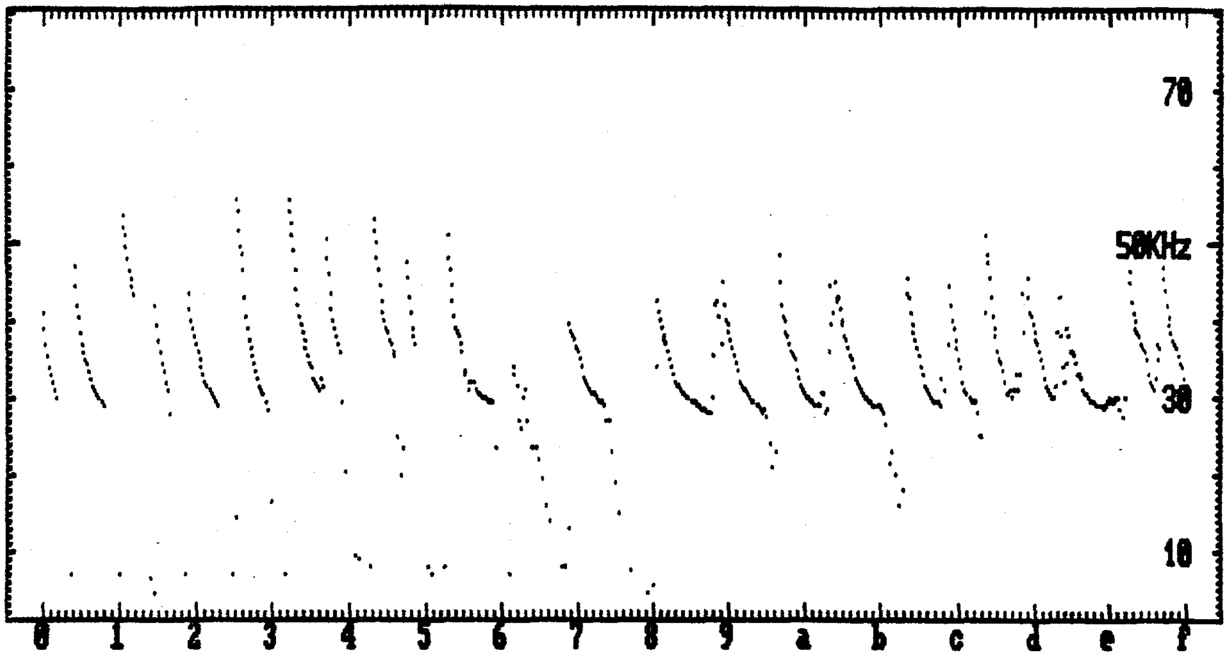
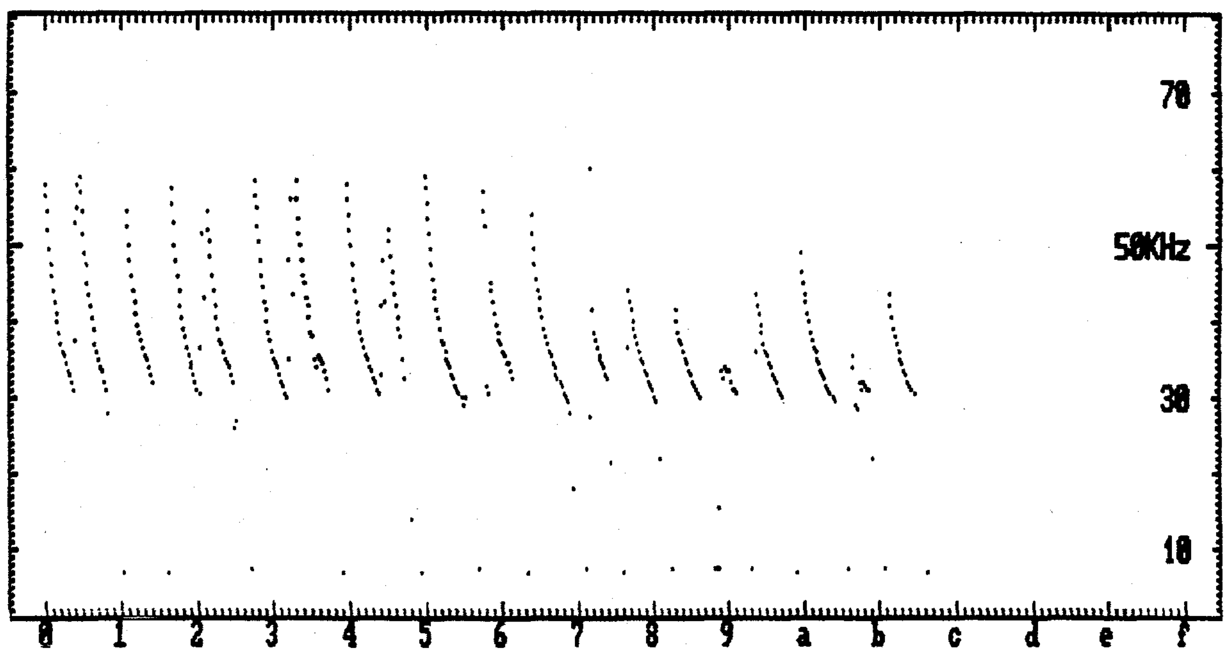


Figure 11 a

TAPE: Computer DATE: 05/21/96 LOC: Pueblo Canyon Effluent Area
SP: Antrozous pallidus SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65211014.45#
DUR = 5.46 ms TBC = 91.6 ms FRE = 31.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 396 Buff = 3 % F 7



TAPE: Computer DATE: 05/21/96 LOC: Pueblo Canyon Effluent Area
SP: Antrozous pallidus SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65211014.43#
DUR = 6.02 ms TBC = 135 ms FRE = 29.5 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 260 Buff = 1 % F 7

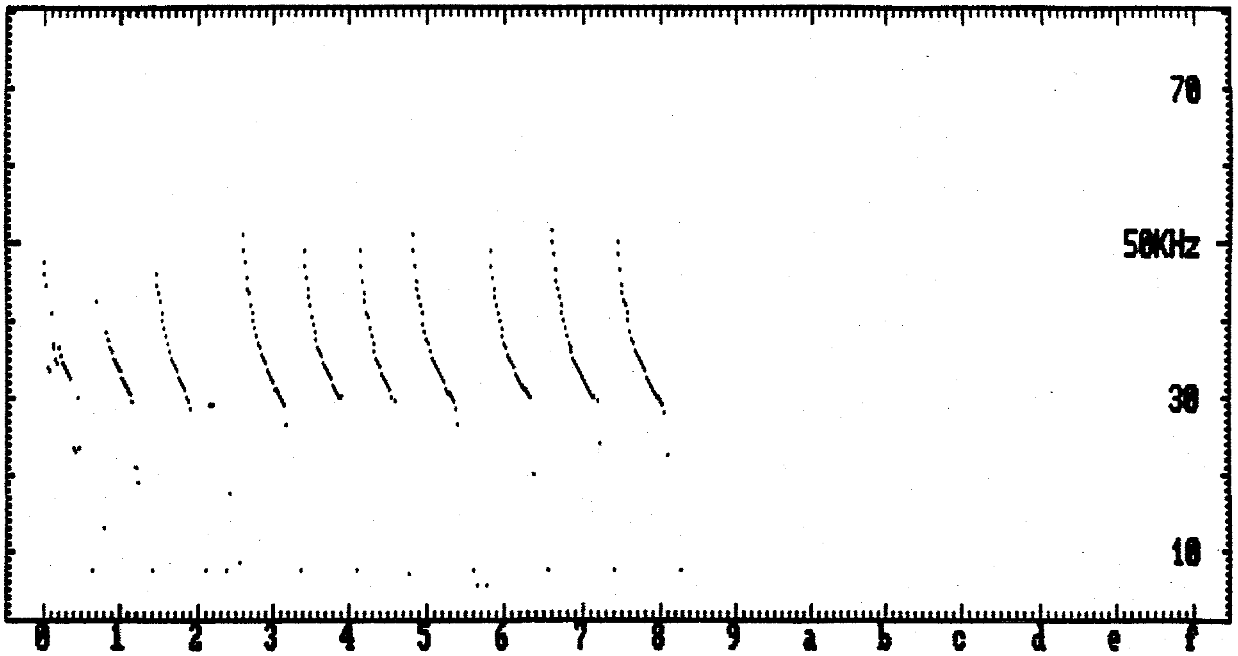


Figure 11 c

TAPE: Computer DATE: 05/21/96 LOC: Pueblo Canyon Effluent Area
SP: Antrozous pallidus SPEC:
NOTES: Hand release.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 65210956.31#
DUR = 4.16 ms TBC = 45.4 ms FRE = 31.5 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 316 Buff = 2 % F 7

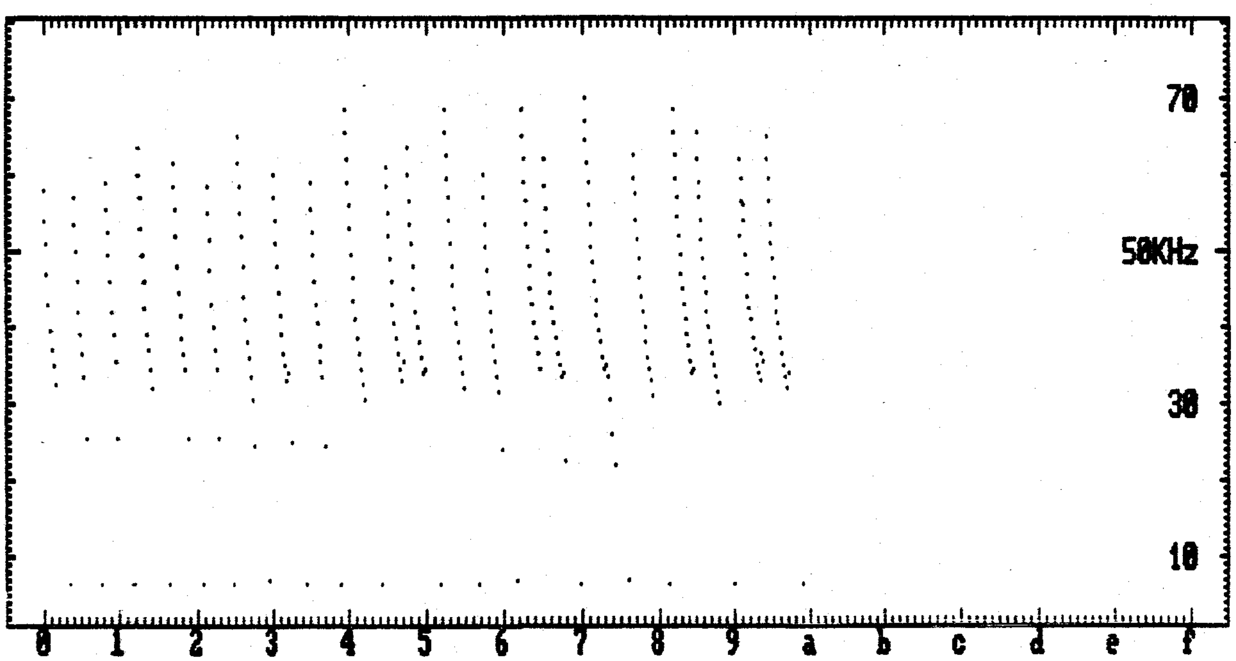


Figure 12

TAPE: [illegible] DATE: [illegible] 30/96 LOC: Lower Falls Trail Transect [illegible]
SP: Tadarida brasiliensis SPEC:
NOTES: Recording of free-flying bat along Rio Grande.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 67302037.27#
DUR = 10.4 ms TBC = 569 ms FRE = 28.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 438 Buff = 2 % F 7

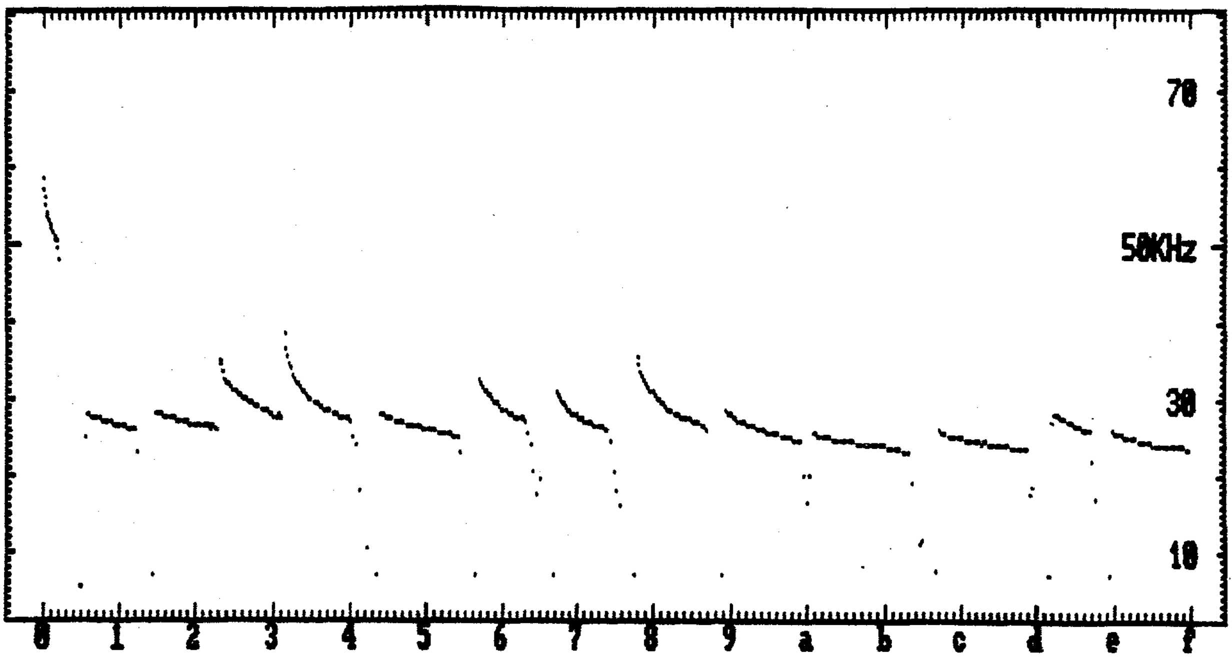
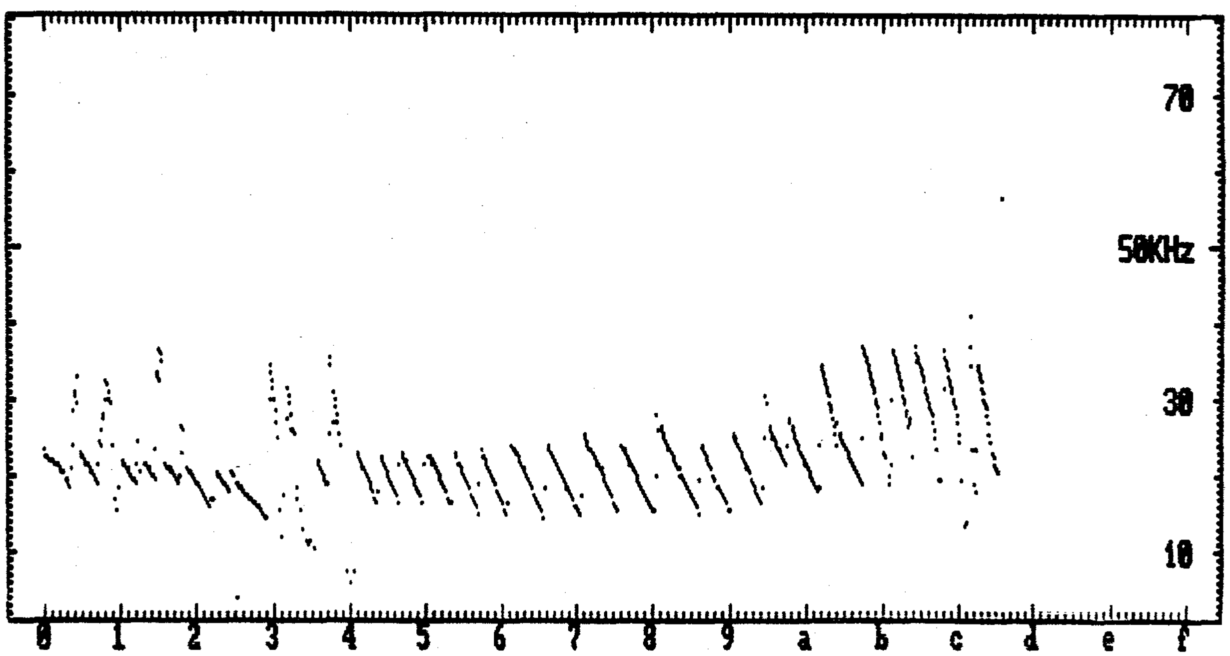


Figure 13

TAPE: computer DATE: 07/15/96 LOC: stockpond@ski trailhead; 8930; P.5
SP: Nyctinomops macrotis SPEC:
NOTES: female; lactating; hand release; captured at stockpond P.1

Compressed 0 to 80 kHz Div = 8 Cal = 40000 67151128.11#
DUR = 3.44 ms TBC = 231 ms FRE = 18.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 641 Buff = 11 % F 7



TAPE: computer DATE: 08/11/96 LOC: Capulin Canyon
SP: Pipistrellus hesperus SPEC:
NOTES: Recording of free-flying foraging Pipistrellus in Capulin Canyon.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 68112200.06#
DUR = 6.06 ms TBC = 193 ms FRE = 42.5 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 573 Buff = 19 % F 7

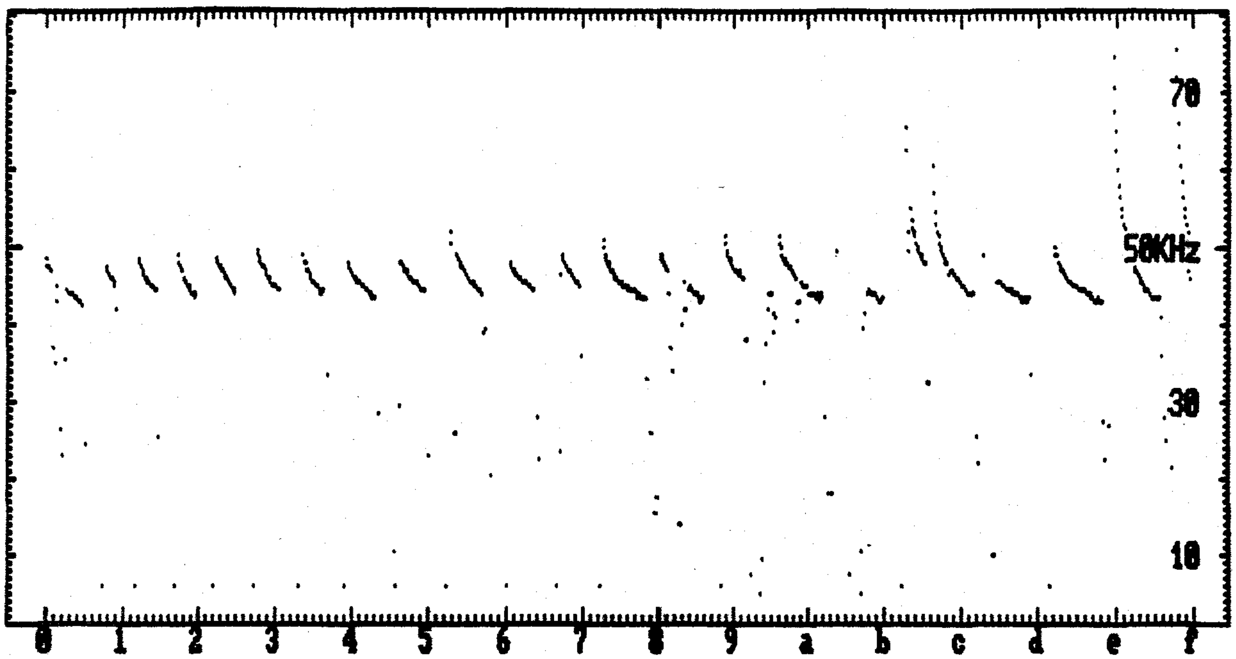
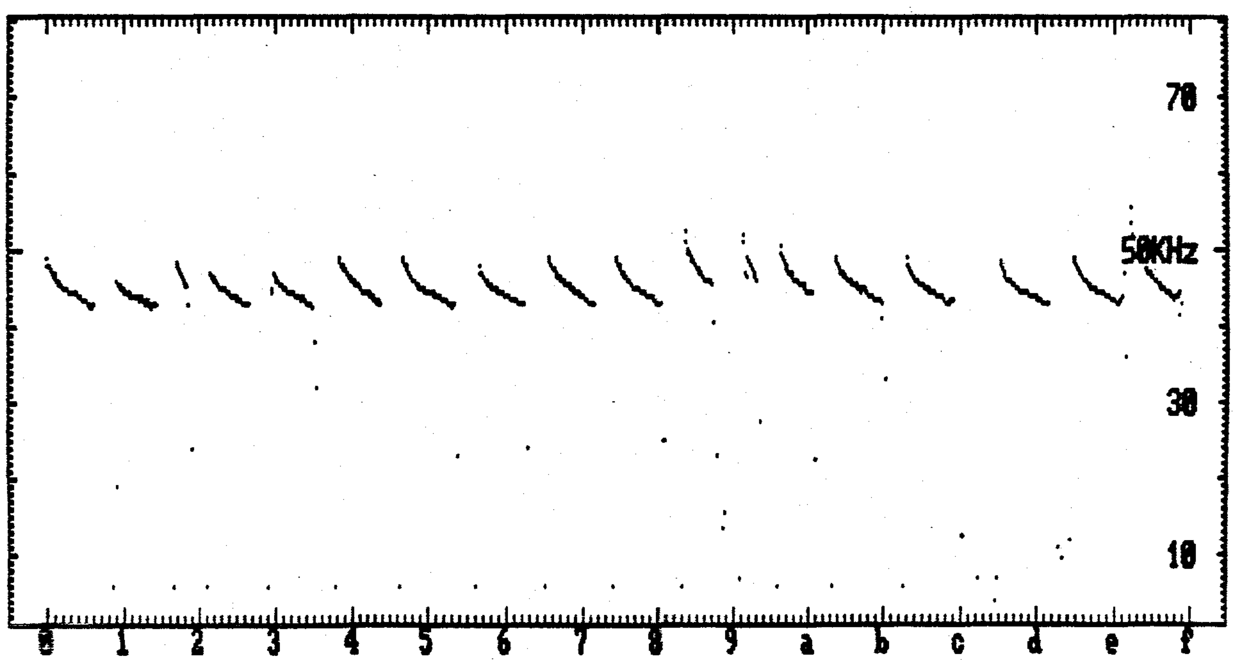


Figure 14 b

TAPE: computer DATE: 08/11/96 LOC: Capulin Canyon
SP: Pipistrellus hesperus SPEC:
NOTES: Recording of a free-flying foraging Pipistrellus in Capulin Canyon.

Compressed 0 to 80 kHz Div = 16 Cal = 40000 68112200.24#
DUR = 7.95 ms TBC = 191 ms FRE = 44.0 kHz
TOTAL - 160 ms TICKS - 10 ms Npts = 599 Buff = 11 % F 7



October 1, 1997

APPENDIX B

PLAN FOR STUDIES OF BATS AND CONTAMINANTS AT LOS ALAMOS NATIONAL LABORATORY AND THE JEMEZ MOUNTAINS

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BACKGROUND

As part of ongoing cooperative efforts to inventory bats in the Jemez Mountains, a preliminary survey should be conducted to evaluate the potential impact of environmental contaminants on bats of this region. Some contaminants have been documented as playing a role in some declining populations of bats in the United States (Geluso et al. 1976; see reviews by Clark 1981a, 1988a,b). There are several possible sources of contamination in the Jemez Mountains. Bats may be exposed to radionuclides through drinking contaminated water at local sources on Los Alamos National Laboratory (LANL), such as the pond at Technical Area (TA) 53, as well as from pockets of terrestrial contamination. LANL also has local sources of metal and PCB contamination (Terry Foxx and Dave Keller, LANL, personal communication). Metals of greatest concern are lead, mercury, cadmium, and antimony (Phil Fresquez, LANL, personal communication). Frijoles Creek at Bandelier National Monument (BAND) has been contaminated by DDT from past storage and leakage at the maintenance area near the Visitor Center. More general contamination with DDT and its principal metabolite, DDE, is of concern because New Mexico has higher background levels of this chemical in the environment than most other states, stemming largely from the southeastern part of the State; concentrations in songbirds from the Los Alamos area were also elevated in relation to other regions (Clark and Krynitzsky 1983a).

The purpose of this paper is to provide a brief synopsis on bats and contaminants and a basic plan for the collection of samples. Such sampling would be a preliminary effort to determine if there is a need for further, more detailed studies of environmental contaminants in bats of the Jemez Mountains. Emphasis is on designing collections and analyses such that results will be comparable with previous studies in the peer-reviewed literature. Interpretation of results will otherwise be difficult. A very brief synopsis of knowledge on selected contaminants in bats is provided below, with a summary of representative references (not entirely comprehensive) given in Tables 1 and 2. Final details on total sample sizes and types of analyses also need to be decided by LANL based on budgetary considerations.

Radionuclide Contamination of Bats

There are no well-known references on radionuclide contamination of bats, and it is likely this is because bats have never been examined for evidence of these contaminants. We conducted a search of the Wildlife Review database, examined a recent published review on radiation studies of wild mammals (Eisler 1994), and made inquiries of the U.S. expert on bats and contaminants (Dr. Donald R. Clark, Jr. at the USGS Biological Resources Division (BRD) station at Texas A&M University), and of a BRD biologist who had worked at the Savannah River Ecology Laboratory (Dr. Jeff Lovich). None of these efforts suggested that such studies have been undertaken.

Organochlorine Contamination of Bats

Organochlorines have been a major focus of studies on the occurrence and impacts of contaminants on bats, principally because of their delayed neurotoxicity (Clark 1981a). The major emphasis has been on DDT and metabolites, and to a lesser extent PCBs, dieldrin, and heptachlor. Other organochlorines have not been a focus of major studies. Residue concentrations of the pesticide DDT and DDE as well as PCBs and other organochlorines have been determined in carcasses of bats in separate studies of several species worldwide (see Table 1 for a representative overview). Feeding and reproductive studies have also been carried out using DDT, DDE, dieldrin, and PCBs on a few species, including free-tailed bats (*Tadarida brasiliensis*) and big brown bats (*Eptesicus fuscus*) (Clark and Prouty 1977, Geluso et al. 1976, Clark and Kroll 1977, Luckens 1973, Luckens and Davis 1964, 1965). Based on captive feeding studies and well-designed field sampling efforts, diagnostic lethal concentrations of some organochlorines have been determined in brains, and relationships have been quantified among concentrations in brains, carcasses, and guano (see for example, Clark et al. 1978a, references in Clark 1981a, 1988a,b). Recent studies also demonstrate predictive equations for diagnostic lethal contamination based on analysis of museum skins (D.R. Clark, Jr., personal communication). Hence, results of surveys for organochlorine residues can be interpreted on the basis of these prior studies (Table 1), several of which included bat species found to be common to the Jemez Mountains that are not considered Species of Concern.

Bats are not unusually sensitive to organochlorines such as DDE or DDT in terms of lethality, the degree of which depends largely on the amount of fat present in the body (Clark 1988a). However, because bats have annual cycles of fattening and mobilization of lipid reserves (either slowly through hibernation or more rapidly though migration), there are vulnerable points in the annual cycle during which mobilized lipids cause the release of organochlorines to the bloodstream. These organochlorines then concentrate in the more lipid-rich brain, causing mortality through neurotoxicity. Organochlorines are also passed to the developing young through milk, which has a high lipid content, and juvenile mortality due to organochlorine poisoning has been documented in some species, including lethal poisoning during simulations of migration (Geluso et al. 1976, Clark et al. 1978a). Nursing or newly volant young bats and males are usually highest in organochlorine residues (adult females, in contrast, excrete lipophilic organochlorines through the lipid-rich milk) (Clark 1981a).

Metal Contamination of Bats

Studies of metals in bats have been less extensive than those of organochlorines, and features of representative surveys are provided in Table 2. In general, concentrations reported in tissues of bats have not been interpreted thus far to be indicative of serious problems that could impact populations (with the possible exception of lead). However, sampling efforts have been small, and extensive corollary studies of reproduction or histopathology have not to our knowledge been carried out. Basic surveys of metals in bats at LANL will add to the existing worldwide knowledge on bats and metals, and results could be interpreted against the limited information that currently exists (Table 2).

SUGGESTIONS FOR SAMPLING

Carcasses for Radionuclide Analysis

We will focus on collecting male pallid bats (*Antrozous pallidus*) from lower Los Alamos Canyon for radionuclide analysis. Pallid bats are not Species of Concern. They forage close to and on the ground (see Hermanson and O'Shea 1983 for review), where contamination may be highest, and are relatively large compared to most bats at LANL. Larger size will allow sacrifice of fewer individuals to reach the required pooled sample mass of 30 g (about 3-4 bat carcasses) per individual analysis. Big brown bats (*Eptesicus fuscus*) from Los Alamos or Pueblo canyons should also be sampled to provide a species with a contrasting foraging style (it is primarily an aerial feeder). Pallid bats and big brown bats will also be collected off-site to provide background controls. Up to 10 pooled samples of bats from LANL and 6 from off-site will be collected in summers 1997 and 1998. Carcasses will consist of the head and body after removal of skin and pelage, wings, feet, stomach, and intestines. Attempts will be made to group pooled individuals on the basis of canine tooth wear as an index of relative age (Christian 1956, Anthony 1988). Canine tip width will be measured using an ocular micrometer and dissecting scope after dissection. Precautions will be followed in preparing laboratory samples to avoid potential exposure to rabies virus, including preparations of samples under a fume hood. BRD personnel handling samples will receive a pre-exposure rabies immunization series.

Individual bats will be sacrificed following approved animal welfare protocols of the U.S. Geological Survey's Midcontinent Ecological Science Center. Intact bats will be weighed and frozen individually in plastic ziplock bags provided by the analytical laboratory at LANL ESH-20. Handling of sacrificed bats will be done wearing disposable surgical gloves also provided by LANL. Bags with individual bats will include labels with species, collection site, date of collection, sex, fresh weight, and collectors names. Chain-of-custody security tape will be used to seal bags and a LANL chain-of-custody log maintained. Samples will be analyzed at LANL in the ESH-20 laboratory facility following LANL Standard Operating Procedures. Concentrations of seven radionuclides will be determined (P. Fresquez, *in litt*), including ^{3}H, ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, ^{90}Sr, ^{241}Am, and total U.

Guano for Radionuclide, Organochlorine, and Metals Analysis

Initial sampling to determine exposure of bats to selected environmental contaminants should include guano. As summarized in Tables 1 and 2, there are a number of reference studies on organochlorines and metals in guano with which results can be compared. As noted by Clark et al. (1982):

" As a survey technique, the collection and analysis of a single guano sample has three advantages over analyses of bats themselves. First, it probably provides a more accurate, longer-term measure of the contaminant condition of the colony tested because a single guano sample contains feces from many times more bats than could reasonably be analyzed separately, and the time period represented (assuming the guano is taken from the surface) is days or weeks rather than a single instant. Second, because only one analysis (or as a precaution against analytical error, two analyses of subsamples) is required, the expense is minimized. Third, it is not necessary to collect bats.....When a roost is found where organochlorine residues in guano seem high, the investigator can later return to look for mortality....most likely when young begin to fly and mobilize fat stored during nursing."

Previous analyses of contaminants in guano include the metals lead, chromium, zinc, cadmium, and mercury, and organochlorines such as PCBs, DDE, dieldrin, and heptachlor epoxide (Tables 1 and 2). No data are available on radionuclides or general radiation in guano. Some of the guano analyzed by others is from bat species common in the Jemez Mountains (free-tailed bats and big brown bats; Tables 1 and 2).

Guano samples should be collected for analysis from the free-tailed bat roost at Bandelier during the 1997 field season. The guano accumulation at the active Bandelier roost was removed at the end of the 1996 field season, so all samples will represent recent contamination without ambiguity on sample age. This sample should be analyzed for radiation contamination and selected metals of interest. (Additional samples should be collected following a separate protocol avoiding plastics if organochlorine analyses, particularly DDE and PCBs, are desired). Because this colony likely disperses to feed over LANL and the Rio Grande and Cochiti Reservoir (which receive LANL run-off), guano should provide an index to regional contamination of bats. Results may also provide comparison with ongoing LANL studies of radionuclides in fish and foodstuffs. We also suggest analyzing guano samples for radionuclides from beneath currently unused former roosts of what appear to have been free-tailed bats in Pueblo Canyon for location comparisons. Samples should also be collected and submitted from a remote site to serve as a background control. All guano samples will be collected using surgical gloves, sealed disposable plastic scoops, and plastic wide-mouth jars provided by the LANL ESH-20 analytical facility. Precautions will be taken to avoid contamination of the samples by dust particles as much as feasible. The guano will be scooped from the top 10 mm of the accumulated pile and placed directly into wide-mouth jars. Each jar should be filled completely. Small flakes of stone and visible soil particles will be avoided as feasible. The jars will be labelled by location, date, collector's name, sample contents (e.g.,"Tadarida bat guano"), and container number for that location, using the black indelible marker provided by LANL. A red LANL chain-of-custody seal will be placed across the top, and a chain-of-custody form completed.

Minimum Numbers of Samples Anticipated in FY98

During FY98 as many as 12-15 guano samples may be submitted for radionuclide analysis (4 to 5, 30-g samples from the Bandelier roost, 4 to 5 from an off-site roost, and 3 to 5 from an old Pueblo Canyon roost). Up to 20 carcass samples may also be submitted (5 groups of 3 to 4 pallid bats each from Los Alamos Canyon, 5 groups of 3 pallid bats each from off-site; 5 groups of 3 big brown bats each from Los Alamos or Pueblo canyons and 5 groups from off-site. Thus a total of 32-35 samples may be submitted for radionuclide determinations in FY98 pending budgetary approval.

Additional Sampling to be Determined

Much previous work on organochlorine and metal contaminants in bat tissues has focused on carcasses or individual organs (Tables 1 and 2). The majority of studies of organochlorines have stressed carcasses, with brains (small in size and delicate) used to confirm residue concentrations diagnostic of lethal exposure (Table 1). Studies of lead have utilized carcasses and individual organs (Table 2). Mercury determinations have focused on liver, kidney, muscle, and hair, roughly in that order of prevalence in the literature (Table 2). Cadmium studies have focussed on liver and kidney. To our knowledge no studies have determined antimony concentrations.

No bats will be collected for organochlorine or metals analysis until decisions are made at LANL on the desirability of carrying out research on exposure of bats to these specific contaminants and the availability of funding to pay for analysis. A detailed plan will be developed at that time if such collections prove feasible. Large sample sizes and balanced treatments may be difficult to obtain for small, locally contaminated areas. However, we recommend that an initial analysis of guano samples from Bandelier be conducted for organochlorines. Previous studies have sampled about 20 g (field weight) for organochlorine analysis, often doing separate analyses on each half of the sample to control for analytical variation. Guano analyses have been carried out on free-tailed bats from several locations in the southwest and Mexico and can provide a basis for comparison (Table 1). Additionally, bats found dead in Frijoles Canyon, particularly newly volant young, would be valuable to assess for possible mortality from organochlorine exposure due to local DDT contamination. Such individuals should be handled minimally and wrapped in clean aluminum foil, labelled (date, location, species, collector name), and immediately frozen for future dissection and submission for organochlorine analysis (especially brains, for which diagnostic lethal levels of organochlorines of concern have been established). Laboratory preparation of these samples will also require precautions against exposure to rabies virus.

Similarly, final budgetary decisions on total numbers of samples of pallid bats, big brown bats, and guano to be analyzed for radionuclide contamination must be made by LANL in FY98.

Bat Activity at Contaminated Pond in TA-38

The reactor cooling pond at TA-53 is contaminated with tritium. We will attempt to make observations at night, including use of bat detectors and mist nets, to determine if there is any bat activity or drinking at this facility.

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Table 1. Representative surveys of organochlorine contaminant residues in bats. See also Clark 1981, 1988. Dated: September 29, 1997

Species	Region	Contaminant	Material Sampled	Reference
Antrozous pallidus	Arizona	DDE, DDD, DDT, dieldrin, others	[1]carcass	Reidinger 1972, 1976
Eptesicus fuscus	Arizona	DDE, DDD, DDT	carcass	Reidinger 1972, 1976
Eptesicus fuscus	Maryland	DDE, dieldrin, heptachlor epoxide	guano, carcass	Clark et al. 1982
Eptesicus fuscus	Maryland	dieldrin, several organochlorines, PCBs	carcass, neonates	Clark and Lamont 1976a
Eptesicus fuscus	Maryland	DDE	fat	Clark and Krynitsky 1983
Eptesicus fuscus	Maryland	several organochlorines	carcass, brain, milk, stomach contents	Clark and Lamont 1976b
Eptesicus fuscus	Maryland, West Virginia	DDE, DDT, PCBs, dieldrin, others	guano, carcasses, brain, stomach contents	Clark and Prouty 1976
Eptesicus fuscus	Oregon	DDE, DDD, DDT, ΣDDT, dieldrin, others	carcass, brain	Henny et al. 1982
Hipposideros commersoni	Cameroon	Dieldrin	liver	Müller et al. 1981
Lasionycteris noctivagans	Oregon	DDE, DDD, DDT, ΣDDT, dieldrin, t-nonachlor, others	carcass, brain	Henny et al. 1982
Lasiurus borealis	Florida	mirex	unspecified	Wheeler et al. 1977
Leptonycteris sanborni	Arizona	DDE, DDD, DDT	carcass	Reidinger 1972, 1976
Lissonycteris angolensis	Cameroon	Dieldrin	liver	Müller et al. 1981
Macrotus waterhousii	Arizona	DDE, DDD, DDT	carcass	Reidinger 1972, 1976
Micropteropus pusillus	Cameroon	Dieldrin	liver	Müller et al. 1981

1 Definition of carcass varies among investigators. In most studies carcass is body after removal of head, wings, feet, skin, and GI tract.

Table 1. (Cont.).

Species	Region	Contaminant	Material Sampled	Reference
Miniopterus schrebersi	Italy	DDE, DDT	carcass	Corrao et al. 1985
Miniopterus schrebersi	Spain	DDE, DDT, dieldrin, other organochlorines, PCBs	carcass	Hernandez et al. 1993; Fernandez et al. 1993
Myotis californicus	Oregon	DDE, DDD, DDT, ΣDDT, dieldrin, others	carcass, brain	Henny et al. 1982
Myotis dasycneme	Netherlands	DDE, DDD, DDT, dieldrin, HCHs, PCP, DBP, HCB, PCBs	whole body	Leeuwangh and Voute 1985
Myotis daubentoni	England	DDE, DDT, dieldrin	liver, carcass	Jefferies 1972
Myotis evotis	Oregon	DDE, DDD, DDT, ΣDDT, dieldrin, t-nonachlor, others	carcass, brain	Henny et al. 1982
Myotis griscescens	Alabama	DDT, DDD, DDE, PCBs, dieldrin, BHC, chlordane, others	guano, carcass, brain, milk	Clark et al. 1988
Myotis griscescens	Alabama, Missouri	DDE, dieldrin, heptachlor epoxide	guano, carcass	Clark et al. 1982
Myotis griscescens	Missouri	dieldrin, heptachlor epoxide	guano, carcass	Clawson and Clark 1989
Myotis griscescens	Missouri	dieldrin, DDT, DDD, DDE, heptachlor epoxide, oxychlordane, cis-Chlordane, t-nonachlor, cis-nonachlor	brains, carcass	Clark et al. 1983a
Myotis griscescens	Missouri	DDE, dieldrin, heptachlor epoxide	carcass, brain, milk	Clark et al. 1978a
Myotis griscescens	Missouri	dieldrin, DDE, PCBs, heptachlor, oxychlordane, heptachlor epoxide	carcass, brain	Clark et al. 1983b
Myotis lucifugus	Maryland	DDE	fat	Clark and Krynitsky 1983

Table 1. (Cont.). dated: september 29, 1997

Species	Region	Contaminant	Material Sampled	Reference
Myotis lucifugus	Maryland	DDE, PBCs	brains, carcass	Clark and Stafford 1981
Myotis lucifugus	Maryland	DDE, dieldrin, heptachlor epoxide	guano, carcass	Clark et al. 1982
Myotis lucifugus	Maryland, West Virginia	DDE, DDT, PCBs, dieldrin, others	guano, carcasses, brain, stomach contents	Clark and Prouty 1976
Myotis lucifugus	New Hampshire	DDE, DDT, DDD, oxychlordane, dieldrin, others	carcass, brain, stomach contents, milk	Clark et al. 1978b
Myotis myotis	Italy	DDE, DDT	carcass	Corrao et al. 1985
Myotis nattereri	England	DDE, DDT, dieldrin	liver, carcass	Jefferies 1972
Myotis sodalis	Missouri	DDE, dieldrin, heptachlor epoxide	guano, carcass	Clark et al. 1982
Myotis velifer	Texas	DDE (Dieldrin and other organochlorines analyzed but not detected.)	carcass	Thies and Thies 1997
Myotis volans	Oregon	Dieldrin, DDE, DDD, DDT, ∑DDT, heptachlor epoxide, oxychlordane, t-nonachlor	carcass, brain	Henny et al. 1982
Nycticeus humeralis	Florida	mirex	unspecified	Wheeler et al. 1977
Pipistrellus hesperus	Arizona	DDE, DDD, DDT	carcass	Reidinger 1972, 1976
Pipistrellus pipistrellus	England	DDE, DDT, dieldrin	liver, carcass	Jefferies 1972
Pipistrellus pipistrellus	England	lindane	carcass, liver, fat	Boyd et al. 1988
Pipistrellus pipistrellus	Sweden	DDE, DDT, PCBs	muscle	Gerell and Lundberg 1993
Pipistrellus pipistrellus	Spain	Dieldrin, other organochlorines, PCBs	carcass	Guillen et al. 1994; Fernandez et al. 1993
Pipistrellus subflavus	Maryland	DDE	fat	Clark and Krynitsky 1983

Table 1. (Cont.). dated: september 29, 1997

Species	Region	Contaminant	Material Sampled	Reference
Pipistrellus subflavus	Maryland, West Virginia	DDE, DDT, PCBs, dieldrin, others	guano, carcasses, brain, stomach contents	Clark and Prouty 1976
Plecotus auritus	England	DDE, DDT, dieldrin	liver	Jefferies 1972
Rhinolophus ferrum-equinum	Spain	Dieldrin, DDE, DDT, other organochlorines, PCBs	carcass	Hernandez et al. 1993; Fernandez et al. 1993
Tadarida brasiliensis	Arizona	DDE, DDD, DDT	carcass	Reidinger 1972, 1976
Tadarida brasiliensis	Arizona	dieldrin, DDE, DDD, DDT, toxaphene	carcass, guano, fetuses, mammaries	Reidinger and Cockrum 1978
Tadarida brasiliensis	New Mexico, Arizona, Texas, California	Dieldrin, DDE, DDT, other organochlorines, PCBs	carcass	Geluso et al. 1981
Tadarida brasiliensis	New Mexico	DDE, DDT, dieldrin	carcass, brain	Geluso et al. 1976
Tadarida brasiliensis	Mexico	DDT, DDD, DDE, PCBs, BHC, dieldrin, chlordane	guano	Clark et al. 1995
Tadarida brasiliensis	Texas, Oklahoma	DDE (dieldrin and other organochlorines analyzed but not detected)	carcass, brain	Thies et al. 1996
Tadarida brasiliensis	Texas, Oklahoma	DDE (dieldrin and other organochlorines analyzed but most not detected)	carcass, brain, embryos	Thies and McBee 1994
Tadarida brasiliensis	Texas	DDE (Dieldrin and other organochlorines analyzed but not detected.)	carcass	Thies and Thies 1997
Tadarida brasiliensis	Texas	DDT, DDD, DDE, PCBs, dieldrin, BHC, chlordane, others	guano, carcass, brain, embryo	Clark et al. 1975
Tasarida brasiliensis	Texas	DDE, dieldrin, heptachlor epoxide	guano, carcass	Clark et al. 1982

Table 2. Representative surveys of metal concentrations in bats.

Species	Region	Metal	Material Sampled	Reference
Antrozous pallidus	Arizona	mercury	liver, muscle	Reidinger 1972
Eptesicus fuscus	Arizona	mercury	liver, muscle	Reidinger 1972
Eptesicus fuscus	Maryland	lead	carcass, guano	Clark 1979
Eptesicus serotinus	Germany	lead, cadmium, nickel, chromium, copper	whole body, carcass, hair, lung, muscle, liver, kidney, femur, nails	Streit and Nagel 1993a
Miniopterus schreibersi	Japan	mercury	hair, kidney, liver, muscle	Miura et al. 1978
Myotis austroriparius	Florida	lead, chromium, zinc, cadmium	guano, liver, kidney	Clark et al. 1986
Myotis daubentoni	Germany	lead, cadmium, nickel, chromium, copper	whole body, carcass, hair, lung, muscle, liver, kidney, femur, nails	Streit and Nagel 1993a
Myotis lucifugus	Maryland	lead	carcass, guano	Clark 1979
Myotis mystacinus	Germany	lead, cadmium, nickel, chromium, copper	whole body, carcass, hair, lung, muscle, liver, kidney, femur, nails	Streit and Nagel 1993a
Myotis sodalis	Florida	lead, chromium, zinc, cadmium	guano, liver, kidney	Clark et al. 1986
Nyctalus noctula	Germany	lead, cadmium, nickel, chromium, copper	whole body, carcass, hair, lung, muscle, liver, kidney, femur, nails	Streit and Nagel 1993a

Table 2. (Cont.)

Updated: September 11, 1997

Species	Region	Metal	Material Sampled	Reference
Pipistrellus abramus	Japan	Mercury	hair, kidney, liver, muscle	Miura et al. 1978
Pipistrellus hesperus	Arizona	Mercury	liver, muscle	Reidinger 1972
Pipistrellus pipistrellus	Sweden	Cadmium, Mercury	liver, kidney	Gerell and Lundberg 1993
Pipistrellus pipistrellus	Germany	Lead, Cadmium, Nickel, Chromium, Copper	whole body, carcass, hair, lung, muscle, liver, kidney, femur, nails	Streit and Nagel 1993a
Pipistrellus pipistrellus	Germany	Lead, Cadmium, Nickel, Chromium, Copper	carcass, liver, kidney, spleen, lung, milk, gut content	Streit and Nagel 1993b
Pipistrellus subflavus	Virginia	Mercury	liver, muscle	Powell 1983
Plecotus auritus	Germany	Lead, Cadmium, Nickel, Chromium, Copper	whole body, carcass, hair, lung, muscle, liver, kidney, femur, nails	Streit and Nagel 1993a
Rhinolophus cornutus	Japan	Mercury	hair, kidney, liver, muscle	Miura et al. 1978
Rinolophus ferrum-equinum	Japan	Mercury	hair, kidney, liver, muscle	Miura et al. 1978
Tadarida brasiliensis	Arizona	Mercury	guano	Petit and Altenbach 1973
Tadarida brasiliensis	Arizona	Mercury	liver, muscle	Reidinger 1972
Tadarida brasiliensis	Oklahoma	Lead, Cadmium, Arsenic	liver	Thies and Gregory 1994

Table 2. (Cont.) Updated: September 11, 1997

Species	Region	Metal	Material Sampled	Reference
Tadarida brasiliensis	Texas	Lead, Cadmium, Arsenic	liver	Thies and Gregory 1994
Vespertillio superans	Japan	Mercury	hair, kidney, liver, muscle	Miura et al. 1978

Appendix C. Descriptions of sites netted on Bandelier National Monument (BAND) and Los Alamos National Laboratory. Elevation of each site, listed in meters, is enclosed in brackets after the site name. Names in parentheses (e.g., P 1, L 1) are names used to monitor water sources at BAND.

Sites At and Around Los Alamos National Laboratory

Icehouse Pond [2348]: This is a perennial pond near the entrance to Technical Area (TA) 16. This site was netted by Tyrell and Brack (1992), who called it Pond TA-16. The surrounding vegetation is ponderosa pine forest and mostly surrounds the pond. During 1995 and 1997 the pond was approximately 15 m by 25 m and was one meter deep; during 1996 size and depth varied appreciably over the course of the season. After the summer rains of 1996 started it was almost too deep to work. The site is on USGS Frijoles, NM, 7.5 minute quadrangle, about three-quarters of a mile north of the intersection of routes 501 and 4; the pond is on the east side of Route 501. We netted this site on 5 September 1995. During 1996 this was the most frequently netted LANL location; we netted here on 22 and 30 May, 5 18, 25, and 28 June, 2 and 18 July, and 6 and 13 August of 1996. In 1997 we netted here on 9 and 27 June and on 13 July. During much of 1997 it was frequently too deep to net safely.

TA-15 Cement Pond [2317]: We netted this large (approximately 45 m across) cement pond located in TA-15 of LANL. The pond is surrounded by ponderosa pine forest and a large grassy meadow to the west. We netted here on 17 July 1996.

Los Alamos Canyon Reservoir [2213]: This area includes two sites near the reservoir; one is an ephemeral pool approximately 5 m by 5 m and 25 cm depth; the other is at a widened stream flow approximately 5 m across with a depth of 10 cm. Both sites are products of runoff from Los Alamos Reservoir. The site is in ponderosa pine forest. The reservoir is shown on USGS Guaje Mountain 7.5 minute quadrangle and is located on National Forest Service land; permission was obtained from the Forest Service prior to netting. We netted this site on 11 and 15 September 1995 and 1 June 1996. It was not netted during 1997.

Mortandad Canyon [2165]: We netted a shallow pool, approximately 2 m by 3 m, surrounded by cattails and part of a small wetland in the canyon. The surrounding forest consists of *Pinus ponderosa.* This are is shown on USGS Frijoles, NM, 7.5. minute quadrangle and is located southeast of Los Alamos on Pajarito Road. The site is accessed by taking the second left after the water tower. The pool is about 1.3 mi downstream from the head of Mortandad Canyon. We only netted this site on 6 September 1995.

Pueblo Canyon Waste Facility [2006]: This site is a sewage treatment plant located in Pueblo Canyon. Five sewage ponds, approximately 10 m in diameter are surrounded by turf grass within the facility enclosure. Nets were set over the sidewalks and grass near the tanks. Vegetation surrounding the facility is predominantly ponderosa pine forest. We netted this site on 23 May, 24 July, 14 August, and 5 September 1996. In 1997, we netted here on 29 May, 5 and 14 July, and 11 and 16 August.

Pajarito Wetland [2000]: This site is a small wetland located just south of the Pajarito Canyon Road, about one-half mi west of Route 4. Dominant vegetation species in the wetland include *Salix exigua, Populus* spp., rushes, and sedge species. Tree species in the surrounding forest include *Pinus edulis, Juniperus* spp., and *Juncus interior.* This site is bordered by a burn area to the immediate south and west. We netted this site once on 2 June 1995. It was dry during much of our study.

Pueblo Canyon Effluent [1973]: We netted the stream running from the Pueblo Canyon Waste Facility approximately .25 to .5 mi down from the source. There is a meadow composed of dense grasses surrounding the stream. Tree species in area include *Pinus ponderosa, P. edulis,* and *Juniperus* spp. We netted this site on 24 and 25 April, 21 and 29 May, 27 June, and 10 July 1996. In 1997 we netted here on 29 May and 12 and 13 June.

Los Alamos Canyon County Line Fence [2000]: This site is a stream located in the bottom of Los Alamos Canyon on the border of Los Alamos and Santa Fe counties. Vegetation in the canyon bottom includes *Pinus ponderosa* and various shrub species. We netted this site on 22 July and 28 August 1996.

Los Alamos Canyon - Upper Puddle [1753]: This pond in the lower Los Alamos Canyon road was filled from runoff and was about 3 m by 15 m in size. Surrounding vegetation was mostly *Pinus ponderosa.* We netted this site on 22 July 1996.

Los Alamos Canyon - Otowi Well 4 [1738]: This site is a stream located in lower Los Alamos Canyon east of the Otowi Pump House and reached by driving west of State Road 4 in the canyon. There are a number of Bandelier tuff cliffs to the north, and the surrounding forest is comprised mainly of *Pinus ponderosa* and various shrub species. Sedges and grasses are present along the stream banks. We netted this site on 22 July 1996.

Los Alamos Canyon - Cliffs [2012]: These sites were against cliffs in lower Los Alamos Canyon where we found guano, likely from night-roosting bats, in excavations in the cliff walls. GPS readings were 398311e 3969956n and 388617e, 3970178n. Vegetation consisted of *Pinus edulis* and *Juniperus* spp. We netted here on 27 and 28 August 1996, and on 17 July and 21 and 22 August 1997.

Los Alamos Canyon, Lower [1982]: We netted over several small pools in the bottom of the canyon where the creek bed flattens out and runs through open forest of *Pinus ponderosa.* This location is on USGS White Rock, NM 7.5 min. quadrangle and, like those localities described immediately above, was accessed through a locked gate west off Route 4 in the canyon, about 0.75 mi. south of the intersection of routes 4 and 502, as Route 4 heads south to White Rock.

We netted here on 13 and 19 September 1995. During most of 1996 this site was dry. In 1997 we netted here on 27 May, 11 June, 4, 9, and 14 July, and 9 August.

Rendija Canyon [2012]: This site is an ephemeral pool in a meadow .75 km east of the Sportsman's Club. At time of netting, the pool measured 2.5 m by 10 m. The meadow consists primarily of *Bromus* and *Poa* species. *Pinus ponderosa, P. edulis,* and *Juniper* spp. are the predominant tree species in the canyon. We netted here on 19 June 1997.

Guaje Canyon [1982]: We netted bats over this small, riparian-bordered stream at a point near where it crosses the dirt road leading up the canyon bottom, just past the locked gate. This site is located on USGS Puye, NM 7.5 min. quadrangle (T20N, R7E, Sec 31 SW). Grasses in the surrounding clearings included various *Bromus* and *Poa* species. The predominant tree species are *Pinus ponderosa* and *Quercus gambelii,* with scattered stands of box elder in the canyon bottom along the stream bed. We netted this site on 16 June 1997.

White Rock Sewage Lagoons [1890]: This site is a sewage facility located on the northeast edge of White Rock overlooking White Rock Canyon. Nets were stretched across 2 settling ponds, each measuring approximately 14 meters in diameter. Habitat surrounding the facility is predominantly comprised of *Pinus edulis* and *Juniperus* spp. Steep cliffs drop away to the north and east of the facility and the Rio Grande runs within 1 kilometer of this site. We netted here on 8 June 1997.

Sites at Bandelier National Monument

North Upper Stock Pond (P 7) [2774]: This perennial pond is 100 m directly north of Meadow Pond and is approximately 5 m in diameter and has a depth of 50 cm. Its margins are thickly vegetated with grasses and sedges; this, plus its small size, likely restricts the use only to agile flyers. Grasses and herbaceous plants surrounding the pond and in the meadow include *Agoseris aurantiaca, Allium macropetalum, Arenaria* spp., *Bromus* spp., *Carex* spp., *Danthonia parryi, Geranium caespitosum, Iris missouriensis, Juncus* spp., *Poa* spp., and *Trifolum* spp. Trees and woody perennials surrounding the meadow include *Abies concolor, Juniperus scopulorum, Picea engelmanii, Pinus ponderosa, Populus tremuloides, Pseudotsuga menziesii, Quercus gambelii,* and *Ribes* spp. We netted this site on 8 August 1995.

Upper Stock Pond (P 3) [2765]: This is a perennial stock pond located at the southern base of Cerro Grande in the Upper East Fork of Frijoles Creek where the creek bed opens onto a narrow, sloping meadow north of State Route 4. The site was accessed by following the upper East Fork 0.3 mi. north from where it crosses Route 4 in the northwest extension of BAND. The pond was approximately 8 m by 12 m and at least one meter deep. Grasses and herbaceous plants surrounding the pond and in the meadow included *Agoseris aurantiaca, Allium macropetalum, Arenaria* spp., *Bromus* spp., *Carex* spp., *Danthonia parryi, Geranium caespitosum, Iris missouriensis, Juncus* spp., *Poa* spp., and *Trifolum* spp. Trees and woody perennials surrounding the meadow include *Abies concolor, Juniperus scopulorum, Picea engelmanii, Pinus ponderosa,* *Populus tremuloides, Pseudotsuga menziesii, Quercus gambelii,* and *Ribes* spp. We netted here on 19 July 1995.

Meadow Pond (P 1) [2729]: This large perennial pond is located approximately 200 m northwest of the intersection of State Route 4 and St. Peters Dome Road (Hwy. 289), past the paved parking area. The pond is approximately 30 m by 70 m and is at least one meter deep with a soft muddy bottom. It is located in a large meadow which is surrounded by mixed conifers. Grasses and herbaceous plants surrounding the pond and in the meadow include *Agoseris aurantiaca, Allium macropetalum, Alopecurus aequalis, Bromus* spp., *Carex* spp., *Cercium* spp., *Danthonia parryi, Elymus* spp., *Eragrostis* spp., *Geranium caespitosum, Iris missouriensis, Phleum alpinum, Phleum pratense, Poa* spp., and *Trifolium* spp. Trees and woody perennials surrounding the meadow include *Juniperus scopulorum, Picea engelmanii, Pinus ponderosa, Populus tremuloides, Pseudotsuga menziesii, Quercus gambelii,* and *Ribes* spp. We netted this site on 18 and 20 July and 14 August 1995; 20 May and 15 July 1996; and 4, 17, and 30 June and 15 July 1997.

Ski Trailhead Pond (P 5) [2723]: This is a perennial stock pond 150 m south of the (cross-country) ski trailhead located on the south side of State Route 4, 100 m east of the intersection of State Route 4 and Highway 289. The pond is approximately 10 m by 25 m and is 75 cm deep. The pond faces an open field of *Phleum* spp. to the north and is surrounded by mixed conifer forest on all other sides consisting of *Quercus gambelii, Juniperus scopulorum, Picea engelmannii, Pinus ponderosa, Populus tremuloides, Pseudotsuga menziesii,* and *Ribes* spp. We netted this site on 31 July and 7 August 1995. This site was netted most frequently of all BAND locations during 1996. During 1996 we netted it on 31 May, 6, 10, and 24 June, 15 and 29 July, and 6 September. In 1997 we netted here on 31 May, 23 June, 1, 15, 19, and 23 July.

Dome Road Stock Pond (P 2) [2710]: This is a small stock pond at the headwaters of the upper west fork of Frijoles Creek. It is located about 50 m east of St. Peter's Dome Road (Hwy. 289), and 0.1 mile southwest of the junction of State Route 4 and Highway 289. The pond is formed in a stone basin measuring approximately 5 m by 10 m, and 20 cm deep. The plant community surrounding the pond includes *Picea engelmanii, Pinus flexilis, Pinus ponderosa, Populus tremuloides, Pseudosuga mensiezii, Ribes* spp., and *Quercus gambelii* as well as grasses and annuals. We netted this site on 2 and 16 August 1995 and on 28 May 1997.

Lower Stock Pond - (P 4) [2640]: This is a large pond in the upper East Fork of Frijoles Creek below State Route 4. Access is from the unpaved parking area on the north side of State Route 4, 0.1 mi. southeast of where the upper East Fork of Frijoles Creek crosses State Route 4 in the northwest extension of BAND. The pond is approximately 0.5 mi due south of the parking area on State Route 4. The pond is round, approximately 20 m in diameter, and has a depth of 50 cm. The water level fluctuates considerably here, as the pond margins are usually visible to a distance of 5 m beyond the water's edge. The plant community is a mixed conifer forest consisting of *Quercus gambelii, Juniperus scopulorum, Picea engelmanii, Pseudotsuga menziesii,* and *Ribes* spp. Grasses and herbaceous plants surrounding the pool include *Agoseris* *aurantiaca, Allium macropetalum, Alopecurus aequalis, Arenaria* spp., *Bromus* spp., *Carex* spp., *Elymus* spp., *Geranium caespitosum, Iris missouriensis, Juncus* spp., *Phleum alpinum, Phleum pratense, Poa* spp., and *Trifolium* spp. We netted this site on 19 July and 3 August 1995.

Bandelier Sewage Lagoons (L 1-3) [2012]: The sewage lagoons at Bandelier National Monument are formed by three large pools approximately 30 m by 100 m; pool depths are unknown to us. The lagoons are located on Frijoles Mesa about 0.5 mi south of the Juniper Campground. From the BAND entrance, the lagoons are reached by turning right onto the Juniper Campground road, taking the first left turn, and following the left fork of this road to its end (ca. 0.5 mi). The lagoons have mildly sloping plastic-covered banks that are devoid of vegetation. The dominant plant community surrounding the lagoon is piñon-juniper woodland (*Juniperus monosperma, Juniperus scopulorum,* and *Pinus edulis*). We netted this site on 1 August 1995.

Frijoles Creek at Bandelier Visitor Center [1854]: We netted Frijoles Creek at a point approximately 200 m northwest of the visitor center where it widens for about 20 m to form a flat, gently flowing stream, less than 30 cm deep. Riparian vegetation lines the creek, forming a potential flyway for bats. Trees and woody perennial plants in the canyon include *Acer negundo, Alnus tenuifolia, Betula occidentalis, Pinus ponderosa, Populus angustifolia, Populus fremontii, Ribes* spp., and *Salix scouleriana.* We netted this site on 26 and 27 July, and 17 August 1995; and on 30 May and 15 August 1997.

Frijoles Creek at Rainbow House Crossing [1835]: We netted Frijoles Creek where it widens to form a flat, gentle stretch about 60 m long and less than 30 cm deep. This location is 0.1 mi along the horse trail that descends from the stables at Frijoles Creek. Trees and woody perennial plants within the canyon include *Acer negundo, Alnus tenuifolia, Betula occidentalis, Pinus ponderosa, Populus angustifolia, Populus fremontii, Ribes* spp., and *Salix scouleriana.* We netted this site 9 August 1995; 18, 19 July and 12 August 1996; and 30 May, 6 and 30 June, and 18 July 1997.

Sites Netted on the Santa Fe National Forest

East Fork of Jemez River [2423]: We netted along the East Fork of the Jemez River about 50 m southeast of where it passes beneath State Road 4, south of the Baca land grant. There are two large culverts beneath the highway just west of where we placed nets over the river. Tree species in the surrounding forest include *Pinus ponderosa,* and *Picea engelmanii* and short grasses were prevalent along the open banks. We netted this site on 21 July and 8 August 1996 and on 7, 12, and 24 July 1997.

Las Conchas [2563]: This site is located one mile west of the Las Conchas Campground off of State Road 4, at a point where the river passes beneath the road. We set nets at various points across the river to the north of the road. This site is less than 2 miles east of the site described above and hosts a similar assemblage of plant species. We netted this site on 19 August 1997.

Appendix D. Species accounts of bats known from the Jemez Mountains. Eight of the bat species known to inhabit the Jemez Mountains are former Federal C2 Candidate Species, now referred to as "species of concern." These species are *M. ciliolabrum, M. evotis, M. thysanodes, M. volans, M. yumanensis, E. maculatum, C. townsendii,* and *N. macrotis.* Population trends are unknown for all of these species. However, consensus among researchers is that populations of *C. townsendii* in the west have been declining. The State of New Mexico lists *E. maculatum* as an endangered species, group 2, meaning that its "prospects of survival or recruitment in New Mexico are likely to be in jeopardy within the foreseeable future."

Myotis californicus (California Myotis): California myotis were captured at Frijoles Creek near Rainbow House Crossing, Icehouse Pond, upper Los Alamos Canyon, and the Pueblo Canyon Waste Facility. These sites range between 1753 and 2729 in elevation, but most captures were in low-elevation piñon-juniper habitats. *M. californicus* had the third lowest mean elevation of capture. This species ranks thirteenth in frequency of capture and eighth in distribution across sites. Males were captured at more sites than females during the study period and the average number of males captured during 1995 was higher than in 1996 or 1997. Females were only captured during 1996, but a majority were reproductive indicating that breeding occurs in the Jemez Mountains. Active roosts of this species have not yet been located in the Jemez Mountains (it is too small to carry current radio transmitters), but elsewhere during the summer, these bats are known to inhabit lowland, rocky canyons and roost in trees, rock crevices, and various human-made structures (e.g. bridges, buildings, etc.). During the winter they have been found hibernating in caves, mines, and rock crevices. In some areas of its range this species may be sporadically active during the winter months.

Myotis ciliolabrum (Western Small-footed Myotis): Small-footed myotis were captured at Frijoles Canyon near Rainbow House Crossing and the Bandelier Visitor Center, Icehouse Pond, lower Los Alamos Canyon, Lower Pond, Meadow Pond, Pueblo Canyon, Ski Pond, and at the White Rock Sewage Lagoons. These sites range between 1753 and 2729 meters in elevation. *M. ciliolabrum* had the fourth lowest mean elevation of capture. This species ranks sixth in frequency of capture and fifth in distribution across sites. Males were captured at more sites than females and more bats were captured per night during each successive year of the study. The mean number of females captured per night during 1995 was relatively equal to the mean number captured in 1996, but increased during 1997. A majority of females captured during all years have been reproductive, indicating that breeding occurs in the Jemez Mountains. Active roosts of this species have not yet been located in the Jemez Mountains (it is too small for current radio transmitters), but elsewhere during the summer these bats are known to roost in small rock crevices, in trees, and in various human-made structures. During the winter they have been found hibernating in caves, mines, and rock crevices, usually in small numbers. This is the second most commonly encountered species wintering in abandoned mines in New Mexico (J.S. Altenbach, personal communication).

Myotis evotis (Long-eared Myotis): This species was captured at Dome Pond, the East Fork of the Jemez River, Frijoles Canyon near the Bandelier Visitor Center, Guaje Canyon, Icehouse

Pond, lower Los Alamos Canyon, Lower Pond, Meadow Pond, Mortandad Canyon, North Upper Pond, Pajarito Wetland, Pueblo Canyon Effluent Stream, Ski Pond, and Water Canyon. These sites range between 1753 and 2774 meters in elevation. Long-eared myotis ranked third highest in mean elevation of capture and there appears to be an elevational segregation of sexes (Table 13). Most of these sites are high-elevation mixed conifer forest, yet some are lower-elevation pine forest. This species ranked fourth in frequency of capture and tied *M. thysanodes* for second in distribution across sites. Males were captured at more sites than females and the mean number of both males and females captured per night has decreased each year. This trend may be a result of our increased sampling at lower-elevation sites during 1996 and 1997. A majority of females captured in 1995 were non-reproductive, but this trend reversed in 1996. Again in 1997, a majority of the females captured were female. Of all females captured during the study period, slightly more have been diagnosed as non-reproductive than reproductive. We followed two female and one male *M. evotis* to 10 day roosts. Each bat was followed for 8 days. This species used an average of 3.7 roosts (range 2-5) while we tracked them, with the male moving the most. All females roosted in rock crevices and the male moved between snags and rock crevices. On average, roosts faced southeast. These bats generally roosted near or on the ground ($\bar{x} = 2$ m, range 0-12). This species had the highest average roost elevation and among the lowest average distance traveled from point of capture to first roost. We suspect that most of these bats roosted alone or in small groups, as we never observed emergencies of more than one bat from the same crevice. However, at three roosts we observed other presumed conspecifics roosting alone in rock crevices near the ground within a few meters of the instrumented bats. Elsewhere during the summer, long-eared bats are known to inhabit trees, rock crevices (including rocks and stumps low to the ground), and buildings. During the winter they have been found in mines and caves, but probably hibernate in rock crevices as well.

Myotis thysanodes (Fringed Myotis): Individuals were captured at Dome Pond, East Fork of the Jemez River, Frijoles Creek near the Bandelier Visitor Center and Rainbow House Crossing, Guaje Canyon, Icehouse Pond, upper and lower Los Alamos Canyon, Lower Pond, Meadow Pond, North Upper Pond, Pajarito Wetland, Pueblo Canyon Effluent Stream, and Ski Pond. These sites range between 1753 and 2774 meters in elevation. Fringed myotis had the sixth lowest mean capture elevation. This species ranked seventh in frequency of capture and ranked second, with *M. volans*, in distribution across sites. Females were captured at more sites than males. The mean number of bats captured per night in 1995 was higher than other for both males and females. During 1995 a majority of females were reproductive, while in 1996 the majority were non-reproductive. This trend reversed again in 1997, when a slight majority of captured females appeared reproductive. Overall, more females captured appeared reproductive than non-reproductive. Seven lactating female *M. thysanodes* led us to their daytime retreats (n=8). Instrumented bats were followed an average of 9.7 days (range 3-18). All of these bats roosted in rock crevices and solution pits high on cliff walls. This species had the third highest average roost height (15m, range 9-23) of any species studied. These bats used an average of 1.7 roosts (range 1-2). However, these numbers likely under represent the amount of roost changing that may actually occur. Roosts were difficult to locate precisely, because of the inaccessibility and abundance of cavities. Bats may have been moving between adjacent cavities within a small area, but we were unable to precisely document such movements from a distance. In other areas, reproductive females of this species are known to change roosts, yet remain within a small area on a daily basis (Cryan 1997). Roosts of this species had the lowest average elevation of any species studied. Fringed myotis moved less from point of capture to first roost than most other species and exhibited some of the shortest movements between roosts. Average colony size was 66 bats (range 4-162). On average, roosts faced southeast. Elsewhere during the summer months, this bat is known to form small colonies in rock crevices, caves, mines, trees, and buildings. Colonies in rock crevices are known to change roosts frequently, but usually remain within the same general vicinity. The winter habitat of these bats is virtually unknown. However, physiological evidence suggests that this species may migrate short distances to warmer areas during the winter.

Myotis volans (Long-legged Myotis): This species was captured at Dome Pond, East Fork of the Jemez River, Frijoles Creek near the Bandelier Visitor Center and Rainbow House Crossing, Icehouse Pond, Las Conchas, lower Los Alamos Canyon, Meadow Pond, North Upper Pond, Pueblo Canyon Waste Facility, Ski Pond, and White Rock Sewage Lagoons. These sites range between 1753 and 2774 meters in elevation. *M. volans* had the sixth highest mean elevation of capture. This species ranked fifth in frequency of capture, and fourth in distribution across sites. Males and females were captured at a nearly equal number of sites. The average number of males captured per night each year has steadily declined, while the number of females captured per night was higher and increased dramatically during 1997. No reproductive females were captured in 1995 and only a few were reproductive during 1996. However, during 1997 capture success of females increased and more reproductive female *M. volans* were captured than those diagnosed as non-reproductive. The number of non-reproductive females captured during the entire study period was greater than the number of reproductive females. Half of the non-reproductive females that were captured in 1995 and 1996 were caught after mid-June, so this low reproductive rate in the early years may not entirely be the result of sampling bias. We successfully tracked two lactating and one pregnant female *M. volans* for an average of 5 days (range 4-7). A pregnant female tagged at the Pueblo Canyon Waste Facility in May 1997 was found roosting in houses in Los Alamos; the others used crevices in rock "hoodoos." This species traveled further from point of capture to first roost than all but two other species. Average roost height was 10 meters (range 3-25). Roosts of this species had the second highest average elevation. This pregnant female was the only one to move (<100 m) between roosts while under our observation. The most accurate emergence count for this species was six bats, but up to 50 bats were seen flying from the general area of one of the hoodoo roosts. In addition, we found this species roosting elsewhere on LANL. Three bats were seen roosting beneath a strip of aluminum flashing on the roof edge of a building 40-23 on 11 July 1997. The site was visited again on 16 July 1997, at which time 24 bats were seen in the same spot. One bat was removed from the roost; it was an adult, non-reproductive, female *M. volans*. Elsewhere long-legged bats are known to form summer colonies in rock crevices, trees, and buildings. These bats rarely use caves as day roosts, but frequently use them as night roosts. With the exception of a small population consistently found hibernating in Jewel Cave and records of these bats hibernating in Oregon, very little is known of the winter habits of this species throughout its range.

Myotis yumanensis (Yuma Myotis): Individual Yuma myotis were captured at Dome Pond, Frijoles Creek near Rainbow House Crossing, Meadow Pond, Pueblo Canyon Waste Facility, the Bandelier Sewage Lagoons, and Ski Pond. These sites range between 1835 and 2729 meters in elevation. *M. yumanensis* had the seventh highest mean elevation of capture. This species ranked eleventh in frequency of capture and tied with *T. brasiliensis* for seventh in distribution across sites. Females were captured at more sites than males. The average number of both males and females captured during 1995 was higher than during 1996 or 1997. A majority of the females caught in 1995 and all of the females captured in 1996 were non-reproductive, but they apparently raised young at the Bandelier Cave, based on the carcass of a young of the year found near the visitor center and observations of Bandelier personnel. Low observed reproductive rates may be due to the small sample size of females captured. Active roosts of this species have not yet been located in the Jemez Mountains, but elsewhere during the summer months these bats can be found roosting in caves, mines, buildings, and bridges. Of all the *Myotis* species, this is the most frequently associated with bodies of water. The winter retreats of these bats are unknown.

Lasiurus cinereus (Hoary Bat): Hoary bats were captured at Dome Pond, the East Fork of the Jemez River, Frijoles Creek near Rainbow House Crossing and the Bandelier Visitor Center, Guaje Canyon, Icehouse Pond, lower Los Alamos Canyon, Los Alamos Canyon Reservoir, Meadow Pond, Pueblo Canyon Effluent Stream, Rendija Canyon, and Ski Pond. These sites range between 1753 and 2729 meters in elevation. Hoary bats had the eighth highest mean elevation of capture. This species ranked third in frequency of capture and, with *E. fuscus,* ranked third in distribution across sites. The mean number of males captured per night during 1997 was dramatically higher than in 1995 and 1996. Females were not captured during 1995 and 1996, but in 1997 we captured 7 females, one of which appeared pregnant. Females are probably elsewhere in the species' range. *L. cinereus* roosts are primarily in the foliage of trees and shrubs. They roost alone or in small family groups, usually not exceeding more than 3 or 4 individuals. This species is known to migrate northward in the spring, and during the summer months, adult males are mostly in the western U. S. while females spend the summer in the East giving birth and rearing young (Findley and Jones 1964).

Lasionycteris noctivagans (Silver-haired Bat): Silver-haired bats were captured at Dome Pond, the East Fork of the Jemez River, Frijoles Creek near the Bandelier Visitor Center, Guaje Canyon, Icehouse Pond, Las Conchas, lower Los Alamos Canyon, Lower Pond, Meadow Pond, Pueblo Canyon Effluent Stream, Pueblo Canyon Waste Facility, Rendija Canyon, Ski Pond, and TA-15 Cement Pond. These sites range between 1753 and 2729 meters in elevation, and silver-haired bats ranked second highest in mean elevation of capture. This bat species was captured most frequently and also had the widest distribution across sites. The mean number of bats captured per night increased during each year. All females captured during the study were non-reproductive, but all of these bats were captured early in the season (23 April - 17 June) and may not have been showing signs of pregnancy. Silver-haired bats are considered "tree bats" and are known to roost primarily beneath the bark and in cavities of trees. Studies have shown that maternity colonies are usually found roosting in areas of high snag densities within a forest (Mattson et al. 1996). Sexes segregate geographically during the summer and females are typically found in northern parts of the range. These bats are assumed to be migratory but very little is known about their movements or winter habits. They have been found hibernating in dead trees, buildings, ships, and rock crevices. This species rarely enters mines and caves, although they have been found torpid in cave crevices.

Pipistrellus hesperus (Western Pipistrelle): Western pipistrelles were captured at Frijoles Creek near the Bandelier Visitor Center, the Pueblo Canyon Waste Facility, and along the cliffs of lower Los Alamos Canyon; all captures were males. These sites range between 1829 and 2006 meters in elevation. This species ranked second to last in frequency of capture and was second to last in distribution across sites. This species was not captured during 1995. *P. hesperus* had the second lowest mean capture elevation. Active roosts of this species have not yet been located in the Jemez Mountains (it is too small for transmitters), but elsewhere pipistrelles are commonly found roosting solitarily or in very small groups in rock crevices in areas of abundant, low elevation cliffs and canyons. They are never found roosting in large numbers, and maternity colonies rarely number more than 12. They have also occasionally been found during the day in dense, low lying vegetation and beneath rocks on the ground. *P. hesperus* is known to hibernate in caves, mines, and rock crevices but it also is active during the winter in the Southwest.

Eptesicus fuscus (Big Brown Bat): Big brown bats were captured at Dome Pond, East Fork of Jemez River, Frijoles Creek near the Bandelier Visitor Center and Rainbow House Crossing, Icehouse Pond, lower Los Alamos Canyon, Lower Pond, Meadow Pond, Pueblo Canyon Waste Facility, Rendija Canyon, Ski Pond, and TA-15 Cement Pond. These sites range between 1753 and 2729 meters in elevation. This species ranked second in frequency of capture and third in distribution across sites. Males and females were captured at the same number of sites and the mean numbers of male and female bats increased each year during the study. Reproductive to non-reproductive ratio of females in 1995 was equal, in 1996 there were more reproductive than non-reproductive females, and in 1997 reproductive females far exceeded non-reproductive females. Overall, a majority of the females captured during the study were reproductive. This species had the seventh lowest mean capture elevation and there was a statistical difference in mean elevation between males and reproductive females, with reproductive females being more frequently encountered at lower elevations. The roosts of five female *E. fuscus* (two pregnant, two lactating, and one unknown reproductive status) were found by radio tracking. This species was tracked for an average of 9.3 days (range 3-22). During 1996 and 1997, we radio tagged different pregnant females at the Pueblo Canyon Waste Facility and followed them both to the same large ponderosa pine snag in upper Pueblo Canyon. Use of the same site over two years suggests site fidelity in this species. Another snag roost in Rendija Canyon was used by a female of unknown reproductive status, although we suspect she was pregnant. The two other instrumented females both roosted in the walls or attic of an apartment complex in Los Alamos, located just off a branch of lower Los Alamos Canyon. The average distance traveled by big brown bats from point of capture to first roost ranked fourth highest among species studied. Colony size averaged 39 bats (range 25-51). Big brown bat roosts are also frequently associated with human dwellings and structures. They are known to roost in trees, rock crevices, caves, and mines during the summer. During the winter these bats hibernate in caves, mines, and buildings.

Euderma maculatum (Spotted Bat): Spotted bats were captured at the East Fork of the Jemez River, along the cliff faces in lower Los Alamos Canyon, at Meadow Pond, and Ski Pond. These sites range between 1829 and 2729 meters in elevation. *E. maculatum* had the fourth highest mean capture elevation. These bats ranked twelfth in frequency of capture and tied for second to last in distribution across sites. Though this species was only captured at four sites, its audible calls were heard at nearly every site netted in 1996 and 1997, including areas on LANL and BAND. Earlier research has indicated the presence of this bat at a majority of sites censussed in the western Jemez Mountains (Cryan 1993). A majority of the spotted bats captured during the study period were female. Females captured in 1995 were all reproductive, all captured in 1996 were diagnosed as non-reproductive. However, the 2 captured in 1996 were caught early in the season (6 June) and signs of pregnancy may not have been apparent yet. Both of the adult females captured in 1997 were reproductive. The two juveniles captured in lower Los Alamos Canyon are direct evidence that this species is breeding in the Jemez Mountains. We successfully tracked five *Euderma maculatum* to their roosts. Two lactating females, one male, and two juvenile females were followed for an average of 9.2 days (range 5-14) to an average of 1.6 roosts (range 1-2). All of these bats roosted in rock crevices high on cliff walls. Average height of known roosts was 16 m (range 7-21), and their orientation was southeast. It was difficult to locate some higher roosts, partly due to the occasional tendency of this species to emerge when light levels were inadequate to see, and the highest roosts are not included in this average. The average elevation of *E. maculatum* roosts was the third lowest of all species studied. Individuals of this species that were tagged on the Santa Fe National Forest traveled further from point of capture to first roost (13-17 km) than any other species except *N. macrotis*. One female engaged in nightly foraging bouts that we estimated covered at least 50 km roundtrip distance. Conservative emergence counts averaged six bats (range 1-30), but some colonies may have had greater numbers of bats. At LANL, two juvenile spotted bats were captured in mist nets set along cliffs on the north side of Los Alamos Canyon. These bats roosted in south-facing rock crevices in the same cliff, but always at separate locations in small groups of 4 to 12 individuals. The young changed roost locations frequently and roosts were frequently too high to count the numbers of exiting bats accurately. One roost location used on 25 August was only about 6 m above the ground and housed five individuals. We had the impression that there are other colonies of spotted bats along the canyon as several times we saw small, cohesive groups of spotted bats flying down-canyon towards the Rio Grande.

Corynorhinus townsendii (Townsend's Big-eared Bat): Townsend's big-eared bats were captured at Icehouse Pond, lower Los Alamos Canyon, North Upper Pond, and Pueblo Canyon Effluent Stream. These sites range between 1753 and 2774 meters in elevation. This species had the fifth lowest mean capture elevation. Big-eared bats ranked last in frequency of capture and second to last in distribution across sites. Both *C. townsendii* captured in 1995 were reproductive females and the five captured in 1996 and 1997 were male. Although this species is not found in abundance anywhere within its range, big-eared bats are perhaps the most commonly encountered bat in surveys of caves and mines in western North America. We tracked two male *C. townsendii* for an average of 10.5 days (range 6-15). Both bats roosted in cavities within rock walls close to the ground. These bats were captured in harp traps at night roosts in lower Los Alamos Canyon and both flew very short distances to their initial day roosts. However, one of these males later flew from lower Los Alamos Canyon to a roost in upper Pueblo Canyon, a distance of 1.4 km. Both bats apparently roosted alone. Elsewhere in its range, this species is extremely intolerant of disturbance in the roosts and often abandons a site after such disturbance. These bats have not been found entering crevices and are typically seen roosting on exposed ceiling surfaces of caves and mines. With the exception of arid regions, they have been occasionally found roosting in undisturbed buildings during the summer.

Antrozous pallidus (Pallid Bat): Pallid bats were captured at Frijoles Creek near the Bandelier Visitor Center and Rainbow House Crossing, at various sites in lower Los Alamos Canyon, Pueblo Canyon Effluent Stream, and the Bandelier Sewage Lagoons. These sites range between 1738 and 2012 meters in elevation and are predominantly low elevation piñon pine-juniper habitat. Pallid bats had the lowest mean capture elevation of any species studied. This species ranked eighth in frequency of capture and sixth in distribution across sites. Males were captured at more sites than females, and the mean number of bats captured per night was greatest during 1996. All females captured in 1995 were reproductive, yet no females of this species were captured during 1996. One lactating female and two juveniles were captured during 1997. We followed two male and one lactating female *A. pallidus* for an average of 12.7 days (range 11-15). These bats roosted in crevices on cliff faces, except on one occasion when a male was found in the ceiling of a small cave. Pallid bats used an average of 3 roosts (range 2-4) while we followed them. Roosts averaged 13 m (range 1-20) in height and typically faced south. This species had the second lowest capture elevation and exhibited a narrower elevational range than any other species. Movements of *A. pallidus* from capture to first roost and movements between roosts were among the shortest. Colony sizes were small, ranging from 1 to 12 individuals. The tagged female roosted in a small group that appeared to be a nursery colony. An exit count at her main roosting area on 16 July numbered four bats, but on 30 July the count increased to 12, concordant with an increase that might be expected once young became volant. We found this species roosting in rock crevices, and one such roost site was a small maternity colony located in lower Los Alamos Canyon. Numerous recently used pallid bat night roosts were discovered in cavettes formed by ancient Indians in Pueblo and Los Alamos Canyons. Maternity colonies typically range in size from approximately 12-200 individuals and frequently change roost locations, possibly in order to maximize thermal efficiency. Winter habits are unknown though some researchers have suggested that they remain within the general summer range, but may make short migrations between summer and winter roosts. In some desert areas, Pallid bats may arouse from hibernation to forage on warm winter nights.

Tadarida brasiliensis (Brazilian Free-tailed Bat): Individuals were captured at Frijoles Creek near the Bandelier Visitor Center, Icehouse Pond, Lower Pond, Meadow pond, the Bandelier Sewage Lagoons, and Ski Pond. These sites range between 1854 and 2729 meters in elevation. This species had the highest mean elevation of capture for any species studied. Free-tailed bats ranked tenth in frequency of capture and tied for seventh in distribution across sites. Females have been captured at more sites than males. The mean number of this species captured during 1995 was higher than in 1996 or 1997. All females captured during 1995 and 1997 were reproductive, yet no females were captured during 1996. These bats form colonies of great numbers in caves throughout southwestern North America. A large, well-known maternity colony of several thousand Brazilian free-tailed bats was active at Bandelier National Monument. Several previously used but inactive diurnal roosts likely attributed to this species were discovered in rock crevices in cliffs along Pueblo Canyon. One of these housed 540 bats in late August 1996, presumably migrants in transit, and was used briefly in late spring 1997. Elsewhere, colony size can range from a few individuals to 20 million or more. Colonies are also known from buildings and bridges. During the winter months some individuals remain in the summer range, while most migrate long distances to warmer latitudes.

Nyctinomops macrotis (Big Free-tailed Bat): Big free-tailed bats were captured at the East Fork of the Jemez River and Meadow Pond. These sites range between 2423 and 2729 meters in elevation and are ponderosa pine-mixed conifer habitats. This species had the fourth highest mean elevation of capture. Big free-tailed bats ranked ninth in frequency of capture and were captured at fewer sites than any other species. Males were not captured during the study. Females were not captured in 1995, but were in 1996 and 1997. A majority of the females captured have been female. The roosts of four lactating female *N. macrotis* were located during the summer of 1997. In addition, we found another roost occupied by this species near one of the roosts used by a marked bat. Bats were tracked for an average of 5.3 days (range 1-8). All of these bats roosted in crevices high on cliff faces and the roosts were higher, on average, than those of any other species studied. Roosts generally faced south and east. On one occasion, a marked bat changed roosts, but others apparently remained in the same locations during the time we followed them. These bats flew farther from initial point of capture to first roost than any other species studied. The average distance from point of capture to first roost was 18.2 km. The longest recorded distance of travel on a single night was 30 km, while the shortest distance was 11 km. Average colony size was 100 (range 6-220) bats, based on conservative counts. However, a colony in San Diego Canyon that was observed on several occasions most likely numbers far more than 220 individuals. Very little is known about the natural history or roosting habits of this species. There have been no published reports of known roost locations in the United States for more than 20 years, and the sites we discovered in the Jemez Mountains are the only recently known breeding colonies of which we are aware. The winter habits are unknown, though this species is believed to migrate long distances.

Appendix E. Characteristics and locations of roosts found by radio tracking

Species	Sex	Rep..	Roost Type	Elevation (m)	Orientation (degrees)	Height (m) aboveground	Width (mm)	Distance (km) from previous site	Distance (km) from previous location	Other Bats	Location
M. evotis	M	NSC	snag	2500	60	6.00	*	-	1.00	0	
M. evotis	M	NSC	rock crevice	2494	100	4.00	25	0.15	-	0	
M. evotis	M	NSC	snag	1585	60	12.00	*	0.15	-	0	
M. evotis	M	NSC	rock crevice	2494	110	0.25	30	0.10	-	0	
M. evotis	M	NSC	rock crevice	2500	220	1.00	35	0.35	-	0	
M. evotis	F	UNK	rock crevice	2402	90	0.50	15	-	0.25	0	
M. evotis	F	UNK	rock crevice	2396	150	0.00	15	35.00	-	0	
M. evotis	F	UNK	rock crevice	2393	120	0.00	30	0.03	-	0	
M. evotis	F	UNK	rock crevice	2405	110	0.00	25	0.05	-	0	
M. evotis	F	LAC	rock crevice	2542	215	0.00	*	15.20	-	0	13 378166, 3973347
M. thysanodes	F	LAC	rock crevice	1845	180	15.00	*	-	0.25	3	
M. thysanodes	F	LAC	rock crevice	1848	180	15.00	*	-	0.25	*	
M. thysanodes	F	LAC	rock crevice	1835	180	15.00	*	-	0.25	*	
M. thysanodes	F	LAC	rock crevice	2439	85	10.00	*	-	3.52	128	13 372999, 3963797
M. thysanodes	F	LAC	rock crevice	1860	95	>10.00	*	-	0.50	27	13 385300, 3959350
M. thysanodes	F	LAC	rock crevice	1860	50	>10.00	*	0.10	-	*	13 385310, 3959330
M. thysanodes	F	LAC	rock crevice	2195	170	23.00	40	-	6.88	13	13 376150, 3964296
M. thysanodes	F	LAC	rock crevice	2195	180	9.00	10	0.20	-	161	13 376197, 3964551
M. volans	F	PRG	building	2195	*	5.00	50	-	4.50	*	13 385010, 3973595
M. volans	F	PRG	building	2195	220	5.00	*	0.10	-	*	13 385010, 3973495
M. volans	F	LAC	rock crevice	2378	45	25.00	*	-	6.00	5	13 373025, 3964050
M. volans	F	LAC	rock crevice	2311	*	3.00	*	-	9.30	5	13 374734, 3958041
E. fuscus	F	UNK	snag	2095	0	15.00	*	-	1.00	33	
E. fuscus	F	PRG	building	2201	350	4.00	20	-	4.80	46	13 383490, 3971110
E. fuscus	F	LAC	snag	2095	0	15.00	*	-	1.00	25	
E. fuscus	F	PRG	building	2201	350	4.00	20	-	4.80	51	13 383500, 3971110
E. maculatum	F	LAC	rock crevice	2056	105	20.00	40	-	17.60	14	13 344927, 3957356
E. maculatum	F	LAC	rock crevice	2226	60	14.00	30	-	13.60	6	13 345706, 3959575
E. maculatum	F	LAC	rock crevice	2053	90	21.00	50	0.80	-	15-30	13 345248, 3958416
E. maculatum	M	NSC	rock crevice	2287	225	>10.00	*	-	8.80	0	
E. maculatum	F	JUV	rock crevice	2005	190	>10.00	*	-	0.01	4-12	13 389579, 3969673
E. maculatum	F	JUV	rock crevice	2060	188	7.00	*	0.01	-	0	13 389318, 3969790

Appendix E. (Cont.)

Species	Sex	Rep.	Roost Type	Elevation (m)	Orientation (degrees)	Height (m) aboveground	Width (mm)	Distance (km) from previous site	Distance (km) from previous location	Other Bats	Location
E. maculatum	F	JUV	rock crevice	2047	180	>10.00	*	-	0.01	9	13 388986, 396981[illegible]
E. maculatum	F	JUV	rock crevice	2050	175	>10.00	*	0.50	-	*	13 396950, 3889200
C. townsendii	M	NSC	rock cavity	2175	180	4.00	330	-	1.00	0	13 382699, 3972236
C. townsendii	M	NSC	cavette	2016	190	3.00	800	-	0.10	0	13 388616, 3970189
C. townsendii	M	NSC	rock cavity	2043	350	0.10	*	1.40	-	*	13 389900, 3969871
A. pallidus	M	NSC	rock crevice	2165	180	20.00	*	-	1.00	0	
A. pallidus	M	NSC	rock crevice	2165	185	20.00	*	0.70	-	0	
A. pallidus	M	NSC	rock crevice	2165	180	15.00	50	0.10	-	0	
A. pallidus	F	LAC	rock crevice	2026	165	20.00	*	-	0.50	5	13 387598, 3969759
A. pallidus	F	LAC	rock crevice	2026	180	5.00	*	0.05	-	*	13 387598, 3999579
A. pallidus	M	NSC	rock crevice	2012	175	15.00	*	-	0.20	*	
A. pallidus	M	NSC	rock crevice	2027	185	14.00	*	0.30	-	*	
A. pallidus	M	NSC	cavette	2016	185	1.00	1350	0.30	-	0	13 388616, 3970189
A. pallidus	M	NSC	rock crevice	2012	190	10.00	*	0.40	-	*	
N. macrotis	F	LAC	rock crevice	2104	85	30.00	*	0.50	-	*	13 344420, 3956128
N. macrotis	F	LAC	rock crevice	2311	185	15.00	10	-	11.00	48	13 377950, 3960288
N. macrotis	*	FOUND	rock crevice	2311	115	12.00	*	-	-	43	13 377950, 3960288
N. macrotis	F	LAC	rock crevice	2100	90	35.00	50-300	-	30.00	>220	
N. macrotis	F	LAC	rock crevice	1921	220	9.00	40	-	13.60	5	13 377950, 3960288

Appendix F. Descriptions and locations of roosts found by visual search.

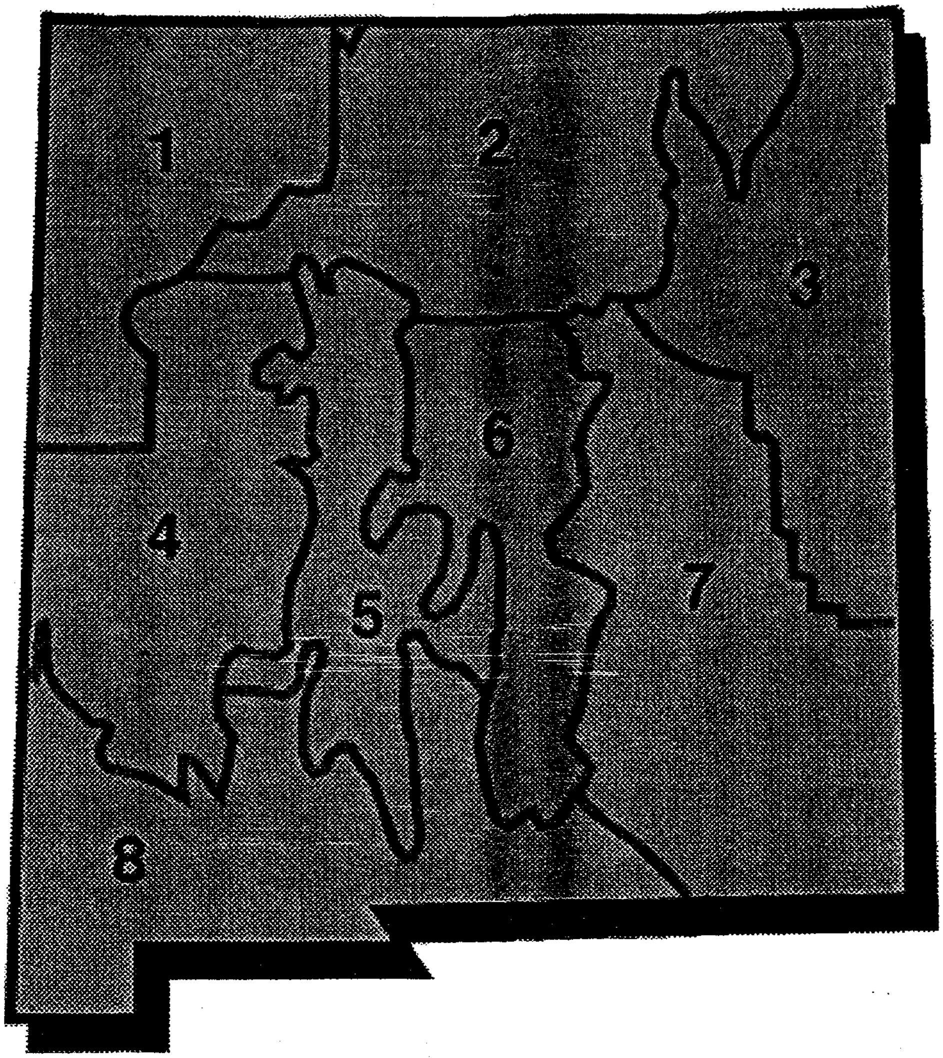
Characteristics of Roost	General Location	Date Observed	UTM Coordinates (elevation)
Large, inactive diurnal roost in vertical crevice overhang, significant guano accumulations, roost area with odor of free-tailed bats	Pueblo Canyon, Otowi Mesa, south-facing cliff, SW ¼ of Section 7, T 89E, R 70N	27-Jun-96	NT
Inactive, diurnal roost in bowl-shaped depression in mesa, open grotto 2 m above cliff base. About 1000 c.c. accumulation of small droppings, probably less than 1 year old	Pueblo Canyon, unnamed south-facing cliff, NE ¼ of Section 17, T 89E, R 70N	26-Jun-96	NT
Transient diurnal roosts (3), *Myotis*-sized droppings, near and inside grottos	Pueblo Canyon, west end of unnamed mesa, south-facing cliff, NW ¼ of Section 17, T 89E, R 70N	26-Jun-96	NT
Night roosts (3), *Antrozous*-sized droppings	Pueblo Canyon, west end of unnamed mesa, south-facing cliff, NW ¼ of Section 17, T 89E, R 70N	26-Jun-96	NT
Night roosts (2), *Antrozous*-sized droppings	Pueblo Canyon, Otowi Mesa, south-facing cliff, NE ¼ of Section 18, T 89E, R 70N	27-Jun-96	NT
Transient diurnal roosts (3), including *Myotis*-sized droppings	Pueblo Canyon, Otowi Mesa, south-facing cliff, NE ¼ of Section 18, T 89E, R 70N	27-June-96	NT
Inactive, diurnal roost in bowl-shaped depression in grotto, medium sized, older droppings	Pueblo Canyon, Otowi Mesa, south-facing cliff, SW ¼ of Section 7, T 89E, R 70N	27-Jun-96	

Appendix F. (Cont.)

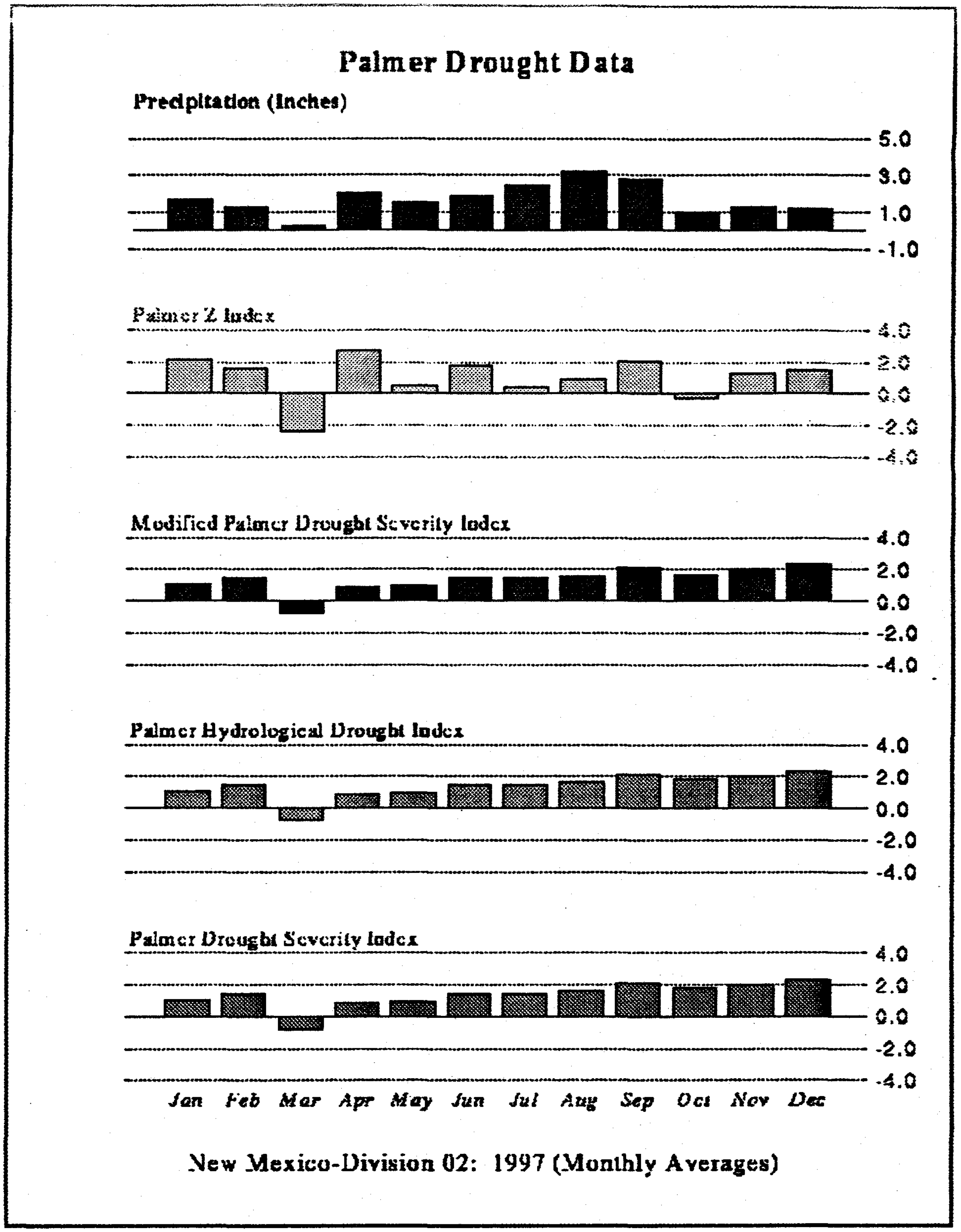
Characteristics of Roost	General Location	Date Observed	UTMCoordinates (elevation)
Small, cylindrical chute (7-10 cm diameter) in vertical cliff, 3 m above cliff base. About 100 *Myotis*-sized pellets. Very recently used diurnal roost	Pueblo Canyon, Kwage Mesa, south-facing cliffs	26-Aug-96	13 386403, S 3971817 (2068 m)
Diurnal roost, large vertical crevice about 10 m above tuff layer, numerous scattered *Tadarida*-sized pellets at base of cliff	Pueblo Canyon, Kwage Mesa, south-facing cliffs	26-Aug-96	NT
Diurnal roost, large vertical chute, about 40 m above cliff base, numerous scattered *Tadarida*-sized pellets at base of cliff	Pueblo Canyon, Kwage Mesa, south-facing cliffs	26-Aug-96	13 386830, S 3971734 (2052 m)
Night roosts (3), one with *Antrozous*-sized droppings, two smaller, in group of about 12 grottos, fresh for 1996	Pueblo Canyon, Kwage Mesa, south-facing cliffs	28-Aug-96	13 387059, S 3971661 (2052 m)
Active diurnal roost, 540 *Tadarida* counted at emergence. Large, double vertical chutes about 40 m above cliff base	Pueblo Canyon, Kwage Mesa, west end, south-facing cliffs	28-Aug-96	13 387332, S 3971573 (2046 m)
Night roost with numerous *Antrozous*-sized droppings	Lower Los Alamos Canyon, south-facing cliffs, NW ¼ of Section 20, T 19N, R 7E	27-Aug-96	12 389524, 5 3969883 (1999 m)
Night roost with numerous *Antrozous*-sized droppings	Lower Los Alamos Canyon, south-facing cliffs, NW ¼ of Section 20, T 19N, R 7E	27-Aug-96	13 389475, S 3969892 (1991 m)

Appendix F. (Cont.)

Characteristics of Roost	General Location	Date Observed	UTM Coordinates (elevation)
Night roost with *Antrozous*-sized droppings, culled sphingid moth wings	Lower Los Alamos Canyon south-facing cliffs, NW ¼ of Section 20, T 19N, R 7E	27-Aug-96	13 389311, S 3969956 (2013 m)
Diurnal roost, vertical crevice about 8 m above cliff base, *Antrozous*-sized droppings	Lower Los Alamos Canyon south facing cliffs, NW ¼ of Section 20, T 19N, R 7E	27-Aug-96	13 388905, S 3970038 (2019 m)
Night roost in grotto with two internal vertical chutes, pellet size range indicates use by several species, including *Antrozous*. Verified active by net capture of *Antrozous* entering at night	Lower Los Alamos Canyon, south-facing cliffs. NE ¼ of Section 19, T 19N, R 7E	28-Aug-96	13 388617, S 3970178 (2006 m)



Appendix G. Climatic data for the Jemez Mountains, New Mexico.



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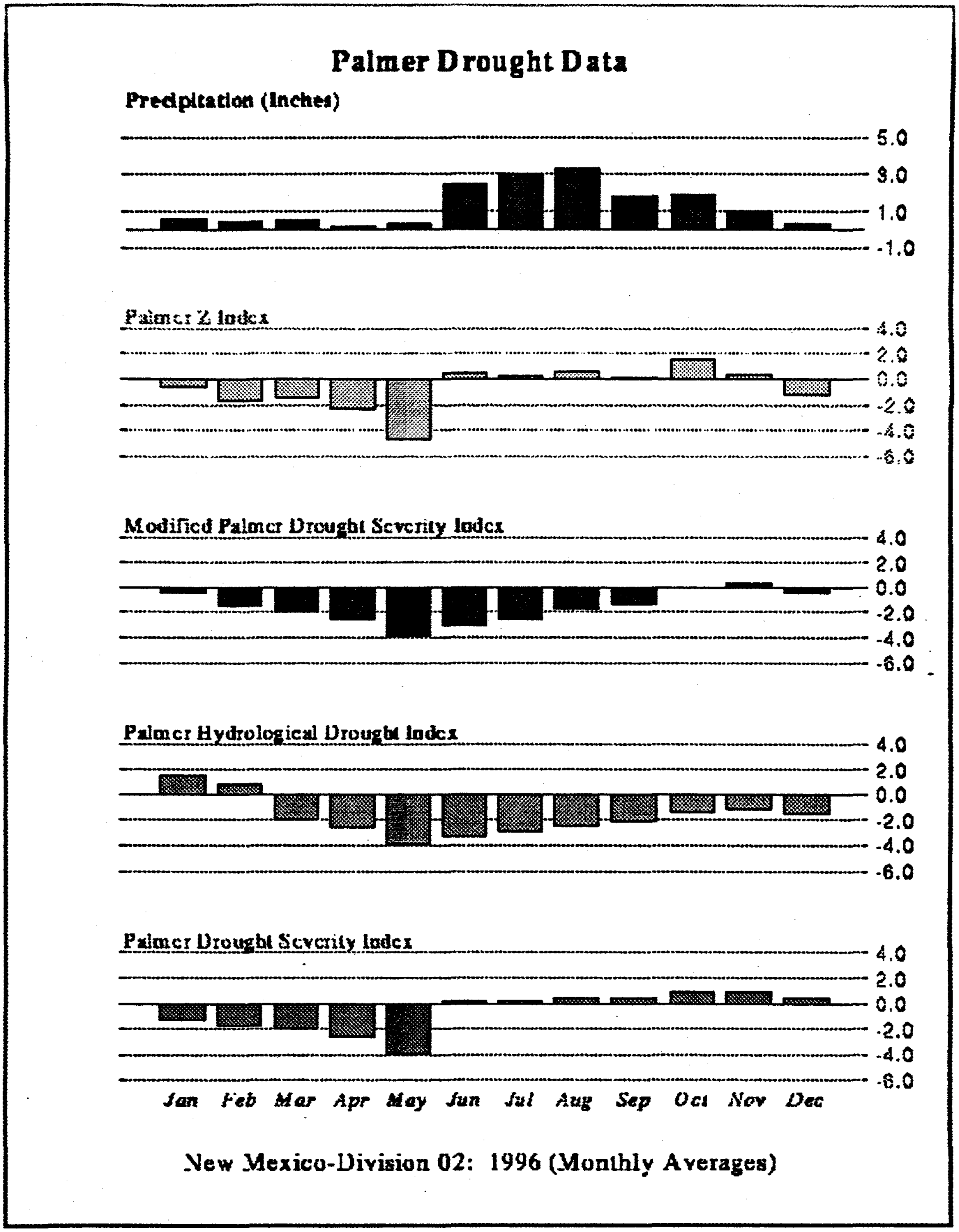

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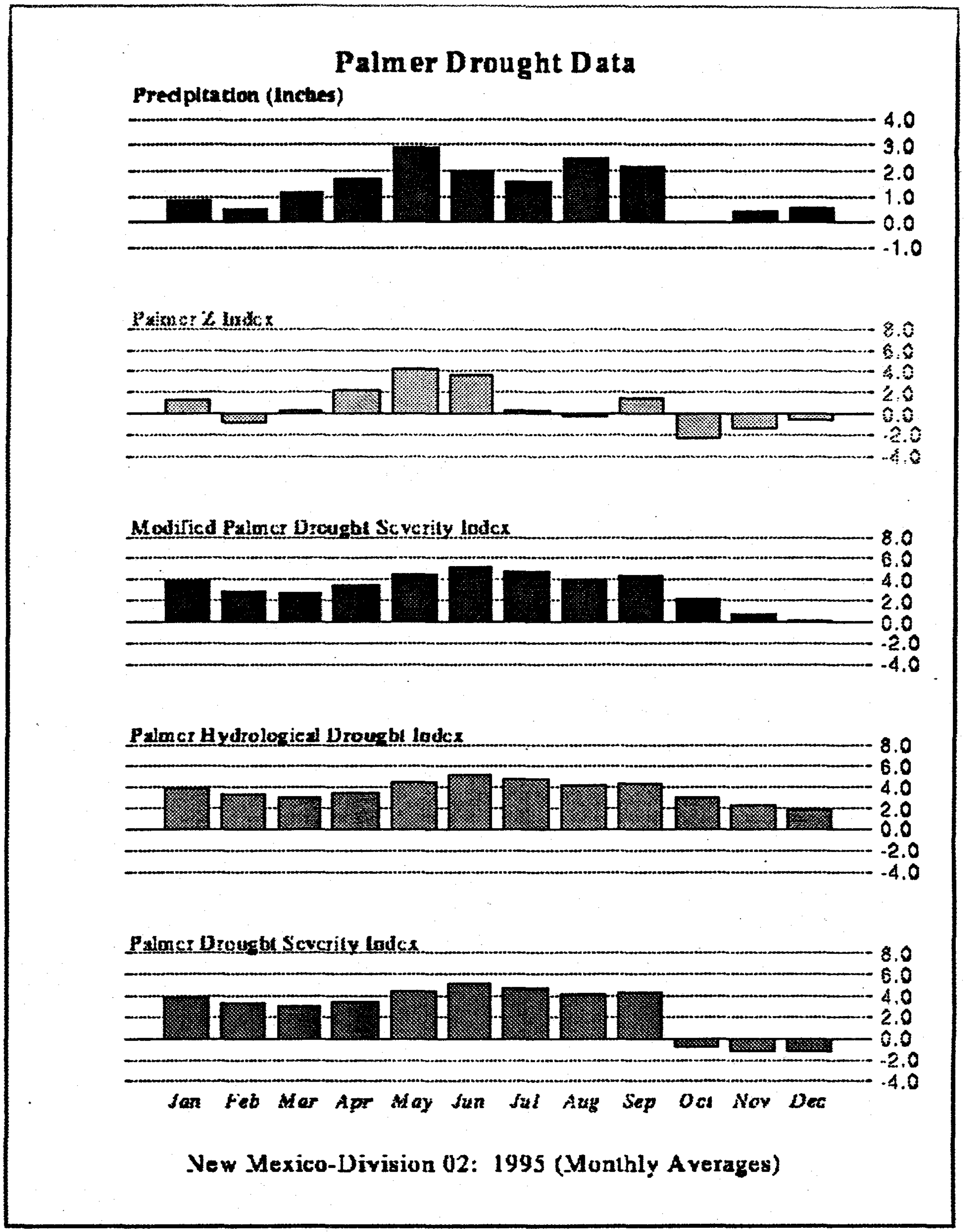

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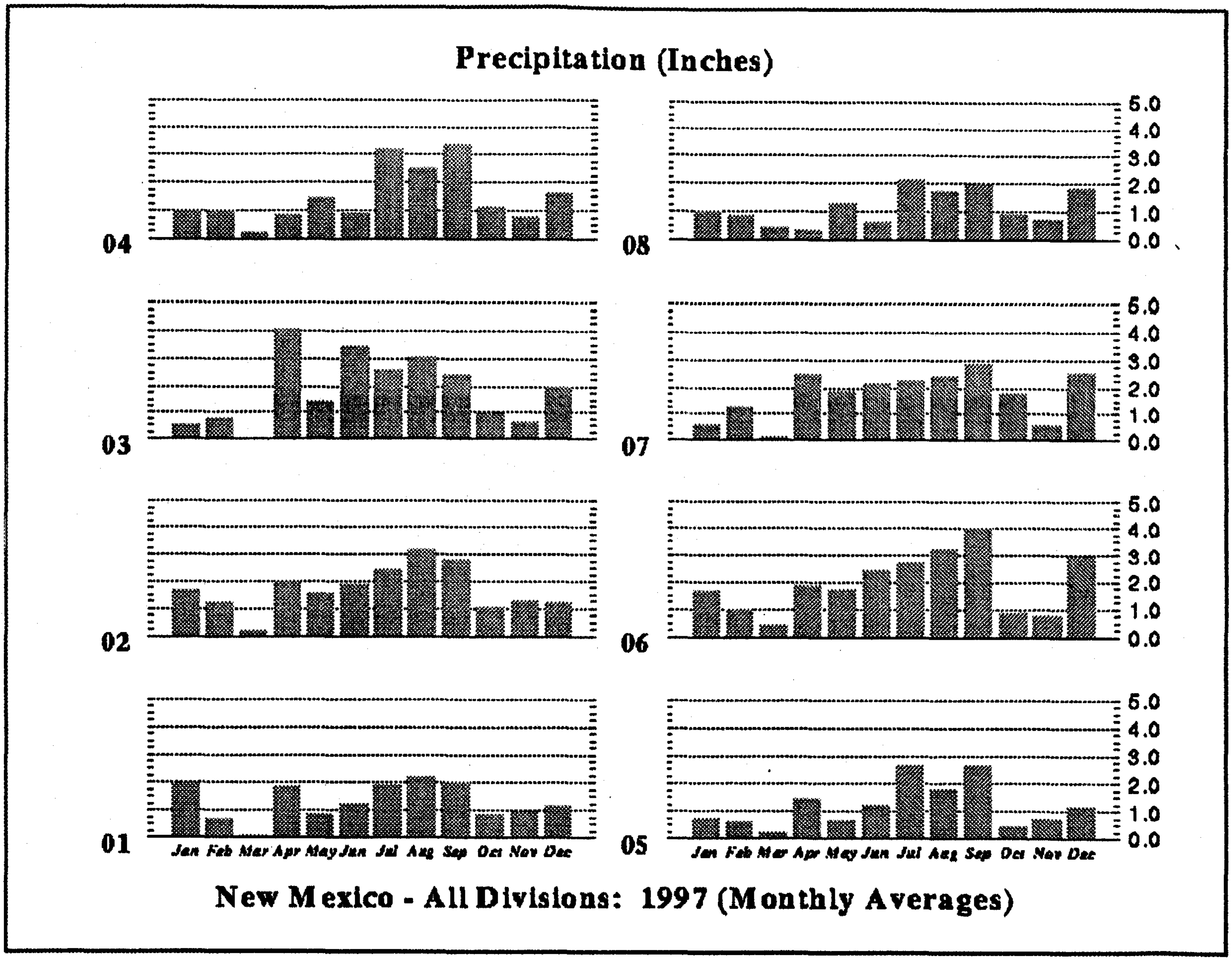

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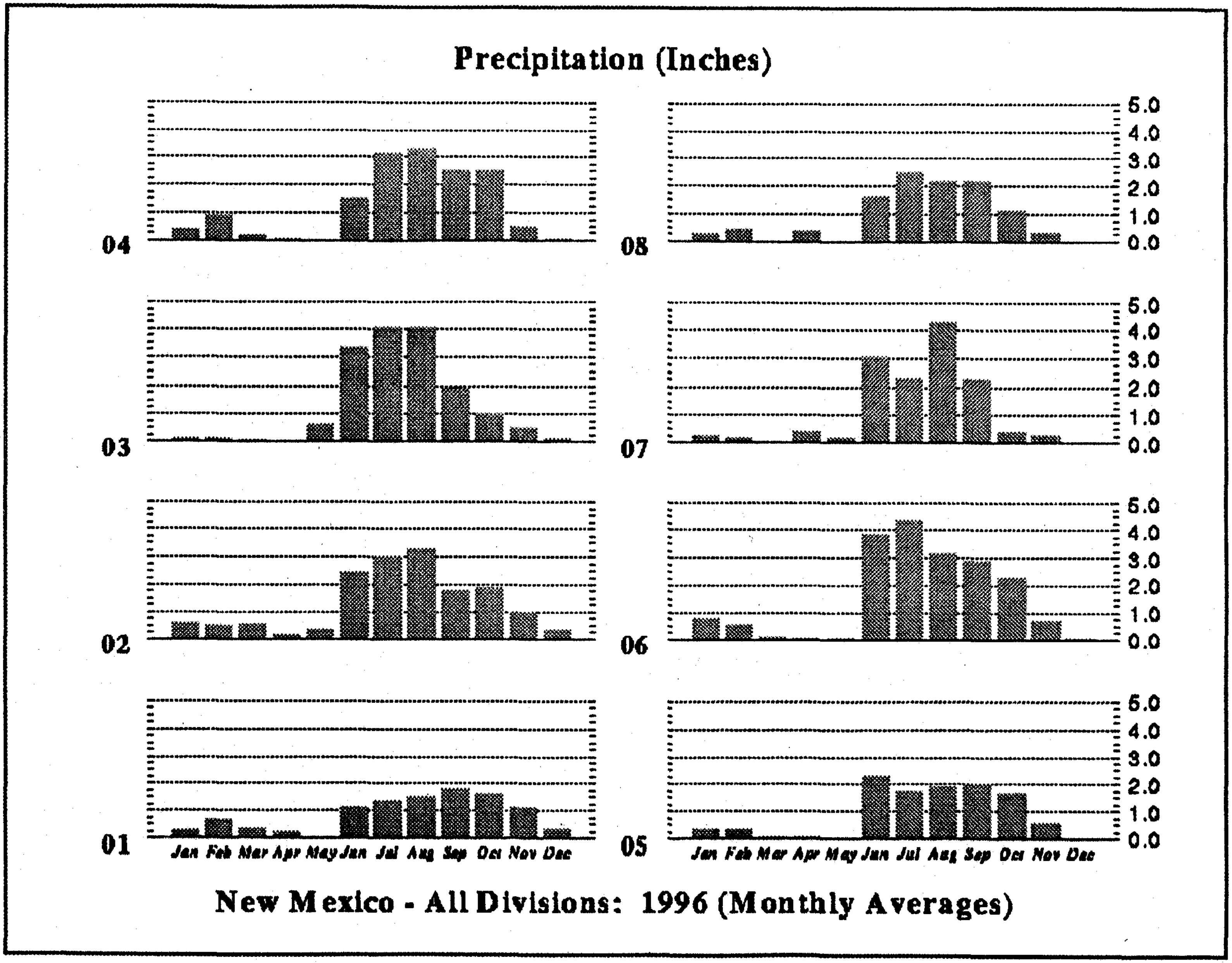

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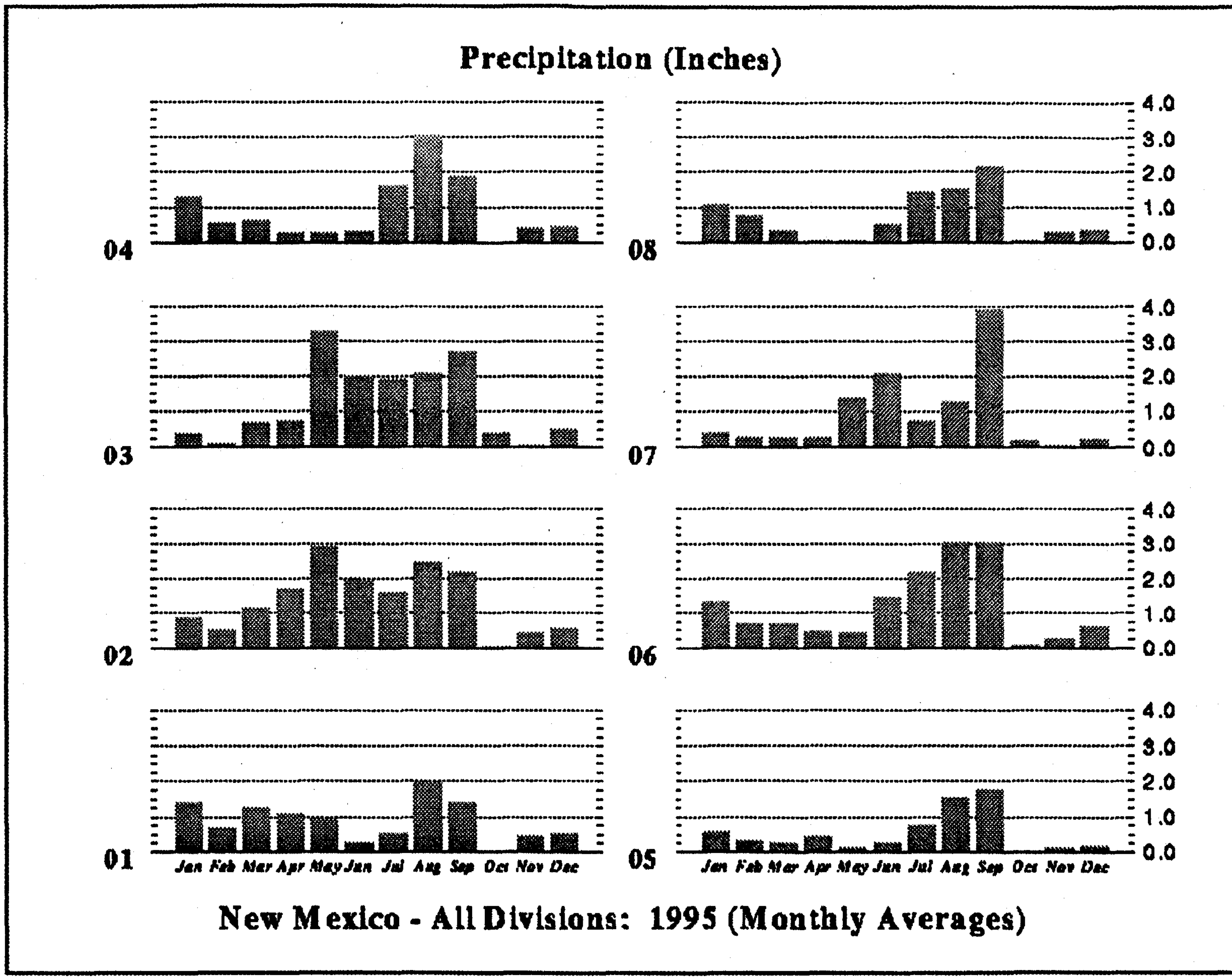

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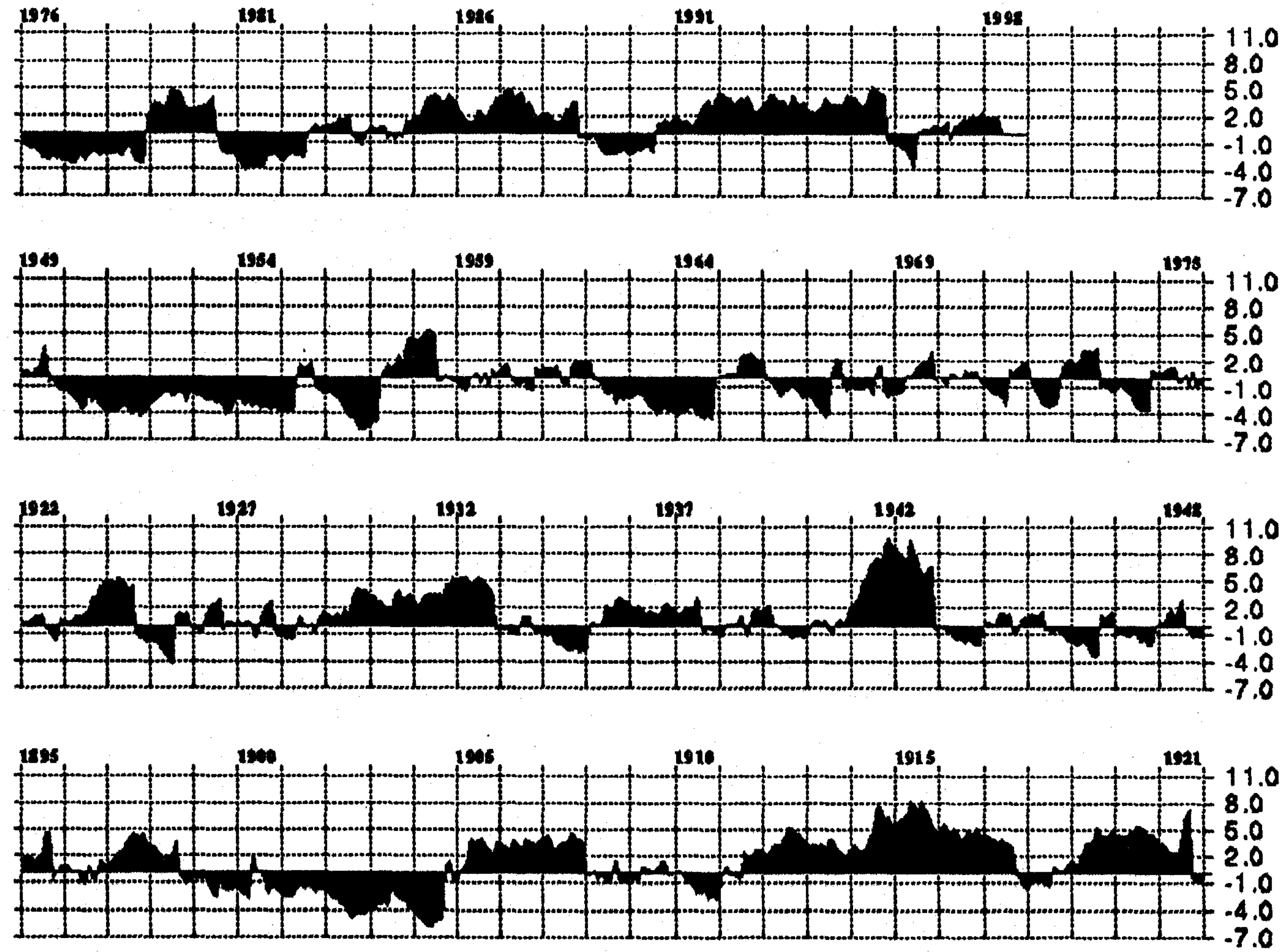
Palmer Drought Severity Index



New Mexico - Division 02: 1895-1998 (Monthly Averages)

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