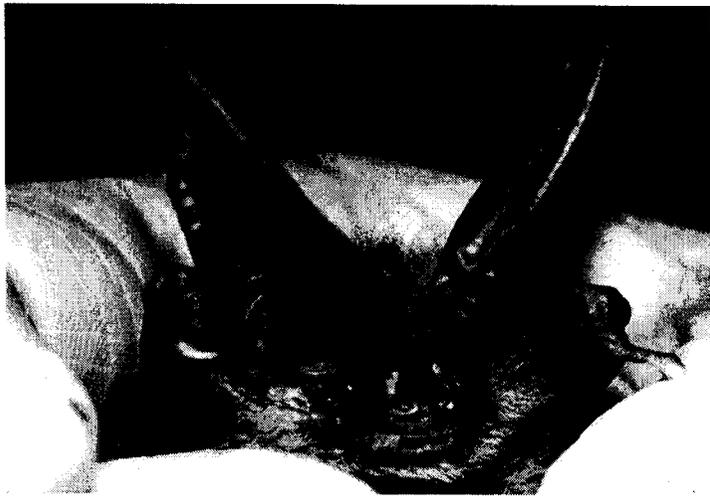


Seasonal Patterns of Bat Distribution along an Altitudinal Gradient in the Sierra Nevada

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EXECUTIVE SUMMARY

The bat species assemblage was investigated along an elevational gradient in the Sierra Nevada, from the floor of the Central Valley to Tioga Pass in Yosemite National Park, following the State Route 120/Tioga Road corridor. Using three survey methods -- bridge roost, acoustic, and to a limited extent, mist-netting surveys -- we documented seventeen species as occurring on the western slope of the central Sierra Nevada, and provided the first records of silver-haired bats (*Lasiurus noctivagans*), red bats (*Lasiurus blossevillii*) and the long-legged myotis (*Myotis volans*) for Yosemite National Park. By examining distribution at approximately 1,000 m intervals, we detected 14 species below 1,000 m, 17 species in the range between 1,000 and 2,000 m (all occurring within Yosemite National Park), and 14 species above 2,000 m. The greatest diversity was observed in the mid-elevation range where high and low elevation species overlap.

Thirteen of the seventeen bat species that occur in Yosemite National Park and/or vicinity have been documented using bridge roosts somewhere in their range. Twelve were identified using bridges in this study. Ten used bridges as night roosts; seven were also found roosting in the day during the summer; four used bridges as maternity sites; four species, including two not found on bridges in the summer, were found day-roosting in the winter. There were both seasonal and elevational differences in patterns of bridge use. Bridges were used most heavily in the summer at lower elevation where the difference between bridge temperature and ambient was greater, and where, outside the park, less natural roosting habitat (e.g., fractured rock cliffs and large diameter defective trees) was available. Also, there tend to be notable differences between structural features used as day roosts and those used as night roosts, with day roosts, in general, being more cryptic.

Acoustic surveys were conducted at eleven monitoring stations along the elevational gradient, generally in association with monitored bridge sites. Sixteen species were identified acoustically. The maximum number of species detected at one site was fourteen at one mid-elevation site. The highest elevation site yielded seven species. Bat activity (as measured in number of acoustic files obtained per minute over the sampling period) was high at low and mid-elevation sites from June through October, and from July through September at high elevation sites. Acoustic activity was higher at sites associated with flowing water, relative to terrestrial sites (or lakes and ponds).

Bridge roost and acoustic surveys were complementary techniques, with acoustic surveys documenting some species not found under the bridges, and some bats found under the bridges clarifying identification or revealing species not detected acoustically.

All seventeen species documented for the area were captured at least once. Of the thirteen species shown to have reproductive populations, most appeared to be concentrated at low to mid-elevations, with only *Myotis lucifugus* encountered only at higher elevations.

When considering the results of all survey methods, *Myotis yumanensis*, *Tadarida brasiliensis*, *Eptesicus fuscus* and *Myotis californicus* were the most commonly detected taxa; *Corynorhinus townsendii*, *Lasiurus blossevillii*, *Myotis thysanodes*, *Myotis volans*, and *Pipistrellus hesperus* were localized or everywhere uncommon. *Myotis lucifugus*, while locally common at higher elevation, may be genetically distinct from other populations currently presumed to belong to the same subspecies.

The documented importance of bridge roosts, and the striking elevational and seasonal patterns to bat distribution suggest that bat populations would benefit from cooperative management strategies among the agencies (Caltrans, the Park Service and the Forest Service).

While recommended conservation actions would vary from species to species, all conservation strategies should include the following objectives: to investigate species specific, regional roosting requirements; to evaluate availability of species specific roosting habitat (e.g., large diameter snags, caves, cliffs, abandoned mines, bridges and/or other human structures); protect and share information regarding known roosts or roosting areas; identify important foraging areas; protect known foraging areas, particularly in riparian zones and meadows; and support riparian restoration efforts.

Priorities for future research include: determining the elevational limits for breeding populations, investigating the roosting requirements for species that raise their young in the Sierra Nevada, and investigating the apparent upslope fall migration of certain species.

1.0 INTRODUCTION

1.1. Project Goals

This study examined seasonal distribution of bat species along an altitudinal transect in the central Sierra Nevada, using State Route 120/Tioga Road as the primary survey corridor. This highway originates in the Central Valley at 12 m, crosses the Sierra Nevada, reaching 3,031 m at Tioga Pass, and then continues east to the Nevada border. It traverses both the Stanislaus National Forest and Yosemite National Park.

Support from the California Department of Transportation, the California State University at Sacramento (CSUS) Foundation, the Yosemite Association, and the Yosemite Fund allowed us to address the following tasks simultaneously:

- 1) examine the seasonal distribution of bat species along an altitude gradient in the central Sierra Nevada;
- 2) document and evaluate significance of bridge roosts used by bats along this gradient;
- 3) evaluate potential impacts to bat populations from proposed highway modifications along Route 120;
- 4) compare the results of two bat survey methods (bridge surveys and acoustic surveys) by implementing them in parallel;
- 5) conduct a pilot molecular genetic survey comparing morphologically distinctive *Myotis lucifugus* found at high elevation in the Sierra Nevada with a northern California population of *M. lucifugus* and outgroup samples to preliminarily assess the level of genetic differentiation;
- 6) to consider ways that coordination among agencies (Park Service, Forest Service, and Caltrans) could enhance management of bat populations in this region.

1.2. Roosting Ecology: Bats and Bridges

Bats use a wide variety of roost sites, which, for North American species, fall into three partly overlapping categories: crevices, cavities, and foliage. In natural settings, cavity roosting species aggregate on open surfaces inside darkened chambers, such as caves or large tree hollows; crevice roosting species occupy a variety of "slots" -- rock crevices, exfoliating tree bark, rotting wood in snags (Barclay and Brigham 1996, Fenton 1983, Kunz 1982). While some species appear to be obligate cavity or crevice dwellers, there is a continuum between crevices and cavities, and many species use both types of roosts. With the exception of a few foliage roosting species, most North American bat species also use cave-like spaces and/or crevices in man-made structures, such as old mine workings, tunnels, buildings, and bridges.

Although bridge roosting by bats has been recognized for some time (Barbour and Davis 1969, Constantine 1961, Davis and Cockrum 1963, Stager 1943), it is only recently that this issue has received focused research attention, and that the significance of these sites has begun to be appreciated (Adam and Hayes 2000, Billington and Norman 1997, Erickson et al. 2000, Perlmeier 1996, Pierson et al. 1996).

Bridges are used as both day roosts and night roosts, although night roosting is more common. Different bridge structural features are often used for these two types of roosts. Day

roosts occur primarily in elevated crevices or poorly illuminated larger cavities, where daily fluctuations in air temperature are buffered, and the space offers some protection from predators, disturbance, rain and wind. One of the most common locations is an expansion joint that has lost its packing. Flying bats can enter from below, and are out of reach of common terrestrial predators (e.g., snakes, skunks). During the late spring through the early fall, the most significant use (for the persistence of local populations) is by breeding females who select bridge roosts to raise their young. Bridges may also have day-roosting bats that are males or non-reproductive females. In both the spring and the fall, bridges may also serve as short-term refuge sites for substantial aggregations of migrating bats. A number of bridges in the Central Valley are occupied in winter by the Mexican free-tailed bat, *Tadarida brasiliensis* (G. Erickson, personal communication; E.D. Pierson and W.E. Rainey, personal observation). Winter use at other elevations had not been investigated prior to this study.

Night roosts are sites, usually near foraging areas, at which bats rest (often in clusters) between foraging bouts. In night roosts, they may process large insect prey, feed volant but still dependent young, and engage in social interactions. Bridge night roosts are typically in more exposed sites than day roosts, but nevertheless still offer protection from both wind and rain. Temperature appears to be a key factor in selection and occupancy patterns of night roosts, with bats seeking sites that retain heat well into the night (Perlmeter 1996, Pierson et al. 1996). Concrete girder bridges, offering a matrix of sheltered, warm air pockets, are often used as night roosts.

1.3. Seasonal and Elevational Distribution

Although bat species distribution has been investigated in relation to elevation in the Swiss alps (Barataud 1998) and at sites in Colorado (Storz and Williams 1996), New Mexico (Jones 1965), South Dakota (Cryan et al. 2000), and the White and Inyo mountains of California (Szewczak et al. 1998), it has not been investigated in the Sierra Nevada since Grinnell and Storer's 1924 study (Grinnell and Storer 1924). Grinnell and Storer conducted extensive faunal surveys along an elevational gradient, but the only survey tool available to them for bats was a shotgun, and they documented only nine species.

Seasonal distribution along a north-south gradient has been investigated to some degree for the migratory lasiurine bats and *Tadarida brasiliensis* (Barbour and Davis 1969, Dalquest 1943, Findley and Jones 1964, Pierson et al. 1999, Tenaza 1966). Few studies, however, have investigated a possible link between seasonal movements and elevation. There is evidence that some hibernating species may move higher in elevation in the winter (Barclay 1991, Cryan et al. 2000, Sherwin et al. 2000, Szewczak et al. 1998), and that some non-hibernating species (e.g. *Eumops perotis*) move down (Pierson and Rainey 1998a).

2.0 MATERIALS AND METHODS

2.1 Museum and Literature Records

To examine background information on the recent and historic distribution of bat species in the Central Sierra Nevada, records were compiled from publications (Allen 1919, Grinnell 1916 & 1918, Grinnell and Storer 1924, Harris and Findley 1962, Miller and Allen 1928) and museum collections. Most specimen records (59%) are from the Museum of Vertebrate Zoology (MVZ) at University of California, Berkeley. Others are from the California Academy of Sciences (CAS),

Carnegie Museum of Natural History (CM), California State University at Humboldt (CSUH), California State University at Long Beach (CSULB), California State University at Northridge (CSUN), Los Angeles County Museum (LACM), Michigan State University (MSU), Museum of Comparative Zoology at Harvard (MCZ), Occidental College (MLZ), Santa Barbara Natural History Museum (SBNHM), the San Diego Natural History Museum (SDNHM), Texas A & M (TCWC), University of California at Los Angeles (UCLA), University of California at Santa Barbara (UCSB), University of Kansas (KU), and Yosemite National Park Museum (YNP).

2.2. Study Sites

The study area was located in the central Sierra Nevada of California, and covered an altitudinal transect that followed State Route 120 from the floor of the Central Valley to the crest of the Sierra Nevada at Tioga Pass in Yosemite National Park. Limited surveys were conducted on the eastern slope of the Sierra.

2.2.1. Altitudinal Transect

All bridges along the Route 120 corridor and on many associated county roads and state highways were surveyed at some point during the study. Fifteen were selected for repeated monitoring. The lower and mid-elevation sites were checked monthly between April and October, with a subset being examined in November and December. The high elevation sites could only be checked between June and October since the highway is subject to winter closure from ca. November 1 to June 1 every year.

Acoustic monitoring stations were established at eleven localities along this altitudinal transect from ca. 60 m to > 3,000 m (with one additional locality on the east slope that was sampled only once -- Appendix I). Seven sites were in association with the regularly monitored bridge sites, and four additional sites were added at higher altitudes where no bridges were available. Those acoustic stations associated with bridges were at least 50 m removed from the bridge in presumed foraging areas. Although it is likely that some of the bats detected acoustically were the same individuals observed roosting under the bridges, the acoustic sampling was conducted so that it did not monitor entry or exodus from bridge roosts.

2.2.2. Sites Within Yosemite National Park

Approximately 90 km of the Route 120 corridor occurs within Yosemite National Park, where (heading east) it becomes first Big Oak Flat Road and then Tioga Road. Six of the eleven monitoring stations along this transect were located within park boundaries.

Bat surveys, conducted by E. D. Pierson and W.E. Rainey, have been ongoing in Yosemite National Park since 1993. Data collected between 1993 and 1995 have been previously reported (Pierson and Rainey 1993, 1995 and 1996b). Nevertheless, to provide Yosemite National Park with a summary, prior records relevant to seasonal and altitudinal distribution, are included here. In addition to sites along the Route 120 corridor, prior park study sites include Yosemite Valley, Hetch Hetchy, Wawona, and a small selection of back country sites.

2.3. Bridge Surveys - Protocol

2.3.1. Inspection of structure

Each bridge was initially inspected during the day to evaluate whether it had any structural features that could be used by bats either as a day roost or a night roost. The site was surveyed for the presence of bats or bat sign (guano, culled insect parts and/or characteristic urine staining). If bats were present at the time of survey, the site was determined to be a day roost. If guano or other bat sign was observed, but bats were not present, the bridge was targeted for follow up day and/or night surveys, depending on whether the location of the bat sign suggested day or night use. Those bridges for which complete structural surveys were not possible (i.e., the bridge was too high for adequate visual observation or spanned a large water corridor) were targeted for emergence and/or acoustic surveys. (For a more detailed protocol see Erickson et al. 2000).

2.3.2. Establishing a Survey Schedule

All bridges identified for repeat sampling were checked in summer and fall, and as feasible, in the spring (e.g., highway closure precluded winter and spring sampling of the higher elevation bridges). All bridges were checked three times (June, July and August) during the potential maternity season. They were also checked at least once in the fall (September, October), and once in the spring (April, May) to identify use by migrating species. Due to budget limitations, winter (December or January) surveys were not part of the scope of this study. However, additional surveys were conducted in November and December 2000, after the project had ended.

2.3.3. Temperature Monitoring

After initial surveys for bat activity, temperature loggers (Onset Computer, Pocasset, MA) were placed in 8 concrete bridges in or near the SR120 corridor to monitor roost temperatures. A second logger was generally placed within 100 m of the bridge to record local ambient. Additional ambient temperature loggers were installed at higher and lower elevation sites without bridges which were monitored. Loggers were installed between April and October 1999 and removed after approximately one year, though some were downloaded several times.

Most loggers employed were HOBO H8 8-bit single channel temperature loggers. These have an accuracy optimum of $\pm 1.27^{\circ}\text{F}$ (0.7°C) at 70°F (21°C) which degrades to about $\pm 1.70^{\circ}\text{F}$ (0.9°C) at the limits of the temperature ranges observed in the current study. Logger clock accuracy is also slightly temperature dependent (Whiteman et al. 2000). A smaller number of Stowaway XT loggers (Onset Computer) with similar temperature accuracy were also employed. The circuit boards from both models were removed from the manufacturer's plastic enclosures and coated (except for the thermistor) with low viscosity silicone adhesive to lessen damage from enclosure failure. Loggers were set to sample at hourly intervals (340 day or greater run time), enclosed in two sealed plastic bags with desiccant, and then sealed in a 3"X 1" metal canister.

To lessen vandalism and theft risk imposed by easily visible, white meteorological enclosures on heavily traveled corridors, ambient air temperature canisters were painted to resemble foliage and suspended in shade by wire below tree limbs away from the bole at heights from 1-6 m. Sporadic direct sunlight on the canisters might lead to daytime temperature excursions relative to a standard meteorological enclosure, but night-time air temperatures should be representative. Bridge temperature loggers in the same canisters were temporarily attached to the underside of concrete bridge deck adjacent to girders (at 2-6 m) generally in locations where staining indicated bat night roosting. Exposed surfaces of the canisters were typically coated with a

few cm of foam insulation which was then camouflaged with a coating of local soil to lessen the likelihood of vandalism. These insulated canisters do not necessarily match the thermal micro-environment of night roosting bats, but provide a relative measure of the bridge surface temperature.

Ambient temperature data for Tuolumne Meadow were obtained from the California Data Exchange Center website (<http://cdec.water.ca.gov/>) using Station TUM (37.8730° N 119.3500° W) which was closest station to the SR120 bridge (~0.53 km SE of the bridge along the Lyell fork of the Tuolumne River). The downloaded data were manually reviewed to exclude missing and rogue data points.

The uncorrected logger clock values were adjusted to hourly values on Pacific standard time by linear interpolation. Approximate local sunset times for 1999-2000 for sampling site geographical coordinates were obtained from the U.S. Naval Observatory website (http://aa.usno.navy.mil/AA/data/docs/RS_OneYear.html). Temperatures at local sunset (and hourly intervals thereafter) were also obtained by linear interpolation. When bracketing hourly values were missing, interpolated values were identified as missing and not included in subsequent calculations. Ambient air temperature loggers at the Yosemite Creek bridge and near the Tioga Pass entrance both have multi-day intervals in winter (January- mid April) with narrow diurnal range (or nearly constant 0° C) suggesting partial or complete burial by snow. These data have been dropped as needed from figures presented here. The loggers for ambient air temperature at Knight's Ferry and on the South Fork Tuolumne bridge near Lumsden campground were removed by others, so no data were obtained. The ambient air temperature logger at Carlon /Evergreen Rd S. Fork Tuolumne bridge failed in late December 1999, so data from early 2000 are lacking.

2.4. Acoustic Surveys

2.4.1. Acoustic Equipment

Acoustic sampling was conducted primarily by using broad band frequency dividing Anabat detectors (Titley Electronics, Ballina, NSW, Australia) coupled to laptop computers via zero-crossing analyzers (zcaims). Ultrasound events were stored as files on the computer hard drive for later analysis. On several occasions another broad band detector system, a Pettersson D980 (Pettersson Elektronik AB, Uppsala, Sweden) linked to a DAT recorder was also used.

2.4.2. Survey Design

Two recent acoustic studies (Hayes 1997, Ballantyne and Sherwin 1999) argue that night to night variation in bat activity at any site is sufficiently high that statistically valid data can be obtained only by many nights of repeat sampling at the same sites or by establishing multiple survey points that are sampled concurrently. To the extent possible (based on availability of time and equipment), we chose the latter approach.

Two, and sometimes three, detector systems were deployed at each locality during each sampling period. At most localities, one detector monitored bat activity over water (river, creek, or lake) and the other was placed at a site 50-100 m away from the water to monitor along a forest edge in a clearing or a meadow. In an attempt to control for night to night variation in bat activity, 3 to 5 localities were monitored simultaneously (3 at low elevation, 3 at mid-elevation, and 5 at high elevation). Thus, at least six and sometimes eight detector systems were operating simultaneously.

During each sampling period, three investigators, distributed among three localities, were actively monitoring for bats, while one or more additional detector systems were monitoring passively. Active monitoring has the advantage that the detector operator, with the aid of a spotlight or night vision equipment, can simultaneously make visual observations of calling bats. This facilitates species identification for some acoustically similar taxa, and also allows the observer to make some assessment of the relationship between levels of bat activity and bat abundance (since a bat detector records the number of acoustic events, not the number of individuals). Observers are also able to listen for audible bats (e.g., the mastiff bat, *Eumops perotis*), which may be detected more readily by the human ear than by the normal Anabat transducer. Most detectors incorporate filters to reduce audible [<15 kHz] frequency sounds which are typically not produced by bats).

2.4.3. Acoustic Identification of Species

The effectiveness of acoustic surveys for locating and identifying bats depends on two parameters: 1) how readily a bat can be detected, and 2) with what degree of reliability it can be identified once detected. Detectability is a function of call frequency, call intensity and distance. In general, those species with lowest frequency, highest intensity calls will be detected at the greatest distance.

Identifying bat species based on echolocation calls relies on analysis of a number of call parameters: base frequency, call shape (slope as measured in octaves per second and overall pattern -- e.g., does the slope change during the course of the pulse), pattern of calls within a sequence, interpulse interval, call duration.

For some species, particular combinations of call characteristics allows them to be readily distinguished from all other taxa that might occur in a survey area. Some prior knowledge of the local species assemblage is important because some species could be readily distinguished from all other local species in one area and not in another. For example, *Eumops perotis*, the western mastiff bat, can be readily identified throughout most of California, but in southern Arizona it co-occurs with *Eumops underwoodi*, whose call characteristics are not currently known.

Conducting bat acoustic surveys generally requires knowledge not only of the species specific call characteristics, but also of the biology and ecology of the species involved. For the 17 species found in the Sierra Nevada, there are nine that can typically be identified from Anabat call sequences alone, and 8 for which identification is frequently problematic. Of the nine that can be identified, there are seven for which the Anabat system is effective, and two for which it is generally ineffective (for *Corynorhinus townsendii* because the detection radius for their low intensity calls is limited and for *Euderma maculatum* because the calls are of sufficiently low frequency that the normal Anabat transducer generally fails to detect them). Acoustic surveys can be highly effective for *E. maculatum* using either active observers or a detector system in which the frequency threshold of the high pass filter (which suppresses audible frequency sounds) has been lowered (e.g., Peterssen D980 [Pierson and Rainey 1998], or Anabat Lo-Mike). The seven that can be readily identified using the Anabat system are: *Antrozous pallidus*, *Eumops perotis*, *Lasiurus blossevillii*, *Lasiurus cinereus*, *Myotis evotis*, *Myotis thysanodes*, and *Pipistrellus hesperus*.

Identification based solely on echolocation calls is problematic for three sets of taxa. *Eptesicus fuscus*, *Lasionycteris noctivagans*, and *Tadarida brasiliensis* produce similar echolocation calls in a frequency range of between 20 kHz and 30 KHz. Although all three (especially *T. brasiliensis*) do produce calls that are diagnostic, a large percentage of calls in this frequency range cannot be assigned to a species unless the animal has also been visually observed.

Likewise, *Myotis californicus* and *Myotis yumanensis*, both of which give echolocation calls with a characteristic frequency of ca. 45-50 KHz, can be difficult to distinguish based on call structure alone, although some calls of each species appear to be diagnostic. If visual observation is possible, differences in flight style and foraging behavior often serve to distinguish these species -- e.g., *M. yumanensis* commonly forage by skimming the water surface and *M. californicus* often forage along an irregular flight path in close association with vegetation, often at canopy height.

The most challenging distinctions are for the three *Myotis* species (*M. ciliolabrum*, *M. lucifugus*, and *M. volans*) that have characteristic frequencies of 35-45 KHz. Although visual observations of body size and flight behavior can sometimes serve to distinguish these species, all three are sufficiently poorly known in California that there are many situations in which positive identification is not possible. The features that were used to make tentative identification were: small size and fluttery, erratic flight for *M. ciliolabrum*; medium size, broad wings and water skimming behavior for *M. lucifugus*, and long, narrow wings producing rapid, straight flight for *M. volans*.

2.5. Capture Techniques

Identification of bats in bridge nursery roosts relied upon visual observation with binoculars. No bats were disturbed by capture in a nursery roost. Bats were captured at bridge night roosts (generally between 23:00 and 2:00 h), using rectangular-frame hand nets mounted on telescoping painter's poles. Although bridge night roosts were visited multiple times, with bats counted and identified using a spotlight, no night roost used by aggregations of breeding females was sampled using capture methods more than once per season, and for sensitive species like *Antrozous pallidus* or *Myotis thysanodes*, no more than once a year.

Bats were also captured at a limited number of other sites to obtain demographic information. Following the procedures outlined by Kunz and Kurta (1988), 1.5 inch mesh black nylon or polyester mist nets of a size appropriate to the location (7' or 10' height; lengths of 18', 30', 42' and 60') were set on sectional poles in foraging areas or presumed roosting areas (across creeks or near possible roosting trees). Nets were generally opened 0.5 hrs after local sunset and remained open and closely tended for at least four hours.

On-site processing of netted bats involved species identification (see van Zyll de Jong 1985 for keys); weighing (to 0.1 or 0.01g) in temporary confinement on a portable electronic balance; measurement of one or both forearms with digital calipers (length read to 0.01 mm); assessment of age class (adult, juvenile) from ossification of the metacarpal phalangeal joints (Anthony 1988) combined with body size, pelage color and wing tissue texture; and reproductive characterization using a binocular microscope. For males, characterization involved examination of the testes and checking epididymal tissue for pigmentation or distention; in females mammae were evaluated for nipple development, presence of milk (by expression), and loss of hair.

2.6. Genetic Analysis

The polymerase chain reaction and development of primers (e.g., Kocher et al. 1989) which allow laboratory amplification and subsequent comparison of DNA fragments evolving at a range of different rates provide powerful tools for analysis of patterns of organismal geographic variation. For a pilot study on putative populations of a species with no prior data on genetic

variation from the region, we chose to amplify and sequence a portion of the mitochondrial control region (D-loop). This non-coding region has high variation and is typically useful in analyzing population differentiation. In most vespertilionid bats studied, the segment amplified is composed of a variable number of tandem repeat units (Wilkinson, et al. 1997).

Genetic material from captured and released bats was obtained from wing membrane biopsies taken with a 3 mm disposable dermal biopsy punch and stored at ambient in NaCl saturated 20% DMSO. (Worthington Wilmer and Barratt 1996). To screen for both local and large scale geographical patterns of genetic variation, we compared *M. lucifugus* at two Sierran localities (Tenaya Creek and Lee Vining Creek) with collections from Meiss Ranch, near the California Oregon border. Samples also included *M. yumanensis* from Moccasin Creek in the western Sierra foothills and Tenaya Creek (Appendix I).

Leslie Saidak (laboratory of G.C. McCracken, Zoology Dept. University of Tennessee, Knoxville) conducted the laboratory analysis and provided the sequence analyses summarized below.

DNA extraction employed a chloroform/ salting-out method. Amplification employed primers from Wilkinson and Chapman (1991):

P(mt): 5' TCCTACCATCAGCACCCAAAGC 3'

F(mt): 5' GTTGCTGGTTTCACGGAGGTAG 3'

Annealing temperatures between 50° and 60° were tested, with 56° selected for subsequent reactions. The amplification program began with an initial denaturation step of 95° for 2 minutes, followed by 30 cycles of 95° for 1 minute, 56° for 2 minutes, and 72° for 1.5 minutes. After amplification, PCR products were purified (Qiagen PCR Purification Kit) and sequenced at the UT Molecular Biology Research Facility.

DNA sequences were aligned using Clustal X (Jeanmougin et al. 1998). Phylogenetic trees were created from aligned sequences using PAUP* (Swofford 1998). Previously acquired sequence data from *Tadarida brasiliensis* was used as the outgroup and a sister taxon, *Myotis yumanensis* was included to polarize ingroup relationships. Two phylogenetic trees were constructed. The first was a distance based tree using the evolutionary model of Hasegawa, Kishino and Yano (1985) and created with the neighbor joining search method. The second tree was a maximum parsimony tree using an heuristic search and supported by bootstrapping. Decay analysis was used to determine the strength of each clade of the maximum parsimony tree. In some analyses, additional sequence data on individual *M. lucifugus* from New York and Kentucky and an *M. sodalis* from Kentucky were also included for intraspecific and intrageneric comparisons.

3.0 RESULTS AND DISCUSSION

3.1. Overall Species Diversity

By using three different survey methods -- bridge roost, acoustic, and, to a limited extent, mist-netting surveys -- we documented seventeen bat species on the western slope of the central Sierra Nevada (Table 1), and provided the first records of silver-haired bats (*Lasionycteris noctivagans* -- Pierson and Rainey 1993); red bats (*Lasiurus blossevillii*) and the long-legged

myotis (*Myotis volans*) for Yosemite National Park. All seventeen bat species are now known to occur in the Park. By examining distribution at approximately 1,000 m intervals, we detected 14 species below 1,000 m, 17 species in the range between 1,000 and 2,000 m, and 14 species above 2,000 m. The greatest diversity was observed in the mid-elevation range where high and low elevation species overlap.

The species that were not detected at low elevation were the small-footed myotis (*Myotis ciliolabrum*), the long-eared myotis (*Myotis evotis*) and the little brown bat (*Myotis lucifugus*). The absence of *M. ciliolabrum* may be sampling error, since at the lower elevation sites we relied primarily on acoustic and bridge surveys, neither of which are reliable methods for detecting *M. ciliolabrum*. Although most of the museum records for *M. ciliolabrum* are from southern California, and from mid to higher elevations in the Sierras, there are also records from the Central Valley, suggesting this species would be expected below 1,000 m. Museum records exist for elevations up to ca. 1,500 m in the central Sierra, ca. 1,800 m in southern California mountain ranges, and up to 2,856 m in the White Mountains. Szewczak et al. (1998) found *M. ciliolabrum* primarily above 1,000 m in the White and Inyo mountains.

The absence of *M. evotis* from lower elevation sites is consistent with what is known of their distribution from museum records. While they occur at lower elevations in the coast ranges, along the eastern rim of the Central Valley near Red Bluff (Pierson et al. 2000), and as low as ca. 300 m in the upper Sacramento River drainage (Rainey and Pierson 1996), along the western slope of the Sierra Nevada the lowest elevation records are >1,000 m. Studies conducted elsewhere in the West also indicate that *M. evotis* is primarily a mid to higher elevation species (Kuenzi et al. 1999, Ports and Bradley 1996, Storz and Williams 1996, Szewczak et al. 1998).

The absence of *M. lucifugus* from lower elevations is as expected from museum records for California, where the species is restricted to higher elevations or higher latitudes. While it is found along the northern coast, at relatively low elevations in the northern Coast Range, and in the northern portions of the Central Valley, there are no records for the central Sierra Nevada below 1,000 m.

The species not detected above 2,000 m were the pallid bat (*Antrozous pallidus*), Townsend's big-eared bat (*Corynorhinus townsendii*), and the western pipistrelle (*Pipistrellus hesperus*). Although the majority of museum records for the pallid bat are from mid to lower elevation, this species has been found as high as 3,000 m on the Chagoopa Plateau in Sequoia National Park (D. Graber personal communication) and was the species most frequently encountered roosting in the basal hollows of giant sequoia trees at Giant Forest (1,953 m), also in Sequoia National Park (Pierson and Heady 1996). While this species also occurs in the giant sequoia groves in Yosemite National Park (E.D. Pierson and W.E. Rainey, study in progress), it is perhaps not surprising that it was not found in the lodgepole and fir habitat on Tioga Road, from Yosemite Creek to Tioga Pass. Szewczak et al. (1998) reported no pallid bats above 2,000 m in the White or Inyo mountains.

The absence of Townsend's big-eared bat from sites above 2,000 m may also be sampling error. Although all known nursery sites are at relatively low elevation (the highest in the Sierras being at ca. 1,650 m along the Yuba River), it is possible that males occur much higher. Szewczak et al. (1998) encountered foraging *C. townsendii* as high as 2,210 m in the White Mountains, and reports on two nursery roosts at >1,700 m. They found hibernating animals as high as 3,188 m. This is consistent with the seasonal movement of this species to higher elevations for hibernation in Utah (Sherwin et al. 2000).

Although, during the summer of 2000, in the context of another study, we obtained acoustic records of western pipistrelles, adjacent to a cliff face at 2,076 m in Yosemite National Park, this species has not typically been reported at elevations this high. While records in the range of 1,000 to 1,400 m are fairly common in the southern Sierra, and there is one record in Fresno County for 1,981 m, western pipistrelles are known primarily from lower elevations, where they are associated with cliff habitat. Szewczak et al. (1998) reported this species at 2,740 m in the Inyo Mountains. While pipistrelles were common at some of lowest elevation sites with cliffs nearby, they were rare above 500 m.

The fringed myotis (*Myotis thysanodes*) appears to be confined primarily to the mid-elevation zone. The only records we had at low elevation were an unconfirmed observation at a bridge night roost, and the only higher elevation record was one unconfirmed acoustic record. Although there are a few museum records from lower elevation, the majority from the Sierra Nevada are in the 1,000 to 2,000 m range. If this species occurs higher or lower, it is apparently uncommon.

3.2. Bridge Roost Surveys

3.2.1. Species Assemblage and Overall Patterns of Bridge Use

Thirteen of the seventeen bat species that occur in Yosemite National Park and/or vicinity have been documented using bridge roosts somewhere in their range. Twelve were identified using bridges in this study (Table 2). Ten used bridges as night roosts; seven were also found roosting in the day during the summer; four used bridges as maternity sites; four species, including two not found on bridges in the summer, were found day-roosting in the winter.

Three species (*M. yumanensis*, *T. brasiliensis*, and *E. fuscus*) were numerically dominant (Table 3) and were also found in the largest number of bridges (Fig. 1). *A. pallidus* was also found to be using almost half the surveyed bridges. For other species, bridge use was less predictable.

While this study provided the first winter bridge record for *Myotis evotis*, it yielded no summer records. This result was unexpected since this species has been found using bridge roosts in the summer in Oregon (Cross and Waldien 1994) and elsewhere in California (Pierson et al. 1996). Also, acoustic and netting records indicated it was present in the vicinity of a number of the surveyed bridges.

Bridge use by both *Myotis thysanodes* and *Myotis volans* was more extensive here than in another study along the upper Sacramento River (Pierson et al. 1996). Relatively rare bridge use by *Corynorhinus townsendii*, *Myotis californicus*, and *Myotis ciliolabrum* was consistent with our findings elsewhere in California (Pierson and Rainey 1998b; Pierson et al. 1996).

Our December record for *Lasionycteris noctivagans* using a bridge in Yosemite National Park is noteworthy, since it provides only the second documented instance of bridge use for this species (Perlmeter 1996).

The fact that *Pipistrellus hesperus* was not found using bridges is not surprising since bridge use by this species appears to be extremely rare, and has only been reported twice (D. Constantine personal communication, G. Erickson personal communication).

All twenty bridges included in this altitudinal transect along the Highway 120 corridor between the Central Valley and Sierran crest had some bat use. While eight bridges were used predominantly by one or two species, most were used by multiple species, with as many as ten species being found associated with one bridge (Fig 2).

3.2.2. Seasonal and Elevational Patterns of Bridge Use

Table 3 presents data on bat use of the 20 bridges and one culvert included in the study area. A few of these sites were surveyed only once. Most were visited multiple times between April and October (or at high elevation, where road closures precluded spring sampling, between June and October). A selection were also visited during the winter.

There were both seasonal and elevational differences in patterns of bridge use. By sampling a series of bridges repeatedly between April and October we were able to demonstrate significant shifts in seasonal use among species. For example, *M. thysanodes* was one of the first to appear in April, but had largely vacated the bridge roosts by September. Other species, like *M. yumanensis*, tended to appear somewhat later (although this varied with elevation and the year) and persist later into the fall. While numbers of *M. yumanensis* reached peak densities at night roosts in the summer (Fig. 3), other species appeared to exhibit a largely bimodal pattern, with the largest numbers of animals using the bridges in the late spring to early summer, and again in the late summer and/or early fall, with the minimum number being found in mid-summer. This pattern is most evident for *Eptesicus fuscus* (Fig 3), with aggregations of pregnant females appearing in the night roosts in May and June, virtually disappearing during lactation, and reappearing in mid-August accompanied by volant young. Those *E. fuscus* that were found in bridge night roosts in mid-summer were mostly adult males or non-reproductive females.,

M. volans also exhibited a bi-modal pattern of bridge use, occurring in mid-elevation (859-1,316 m) bridges primarily before and after the reproductive season (in April and again from mid-August through October), although lactating females, one with a nursing young, were captured at one bridge in mid-August. The only July bridge record (a scrotal male) occurred at higher elevation (2,280 m) (Table 3).

While the data presented in Table 3 suggest that *M. thysanodes* may also exhibit this bimodal pattern, we consider it likely that their disappearance from night roosts in June and July 1999 may have been a response to our capture efforts in April of that year. Our experience with this species here and elsewhere is that it is extremely sensitive to disturbance, and will abandon a roost for some time after capture.

T. brasiliensis, which uses some low elevation bridges as day roosts year round, uses night roosts less predictably. One bridge on Big Oak Flat Road in Yosemite National Park was used by large numbers in July; another site along the Tuolumne River was used only during fall migration.

Limited sampling during the late fall and winter indicated that several species were using mid-elevation bridges as day roosts. While the bats were generally torpid when observed, we do not know how long any individual remained at a particular site. We are thus not able to say whether these bridges serve as true hibernating sites, or as more temporary roosts. Since the occupied bridges occur in an elevation zone that experiences frequent non-freezing temperatures (particularly during the day and early evening), it is likely that the bats using these bridges do forage periodically.

Table 4 summarizes the elevational patterns of bridge use. While the lower elevation bridges harbored only seven of the twelve species we detected using bridges along this transect, they attained significance by the size of their populations -- large aggregations of *M. yumanensis*, *T. brasiliensis*, or *E. fuscus* (see Table 3). The mid-elevation bridges tended to have fewer animals, but greater diversity, with all twelve species being found in this elevation range. One bridge was used by ten species, with as many as six species being found at one time. Bat use of bridges declined dramatically at higher elevations. Only four species were found using these bridges, and numbers of animals detected were relatively few. Nevertheless, some of the records were highly significant. For example, the bridge on Tioga Road over Yosemite Creek, which never had more than two night-roosting animals at a time, yielded the first record of *M. volans* for Yosemite National Park, the first individuals of the high elevation *M. lucifugus* (see Section 3.7 below), and two of only four bridge records for *M. ciliolabrum*.

3.2.3. Bridge Use in Relation to Temperature

To examine the role of temperature in the seasonal use of bridges as bat night roosts we installed eight pairs of temperature probes (one fixed to the bridge deck and another hung in a tree nearby) along the elevational gradient. Comparative data were obtained for seven sites. Figures 4a and 4b compare bridge roost temperature with ambient temperature four hours after sunset (approximate time of maximum occupancy in mid-summer) for seven bridges, from lowest to highest elevation, for approximately one year. It is evident from these data that from April through November at all elevations the bridge roosts provide a thermal advantage. What is also evident is that the bridge temperature differential is greatest for the three lowest elevation bridges that also are most heavily used. Not only are the absolute temperatures higher at these bridges, but the differential between the bridge temperature and ambient is greater. It is also striking that temperatures begin to fall, and the thermal advantage of the bridge roosts (i.e., the difference between bridge temperature and ambient) begins to decline at all elevations in September, at approximately the same time our surveys indicate that the bats begin to abandon the bridge night roosts.

Figure 5 shows mean monthly bridge surface temperatures at sunset in relation to elevation, and shows, as would be expected, an inverse relationship between temperature and elevation, with the warmest bridges being at lowest elevation. The lowest elevation sites maintain mean monthly sunset temperatures in excess of 10°C throughout the year. At elevations > 500 m, these temperatures are below 10°C from November through February, and at highest elevation from October through April.

Figure 6 depicts the mean monthly difference between bridge temperatures and local ambient two hours after sunset in relation to elevation, thus providing an indication of how much buffer the bridges provide. This shows that during the critical summer months (May to September) the bridges maintain a substantial differential (generally >10°C) in relation to ambient, and begin to lose this advantage, particularly at higher elevations in September. During those months in which we observed little or no use of night roosts (October to April), the temperature differential is generally <10°C.

While these data are highly suggestive that temperature plays an important role in determining to what extent a structurally suitable bridge will be used as a night roost, there are other factors that need to be considered. Along this transect, the two low elevation bridges and one mid-elevation bridge (South Fork Tuolumne) support the largest number of night-roosting bats; two others, at elevations comparable to S. Fork Tuolumne, experience much less use; and the two high elevation bridges only minimal use.

The most instructive comparison is between the South Fork Tuolumne and Evergreen Road bridges, which appear to have comparable temperature regimes (Fig. 4a), are structurally similar, and located only ca. 6 km apart along the same drainage. Yet, The S. Fork Tuolumne bridge experiences far greater use as a night roost (both numbers of animals and number of species) than does the Evergreen Road bridge. Given that the S. Fork Tuolumne bridge is located on a major highway (SR120) and the Evergreen Road bridge on a sparsely used secondary road, our experience elsewhere, suggesting that the largest night roosts are located in abandoned bridges (Pierson et al. 1996), would have lead us to expect the reverse. The most obvious difference between these two settings is the surrounding habitat. The Evergreen Road bridge is within 100 m of the Yosemite Wilderness and a large stand of old growth sugar pine (*Pinus lambertiana*); the South Fork Tuolumne Bridge is in the Stanislaus National Forest, in an area that has been highly altered by timber harvest. Thus, the Evergreen Road area may offer far more alternative night roosting sites. Similarly, the other three bridges that experience relatively little night roost use (Fig. 4b) are all located within national park boundaries where there is alternative habitat that could provide comparable thermal buffering. These three sites are all surrounded by old growth forest (with high snag density) and are within view of vast expanses of bare fractured rock. Thus to test the hypothesis that bridge use is inversely correlated with elevation (and declining roost temperatures) it would be necessary to examine mid to high elevation bridges in habitats that have been altered by timber harvest, and lack the abundance of granite.

Another observation is that the thermal advantage offered by low and mid-elevation bridges in April, when bridge use is considerable, is not apparently different from that in October, by which time the bridges have been mostly abandoned. The likely explanation for this discrepancy is seasonal behavioral differences. By April, the females of most species are pregnant, and would be seeking warm environments. Their goal would be to minimize the amount of time spent in torpor, since use of torpor extends the length of pregnancy (Racey 1973, Racey and Swift 1981). In the fall, the behavioral goal would be conservation of energy and storage of fat for winter survival. Thus animals would be more likely to seek sites which foster the use of torpor.

3.2.4. Structural Features of Bridges Used as Summer Day Roosts

Ten of the 20 surveyed bridges were used as summer day roosts (Table 3).

Two, located at relatively low elevation, were concrete structures that housed large colonies of both *M. yumanensis* and *T. brasiliensis* in expansion joints. (Although in the vicinity of the Central Valley *T. brasiliensis* may occupy a bridge throughout the year, in the summer it will frequently share the roosting space with other species, including *M. yumanensis*). One of these is an expansion joint in a flat deck (Fig. 7a); the other is an expansion joint located at a bent, where transverse girders form a cavity below the expansion joint.

Two other bridges were of wooden understructure, where bats roosted in narrow crevices between beams (Fig. 7b). One of these was occupied by *M. yumanensis* nursery colony during the late spring and early summer, and by *T. brasiliensis* in the fall, likely during fall migration. The other was occupied by a small colony of *A. pallidus*.

Cavities in bridge abutments housed a nursery colony of *E. fuscus* in one bridge (Fig. 7c), and individually roosting male *C. townsendii* in two others (Fig. 7d).

Although concrete girder bridges are frequently used as night roosts, they do not offer enough protection to serve as day roost sites for nursery colonies. In the spring, however, we

found small numbers of *M. thysanodes*, *M. volans*, and *M. yumanensis* day-roosting under two concrete girder bridges that offered particularly dark and sheltered spaces.

The most unusual roosting site was behind a metal sign affixed to hurricane fencing, designed to preclude public access to a catwalk under a large bridge with a steel I-beam frame. Although we did not observe bats at this structure, it was obvious from the guano deposit it was being used by a small *Myotis* species, most likely *M. yumanensis*. A large colony of *M. yumanensis* has been observed using an identical structure on the Hwy 49 bridge over the Merced River (Br. #40-47) (G. Erickson personal communication, E.D. Pierson and W.E. Rainey, unpublished data) (Fig. 7e).

3.2.5. Structural Features of Bridges Used as Night Roosts

Of the 20 surveyed bridges, 16 are used as night roosts, meaning that the portion of the bridge used at night differs from that used in the day for those 7 bridges that we have designated as both day and night roosts (Table 3).

Twelve bridges were concrete girder structures, where the girders created inverted rectangular box-like spaces that trapped warm air and provided shelter from the wind and rain (Fig. 7f). This design was used by the largest numbers of animals and the greatest diversity of species. Those that were used by large numbers of *T. brasiliensis* (identified either by observing the bats directly or by inferring use from large accumulations of guano attributable, based on shape and odor, to this species) all shared the characteristic that the slope beneath the bridge was steep, and the distance from the ground to the deck was high (20 m or more) at mid-span. It seems likely that this fast-flying species required this configuration for maneuverability.

Three bridges had concrete decks supported by steel I-beams (Fig. 7g). Two of these bridges, which were very large, had roosting areas subject to both temperature fluctuations and wind. Consequently, they were used only sparingly, and never had more than a few animals roosting at one time. The third bridge, which was lower and more sheltered, supported a large *M. yumanensis* night roost. In all cases, the animals roosted on a concrete collar that formed the interface between the I-beam and the deck.

The largest and most predictable *M. yumanensis* night roost was located in a sheltered, exterior corner of a box-beam bridge, where the overhanging deck met the abutment at an acute angle, generating a small cave-like space (Fig. 7h). An additional night roost of *M. yumanensis* was located in a large corrugated metal culvert (ca. 12 feet in diameter), where the animals roosted on the irregular surfaces occurring at culvert junctions.

3.2.6. Structural Features of Bridges Used as Winter Roosts

Four of nine bridges surveyed were used as winter roosts (Table 3). In two bridges the animals were found in particularly dark, sheltered sections of concrete girders. In a third bridge, also of concrete girder construction, the bat (*Lasionycteris noctivagans*) was roosting in a corner, but in a fairly exposed, well lit area. In the fourth bridge, the animal was roosting on the concrete collar of a steel I-beam, on a bridge that was only used as a night roost in the summer.

3.2.7. Ecological and Scientific Value of Bridges

Bridge roosts are of obvious habitat value to bats, particularly in areas like the Central Valley where much of the potential roost habitat (e.g., defective trees in mature riparian forest) is

gone. In some areas bridges may offer the only potential day-roost sites for a large radius. Also, depending on their design, bridges can offer reasonable analogues to natural crevice and cavity roosts. While they are used most ubiquitously by species that appear to be flexible in their roosting requirements (e.g., *M. yumanensis* and *T. brasiliensis*), they occasionally provide critically important roosting opportunities for rare and highly sensitive species, like *C. townsendii* or *M. thysanodes*.

Bridge roosts are also of considerable scientific value in that they provide an efficient and time-effective method for sampling a subset of the local bat community, particularly in forested areas where other means of capture may be more limited (Pierson et al. 1996). Banding and repeat sampling have revealed that several species show a high fidelity to bridge night roosts. Thus these sites offer rare opportunities to gather demographic data (timing of reproduction, age of first reproduction, survivorship) without disturbing animals at sensitive nursery sites. Bats captured at night roosts can be radio-tagged, allowing researchers to locate day roosts, track animals in foraging areas, and investigate the spatial and sociobiological relationship between day roosts and night roosts.

Patterns of guano accumulation under bridges can offer insights into seasonal movement patterns that might otherwise be missed. For example, it is not uncommon to find large accumulations of *T. brasiliensis* guano (and no bats) under bridges in the fall, suggesting that this species used the bridge as a transient roost during migration.

As is true for all sampling methods, bridge surveys sample more effectively for some species than for others. Bridges are most predictably used at lowest elevations by *E. fuscus*, *M. yumanensis*, *T. brasiliensis*, and *A. pallidus*. At mid-elevations a high diversity of species use the bridges, but patterns of use appear less predictable and currently are not well understood. At higher elevations, bridge use by bats decreases dramatically, likely in response to temperature. A significant limitation of bridge roost surveys is that some species are not known to use bridge roosts. This is particularly true for the foliage roosting species (red bats and hoary bats) and those species most dependent on cliff habitat (spotted bats and western mastiff bats).

3.3. Acoustic Surveys

3.3.1. Species Diversity

Acoustic surveys were conducted seasonally at 11 monitoring stations along the altitudinal gradient (Table 5), with most being located in the vicinity of monitored bridges. At most sites, two or more detectors were deployed, with one detector monitoring activity over water and the second activity in a clearing or forest edge at least 50 m away from water. In some cases additional sites in the area were sampled on an exploratory basis.

Sixteen species were identified acoustically at some point in the study (Tables 1 & 5). The maximum number of species detected at one site was fourteen, at a mid-elevation site (1,316 m) along the Tuolumne River (not associated with, but within 6 km of, the bridge site with highest diversity). The highest elevation site yielded seven species, the fewest for any of the repeatedly monitored localities. The only species that could not be successfully identified acoustically was *M. ciliolabrum*. There are, however, a large number of call sequences that had to be labelled "My40" to indicate a *Myotis* species echolocating at 40 kHz that could not be identified. An unknown number of these may be calls of *M. ciliolabrum*.

3.3.2. Patterns of Activity in Relation to Season and Elevation

Bat activity (as measured by number of acoustic files obtained per minute over the sampling period) reached peak levels at low and high elevations in July, August, and/or September, with the pattern being more variable at mid-elevation sites (Fig. 8). The curve for low and mid-elevation sites is quite flat, with relatively high levels of activity beginning in June and persisting into October. At high elevation the activity curve is much steeper, and the season of intense activity much shorter.

Levels of activity did not differ markedly between low and high elevation river/creek sites in July, August, and September. They were, however, much lower at high elevation relative to lower elevations in June and October. These patterns are consistent with the hypothesis that bat activity and presumably insect productivity show a positive response to temperature. As expected, mean monthly ambient temperature at sunset (Fig. 9) declines with increasing elevation. At the low and mid-elevation sites the mean ambient temperature at sunset from June through October is generally 15°C or higher (up to 27°C). At the high elevation sites, mean ambient temperatures in June and October appear to be ca. 13°C or lower, and in July, August and September (with a few notable exceptions) 13°C or higher. Regardless of elevation, and almost regardless of season, mean monthly temperatures drop 3-5°C in the first two hours after sunset (Fig. 10). This means that from June through October, at low to mid- elevations, temperatures during the prime foraging time (first two hours after sunset) generally maintain above 10°C, whereas at higher elevation they drop with some frequency below 10°C, particularly in June and October (Fig. 11). Thus the overall patterns of bat activity we observe acoustically are consistent with other temperate zone studies, which have generally found temperatures ranging from 6-10°C to be a threshold for insect productivity and/or bat activity (O'Donnell 2000, Park et al. 2000, Rydell 1989, 1990 & 1992).

The relatively high levels of bat activity in Tuolumne Meadow in September (Fig. 8) are striking given that the overall temperature profile would suggest the conditions should be marginal (Figs. 9 & 11). We note, however, that this represents one night of sampling, and the results are consistent with our findings in other sampling efforts in the vicinity of Tuolumne Meadow -- on warm nights in the fall (as was the case with our September sample), levels of bat activity can surprisingly high. One possible explanation for this phenomenon is that some bat species, like many bird species, move upslope as lower elevation habitats dry out. Although temperatures are less predictable at high elevation, on warm nights, these more mesic environments are likely to be more productive later in the season.

3.3.3. Patterns of Activity in Relation to Habitat

Bat activity (as indicated by the number of acoustic files obtained per minute over the sampling period) was compared at sites next to and away from a river edge (Fig. 12). At the river sites the detectors were pointed out over a pool of slowly moving water (to minimize interference from water noise). At the lower and mid-elevation localities, the sites away from the river were in clearings or along a forest track. At high elevation, they were on the shore of two small lakes, one that was surrounded by lodgepole forest, and the other in an open meadow setting. There were significant differences in levels of activity between the river and non-river sites at all elevations from June through September, and at the mid-elevation sites in October. At high elevation, levels of activity were low at all sites in October, but highest at the meadow lake located near the Sierran crest.

Also, there were greater differences in levels of activity between sites near moving water

and those away from moving water than there were between comparable sites at different elevations (Fig. 12). Our findings were consistent with those of Grindal et al (1999), who found at sites in Canada that bat activity was much greater in association with water.

3.3.4. Results of Parallel Bridge and Acoustic Surveys Compared

Table 6 compares the species assemblage detected by bridge surveys and acoustic surveys at seven of the regularly monitored sites. Significantly more species were detected acoustically at all the localities, due largely, but not entirely, to the presence of species that do not generally use bridge roosts. When the analysis is confined to the "bridge species," at six of the seven localities there were bridge associated species in the area that were not found under the sampled bridge. For example, *A. pallidus* was detected at four localities and found under only two bridges, *E. fuscus* at all the localities and two bridges, *M. californicus* at six localities and one bridge, *M. evotis* at three localities and no bridges, *M. thysanodes* at five localities and two bridges.

Conversely, there were some species that were found under bridges, for which acoustic records could not be confirmed. This was particularly true for the three 40 kHz *Myotis* species that are difficult to tell apart acoustically (*M. ciliolabrum*, *M. lucifugus*, and *M. volans*). At all bridges where one or more of these species was identified by capture, there were also acoustic records for 40 kHz *Myotis* in the area. While *C. townsendii* was found under two bridges, it was not detected acoustically at any of these localities. This result is not surprising since the low intensity echolocation call of *C. townsendii* makes it one of the species most difficult to detect acoustically.

The results of this study document that conducting bridge and acoustic surveys in parallel provide an effective and time efficient method for obtaining both distributional and demographic information, and that the two methods complement each other.

Although the assemblage of bats using any one bridge in no case reflects the total species assemblage for an area, the tendency of some species to aggregate in bridge night roosts allows the capture of more animals than could reasonably be sampled by any other method. Sampling of bridges can also help resolve species identification for acoustically problematic taxa like the 40 kHz *Myotis* species, and can provide important records for rare taxa, like *C. townsendii* and *M. thysanodes*.

While bridge surveys yield important species specific information, acoustic surveys permit assessment of relative levels of bat activity, and thus are an excellent tool for comparing bat use of differing habitats (e.g., intact versus reduced riparian, old growth versus second growth forest, adjacent to or away from water). Acoustic survey is also the most effective method for identifying certain species that have a distinctive and readily detectable (i.e., relatively high intensity) echolocation call, and are difficult to sample by any other method -- e.g., spotted bats, western mastiff bats, red bats, hoary bats (Corben et al. 1999, O'Farrell et al. 1999, Pierson and Rainey 1996b, Pierson and Rainey 1998c, Pierson et al. 1999). This approach also allows inventory of habitats that could not be effectively sampled in any other way (e.g., bat activity over deep or rapidly flowing rivers, along dense riparian edge, high over open meadows), and has substantially altered our understanding of the distribution of a number of species in California.

3.4. Mist-Netting Surveys

The primary focus of the Route 120 transect was to conduct acoustic surveys in parallel with bridge surveys. While the scope of the project did not provide time for netting surveys at all

sites, a limited number were conducted opportunistically. In an attempt to provide an overview of information available to date for this portion of the Sierra, Table 7 provides a summary of all netting data obtained for the route 120 transect, plus all records obtained during the course of surveys that have been ongoing in Yosemite National Park since 1993. Fig. 13 shows the total number of bats captured for each species. As can be seen by reference to Table 8, of the four species most abundant in net captures, only two (*M. yumanensis* and *E. fuscus*) were also captured at a majority of sites. *T. brasiliensis*, which ranked second in number of animals captured, was detected at only 42.1 % of the sites. Because this species has a tendency to flock forage, net captures for this species are often temporally and spatially clustered. Although *M. lucifugus* ranked third in the number of captures, it was captured primarily at just two high elevation sites (one inside Yosemite National Park and the other on the eastern slope outside the Park). *E. maculatum* and *L. blossevillii* were each captured at only one locality. *M. volans* was captured at only two localities, both outside park boundaries. The relatively high numbers of *E. perotis* reflect netting efforts targeting this species for a radiotracking study (Pierson and Rainey 1995).

Although mist netting efforts were somewhat limited, they did yield records for all seventeen species. While mist netting surveys are labor intensive, sample only a small area, and capture some species more readily than others, in most settings they remain the best method for assessing species composition. With animals in hand it is possible to obtain demographic information, and with rare exceptions to obtain positive species identification. Those species that are sometimes difficult to distinguish morphologically (*M. yumanensis* and *M. lucifugus*, or *M. californicus* and *M. ciliolabrum*) can be distinguished from each other acoustically, and thus positive identification can be obtained by recording bats upon release.

3.5. Relative Abundance

It is difficult to evaluate relative abundance of bat species since each survey method samples some species more readily than others. Nevertheless, it is obvious by any method used that a few species are far more abundant than others, and some are extremely rare. There are also a group for which we lack a reliable census method, and thus cannot assess their relative abundance with any confidence.

Four of the five species most abundant in net captures (*M. yumanensis*, *T. brasiliensis*, *E. fuscus*, and *M. californicus*) (Table 7) were also the species most commonly detected and most widely distributed acoustically (Table 5). The first three were also the species most frequently encountered in bridge roosts (Table 3).

Since *M. lucifugus* is readily captured in nets set over water, and was the second most abundant species in net captures at high elevation on the west side, and the most abundant in net captures at Lee Vining Creek on the east side, the netting records for mid-elevation likely accurately depict this species as rare in this elevation range. This is supported by how few individuals were found in bridge roosts, since this species is known to make extensive use of bridge roosts in Oregon (Adam and Hayes 2000, Cross and Waldien 1994, Perlmeier 1996).

Although *E. perotis* was captured in mist nets in Yosemite Valley and the Wawona area, and detected acoustically at a number of sites at all elevations in the summer and fall, it was not encountered frequently anywhere except Yosemite Valley, Wawona, and, on warm summer nights, in the vicinity of Tuolumne Meadow. It was relatively rare outside the Park.

Five species (*C. townsendii*, *L. blossevillii*, *M. thysanodes*, *M. volans*, and *P. hesperus*) were relatively rare by any method used. For three of these (*M. thysanodes*, *L. blossevillii*, and *P. hesperus*) acoustic surveys also offer a reasonable assessment of relative abundance, since their echolocation calls can be readily detected and identified. While both *L. blossevillii* and *P. hesperus* were more abundant in restricted habitats at lower elevation (red bats in cottonwood/ sycamore riparian and pipistrelles in association with rock outcrops), both were indeed rare in both netting and acoustic records at mid-elevation or high elevation. *M. thysanodes* was extremely rare, perhaps absent, from the lowest and highest elevations, and relatively uncommon at mid-elevations. Since it was detected acoustically (although infrequently) at a number of sites, and appeared in several bridge night roosts, it was likely somewhat under-represented in our net captures, although it still appears to be one of the rarest species in all the areas we sampled.

None of the methods used in this study offer insight into the status of *C. townsendii*. While this species appears to be captured readily in nets in some parts of its range, particularly at desert water holes (Kuenzi et al. 1999, Morrell et al. 1999), it is rarely captured in nets in northern California, perhaps due to differences in foraging ecology. Also, due to a low intensity echolocation call, it is difficult to detect acoustically. The most effective method for locating this species is surveys of likely day roosting areas (predominantly caves and abandoned mines). While one significant roost has been located within Park jurisdiction (Pierson and Fellers 1998), this species is known through other studies to have undergone serious populations declines in the last 40 years, primarily because of disturbance to its roosting sites (Pierson and Fellers 1998, Pierson and Rainey 1996a). Population declines in the Mother Lode -- in known roost sites both north and south of our transect -- have been severe.

Myotis volans, netted at only two localities (both outside Yosemite National Park), was documented for the area primarily because of its propensity for using bridge night roosts. Although this species, which was not known to be present in this area prior to this study, is found repeatedly at certain bridges, not enough is known regarding its behavior to offer an assessment of its relative abundance.

We know from acoustic records (when they could be confirmed with visual observations) that *Lasionycteris noctivagans* is more common than indicated by net captures, although not nearly as abundant as it is in the bat community in the Klamath region and Trinity Alps (Pierson and Rainey 1998b, Rainey and Pierson 1996).

Four other species -- *Antrozous pallidus*, *Euderma maculatum*, *Lasiurus cinereus*, and *Myotis evotis* -- appear to be relatively uncommon, and/or patchily distributed. *E. maculatum*, while everywhere rare, was more abundant in Yosemite Valley and the Wawona area than it was anywhere else in the study area. Although *L. cinereus* is detected during the summer, numbers increase substantially in late summer and early fall, when this species apparently migrates through the area.

3.6. Reproductive Status

Appendix II provides age and reproductive condition by species for all individuals handled (either by capture in mist nets in foraging areas or in hand nets at bridge roosts) during the course of this study. It should be noted for the following discussion that our capture efforts, because they include research conducted over a seven year period in Yosemite National Park, are highly biased towards mid-elevation (1,000-2,000 m). Capture efforts at lower elevation targeted selected bridges, and at higher elevation was limited to a few netting sites. Thus, with a few exceptions

specifically noted, our results regarding reproductive status of bats at low and high elevation should be regarded as preliminary. For some species it is possible to offer commentary based on information gathered outside the context of this study.

Thirteen of the seventeen species had reproductive populations within the study area, as evidenced by the presence of pregnant or lactating females and/or newly volant young in our capture records. The four species for which we obtained no evidence of reproductive populations were *C. townsendii*, *L. noctivagans*, *L. blossevillii*, and *L. cinereus*. The absence of reproductive *C. townsendii* reflects a sampling bias (both the methods used and the limited sampling effort at low elevation), since multiple, currently extant maternity roosts are known for this species below 1,000 m in this region of the Sierras, including one site under Park jurisdiction.

Given how readily reproductive females and juvenile *L. noctivagans* are captured in areas where they occur (Rainey and Pierson 1996, Pierson and Rainey 1998b), and the expectation that, if present, they would occur in the most heavily sampled mid-elevation range, we think it unlikely that reproductive populations of *L. noctivagans* occur in the study area. The closest record for breeding females (MVZ) on the western slope of the Sierras is ca. 125 km to the north in El Dorado County, near Placerville (at 1,130 m), and on the east side of the Sierran crest, ca. 50 km north of Route 120 in the Sweetwater Mountains (at 2,500 m).

Since there is compelling evidence for an association between breeding female *L. blossevillii* and lower elevation cottonwood/sycamore riparian habitat (Pierson et al. 1999 & 2000), we expect that reproductive populations of *L. blossevillii* occur in this habitat at our lowest elevation sites (along the Stanislaus River between Oakdale and Tulloch Reservoir). As evidenced by our own capture records and what can be inferred from museum specimens, it is likely that *L. blossevillii* at higher elevations, including all sites within Yosemite National Park, are either males or migrating animals of both sexes (late summer and fall records).

The capture of only male *L. cinereus* is consistent with what is known for this species elsewhere in the state. It appears that reproductive females are limited to central United States and Canada (Findley and Jones 1964).

All thirteen species showing evidence of reproduction were captured at one or more mid-elevation sites. For a number of species the absence of reproductive individuals at lower elevation is clearly a sampling error since there are multiple records of maternity roosts for some, most particularly *A. pallidus* and *E. perotis*, at lower elevation sites outside the study area.

The only species for which there were clear breeding records above 2,000 m was *M. lucifugus*. In fact, for this species, with the exception of one pregnant female and two juveniles, all breeding records were at high elevation. It is likely that other species also have breeding populations above 2,000 m -- e.g., *E. fuscus* and *M. evotis*, and *M. volans* are among the most likely.

A recent study conducted in South Dakota (Cryan et al. 2000) documented a significant inverse relationship between elevation and relative abundance of reproductive females, with the relative abundance of reproductive females decreasing with increasing elevation. Our data provide evidence of a similar pattern in the Sierra Nevada for at least some species. The most compelling case can be made for *M. yumanensis*, for which most known maternity roosts are at low elevation, the number of adult males increases dramatically with increasing elevation, and only males (interestingly both adult and fully independent juvenile males) are found at high elevation.

3.7. Sierran Form of *Myotis lucifugus*, Little brown bat

3.7.1. Taxonomic Background

On 29 June 1997 two bats of uncertain species identity were captured under the Yosemite Creek bridge on Tioga Road at 2,280 m elevation in Yosemite National Park. Most characteristics (e.g., ear length, foot length, absence of a keel on the calcar, absence of fringe on the uropatagium) linked them to *M. lucifugus*, yet they were larger and had longer, blonder fur than is typical for this species elsewhere in northern California.

A review of the literature suggested that the taxonomic status of *M. lucifugus* in the Sierra Nevada warranted re-examination. A high elevation taxon, later assumed to be *M. lucifugus* (Allen 1919) was first described based on four specimens by H.W. Grinnell (1916) as *Myotis yumanensis altipetens*. These specimens were smaller and darker than the Yosemite Creek bats. A bat fitting the description of our captures was first discovered by G. Allen in 1915 on the side of Mt. Whitney, and was described by him as a new species, *Myotis albicinctus* (Allen 1919). *M. albicinctus*, known from only two specimens, plus the animals described by Grinnell were later included, with little commentary[?], in *Myotis lucifugus carissima* (Miller and Allen 1928), the subspecies which is currently thought to be the only form occurring in the Sierra Nevada (Hall 1981). Harris and Findley (1962) refer to confusion surrounding a light-colored *M. lucifugus* from the eastern slope of the Sierra Nevada, and suggest possible hybridization with *M. yumanensis*.

3.7.2. Size of Sierra Nevada *M. lucifugus*

To evaluate the apparent difference in body size of the Sierra Nevada *M. lucifugus*, we compared forearm lengths for 21 adult females captured at nine localities (at >1,000 m in and around Yosemite National Park) with those of 43 adult females from Meiss Ranch (Butte Valley Wildlife Refuge, Siskiyou County), a site within the range of *M. l. carissima* as defined by Hall (1981) (Table 9). The sample forearm length distributions are almost non-overlapping and mean forearm length is significantly longer for the Sierran sample. Informal characterizations of pelage color reveal considerable color variation in the Sierra Nevada animals (with fur ranging from golden to dark brown), while the Meiss ranch population was more nearly uniformly dark brown, matching typical descriptions elsewhere in the northern range of the species.

3.7.3. Genetic Differentiation of *M. lucifugus* Populations

Sequences were obtained for 16 of the 33 individuals from which DNA was extracted and amplified. Two of the individuals from Tenaya Creek and six from Lee Vining Creek did not amplify well, perhaps due to DNA degradation or point mutations in a primer binding site. Six individuals from Lee Vining Creek, one from Meiss Ranch, and two from Moccasin Creek were apparently heteroplasmic (i.e., two or more PCR products were amplified per individual). While mammals have been generally viewed as having a single maternally inherited mitochondrial genotype, naturally occurring errors in replication of repeated sequences such as are present in the highly variable d-loop region used in this study can create length variations in the population of fragments amplified from an individual. Heteroplasmy from this region has emerged as relatively common in studies of vespertilionid bats (Wilkinson et al. 1997). Heteroplasmy is heritable and provides useful markers in genetic analysis, but for technical simplicity in this pilot project, we opted to sequence only non-heteroplasmic individuals.

Figure 14a is a distance tree based on aligned partial D-loop sequences from:

1. Two California samples of *M. lucifugus* -- Meiss Ranch nominally representing typical *M. l. carissima* and Tenaya Creek representing the form hypothesized to be distinctive based on morphology.
2. Samples of an ecologically similar putative sister species, *Myotis yumanensis* from Tenaya Creek and Moccasin Creek (a lower elevation site 70 km west).
3. Single *Myotis lucifugus* from New York and Kentucky
4. A single *Myotis sodalis* from Kentucky
5. A single *Tadarida brasiliensis* as an outgroup (from a different bat family, the Molossidae)

Figure 14b is a distance tree without the three Eastern U.S. Bats, but including three *M. lucifugus* from Lee Vining Creek which are morphologically similar to Tenaya Creek bats.

Individuals within each of the California *M. lucifugus* populations are more closely related to each other than to individuals from the other population. It is notable, however, that these data suggest that Meiss Ranch sample is no more closely related to Tenaya Creek, than to bats from New York or Kentucky. Genetic differentiation of the Meiss Ranch population is well supported both by the bootstrap value (74%) and the decay index value (3) of the clade containing the Meiss Ranch individuals (data not shown). While relationships among geographically defined samples are generally consistent between the distance based and maximum parsimony trees, the parsimony tree corresponding to Figure 14b differs in the branching order among the California *M. lucifugus* sites. Analysis of mitochondrial sequences from more individuals, as well as nuclear DNA markers, would be necessary to further resolve the relationship among these populations. Nevertheless, despite the movement potential offered by flight (and perhaps seasonal movements imposed by winter conditions at high elevation in the Sierra), there is genetic evidence, consistent with the morphology, of geographical population structure within *M. lucifugus*. Further investigation of the distribution and phylogeography of high elevation populations seems warranted, including the status and distinctness *M. lucifugus* populations of the Transverse ranges (e.g., Big Bear Lake) where recreational development is active.

It is worth noting that *M. lucifugus* and *M. yumanensis* are well separated in this analysis. They are sufficiently similar morphologically in some localities that some individuals cannot readily be assigned to species based on external characters. Some studies concluded this indicated hybridization, but electrophoretic analyses showed fixed protein differences.

4.0 CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

4.1. The Significance of Bridges and Surrounding Habitat: Implications for Management by Caltrans

Bridge use by bats along this altitudinal transect was extensive. Every surveyed bridge was used to some degree as a day (nursery) roost, night roost, or both. As many as ten species used a single bridge, and twelve species were found roosting in bridges at some point. Four species used six bridges as nursery sites. This study strongly suggests that all highway bridges in the Sierra

Nevada are potential bat habitat, and thus should be surveyed prior to any structural alterations or potentially disturbing maintenance work.

These surveys also showed that level of use and the species assemblage shifted seasonally, arguing for multiple, seasonal surveys of any site considered to have potential for use by bats. Additionally, in the mid-elevation range, where species diversity is highest, bridge use is changeable, and quite unpredictable. Thus each bridge needs to be investigated individually. Since voluntary surveys conducted after the conclusion of this study revealed that bats were using a number of the bridges as winter roosts, we recognize, in retrospect, that winter surveys (for accessible bridges) should be included in a seasonal protocol, with each bridge being checked at least twice between mid-November and mid-February.

While this study revealed that certain structures are far more likely to be used by bats than others (e.g., concrete girder bridges as night roosts, expansion joints as day roosts), it also illustrated that bat use cannot be reliably predicted based on structural type alone. This study and others have demonstrated that it is often the structural anomalies, which would not necessarily appear on engineer's plans, that are used by bats (e.g., the roost behind a metal sign).

Also, as is amply demonstrated by the example of the bridge over Yosemite Creek, small numbers of bats do not necessarily mean low significance. From a biological perspective, some of the most important information obtained in this study came from this site, which was used by relatively few animals.

We also note that predictions regarding use and significance of higher elevation bridges should not be made based on this study alone, since the higher elevation sites were all within Yosemite National Park, where extensive alternate roosting habitat was available. We recommend that additional investigations of bridge roosting be conducted along other trans-Sierran highways, where the habitat has been altered by timber harvest and/or lacks the granite features so prominent in Yosemite.

As was also shown in this study, bodies of water, particularly flowing water, are favored foraging areas for most bat species. Because bridge roosts (particularly those over water) are often located in close proximity to foraging areas, Caltrans should consider the impacts of road/bridge construction and maintenance activities on potential foraging areas, particularly any activities that would result in degradation of riparian habitat or reduction in insect productivity.

Genetic investigations of *Myotis lucifugus* suggests that the high Sierran form may be genetically distinct from populations currently considered to belong to the same subspecies, *M. l. carissima*. The status of this high Sierran form is unknown, and should be given special consideration in projects involving sites at >2,000 m.

4.1.2. Mitigation

Given the importance of bridge roosts for many bat species, we recommend that Caltrans routinely conduct surveys for bats prior to any bridge modifications. For bridges being used by bats construction activities should take place, to the extent possible, outside times of most critical use (e.g., roosts being used as day roosts for raising young, as night roosts for pregnant females or females with still dependent young, or as hibernating sites). When construction activity necessitates elimination of an existing roosting site, alternate and equivalent habitat should be provided. In some cases this may involve a two-step process: providing temporary habitat during construction, and incorporating permanent habitat into the new or remodelled structure.

The need for and degree of mitigation recommended will depend on the significance of the roost and the degree of disturbance a particular project will cause. For any nursery roost, no matter what species or what size the roost, every effort should be made to insure that animals are not destroyed. To avoid mortality, construction should be performed outside the nursery season, or animals should be excluded from the roost prior to construction (and prior to the onset of the nursery season) by altering the structure of the roost to make it unsuitable or unavailable to the animals (e.g., filling expansion joints when animals are not present).

For significant roosts (large, regionally significant roosts for any species, or nursery roosts of any size for rare species), the first choice would be to avoid impacts to the existing roost. Sometimes avoidance can be achieved by performing construction activities outside the nursery season. If it proves necessary to displace a significant nursery colony, then alternate roosting habitat should be provided. This alternative habitat should mimic the existing habitat as closely as possible, and be located close by. The small, commercially available “bat houses” are not likely to provide suitable alternate roosting habitat for any California bat species. In cases of bridge replacement, alternate roost sites should be offered during the construction phase, and bat habitat with comparable spatial and thermal characteristics should be incorporated into the new structure.

In areas where riparian habitat is degraded, restoration projects may be appropriate, and could be of potentially significant benefit to the bat community. This is particularly true at lower elevations, where restoration of cottonwood/sycamore/oak riparian would benefit a number of species.

4.2. Elevational and Seasonal Patterns: Implications for Management of Bat Populations in the Central Sierra Nevada

The Sierra Nevada Ecosystem Project identified the three greatest potential risks to terrestrial vertebrates in the Sierra Nevada as “continuing appropriation of native foothill communities, damage to riparian systems, and compromise of remaining late-successional forests” (Graber 1996). This study suggests that all three are important to bat populations.

This study documented changes in the species assemblage with both elevation and season, with the highest diversity (all species being present) in the mid-elevation range between 1,000 and 2,000 m. Additionally, demographic data suggest that, with the exception of *M. lucifugus* (Sierran form), most species that have reproductive populations in the Sierra Nevada may rear young predominantly at low to mid-elevation where temperatures are warmer.

This finding has profound implications for the management of bat populations, since most maternity sites may be located outside National Park boundaries, primarily on Forest Service or privately owned land. It also highlights the key role of the limited areas below 2,000 m within the park, particularly the river canyons and large creek drainages and their associated forest and cliff habitat (e.g., Yosemite Valley, Hetch Hetchy, Lake Eleanor, and Wawona). In these areas, as elsewhere, primary natural roost sites are likely to be rock crevices, and tree defects (e.g., cavities and bark crevices in large diameter snags). Because the areas of most intense recreational activity (especially Yosemite Valley) are in this elevation range, special consideration should be given to examining human impacts on bat populations. These include: activities that result in degradation of riparian habitat, removal of “hazard” trees without first considering whether they might contain cavities with significant bat colonies, rock climbing in the vicinity of nursery roosts, and trampling of meadows (which provide important summer foraging habitat). Focal studies are needed for at

risk species (particularly the pallid bat, *A. pallidus*, and some of the more poorly known *Myotis* species) to identify species specific roosting and foraging requirements in the central Sierra Nevada.

The apparent concentration of breeding populations at mid and lower elevations does not mean that higher elevation habitats are of no consequence to bats. These habitats support what appears to be a genetically differentiated form of *M. lucifugus*, whose distribution may be limited to the Sierran crest. Also, the elevational breeding range for a number of species remains mostly unknown, and may well extend to higher elevations. It is evident from this study that higher elevations within Yosemite National Park provide important foraging habitat throughout the summer, with the suggestion that some species may move upslope or migrate along the crest in the late summer and early fall, at a time when the high elevation meadows and aquatic habitats are likely at maximum productivity (and lower elevation habitats are rapidly drying). Thus this habitat may provide resources at a time of year when many bat species mate and individuals are accumulating fat stores in preparation for winter hibernation

Mid-elevation forest habitat, particularly in the ponderosa pine/black oak communities, may be critical for maintaining a number of California's bat species. This habitat is under pressure by expanding human populations in the Sierran foothills (Duane 1996). Current timber harvest practices (on both Forest Service and private land) do not favor retention of those features most needed by the majority of bat species --a diverse, multi-age forest that includes mature black oak (with many structural flaws), large diameter ponderosa, Jeffrey or sugar pine snags, and enough green trees to insure adequate snag recruitment. In this context, the protection of wilderness lands within the National Park is likely critical to the long-term maintenance of populations for many bat species.

This study is consistent with work elsewhere is showing the importance of water corridors and adjacent riparian areas to foraging bats. Levels of bat acoustic activity during the summer months was two to six times greater adjacent to flowing water than it was away from water. Degradation of riparian habitats resulting from the factors identified by Kondolf et al. (1996), including recreation, grazing, road construction, water impoundments, agricultural encroachment, and urbanization are likely to have negative impacts on bat diversity. Certain changes may, however, favor local increases for some taxa (e.g., water impoundments expand foraging habitat for surface skimmers).

Regionally based conservation strategies, designed and implemented by cooperating agencies, are needed for a number of bat species. While recommended conservation actions would vary from species to species, all conservation strategies should include the following objectives: delineate the elevational range of breeding populations; investigate species specific, regional roosting requirements; evaluate availability of species specific roosting habitat (e.g., large diameter snags, caves, cliffs, abandoned mines, bridges and/or other human structures); protect and share information regarding known roosts or roosting areas; identify important foraging areas; protect known foraging areas, particularly in riparian zones and meadows; and support riparian restoration efforts.

4.3. Priorities for Future Research

- **Determine elevational limits for breeding populations**

Knowledge of bat distribution in the Sierra Nevada is extremely sketchy. Consequently,

for this study and prior surveys within Yosemite National Park (Pierson and Rainey 1993 & 1995) we chose to sample over a broad area and large elevational range. Many sites were visited only once, and much of the data was obtained primarily by acoustic survey. Also, attention was focused on sites that were most accessible and/or received high recreational use. Within the Park, the most data have been gathered in Yosemite Valley, Wawona, and in the vicinity of Tuolumne Meadow (at ca. 1200 and ca. 2,600 m). This leaves a possibly critical elevational range (1,500-2,500 m) that has, as yet, received little or no attention. The suggestion that reproductive activity is limited or absent for many species at high elevation identifies the intermediate elevations as key to determining the extent to which bat populations are locally reproducing in the park. Establishing elevational limits of reproduction for each species would aid in predicting their sustainability, independent of land use and habitat changes at lower elevations outside the park.

Consequently, we recommend that intensive mist-netting surveys be conducted along an elevational gradient, primarily within Yosemite National Park, to determine the elevational limits and relative abundance for breeding populations of the 13 species known to raise young in this region. This investigation should focus on elevations of 1,200 m and higher, sampling at regular intervals along an elevational gradient in the major drainages (South Fork of Merced River, Main Fork of Merced River, Tuolumne River, and Jack Main Canyon).

- **Investigate the roosting requirements for species that raise young in the Sierra Nevada**

Roosting requirements for breeding females remain poorly known for a number of the special concern species. Studies of habitat requirements (roosting and foraging) were conducted in Yosemite for the spotted bat, *E. maculatum*, and the western mastiff bat, *E. perotis* (Pierson and Rainey 1996b). Comparable focal studies are needed for other species, particularly those most likely to be reliant of late successional forests and roost in large snags (e.g., the fringed myotis, *M. thysanodes*, and the long-legged myotis, *M. volans*). Also important would be an investigation of roost requirements for the pallid bat, *A. pallidus*, since this is a species likely being heavily impacted by loss of oak woodland at lower elevations.

- **Investigate the apparent upslope migration of certain species**

This study suggested that some bat species move upslope in the fall, at a time when most California species mate and accumulate fat reserves for winter hibernation. An intensive netting effort at higher elevations in the fall (late August through early October) is needed to identify which species are reliant on high elevation habitat during this critical time in their annual cycle. Parallel insect sampling and guano analysis would identify the prey base.

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Table 1. List of bat species found in three elevation ranges in the Sierra Nevada, showing detection method used. "X" = confirmed identification; "X.q" = an unconfirmed identification; asterisk (*) = record from east side of Sierra.

		Acoustic Bridge Roost Net Capture # SPP		
<1,000 m		14		
<i>Antrozous pallidus</i>	Pallid bat	X	X	
<i>Corynorhinus townsendii</i>	Townsend's big-eared bat	X	X	
<i>Eptesicus fuscus</i>	Big brown bat	X	X	X
<i>Euderma maculatum</i>	Spotted bat	X		
<i>Eumops perotis</i>	Western mastiff bat	X		
<i>Lasionycteris noctivagans</i>	Silver-haired bat	X		
<i>Lasiurus blossevillii</i>	Red bat	X		
<i>Lasiurus cinereus</i>	Hoary bat	X		
<i>Myotis californicus</i>	California myotis	X		
<i>Myotis thysanodes</i>	Fringed myotis		X.q	
<i>Myotis volans</i>	Long-legged myotis	X	X	X
<i>Myotis yumanensis</i>	Yuma myotis	X	X	X
<i>Pipistrellus hesperus</i>	Western pipistrelle	X		
<i>Tadarida brasiliensis</i>	Mexican free-tailed bat	X	X	
No. Species		13	6	3
1,000 to 2,000 m		17		
<i>Antrozous pallidus</i>	Pallid bat	X	X	X
<i>Corynorhinus townsendii</i>	Townsend's big-eared bat		X	X
<i>Eptesicus fuscus</i>	Big brown bat	X	X	X
<i>Euderma maculatum</i>	Spotted bat	X		X
<i>Eumops perotis</i>	Western mastiff bat	X		X
<i>Lasionycteris noctivagans</i>	Silver-haired bat	X	X	X
<i>Lasiurus blossevillii</i>	Red bat	X		X
<i>Lasiurus cinereus</i>	Hoary bat	X		X
<i>Myotis californicus</i>	California myotis	X	X	X
<i>Myotis ciliolabrum</i>	Small-footed myotis		X	X
<i>Myotis evotis</i>	Long-eared myotis	X	X	X
<i>Myotis lucifugus</i>	Little brown bat	X	X	X
<i>Myotis thysanodes</i>	Fringed myotis	X	X	X
<i>Myotis volans</i>	Long-legged myotis	X	X	
<i>Myotis yumanensis</i>	Yuma myotis	X	X	X
<i>Pipistrellus hesperus</i>	Western pipistrelle	X		X
<i>Tadarida brasiliensis</i>	Mexican free-tailed bat	X	X	X
No. Species		15	12	16
> 2,000 m		14		
<i>Eptesicus fuscus</i>	Big brown bat	X		X
<i>Euderma maculatum</i>	Spotted bat	X		
<i>Eumops perotis</i>	Western mastiff bat	X		
<i>Lasionycteris noctivagans</i>	Silver-haired bat	X		X*
<i>Lasiurus blossevillii</i>	Red bat	X		
<i>Lasiurus cinereus</i>	Hoary bat	X		X
<i>Myotis californicus</i>	California myotis	X		
<i>Myotis ciliolabrum</i>	Small-footed myotis		X	
<i>Myotis evotis</i>	Long-eared myotis	X		X*
<i>Myotis lucifugus</i>	Little brown bat	X	X	X
<i>Myotis thysanodes</i>	Fringed myotis	X.q		
<i>Myotis volans</i>	Long-legged myotis	X	X	X*
<i>Myotis yumanensis</i>	Yuma myotis	X	X	X
<i>Tadarida brasiliensis</i>	Mexican free-tailed bat	X		X
No. Species		12	4	8

Table 2. Bridge use by northern California bat species. Roost type is indicated as DR for day roost, NR for night roost, and WR for winter roost. Species found to be using bridges in this study, and the type of roost use, are indicated in bold. An asterisk (*) indicates that one or more day roosts was also a maternity roost.

SPECIES KNOWN TO USE BRIDGES		ROOST TYPE	REFERENCES
Family Vespertilionidae (mouse-eared bats)			
<i>Antrozous pallidus</i> ^a	Pallid bat	DR*, NR	2, 4, 6, 9, 10, 11
<i>Corynorhinus townsendii</i> ^{a,b}	Townsend's big-eared bat	DR, NR	1, 4, 8, 9, 11
<i>Eptesicus fuscus</i>	Big brown bat	DR*, NR	1, 2, 4, 5, 8, 9, 10, 11
<i>Lasionycteris noctivagans</i>	Silver-haired bat	NR, WR	8, 14
<i>Myotis californicus</i>	California myotis	DR, NR	1, 2, 4, 5, 8, 11
<i>Myotis ciliolabrum</i> ^b	Small-footed myotis	DR, NR	5, 14
<i>Myotis evotis</i> ^b	Long-eared myotis	NR, WR	1, 4, 8, 9, 11
<i>Myotis lucifugus</i>	Little brown myotis	NR	1, 2, 4, 8, 10, 11
<i>Myotis thysanodes</i> ^{b,c}	Fringed myotis	DR, NR	1, 4, 10, 11
<i>Myotis volans</i> ^{b,c}	Long-legged myotis	DR, NR, WR	1, 4, 8, 10, 11
<i>Myotis yumanensis</i> ^b	Yuma myotis	DR*, NR, WR	1, 2, 4, 5, 8, 9, 10, 11
<i>Pipistrellus hesperus</i>	Western pipistrelle	DR, NR	3, 6
Family Molossidae (free-tailed bats)			
<i>Tadarida brasiliensis</i>	Mexican free-tailed bat	DR*, NR	5, 7, 10, 11
SPECIES NOT KNOWN TO USE BRIDGES			
Family Vespertilionidae (mouse-eared bats)			
<i>Euderma maculatum</i> ^{a,b}	Spotted bat		
<i>Lasiurus blossevillii</i> ^c	Red bat		
<i>Lasiurus cinereus</i>	Hoary bat		
Family Molossidae (free-tailed bats)			
<i>Eumops nerotus</i> ^{a,b}	Western mastiff bat		

^a Mammal of Special Concern or Sensitive Species, CDFG

^b USFWS Special Concern (Former Category 2 Candidate)

^c Proposed as Mammal Species of Special Concern, CDFG

1 Adam and Hayes 2000

2 Barbour and Davis 1969

3 D. Constantine personal communication

4 Cross and Waldien 1994

5 Davis and Cockrum 1963

6 G. Erickson (Caltrans) personal observation (July 2000)

7 Murphy 1990

8 Perlmeter 1996

9 Pierson and Rainey 1998b

10 Pierson et al. 1996

11 This Study

Table 3. Number of hand net captures or visual observations for bat species at bridge roosts in Yosemite National Park and surrounding localities, between 1994 and 2000. An asterisk (*) denotes a first record for the Park; a double asterisk (**) denotes first capture of high elevation form of *M. lucifugus*. DR = day roost; NR = night roost; WR = winter roost; P = present; G = species inferred from guano. Data are ordered seasonally from low to high elevation sites along the Highway 120 corridor, and associated roads or highways.

LOCALITY	DATE	ROOST TYPE	SPECIES										# BATS	# SPP				
			ANPA	COTO	EPFU	LANO	MYCA	MYCI	MYEV	MYLU	MYTH	MYVO			MYYU	MVSP	TABR	
OUTSIDE YOSEMITE NATIONAL PARK																		
Orange Blossom - 33 m																		
	29-Apr-99	DR													>100		1	
	29-Jun-99	DR													~500	few	~500	2
	15-Aug-99	DR													~300	~300	~600	2
	16-Dec-00	WR															0	0
Wildcat Culvert - 55 m																		
	15-Aug-99	NR													~30		~30	1
Don Pedro - 260 m																		
	17-Jun-99	DR															0	1
	17-Jun-99	NR													1		1	1
	15-Aug-99	NR	1												1	1	3	3
	16-Sep-99	NR															0	0
Jacksonville Rd - 260 m																		
	15-Aug-99	NR	P												~200		~200	3
	16-Sep-99	NR													~25		~25	1
Moccasin Creek, Hwy 120 - 274 m																		
	17-Jun-99	NR													~100		~100	1
	14-Jul-99	NR													~300	1	~300	2
	15-Aug-99	NR													>300		>300	1
	16-Sep-99	NR													~50		~50	1

Table 3. Cont'd

LOCALITY	DATE	ROOST TYPE	ANPA	COTO	EFFU	LANO	MYCA	MYC	MYEV	MYLU	MYTH	MYVO	MYU	MYS	TABR	# BATS	# SPP
Moccasin Ck, Hwy 49 - 312 m																	
	29-Jun-99	DR														-20	1
	29-Jun-99	NR			-20										G	0	1
	07-Oct-94	DRNR				G									G	0	2
Jackass Creek, Hwy 49 - 360 m																	
	29-Jun-99	NR	G		G										G	0	2 or 3
	07-Oct-94	NR	G		G										G	0	2 or 3
Bear Creek, Briceburg - 361 m																	
	29-May-97	DR											>500		>500	>1,000	2
	24-Jun-97	DRNR	P										>1,000		>500	>1,500	3
	07-Jun-98	DR											~100		~500	~600	2
	15-Jul-99	DR											>1,000		>500	>1,500	2
Lumsden - S.Fk. - 451 m																	
	28-Apr-99	NR														0	0
	12-Jul-99	NR											5		5	10	2
	14-Aug-99	NR	1										15		2	18	3
	15-Sep-99	NR											2	9		11	2
	20-Oct-99	NR														0	0
Lumsden - Main Fk. - 471 m																	
	29-Apr-99	DR														0	0
	11-Apr-00	DR											0			-200	1
	30-Jun-99	DR											>200		few	>200	2
	14-Aug-99	DR											0		0	0	0
	15-Sep-99	DR											0		0	0	0
	20-Oct-99	DR													P		1

Table 3. Cont'd

LOCALITY	DATE	ROOST TYPE	ANPA	COTO	EPRJ	LANO	MYCA	MYC	MVEV	MYLU	MYTH	MYVO	MYU	MYS	TABR	# BATS	# SPP	
Sidewall Viaduct - 914 m																		
	31-May-97	NR			~40										15	~55	2	
	15-Jun-99	NR			~100											~100	1	
	12-Jul-99	NR			3									2		5	2	
	14-Aug-99	NR			~30							Few	5	6	~45	4		
	16-Sep-99	NR								1	2	1			1	8	4	
	20-Oct-99	NR									1					1	1	
	16-Nov-00	WR														0	0	
	16-Dec-00	WR														0	0	
Berkeley Tuolumne Camp - 1,078 m																		
	01-Jun-98	DR														3	~23	2
Tuolumne - S. Fk. East - 1,134 m																		
	29-Apr-99	DR									8	1	1				10	3
	27-Apr-99	NR									43	7					50	2
	28-Apr-99	NR							1	8							9	2
	31-May-97	NR	4		1						2		1				8	4
	30-Jun-99	NR	1		3								4	1			9	3
	01-Jul-98	NR	4		2		2			1	12	10					31	6
	12-Jul-99	NR		1							1	1					3	3
	14-Aug-99	NR	12		1						4	3	7		2		29	6
	13-Sep-98	NR	2		5							8	5	2			22	4
	15-Sep-99	NR									2	2	5	1			10	4
	20-Oct-99	NR										1	1				2	2
	16-Nov-00	WR										11	1				12	2
	16-Dec-00	WR						1				1					2	2

Table 3. Cont'd

LOCALITY	DATE	ROOST TYPE	ANPA	COTO	EFPU	LANO	MYCA	MYCI	MYEV	MYLU	MYTH	MYVO	MYU	MYSF	TABR	# BATS	# SPP
Tuolumne Meadow - 2,616 m																	
	16-Jun-99	NR														NA	NA
	14-Jul-99	NR														0	0
	16-Aug-99	NR												G		0	0
	17-Sep-99	NR												G		0	0
	21-Oct-99	NR												G		0	0

Table 4. Bridge use by bats along an altitudinal transect in the central Sierra Nevada.

ALTITUDE	SPECIES	# BRIDGES USED	% BRIDGES USED
Less than 1,000 m		(n=12)	
	<i>Antrozous pallidus</i>	6	50.0
	<i>Corynorhinus townsendii</i>	1	8.3
	<i>Eptesicus fuscus</i>	6	50.0
	<i>Myotis californicus</i>	0	0.0
	<i>Myotis ciliolabrum</i>	0	0.0
	<i>Myotis lucifugus</i>	0	0.0
	Myspp.	5	41.7
	<i>Myotis thysanodes</i>	1	8.3
	<i>Myotis volans</i>	2	16.7
	<i>Myotis yumanensis</i>	10	83.3
	<i>Tadarida brasiliensis</i>	9	75.0
1,000 to 2,000 m		(n=6)	
	<i>Antrozous pallidus</i>	4	66.7
	<i>Corynorhinus townsendii</i>	2	33.3
	<i>Eptesicus fuscus</i>	5	83.3
	<i>Lasionycteris noctivagans</i>	1	16.7
	<i>Myotis californicus</i>	1	16.7
	<i>Myotis ciliolabrum</i>	1	16.7
	<i>Myotis evotis</i>	1	16.7
	<i>Myotis lucifugus</i>	2	33.3
	Myspp.	4	66.7
	<i>Myotis thysanodes</i>	2	33.3
	<i>Myotis volans</i>	3	50.0
	<i>Myotis yumanensis</i>	4	66.7
	<i>Tadarida brasiliensis</i>	3	50.0
Greater than 2,000 m		(n=2)	
	<i>Antrozous pallidus</i>	0	0.0
	<i>Corynorhinus townsendii</i>	0	0.0
	<i>Eptesicus fuscus</i>	0	0.0
	<i>Myotis californicus</i>	0	0.0
	<i>Myotis ciliolabrum</i>	1	50.0
	<i>Myotis lucifugus</i>	1	50.0
	Myspp.	2	100.0
	<i>Myotis thysanodes</i>	0	0.0
	<i>Myotis volans</i>	1	50.0
	<i>Myotis yumanensis</i>	1	50.0
	<i>Tadarida brasiliensis</i>	0	0.0

Table 5. Cont'd.

DATE	LOCALITY	ANPA	COTO	EPRJ	EUMA	EUPE	LABL	LACI	LANO	MYCA	MYCI	MYEV	MYLU	MYTH	MYVO	MYU	MY40	MY50	PHE	TABR	# SPP
LUMSDEN - 451 m																					
28-Apr-99	Lumnsden A - wooded track								X									X			X
28-Apr-99	Lumnsden B - Ctr. Bridge								X									X			X
28-Apr-99	Lumnsden C - E along rd.								X									X			
28-Apr-99	Lumnsden D - adj. Bridge								X							X		X			
28-Apr-99	Lumnsden - Cmpgrnd								X									X			
15-Jun-99	Lumnsden A - wooded track	X		X				X.q						X				X			X
15-Jun-99	Lumnsden C - E along rd.	X.q		X			X							X				X			X
15-Jun-99	Lumnsden D - adj. Bridge	X.q		X			X							X				X			X
12-Jul-99	Lumnsden A - wooded track								X												X
12-Jul-99	Lumnsden C - E along rd.							X													X
12-Jul-99	Lumnsden D - adj. Bridge							X													X
14-Aug-99	Lumnsden A - wooded track								X												X
14-Aug-99	Lumnsden C - E along rd.								X												X
14-Aug-99	Lumnsden D - adj. Bridge	X						X.q													X
15-Sep-99	Lumnsden A - wooded track								X												X
15-Sep-99	Lumnsden C - E along rd.			X.q					X												X
15-Sep-99	Lumnsden D - adj. Bridge			X.q					X												X
15-Sep-99	Lumnsden - Cmpgrnd								X												X
20-Oct-99	Lumnsden A - wooded track								X												X
20-Oct-99	Lumnsden C - E along rd.	X.q						X													X
20-Oct-99	Lumnsden D - adj. Bridge			X.q				X.q													X
BIG CREEK - 859 m																					
27-Apr-99	Big Creek - little bridge																				X
26-May-97	Sidewall Viaduct - 914 m																				X
17-Jun-99	Big Creek - S near ck								X												X
17-Jun-99	Big Creek - E of little bridge								X												X
14-Jul-99	Big Creek - S near ck								X												X
14-Jul-99	Big Creek - E of little bridge								X												X
14-Aug-99	Big Creek - S near ck								X												X
14-Aug-99	Big Creek - E of little bridge								X												X
16-Sep-99	Big Creek - S near ck	X.q							X												X
16-Sep-99	Big Creek - E of little bridge								X												X
18-Sep-98	Big Creek								X.q												X

11

10

Table 5. Cont'd.

DATE	LOCALITY	ANPA	COTO	EPRJ	EUMA	EJPE	LABL	LACI	LANO	MYCA	MYG	MYEV	MYLU	MYTH	MYVO	MYYU	MY40	MY50	PI-E	TABR	# SPP
22-Oct-99	Big Creek - S near ck						X	X	X								X				X
22-Oct-99	Big Creek - E of little bridge						X	X	X								X	X			X
SOUTH FORK TUOLUMNE - 1,134 m																					
27-Apr-99	S. Fk. Tuol. - at Bridge													X			X	X			X
14-Jun-99	S. Fk. Tuol. - at Bridge	X		X			X	X									X	X			X
15-Jun-99	S. Fk. Tuol.- N along Ck	X.q		X			X.q	X.q					X.q			X	X	X			X
15-Jun-99	S. Fk. Tuol.- clearing			X													X	X			X
12-Jul-99	S. Fk. Tuol.- N along Ck	X		X			X	X.q		X		X		X.q		X	X	X			X
12-Jul-99	S. Fk. Tuol.- clearing	X		X			X	X.q		X		X.q		X		X	X	X			X
12-Aug-99	S. Fk. Tuol.- N along Ck	X		X			X.q	X.q		X		X		X		X	X	X			X.q
12-Aug-99	S. Fk. Tuol.- clearing			X								X		X		X	X	X			X
15-Sep-99	S. Fk. Tuol.- N along Ck	X		X			X.q	X.q									X	X			X
15-Sep-99	S. Fk. Tuol.- clearing			X													X	X			X
20-Oct-99	S. Fk. Tuol.- N along Ck	X.q					X	X		X						X		X			
20-Oct-99	S. Fk. Tuol.- clearing						X	X		X											
CARLON - 1,316 m																					
27-Apr-99	Carlton - at Bridge													X							
27-Apr-99	Carlton - W nr Ck													X			X				
27-Apr-99	Carlton - W on rd													X			X				
06-Jun-98	Harden Flat - 1,350 m																				
14-Jun-99	Carlton - at Bridge	X.q		X			X	X		X		X		X			X				X
14-Jun-99	Carlton C - Mdw			X.q			X	X.q		X		X		X			X				X
15-Jun-99	Carlton- E. at creek			X			X	X		X		X		X			X				X
12-Jul-99	Carlton- E. at creek			X			X	X		X		X		X			X				X
12-Jul-99	Carlton C - Mdw						X	X		X		X		X			X				X
12-Aug-99	Carlton - at Bridge	X.q		X			X	X		X		X		X			X				X
12-Aug-99	Carlton- E. at creek	X		X			X	X		X		X		X			X				X
12-Aug-99	Carlton C - Mdw			X			X	X.q		X		X		X			X				X
12-Aug-99	Carlton - W nr Ck	X.q		X			X	X		X		X		X			X				X
12-Aug-99	Carlton - W on rd			X			X	X		X		X		X			X				X
12-Aug-99	Carlton - W at River	X		X			X	X		X		X		X			X				X

11

14

Table 5. Cont'd.

DATE	LOCALITY	ANPA	COTO	EPRJ	EUMA	ELPE	LABL	LACI	LANO	MYCA	MYCI	MYEV	MYLU	MYTH	MYVO	MYUJ	MY40	MY50	PHE	TABR	# SPP
13-Aug-99	Harden Flat - 1,350 m			X																	
13-Aug-99	Carlton- E. at creek			X								X					X				X
13-Aug-99	Carlton C - Mdw			X		X			X	X		X				X	X				X
13-Sep-98	Harden Flat - 1,350 m					X															
13-Sep-98	Carlton - at Bridge					X			X								X				
15-Sep-99	Carlton- E. at creek			X		X			X	X							X				X
15-Sep-99	Carlton C - Mdw			X.q		X	X.q		X	X							X				X
20-Oct-99	Harden Flat - 1,350 m							X	X	X		X		X.q			X				X
20-Oct-99	Carlton- E. at creek						X	X	X	X						X	X				X
20-Oct-99	Carlton C - Mdw						X	X	X	X						X	X				X

YOSEMITE CREEK, TIOGA ROAD - 2,280 m

13

16-Jun-99	Yosemite Ck A - Cmpgrnd			X																	
16-Jun-99	Yosemite Ck B - Rock/Forest											X									
13-Jul-99	Yosemite Ck A - Cmpgrnd			X		X			X.q			X					X				X
13-Jul-99	Yosemite Ck C - red Fir			X		X.q											X				
13-Jul-99	Yosemite Ck D - Bridge																				
03-Aug-98	Siesta Lake - 2,433 m			X		X			X			X					X				X
16-Aug-99	Yosemite Ck A - Cmpgrnd			X		X			X			X					X				X
16-Aug-99	Yosemite Ck B - Rock/Forest			X		X.q			X.q								X				X
17-Sep-99	Yosemite Ck E - 50m up Br					X				X							X				X
17-Sep-99	Yosemite Ck E - 50m dwn Br					X				X							X				X
21-Oct-99	Yosemite Ck E - 50m up Br							X	X	X							X				X
21-Oct-99	Yosemite Ck E - 50m dwn Br							X.q	X	X							X				X

TENAYA LAKE - 2,488 m

11

16-Jun-99	Tenaya Lk - Pt on Lk																				
16-Jun-99	Tenaya Lk A - along ck			X		X		X	X.q								X				X
13-Jul-99	Tenaya Lk - Pt on Lk			X		X		X									X				X
13-Jul-99	Tenaya Lk B - Mdw			X		X		X									X				X

Table 5. Cont'd.

DATE	LOCALITY	ANPA	COTO	EFRU	EUMA	EJFE	LABL	LACI	LANO	MYCA	MYCI	MYEV	MYLU	MYTH	MYVO	MYVU	MY40	MY50	PHE	TABR	# SPP
04-Aug-98	Tenaya Lk - Pt on Lk				X	X							X			X					X
04-Aug-98	Tenaya Lk B - Mdw				X	X	X						X			X	X				X
05-Aug-98	Tenaya Lk - Pt on Lk					X	X						X			X					X
16-Aug-99	Tenaya Lk - Pt on Lk			X		X	X					X	X			X					X
16-Aug-99	Tenaya Lk B - Mdw					X	X,q						X			X					X
14-Sep-98	Tenaya Lk - Pt on Lk					X		X					X			X					X
17-Sep-99	Tenaya Lk - Pt on Lk					X	X						X			X					X
17-Sep-99	Tenaya Lk B - Mdw					X	X						X			X					X
21-Oct-99	Tenaya Lk - Pt on Lk						X	X							X						X
21-Oct-99	Tenaya Lk B - Mdw						X	X							X						X
TUOLUMNE MEADOW - 2,616 m																					
16-Jun-99	Tuolumne Mdw- SE bridge												X								
16-Jun-99	Tuolumne Mdw -Lambert Pkg																X				
14-Jul-99	Tuolumne Mdw- SE bridge			X		X		X					X				X				X
05-Aug-98	Tuolumne Mdw -Lambert Pkg			X		X		X					X				X				X
16-Aug-99	Tuolumne Mdw- SE bridge			X				X	X								X	X			X
17-Sep-99	Tuolumne Mdw- SE bridge																X	X			
21-Oct-99	Tuolumne Mdw- SE bridge							X	X												X
DANA MEADOW LAKE - 2,930 m																					
16-Jun-99	Dana Mdw				X	X,q							X				X				
14-Jul-99	Dana Mdw			X			X,q					X,q					X				X
06-Aug-98	Dana Mdw			X		X		X	X			X				X					X
16-Aug-99	Dana Mdw			X	X		X	X	X								X				X
17-Sep-99	Dana Mdw			X													X	X			
21-Oct-99	Dana Mdw						X	X,q													X

8

11

Table 5. Cont'd.

DATE	LOCALITY	ANPA	COTO	EPRJ	EUMA	EJFE	LABL	LACI	LANO	MYCA	MYC	MYEV	MYLU	MYTH	MYVO	MYVU	MY40	MY50	PHE	TABR	# SPP
TIOGA PASS ENTRANCE STATION LAKE - 3,017 m																					
16-Jun-99	Tioga Pass Lk			X									X				X				7
13-Jul-99	Tioga Pass Lk					X											X				X
14-Jul-99	Tioga Pass Lk				X			X,q									X				X
16-Aug-99	Tioga Pass Lk		X	X				X	X,q								X				X
17-Sep-99	Tioga Pass Lk							X									X	X			X
21-Oct-99	Tioga Pass Lk						X										X				X
EAST SIDE OF SIERRA - MONO LAKE, NW SIDE OF LAKE - 1,968 m																					
17-Aug-99	Mono Lake County Park			X	X			X								X					
17-Aug-99	Mono Lake, west access							X									X				X
17-Aug-99	Poole Power Plant		X			X											X				X

Table 7. Cont'd.

LOCALITY	ELEV (m)	DATE	SPECIES													# SPP						
			ANPA	COTO	EPRJ	EJMA	ELPE	LANO	LABL	LACI	MYCA	MYCI	MYEV	MYLU	MYTH		MYYO	MYYU	PHE	TABR	# BATS	
OUTSIDE YOSEMITE NATIONAL PARK																						
Hwy 120, Big Oak Flat																						
																				5		
Big Creek	859	02-Jul-98			2														1	1	4	
Carlton Parking	1,316	13-Aug-99			1																4	
Harden Flat	1,350	07-Jun-98																	1		1	
Hwy 120, East of Tioga																						
Lee Vining Ck	2,255	17-Aug-99			6														1	21	2	34

Table 8. Number of bats captured by species at 19 sites, 15 in Yosemite National Park (July 1993-September 1998) and 4 outside the park (July 1998-August 1999), for a total of 28 netting sessions.

Species	Number of bats Captured	Percent of Total Captures	Number of Sites	Percent of Sites
<i>Antrozous pallidus</i>	12	3.1	6	31.6
<i>Corynorhinus townsendii</i>	3	0.8	3	15.8
<i>Eptesicus fuscus</i>	35	9.0	11	57.9
<i>Euderma maculatum</i>	7	1.8	1	5.3
<i>Eumops perotis</i>	18	4.6	5	26.3
<i>Lasionycteris noctivagans</i>	7	1.8	3	15.8
<i>Lasiurus blossevillii</i>	3	0.8	1	5.3
<i>Lasiurus cinereus</i>	11	2.8	6	31.6
<i>Myotis californicus</i>	21	5.4	6	31.6
<i>Myotis ciliolabrum</i>	16	4.1	5	26.3
<i>Myotis evotis</i>	12	3.1	8	42.1
<i>Myotis lucifugus</i>	49	12.6	6	31.6
<i>Myotis thysanodes</i>	5	1.3	4	21.1
<i>Myotis volans</i>	3	0.8	2	10.5
<i>Myotis yumanensis</i>	102	26.2	12	63.2
<i>Pipistrellus hesperus</i>	3	0.8	3	15.8
<i>Tadarida brasiliensis</i>	83	21.3	8	42.1

Table 9. Comparison of forearm (FA) lengths for *M. lucifugus* from Butte Valley, within the range of *M. l. carissima*, and from sites within Yosemite National Park

	Butte Valley (n = 43)	Yosemite National Park (n = 21)
Minimum FA (mm)	34.53	35.34
Maximum FA 9 (mm)	37.81	39.39
Mean FA (mm)*	36.21	37.50

* t Statistic = -5.200 w/ 37 df, p<0.0001

Figure 1. A bar graph showing the number of bridges (n = 20) and/or culverts (n = 1) used by twelve bat species. Species names are abbreviated here and on subsequent figures as follows: *Antrozous pallidus* (ANPA), *Corynorhinus townsendii* (COTO), *Eptesicus fuscus* (EPFU), *Lasionycteris noctivagans* (LANO), *Myotis californicus* (MYCA), *Myotis ciliolabrum* (MYCI), *Myotis evotis* (MYEV), *Myotis lucifugus* (MYLU), *Myotis thysanodes* (MYTH), *Myotis volans* (MYVO), *Myotis yumanensis* (MYYU), *Tadarida brasiliensis* (TABR).

BRIDGE USE BY BAT SPECIES

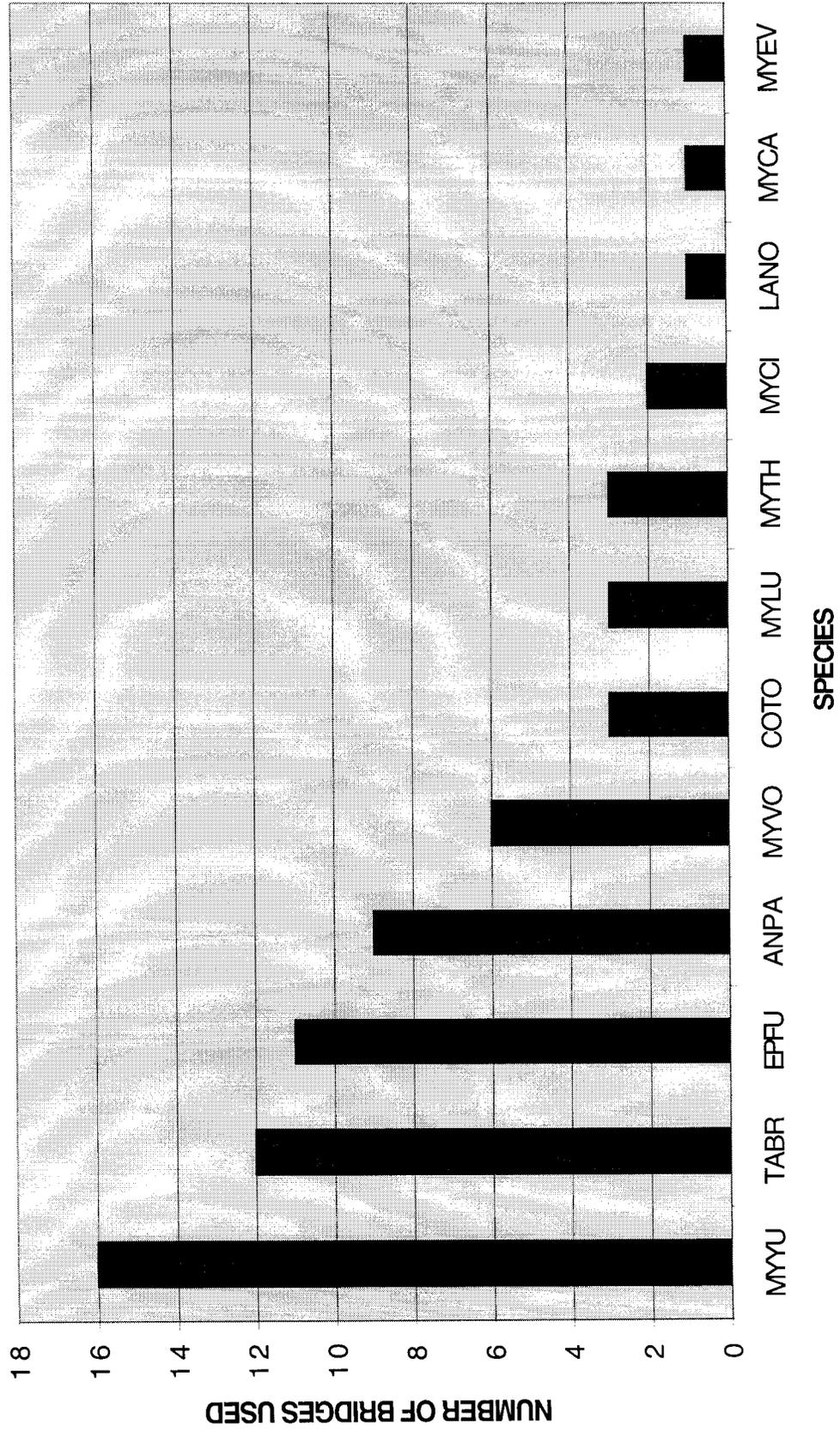


Figure 2. A bar graph showing the number of species per bridge for the twenty bridges surveyed along this transect.

SPECIES DIVERSITY AT BRIDGE ROOSTS

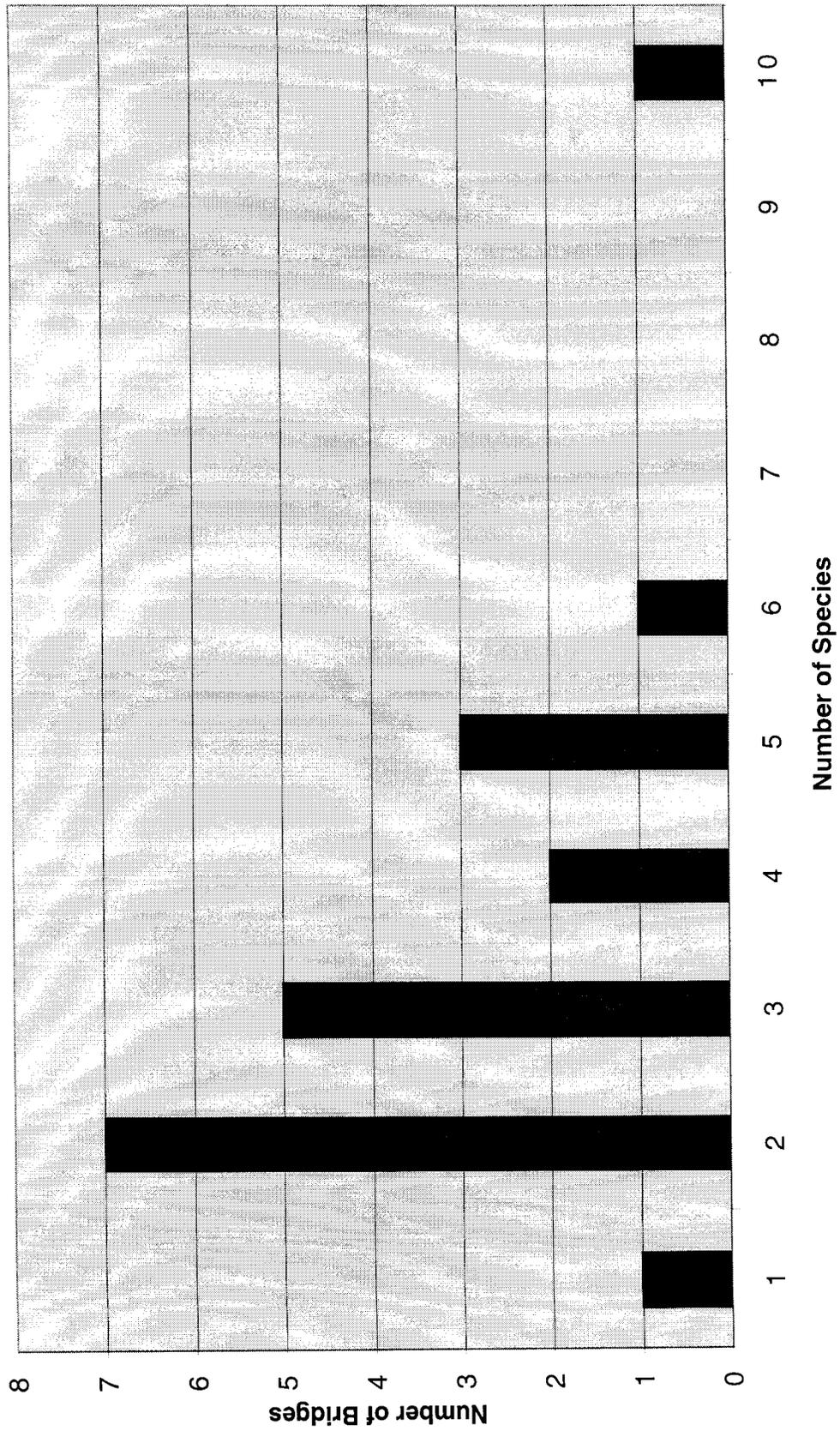


Figure 3. A bar graph showing differences in seasonal patterns of bridge use between *M. yumanensis* at Moccasin Creek and *E. fuscus* at the Sidewall Viaduct.

Seasonal Pattern of Use at Bridge Night Roosts

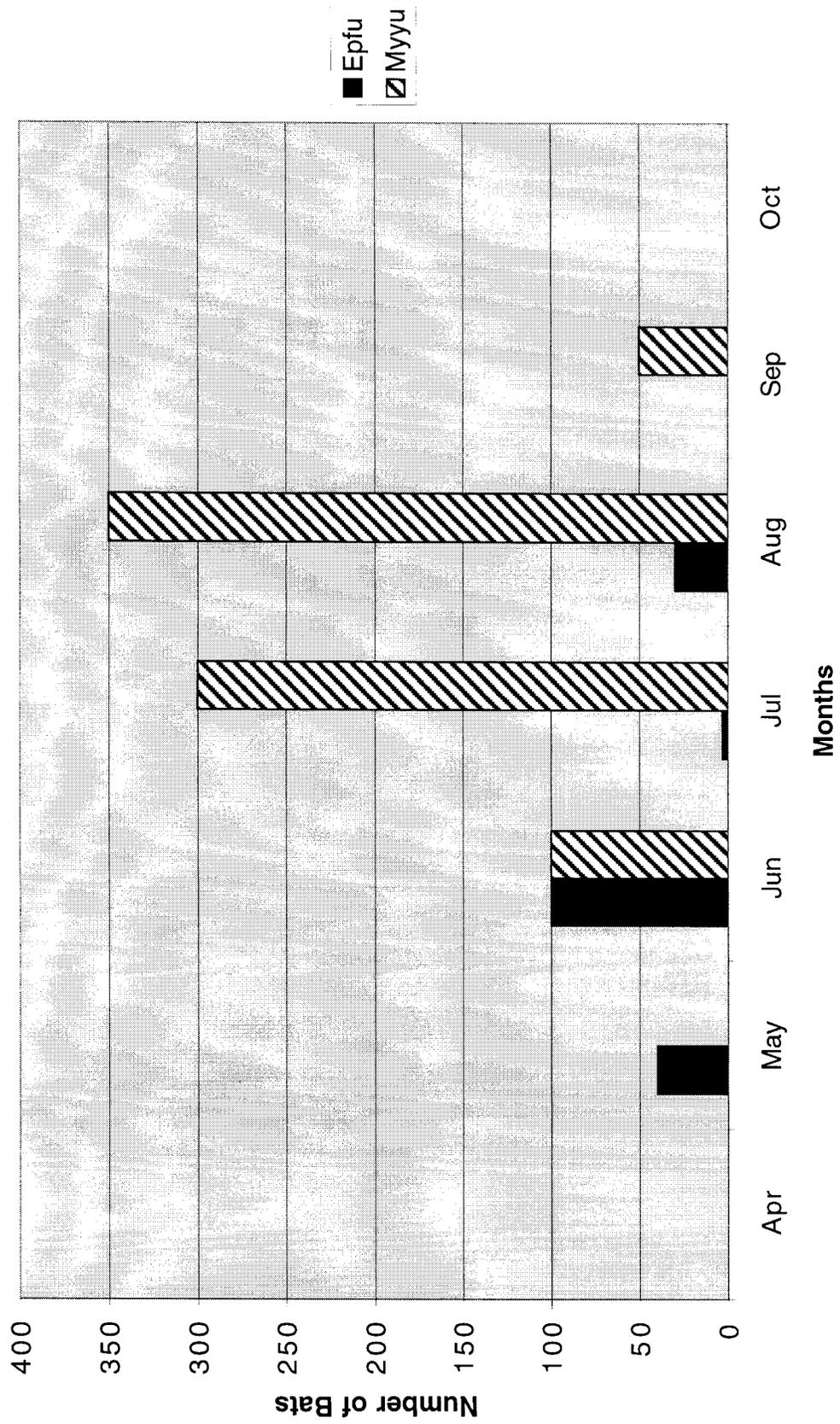
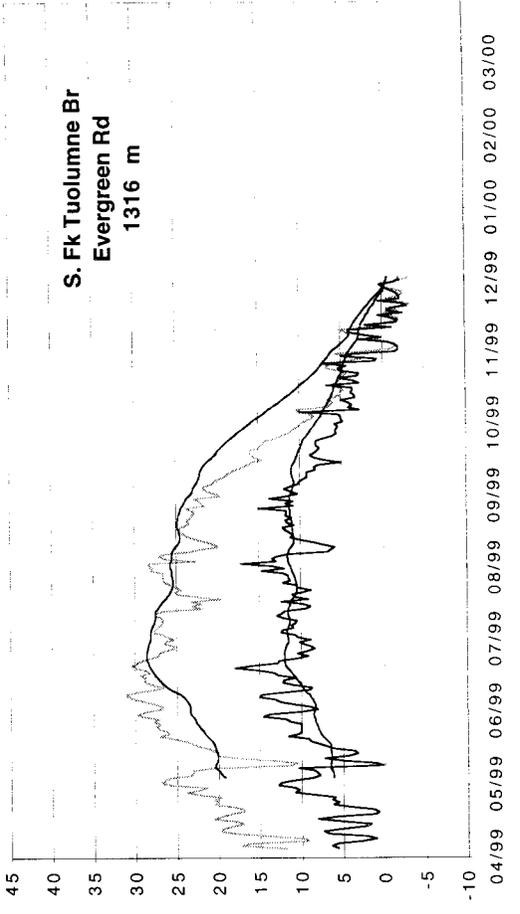
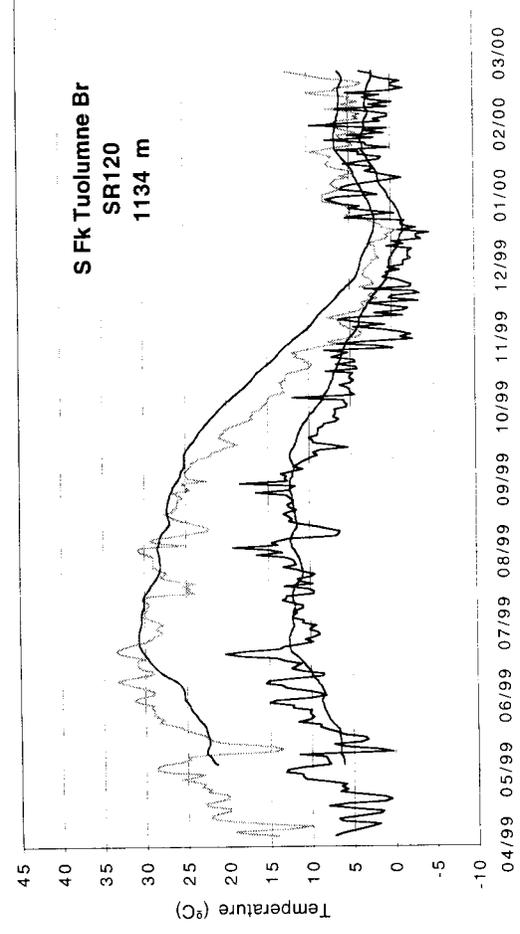
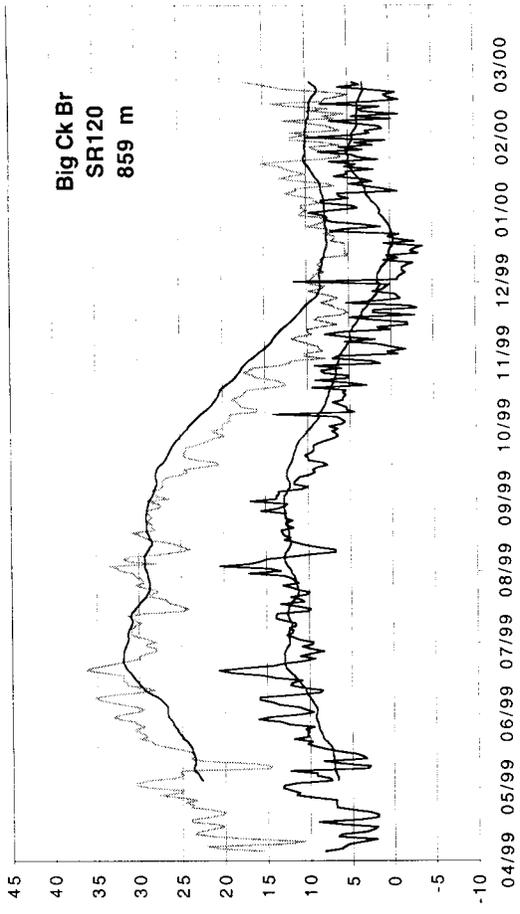
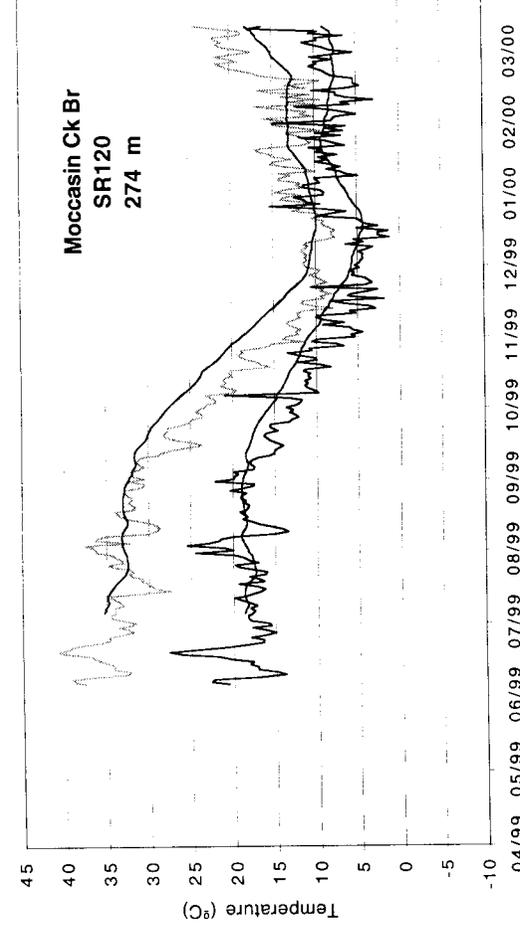


Figure 4a & b. Temperature of ambient air (black) and bridge night roost surface (grey) 4 hours after sunset. Smoothed lines are 30 day moving averages.



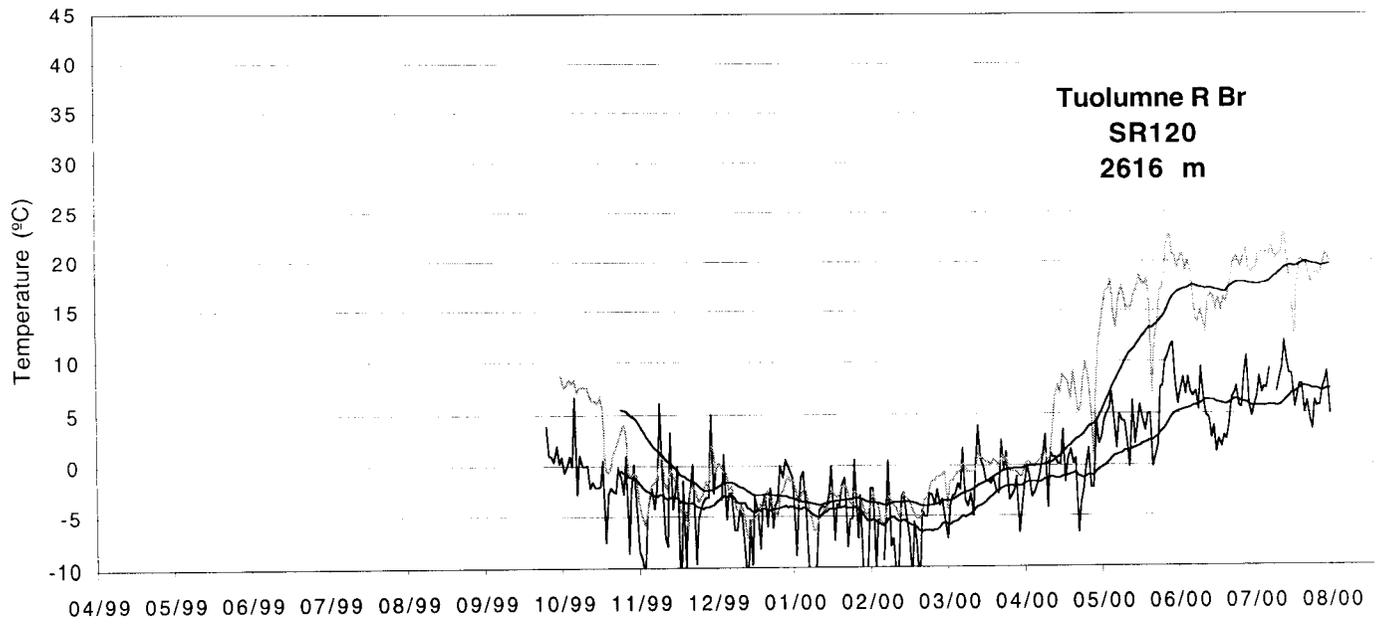
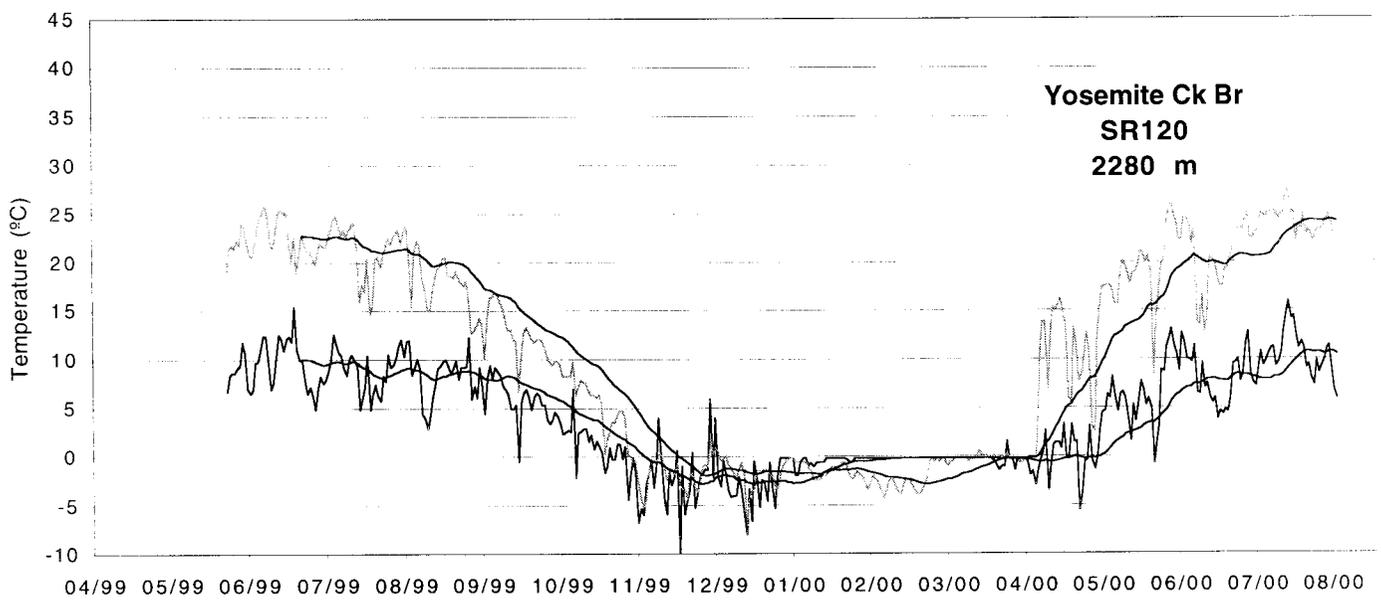
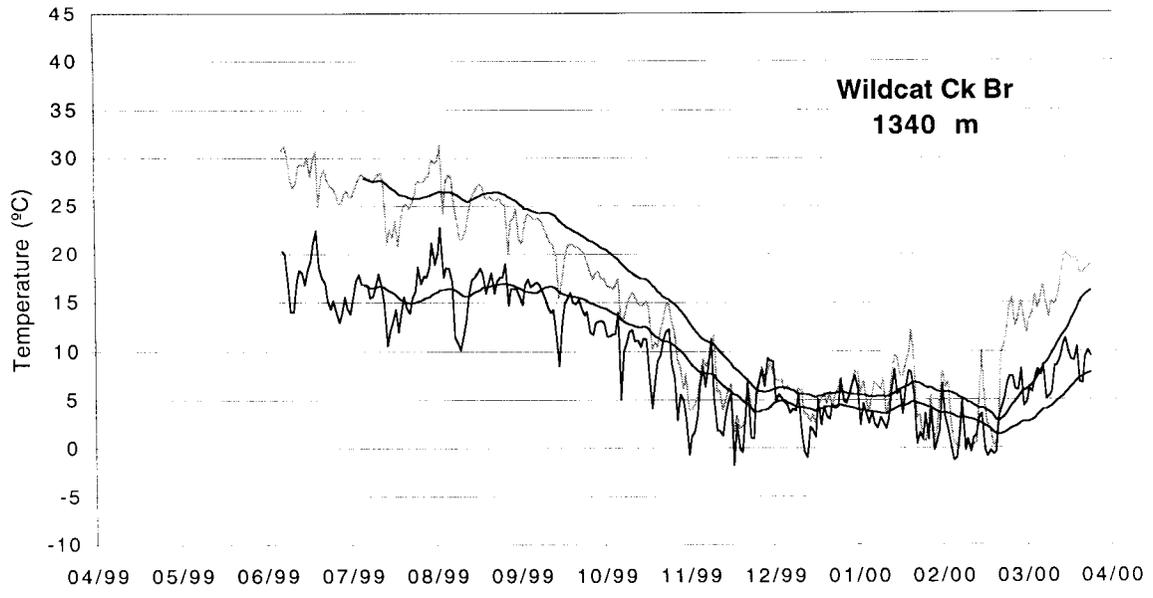


Figure 5. Mean monthly bridge temperature at local sunset vs. elevation. Means are based on at least ten days.

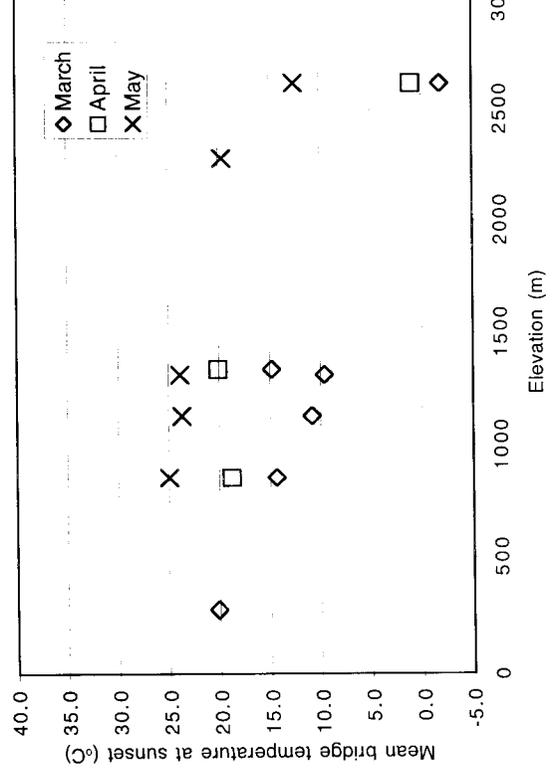
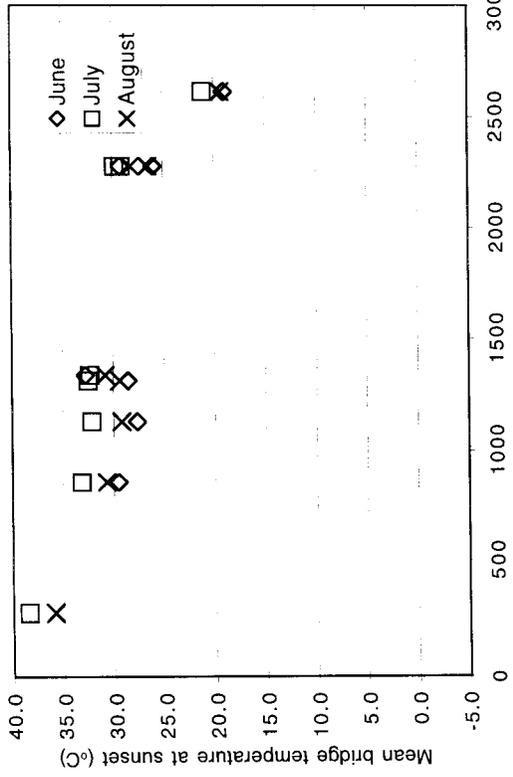
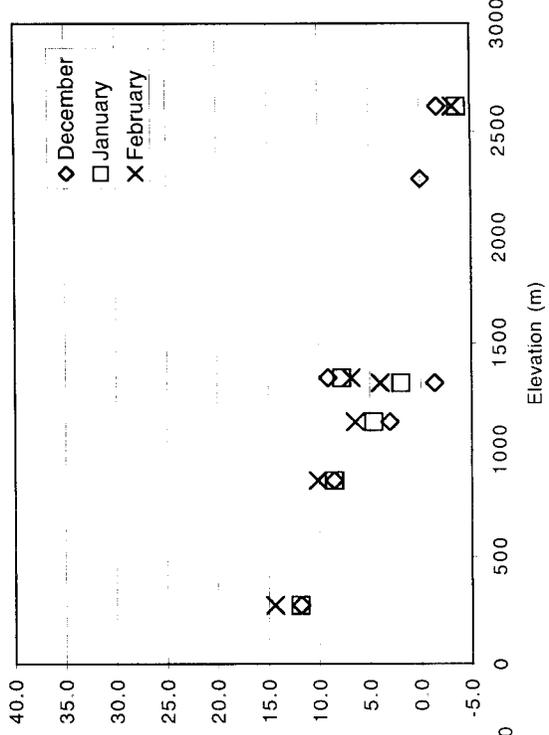
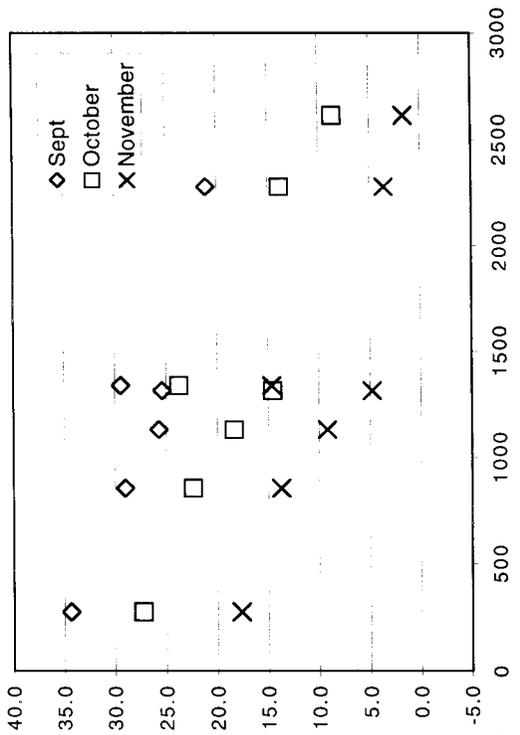


Figure 6. Mean monthly difference (bridge temperature - local ambient) 2 hr after sunset vs. elevation. Means are based on at least ten days.

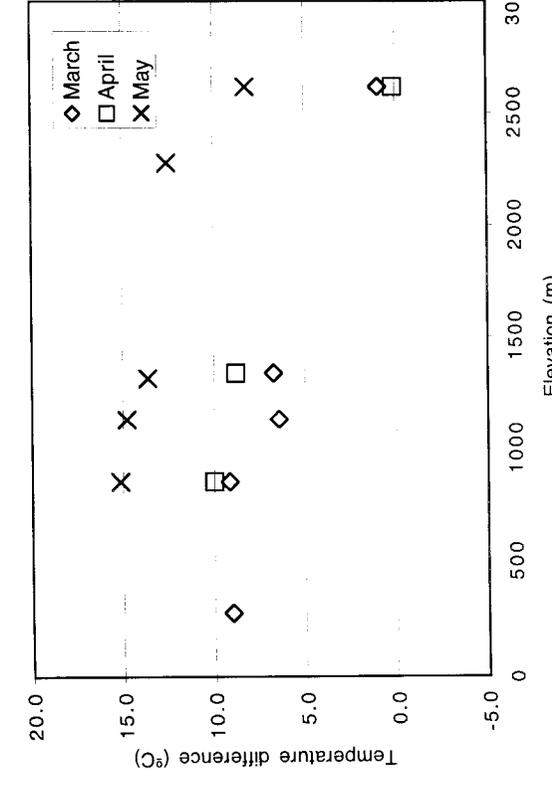
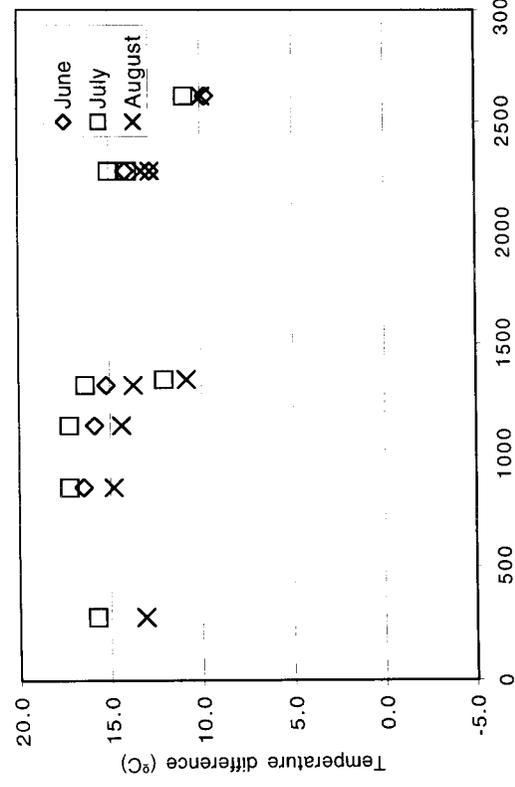
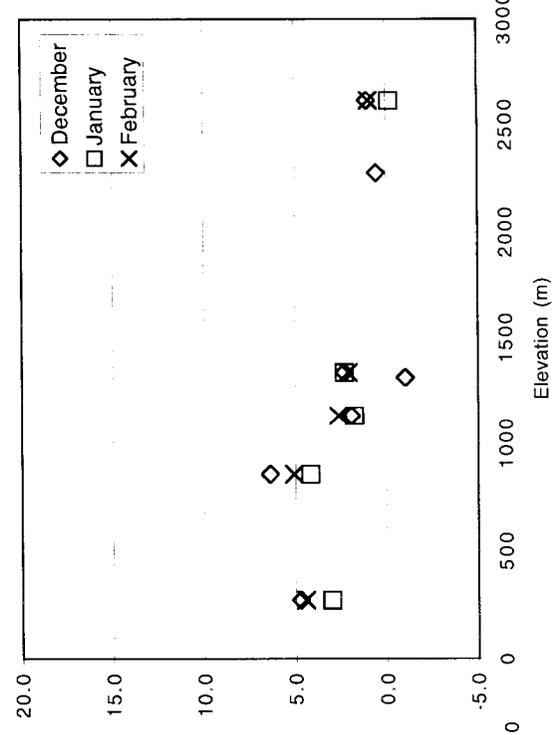
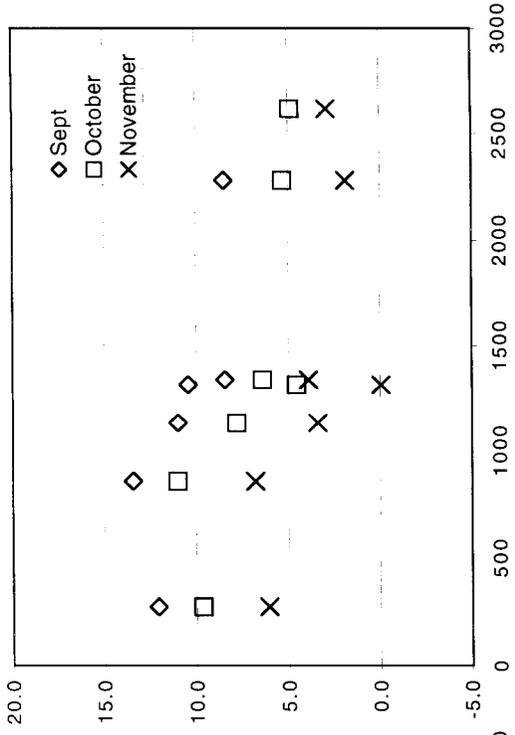


Figure 7a. A day roost in an expansion joint.

- 7b. A roost site located in crevice between two wooden beams. This bridge is not located in the study area, but contains a roost site similar to that found in the two wooden bridges within the study area.
- 7c. A day roost located in a crevice at the junction between the deck and the abutment.
- 7d. A day roost located in a narrow cavity that runs along the outer edge of the bridge deck, perpendicular to the abutment. This bridge also has night roosting on its concrete girders.
- 7e. A day roost located behind a sign posted on hurricane fence gate. The gate is located on a catwalk under a bridge.
- 7f. Night roost sites in a concrete girder bridge.
- 7g. A night roost located on the concrete collar that forms the junction between a steel I-beam and the deck.
- 7h. A night roost located in an exterior overhang at the bridge abutment.

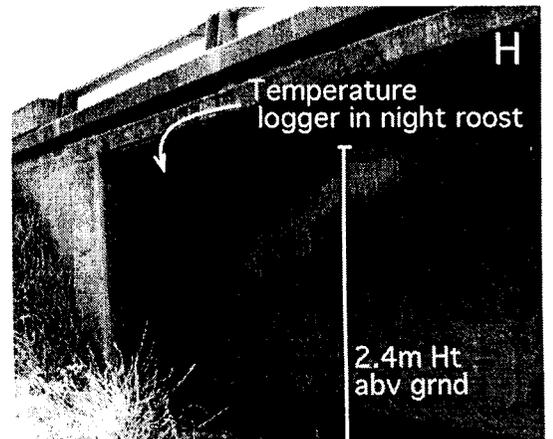
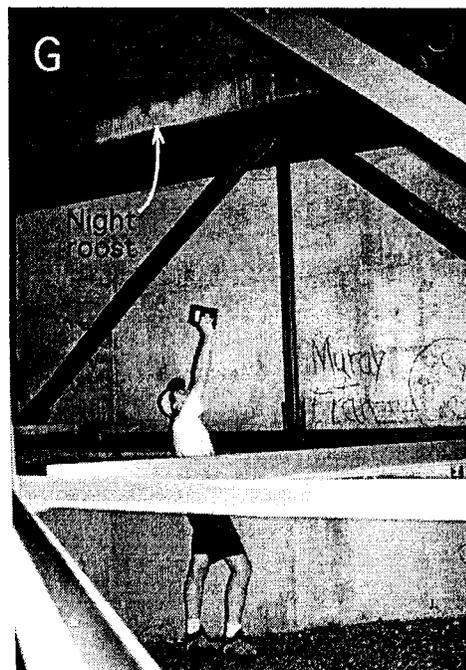
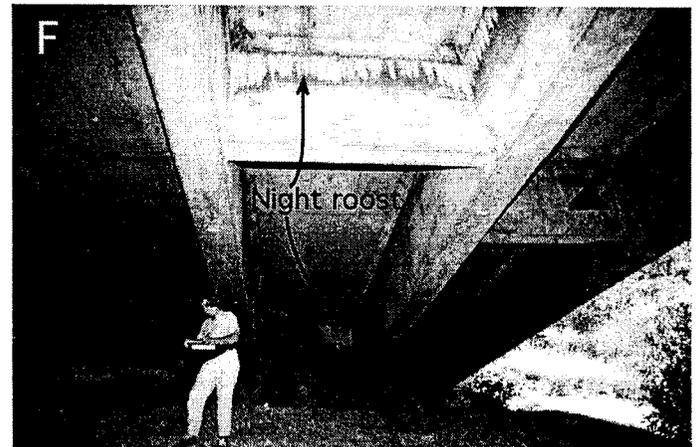
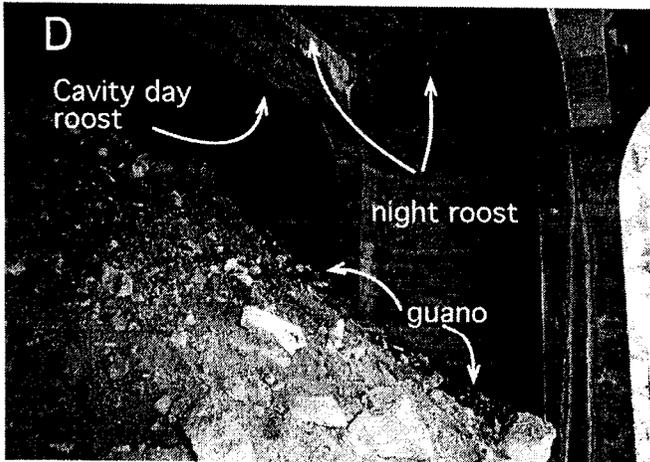
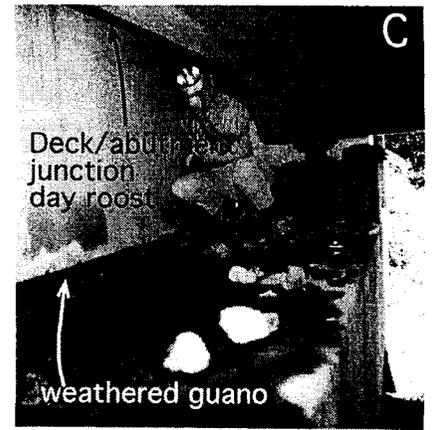
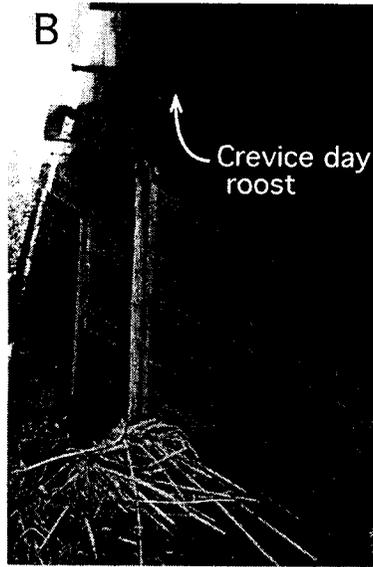
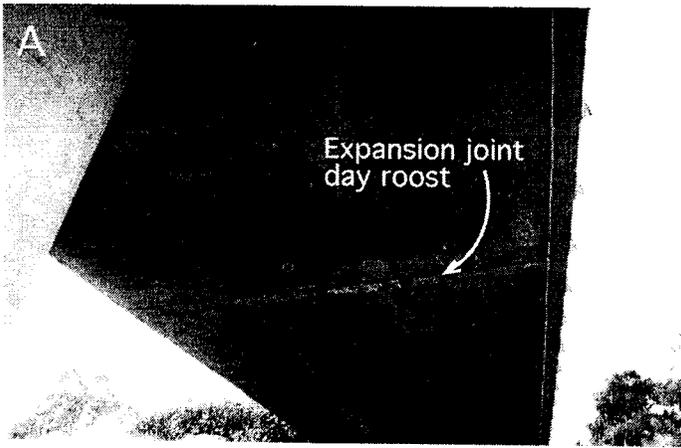
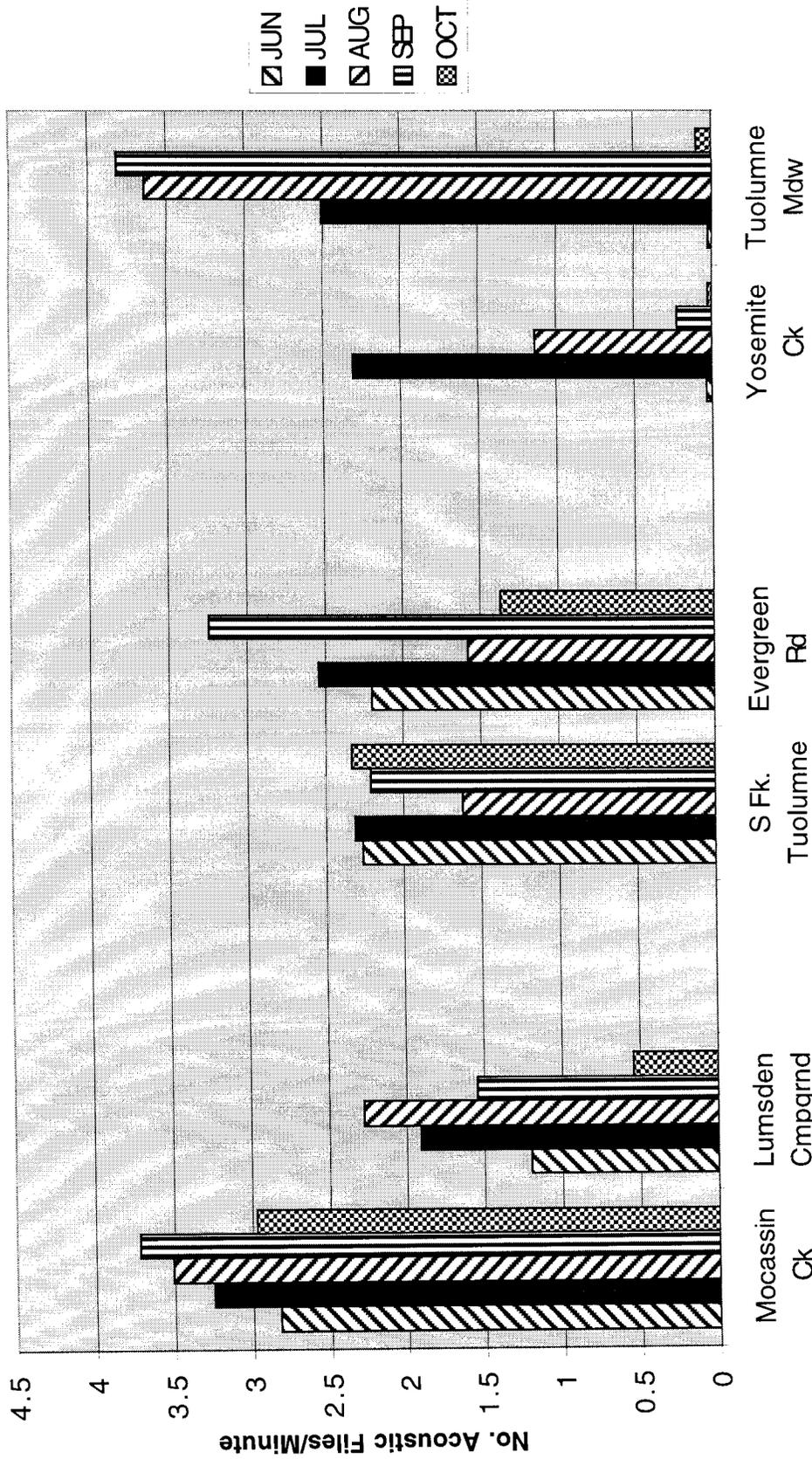


Figure 8. A bar graph showing seasonal (by month) levels of acoustic activity (measured as number of files/ minute), averaged over a sampling period of approximately the first 3 to 4 hours after onset of activity. Data are presented for two sites within each elevation belt (< 1,000 m = low elevation; 1,000-2,000 m = mid-elevation; >2,000 m = high elevation). While the estimates are based on a single night of sampling for each month, sampling at the mid and high elevation sites was generally conducted simultaneously within the same elevation zone. For all sampling periods except August, one of the low elevation sites (Lumsden) was sampled on the same night as the mid-elevation sites. Sampling dates are detailed in Table 5.

Bat Acoustic Activity: Seasonal Patterns



Localities at Low, Mid and High Elevation

Figure 9. Mean monthly ambient temperature at local sunset near night roost survey bridges vs. elevation. Monthly means are based on at least ten days.

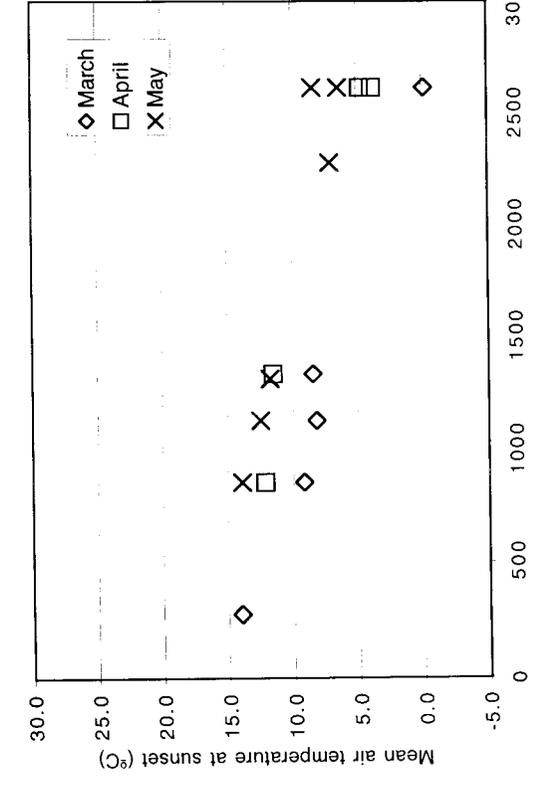
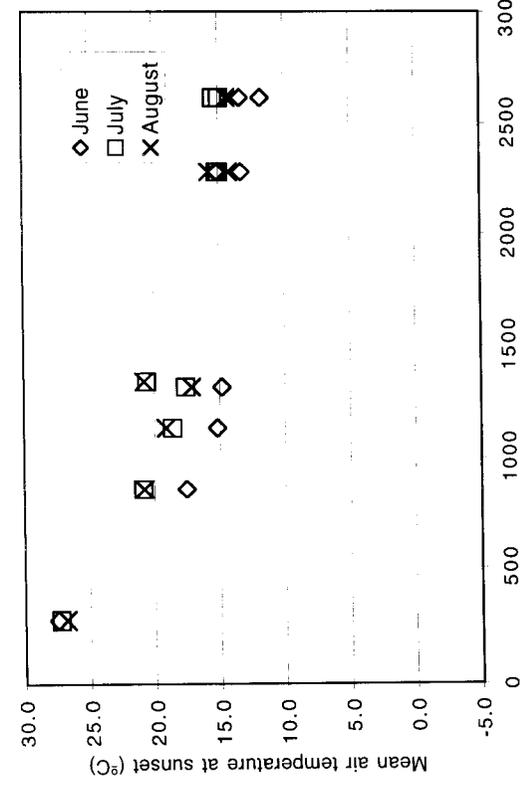
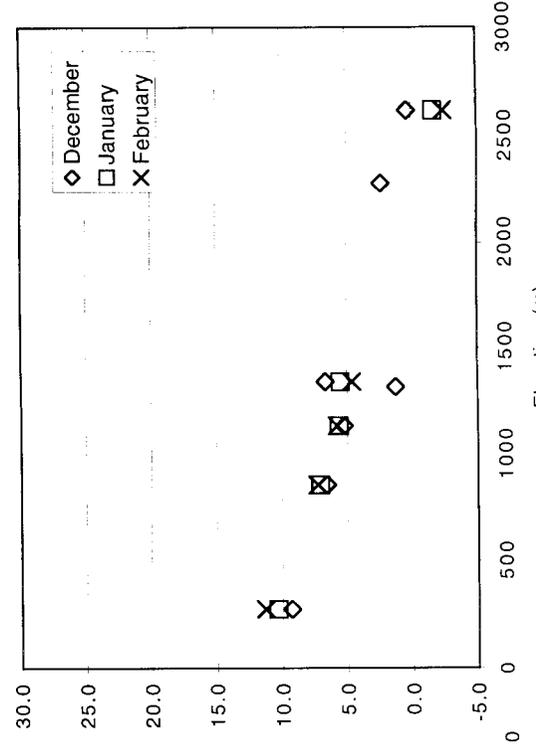
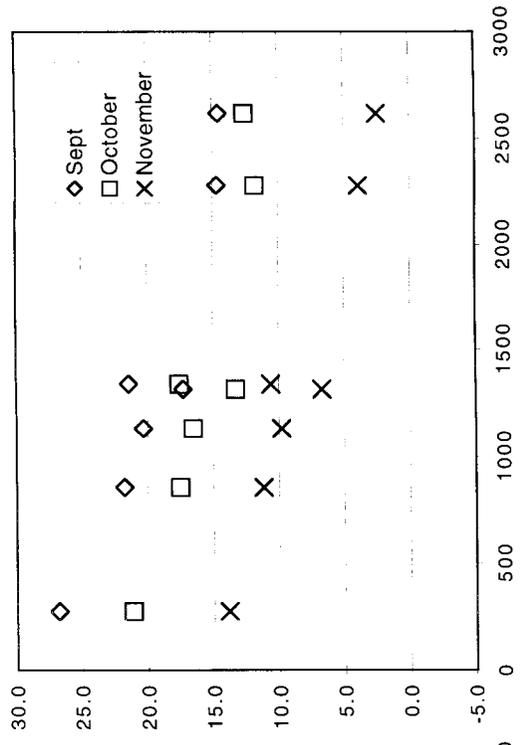


Figure 10. Decrease in ambient temperature over two hours after local sunset by site and date.

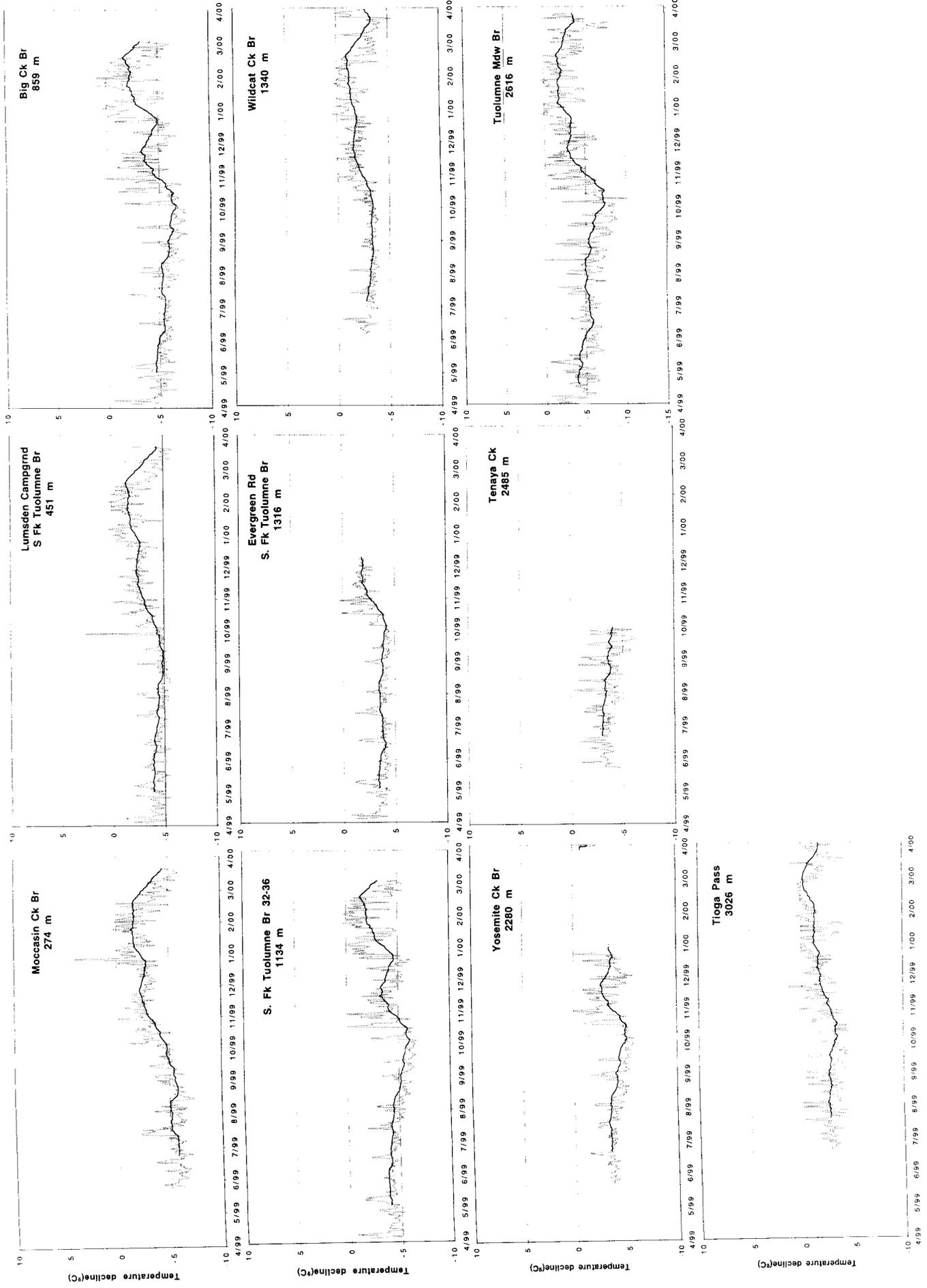


Figure 11. Mean monthly ambient temperature 2 hr after local sunset near night roost survey bridges vs. elevation. Monthly means are based on at least ten days.

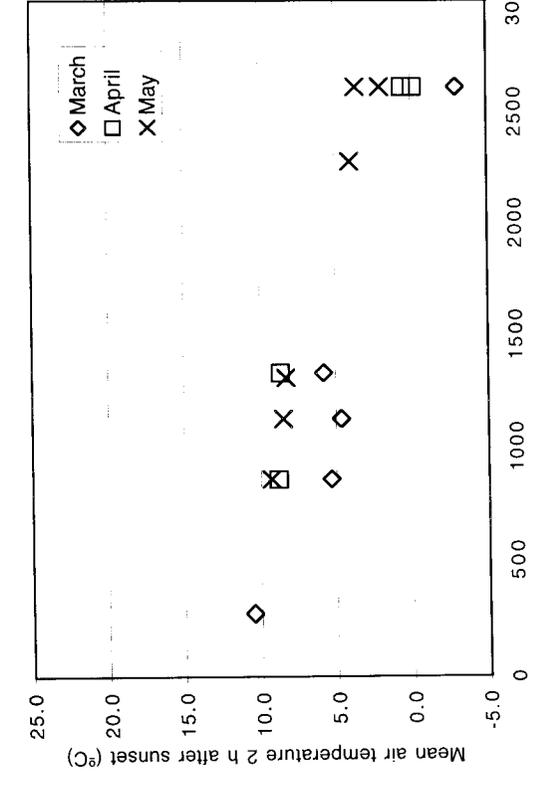
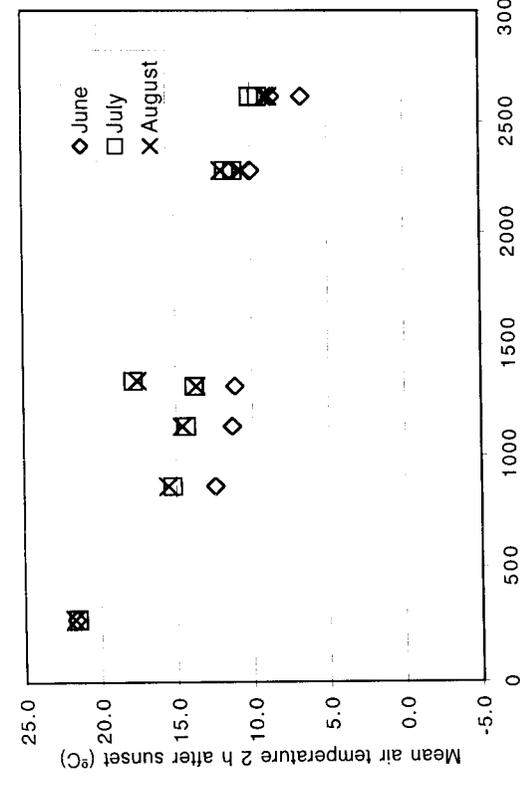
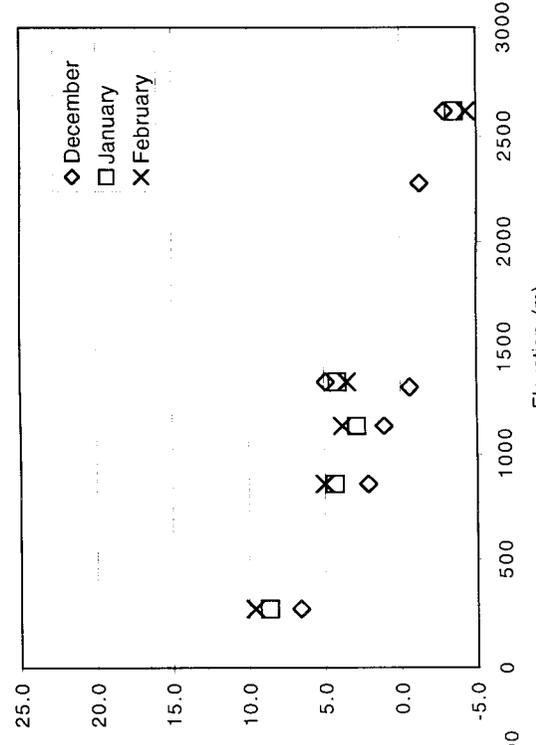
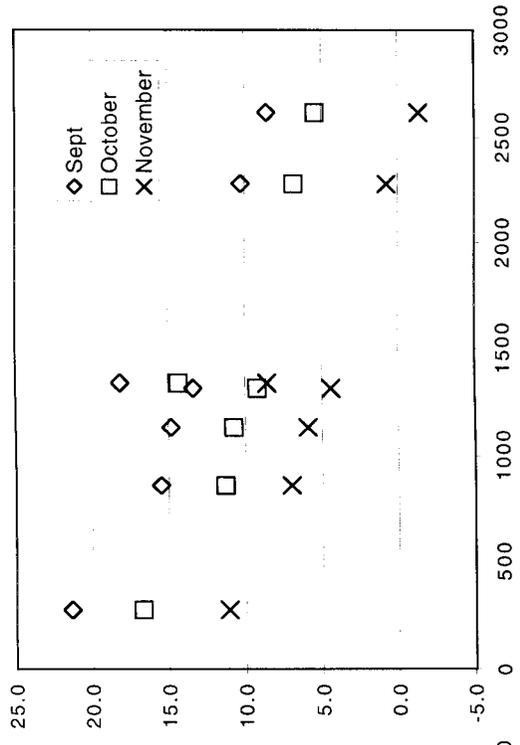
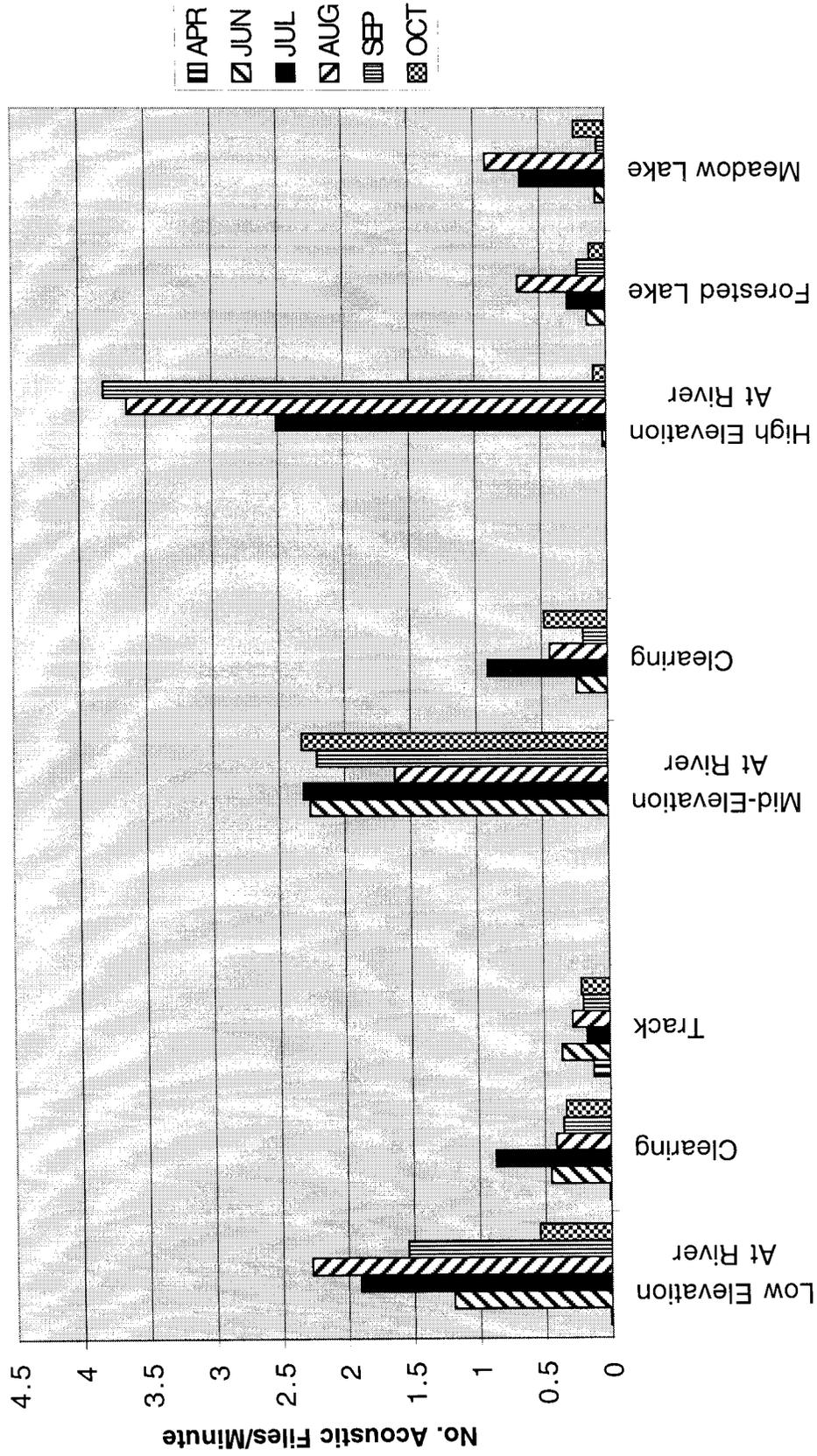


Figure 12. A bar graph comparing bat activity (as measured in the mean number of acoustic files obtained per minute over a three to four hour evening sampling period), at sites adjacent to and away from the river's edge. Data are presented for sites at low, mid, and high elevation along the Tuolumne River drainage. Sites within each elevation zone were sampled simultaneously. The low elevation site was Lumsden, near the confluence of the South Fork and Main Stem of the Tuolumne River; the mid-elevation site was along the South Fork of the Tuolumne River near the eastern crossing of State Route 120; the high elevation site was adjacent to the Dana Fork of the Tuolumne River in Tuolumne Meadow. The "Forested Lake" was at Dana Meadow, and the "Meadow Lake" adjacent to the Tioga Pass entrance station.

Bat Activity At River and Away from River



Localities at Low, Mid and High Elevation

Figure 13. A bar graph showing the relative abundance of bats by species in mist net captures at 19 sites in Yosemite National Park (n = 15) and adjacent areas (n = 4). Data are based on 28 mist-netting sessions conducted between July 1993 and August 1999.

RELATIVE ABUNDANCE OF BATS IN MIST NET CAPTURES

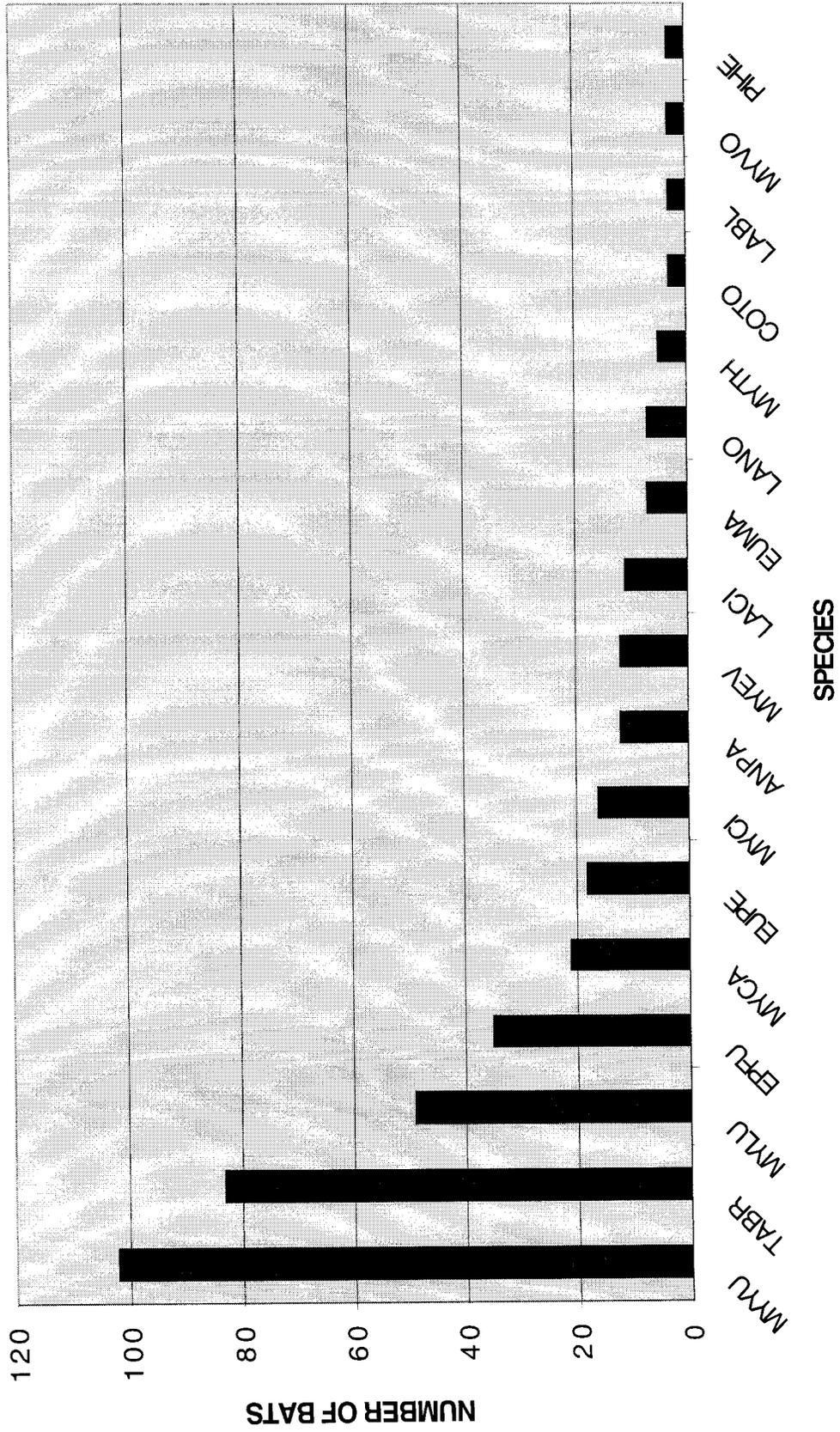
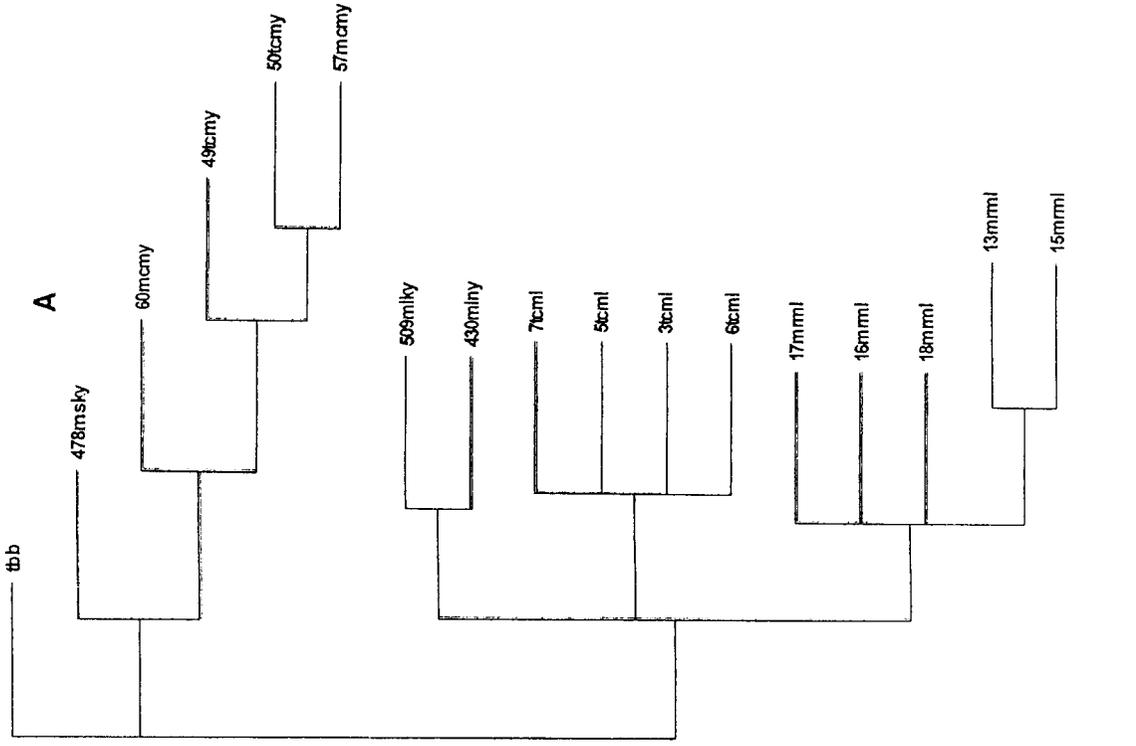


Figure 14a & b. Distance trees based on D-loop sequence data. The identifying code for each sample is explained in the table. The Meiss Ranch animals come from the range of known *Myotis lucifugus carissima*; the Tenaya Creek and Lee Vining animals represent the high Sierran form. The Mexican-free tailed bat, *Tadarida brasiliensis*, serves as the out-group.



D-loop sequences included in trees.

Label	Species	Location
13mrm	<i>Myotis lucifugus</i>	Meiss Ranch
15mrm	<i>Myotis lucifugus</i>	Meiss Ranch
17mrm	<i>Myotis lucifugus</i>	Meiss Ranch
18mrm	<i>Myotis lucifugus</i>	Meiss Ranch
16mrm	<i>Myotis lucifugus</i>	Meiss Ranch
7tcm	<i>Myotis lucifugus</i>	Tenaya Creek
6tcm	<i>Myotis lucifugus</i>	Tenaya Creek
3tcm	<i>Myotis lucifugus</i>	Tenaya Creek
5tcm	<i>Myotis lucifugus</i>	Tenaya Creek
39lvcm	<i>Myotis lucifugus</i>	Lee Vining Creek
41lvcm	<i>Myotis lucifugus</i>	Lee Vining Creek
45lvcm	<i>Myotis lucifugus</i>	Lee Vining Creek
509mlky	<i>Myotis lucifugus</i>	Kentucky
430mlny	<i>Myotis lucifugus</i>	New York
478msky	<i>Myotis sodalis</i>	Kentucky
60mcmly	<i>Myotis yumanensis</i>	Moccasin Creek
57mcmly	<i>Myotis yumanensis</i>	Moccasin Creek
49tcmy	<i>Myotis yumanensis</i>	Tenaya Creek
50tcmy	<i>Myotis yumanensis</i>	Tenaya Creek
tbb	<i>Tadarida brasiliensis</i>	Texas