Night Roost Sampling: A Window on the Forest Bat Community in Northern California

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ABSTRACT

Surveys of night roosts in anthropogenic features, particularly concrete bridges, offer an efficient, but species-selective method for examining the bat community in forested landscapes. In the upper Sacramento River canyon some species (*Antrozous pallidus*, *Eptesicus fuscus*, *Myotis volans*, *Corynorhinus townsendii*) were captured more frequently per person-hour of sampling in night roosts than by mist netting over water, while others (e.g., *Myotis californicus*, *Myotis ciliolabrum*, *Lasiurus* sp., *Lasionycteris noctivagans*, *Euderma maculatum*) never used these sites. Protected, but open-bridge night roosts remain warmer than ambient through most of the night over the summer. Recaptures of *Myotis yumanensis* and small numbers of *A. pallidus*, *E. fuscus*, and *M. volans* indicated fidelity to night roosts through four years of survey. Capture at aggregated night roosts permits long-term monitoring without disturbance to maternity roosts. For species that roost in trees by day, particularly in areas of timber harvest, bridge night roosts may persist longer than day roosts, and offer continuing access to marked populations that switch among day roosts.

INTRODUCTION

Many bat species use night roosting sites, which are separate from day roosts and likely serve both physiological and sociobiological functions (Barclay 1982; Kunz 1982; Lewis 1994). Kunz (1982) discussed four night roost types: resting places, feeding perches (used by sallying predators), feeding roosts (sites where food is consumed), and calling roosts (used for mating displays). For North American temperate-zone bats, the best-characterized night roosts are aggregated resting places. For many species, prey ingestion rates exceed digestion rates. In night roosts bats can digest food between foraging bouts without the energetic costs of returning to the day roost. Sites selected as night roosts generally maintain night-time temperatures greater than ambient, offering thermoregulatory benefits (Anthony et al. 1981; Barclay 1982).

Anthony et al. (1981) noted that for *Myotis lucifugus* in the northeastern United States, night roost sites are less exposed than day roosts.

The opposite appears to be true in parts of the western U.S., where identified night roosts are typically in environmentally buffered, but exposed locations—e.g., inside entrances of abandoned mines, on ceilings of old buildings, and under bridges (Barbour and Davis 1969; Lewis 1994; O'Shea and Vaughan 1977). Bridges (complex structures with high thermal inertia often close to water) are widely used as both day and night roosts (Constantine 1961; Cross and Clayton 1995; Davis and Cockrum 1963; Fraze and Wilkins 1990; Hayward 1970; Hirshfield et al. 1977; Kunz 1982; Lewis 1994).

Assessing species diversity and relative abundance of a forest bat assemblage presents tactical challenges. Recent research using radio-telemetry shows that in forested landscapes in western North America, most bat species (including those best known from studies on building roosts) roost by day in trees (Brigham 1991; Crampton 1994; Grindal 1994; Kalcounis 1994; Morrell et al. 1994; Rainey et al. 1993; Rainey and Pierson 1995; this volume). Tree roosts are generally located in cavities or under bark, often over 10 m above the ground. Given the dispersion of these cryptic roosting sites, and evidence that even in mesic habitats many species travel substantial distances to drink and forage near surface water (Thomas 1988), sampling bat communities typically involves intercepting animals during their nightly activity cycle. Common inventory methods are mist netting near ground level along flyways or areas of concentrated foraging (i.e., near water), monitoring echolocation calls, or locating roosts (Cross 1986; Kunz and Kurta 1988; Thomas and LaVal 1988). Given the differential detectability of species by different methods, some combination is usually required to obtain an overview. This paper examines the efficiency and selectivity of night roost surveys, particularly of bridges, as one approach to sampling species diversity and relative abundance in areas transected by roads.

STUDY AREA

This study was conducted from 1991 to 1995 in northern California (Siskiyou and Shasta counties), along 60 km of the upper Sacramento River (approximately 41°N lat., 122°E long.), between Lakehead and Dunsmuir, from 320 m to 730 m elevation. Within this dissected, high-relief portion of the drainage basin, the habitat is primarily montane hardwood/conifer, dominated by ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), and black oak (*Quercus kelloggii*) (Mayer and Laudenslayer 1988). At lower elevations, grey pine (*Pinus sabiniana*) and Pacific madrone (*Arbutus menziesii*) become common. On the higher slopes (approximately 1800 m elevation), Jeffrey pine (*Pinus jeffreyi*), incense cedar (*Libocedrus decurrens*), red fir (*Abies magnifica*), and white fir (*Abies concolor*) are also common.

The primary historical and current land use is timber production. The resulting landscape is a complex, largely anthropogenic, mosaic dominated by regenerating timber stands of varied ages. Limited development is concentrated along the major transportation corridor (both a railroad and four-lane, interstate highway) paralleling the river in the canyon floor.

Site Selection

In July 1991 a railroad accident released a tank-car load of metam sodium, a soil fumigant, into the Sacramento River above Dunsmuir, killing most macroscopic life in the river up to 60 km south of the spill site (Calif. Dept. Fish and Game 1993). Sampling sites used for this analysis were selected in the context of a larger study examining the impacts of this spill on bat populations. All were located within a few hundred metres of the river.

METHODS

Night Roost Sampling

Bridges, abandoned buildings, and other possible night roost sites (generally on public lands) within 500 m of the Sacramento River in the study section, were examined for evidence of bats (e.g., guano, urine stains, or roosting bats). Bridges included overcrossings along the interstate highway and older bridges on nearby secondary or abandoned roads.

After initial surveys in the summer of 1991 and the spring of 1992, nine bridges, which were consistently used as night roosts, were selected for monitoring, conducted primarily between June and September. These sites were approached at night (generally between 23:00 and 2:00 h), and roosting animals were captured in rectangular-frame hand nets mounted on telescoping painters' poles. Temporary fabric curtains were used to reduce escape at one large *M. yumanensis* night roost under an abandoned bridge and, once contained, bats were captured with hand nets and a harp trap.

To compare ambient with night roost temperatures, a miniature digital temperature logger with an internal thermistor (Onset Computer Model STIB08; equilibration time 15 minutes, maximum error 0.5°C, sampling interval 30 minutes) was attached to the concrete in a night roost site on an interstate highway bridge crossing a secondary road. A second logger simultaneously recorded ambient in shade nearby.

Mist Netting

Mist nets were set on sectional poles over open water (sites chosen for depth <1.5 m and low surface turbulence). Nets typically spanned the width of the river or tributary streams near their confluence with the river. Nets were opened after local sunset and closely tended until midnight. The sample treated here includes 47 nights of netting at 15 stations along the 60-km section. Stations were typically sampled no more than once per year; five stations were sampled in all five years. Net area deployed each night (overall mean = 173 m^2) varied with both site constraints (e.g., narrow, sub-canopy streams) and personnel available to extract bats.

Handling of Animals

In both mist netting and night roost surveys, after identification and measurement, most species were fitted with 2.8- or 3.5-mm, numbered, lipped, metal forearm bands (British Mammal Society or Lambournes' Ltd). Because of concerns about band effects, *Lasiurus* sp., *Corynorhinus townsendii* and species <4.0 g body weight were typically not marked. Consistent with the findings of Herd and Fenton (1983), morphological overlap in co-occurring *M. yumanensis* and *M. lucifugus* left specific identification of some individuals unresolved.

Sampling Effort

To compare efficiency of capture by mist netting at foraging areas and hand netting at night roosts, effort was evaluated by examining the number of bats captured per person hour. To standardize the estimates, it was assumed that mist netting required four persons (although the actual crew was frequently larger), and night roost sampling required two persons (although occasionally the surveys were conducted by one). For mist netting, time was calculated as the actual number of hours that the nets were open, plus 3 hours per netting station per night for set up and disassembly (although setting nets over a 30-m wide, swift river frequently took longer), and night roost sampling was estimated to take 20 minutes for capture, plus 10 minutes for preparation, per site. For two night roosts that harboured large aggregations, we used actual site preparation and capture times.

RESULTS

Structural and Environmental Features of Night Roosts

The predominant bridge designs in the study area on highways or secondary roads were either concrete girder or the more recent concrete box girder. There were two types of concrete girder bridges. The older one, found in all those abandoned to vehicular traffic and a few active bridges, had only longitudinal girders extending below the bridge deck (Figure 1 of Davis and Cockrum 1963). The more common type had both longitudinal and transverse girders, producing (as noted by Lewis 1994) a grid of open, rectangular, concrete cells extending from the underside of the bridge. Box girder bridges have an enclosed, flat underside that offers little or no sheltered vertical surface to which bats might cling.

Thirteen of the 16 concrete girder bridges examined were repeatedly used as night roosts by at least small numbers of bats. Of the three not used, one was brightly lit. Five of the girder bridges harbouring night roosts were abandoned to traffic, one was on a lightly travelled frontage road, and seven were on the interstate highway over intersecting roads. Bats using the latter had almost continuous heavy vehicular traffic overhead, and moderate to almost no traffic beneath. Night roosting was found in one of 11 box girder bridges; in this instance adjoining portions of the north and south interstate lanes had created a 2-m-wide crevice that harboured the bats.

Although some accessible expansion-joint crevices were present, night roost sites were always on open surfaces in areas protected from wind and rain. Bats were in ventral contact with the vertical sides of the girders at the bridge deck junction, often in a corner. In the case of interstate highway overcrossings, occupied sites were separated from the secondary road by support columns. Bats selected sites that were 2–6 m above the ground, typically favouring the highest possible roosting sites. Figure 1 illustrates thermal buffering provided by the concrete girder structure at one of the interstate bridge roosts (Soda Creek) during July 1995. While the monthly mean bridge roost temperature varies 4°C daily and does not drop below 23°C, ambient temperature varies more than 16°C. For at least late June through September, the roost had a positive temperature differential all night (>10°C from midnight to dawn; all data not shown).

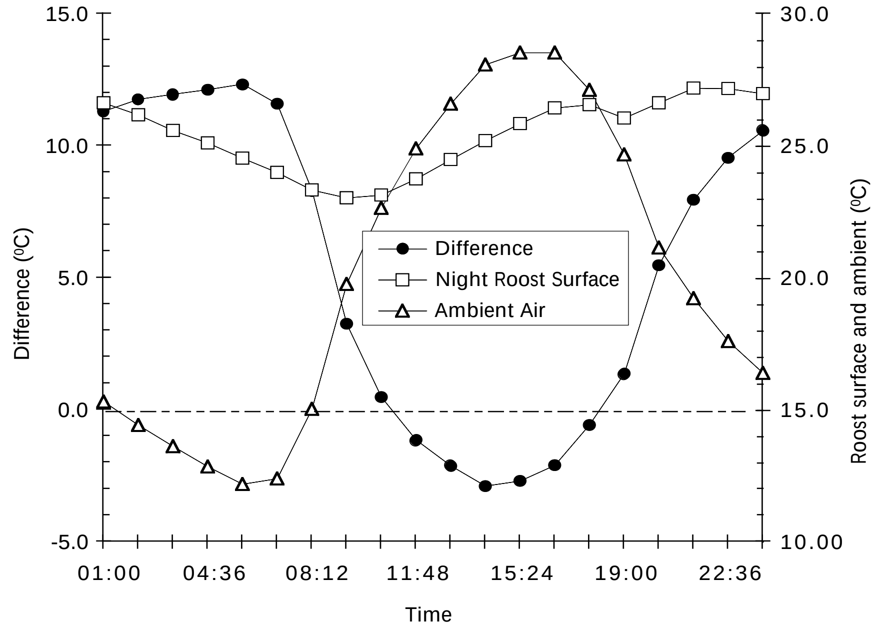

FIGURE 1 *Daily cycle of ambient and surface night roost temperatures, and the differential (roost-ambient) at the Soda Creek interstate highway bridge roost, plotting monthly means for July 1995.*

Only one building, an abandoned house, was identified as a night roost, with bats using several sites, most reliably the attic. A number of tributary streams reached the Sacramento River via large-diameter, concrete-lined tunnels up to several hundred metres long. Bats were not observed night roosting in these relatively cool sites.

Species Diversity, Relative Abundance, and Capture Efficiency

In this study, 17 species of bats were documented as occurring along the upper Sacramento River (Table 1). Fifteen were netted over water; nine of these were also captured at night roosts; two were detected only acoustically (*Eumops perotis*) or acoustically and visually (*Euderma maculatum*). Eight of the 17 species (47%) were never observed at night roosts.

Although 4.5 times as many person hours were expended on mist netting, some species (*M. yumanensis*, *Antrozous pallidus*, *Eptesicus fuscus*, and *Myotis volans*) were captured more times at night roosts than in mist nets (Figure 2). Table 2 lists the five most commonly observed species by both methods. Only two, *M. yumanensis* and *M. lucifugus*, appear on both lists, with *M. yumanensis* being the most frequent by either method. Two of the species most commonly observed in mist nets (*Lasionycteris noctivagans* and *Myotis californicus*) were never observed in bridge night roosts. *C. townsendii*, which was very rare by both sampling methods, being taken only once in a mist net and found at only one night roost site, was known from five day roosts, including two maternity sites (an abandoned train tunnel and an abandoned mine) within the study area. These roosts were located by day roost surveys.

Table 3 gives the relative abundance of six species that were sampled by both mist netting and night roost surveys. Three species, *A. pallidus*, *C. townsendii*, and *M. yumanensis*, were excluded from this comparison because they were selectively targeted for focal studies at particular night

TABLE 1 *Primary detection methods for 17 bat species observed along the upper Sacramento River drainage.*

	Mist nets	Night roosts	Acoustic
Antrozous pallidus	×	×	
Corynorhinus townsendii	×	×	
Eptesicus fuscus	×	×	
Euderma maculatum			×[a]
Eumops perotis			×[a]
Lasionycteris noctivagans	×		
Lasiurus blossevillii	×		
Lasiurus cinereus	×		
Myotis californicus	×		
Myotis ciliolabrum	×		
Myotis evotis	×	×	
Myotis thysanodes	×	×	
Myotis lucifugus	×	×	
Myotis volans	×	×	
Myotis yumanensis	×	×	
Pipistrellus hesperus	×		
Tadarida brasiliensis	×	×	

[a] Species which could be identified acoustically with certainty.

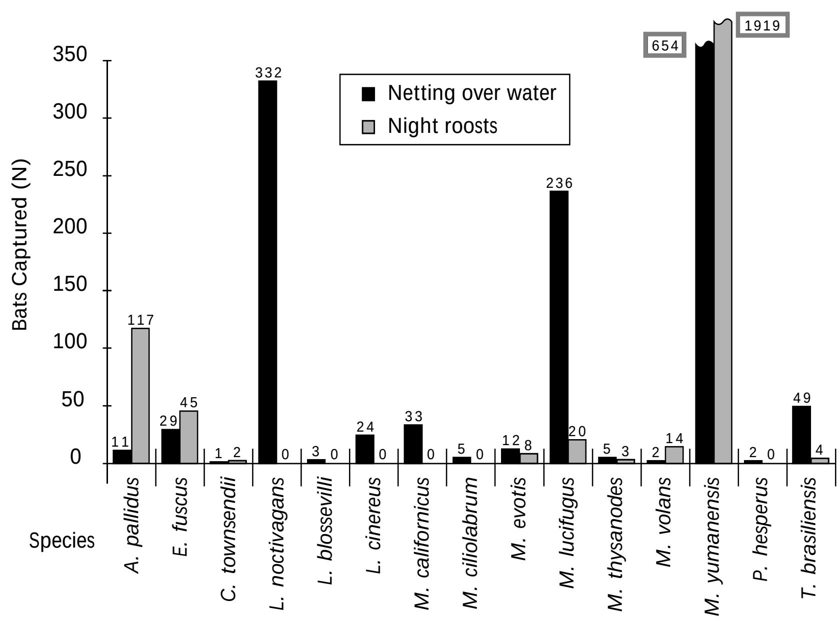

FIGURE 2 *Total number of bat captures by species in mist nets and night roosts along the upper Sacramento River (1991–1995).*

roosts. Four species, *E. fuscus*, *Myotis evotis*, *Myotis thysanodes*, and *M. volans*, were relatively more abundant in the night roost surveys, whereas *M. lucifugus* and *T. brasiliensis* were relatively more abundant in the mist netting surveys.

Pooling data across sites and nights, catch/unit effort was 6.9 times greater at night roosts than by mist net. Eleven bats were captured per

TABLE 2 *Five species most frequently observed in mist nets and night roosts, listed in order of abundance.*

Mist nets	Night roosts
Myotis yumanensis	*Myotis yumanensis*
Lasionycteris noctivagans	*Antrozous pallidus*
Myotis lucifugus	*Eptesicus fuscus*
Tadarida brasiliensis	*Myotis lucifugus*
Myotis californicus	*Myotis volans*

TABLE 3 *Relative abundance of bats species captured randomly in mist nets and at night roosts.*

	Nets		Night roosts	
Species	Ratio	n	Ratio	n
E. fuscus	0.087	29	0.479	45
M. evotis	0.036	12	0.085	8
M. lucifugus	0.709	236	0.213	20
M. thysanodes	0.015	5	0.032	3
M. volans	0.006	2	0.149	14
T. brasiliensis	0.147	49	0.043	4
Totals	1.000	333	1.000	94

person hour at night roosts (2134 bats for 194 hours) versus only 1.7 in mist nets (1399 bats for 780 hours). Depending on the time of night, season, weather, and species, capture success in night roosts varied. When warm and alert the bats could fly as the hand net approached them; when torpid they could be quite slow to drop into a net.

Species Distribution Among Night Roost Sites

Three bridges, all abandoned or little used, housed substantial night roosting aggregations (one of >30 *A. pallidus*, two of 250–450 *M. yumanensis*; Table 4). Two other abandoned bridges, not monitored on a regular basis, had smaller (<100) *M. yumanensis* aggregations. All these aggregations were comprised primarily of adult females, and after mid-summer, volant young (although the *A. pallidus* roost included adult males).

Although none of the interstate highway structures supported large, colonial night roosts, they yielded greater diversity. The number of species found under a particular bridge varied from one to six. Also, the likelihood of encountering particular species varied. *M. yumanensis* was the species most commonly encountered. *E. fuscus* was found under all the interstate highway bridges, and some of the older ones. *M. volans* was found under more than half the bridges. Although *A. pallidus* was found primarily at one colonial night roost, individuals were occasionally found at four other bridges. By contrast, *M. lucifugus* and *M. thysanodes* were found under only two bridges. One of the *M. thysanodes* sites was only a few hundred metres from a building day roost.

The small numbers found simultaneously under the interstate bridges (generally 1–10, with up to 25 *M. yumanensis*) often included several species

TABLE 4 *Distribution of bat species among night roost sites.*

	Species									
	A. pallidus	*C. townsendii*	*E. fuscus*	*M. evotis*	*M. thysanodes*	*M. lucifugus*	*M. volans*	*M. yumanensis*	*T. brasiliensis*	Total no. species
Interstate Highway Bridge										
Castle Ck. I-5			×	×			×	×		4
Conant I-5	×		×	×			×			4
Flume Ck. I-5			×	×	×		×	×		5
Panorama Way I-5			×							1
Sims I-5	×		×			×	×	×		5
Soda Ck. I-5	×		×	×	×		×	×		6
Abandoned or Access Road Bridge										
Boulder Ck.			×			×		C		3
Gibson Rd.	C							×	×	3
Shotgun Ck.	×		×				×	C		4
Building										
La Moine House		×						×		2
Total no. sites	5	1	8	4	2	2	6	8	1	

× = individuals or small groups; C = colonial night roosts.

that typically roosted separately. Individuals captured at these sites included adults of both sexes, plus volant, and occasionally non-volant, young.

C. townsendii was found night roosting only in the attic of one abandoned house. Although this site never contained more than a few individuals at any one time, the species could typically be found there.

Recapture Rates and Site Fidelity

The overall recapture rate was markedly higher at night roost sites than in mist nets. Of the 1399 mist net captures only 58 (4.2%) had been previously banded; whereas 638 of 2134 night roosts captures (29.9%) were recaptures.

Recaptures for the three species most commonly encountered in night roosts, *A. pallidus*, *E. fuscus*, and *M. yumanensis*, show substantial year-to-year roost fidelity. This is best documented for *M. yumanensis* at the Shotgun Creek night roost, which was sampled once per year (in late August), 1991–1995. With the exception of the first year, when about 25% of the animals were captured, over 90% of the animals present were captured in each survey. From a total of 608 recaptures at the site, 506 (83%) were originally banded there, and the proportion increased each year (Figure 3). Figure 4 shows the distribution of intervals between initial capture at this site and recapture events there.

For 93 banded *A. pallidus*, all 18 individuals recaptured at night roosts had been originally captured there or in nets less than 100 m away. Three individuals were caught three times; for two of them there was at least 10 months between each recapture event. While virtually all year-to-year night roost recaptures of *M. yumanensis* were female, an adult male *A. pallidus* was recaptured two years after initial capture.

For *E. fuscus*, night roosting aggregations larger than presumed mother-young pairs were not observed and many individuals, including all of the

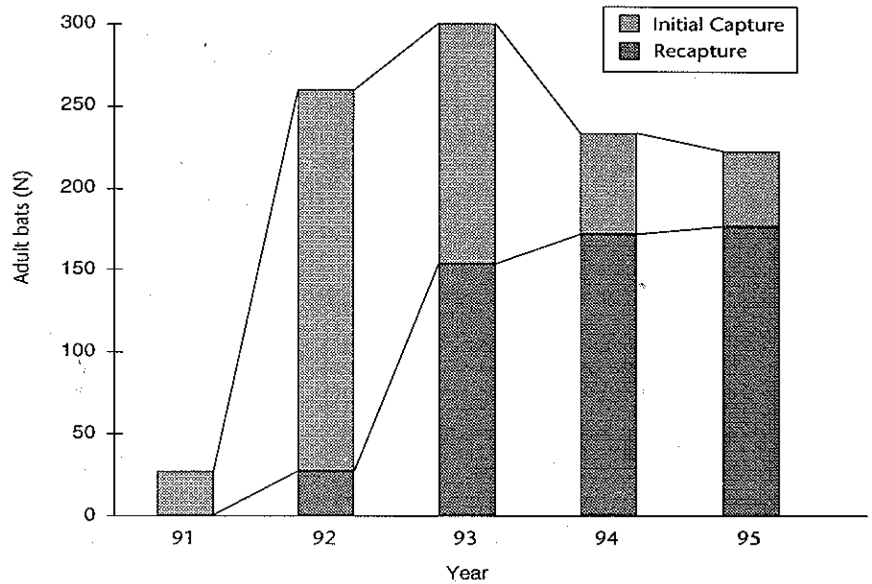

FIGURE 3 *Number of adult female* M. yumanensis *initially captured and recaptured at Shotgun Creek bridge night roost, 1991 through 1995.*

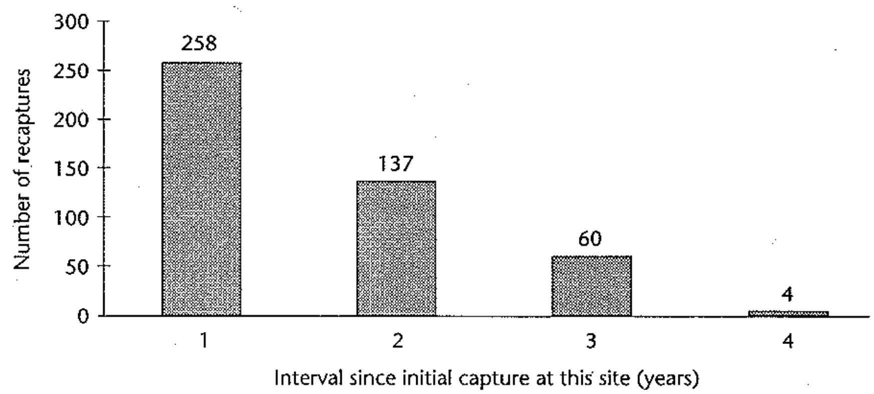

FIGURE 4 *Distribution of intervals in years between initial capture at Shotgun Creek bridge night roost and any subsequent recapture there for* Myotis *sp., 1991–1995.*

males captured, were solitary. Five out of 43 banded *E. fuscus* were recaptured in night roosts. Three were recaptured at the same bridge, one at a different bridge (4.4 km away), and one had originally been captured in a net 1.8 km away. One adult male was captured four times between 1992 and 1995 at the same bridge night roost. A single adult female *M. volans* was recaptured two years later at the same interstate highway bridge.

DISCUSSION

Function of Night Roosts and Role of Bridge Structure

All night roosts in this study were located close to the Sacramento River, identified by netting, radio-tracking, and diet analyses as a major foraging corridor for the bat community in this drainage basin (unpub. obs.). This is consistent with the role of night roosts as resting places for digestion between foraging bouts, although they may also have additional sociobiological functions (Kunz 1982; Lewis 1994).

The observation that concrete girder bridges were used as night roosts and unmodified box girder bridges were not, parallels Lewis's findings (1994) for *A. pallidus* in Oregon, and suggests that bridge structure plays an important role in roost selection. Occupied sites offer vertical surfaces with enough texture for bats to cling to and maintain ventral contact. Although we did not measure relevant parameters, the "cells" typically selected in the gridwork of longitudinal and transverse girders beneath the bridge deck appear well buffered against wind, and partially isolated from the sporadic lights and sound of vehicles passing under the bridge. Bats clearly accommodate to the episodic, subjectively intense, partly audible (to humans) vibration transmitted through the structure from traffic on the bridge deck above. Occupied sites have ready flight access, but are sufficiently high to protect torpid bats from all terrestrial predators. Our temperature data suggest the large, insulated area of the bridge deck and the thermal inertia of these massive structures offer substantial passive thermal buffering, even to solitary night roosting bats.

Notably, the only bridges that harboured substantial aggregations, including large numbers of mother-young pairs (deduced by differing pelage colour), were abandoned or little used. All these bridges crossed streams rather than roads, so there was no vehicular traffic beneath. A physical feature of older concrete bridges that might make them suitable for bats, especially less dextrous young, is more irregular surface texture generated by rougher casting forms, weathering, and efflorescence. In seeking explanations for larger aggregations on older bridges, we should not ignore, however, the role of history for colonies of long-lived animals showing high site fidelity. A potentially important difference between the interstate bridges with low bat numbers and the abandoned bridges is that the latter have been part of the landscape for 50 years longer.

Species Diversity and Relative Abundance

Night roost captures offered relatively efficient access to a subset of the species identified by contemporaneous mist netting and acoustic surveys in a forested area. No species were captured only in night roosts, but some, particularly *A. pallidus*, *E. fuscus*, and *M. volans*, were most readily detected there. Other species were under-represented, e.g., both net captures and acoustic monitoring indicated that *T. brasiliensis* was locally common, yet only scattered individuals were captured at night roosts. Day roost surveys indicated that *C. townsendii* is likely more common in the area than revealed by netting or night roost surveys.

Certainly bridge design, alternative habitat, climate, and season influence what, if any, bat species might be found night roosting along highways elsewhere. For example, we never observed *M. californicus* in a bridge night roost, but it uses them in Oregon (M. Perkins, pers. comm.). Night roosting *E. fuscus* in this study were typically scattered individuals, yet we have observed aggregations (over 75 individuals) at a number of other bridge night roosts in California (unpubl. obs.). Although some studies have suggested that *T. brasiliensis* does not generally night roost in localities separate from the day roost (Krutzsch 1955; Hirshfield et al.

1977), we have observed a night roost of several thousand *T. brasiliensis* in a lava tube about 17 km northeast of the current survey area.

Bridge night roosting does appear to be widespread for *A. pallidus* and *M. yumanensis* (Barbour and Davis 1969; Cross and Clayton 1995; Lewis 1994, pers. obs.), and may be a reasonable indicator of the presence/absence of these species in an area. By contrast, we know of no references to night roosting in structures by the tree and cliff roosting species absent from night roosts in our study area (i.e., *E. maculatum*, *E. perotis*, *L. noctivagans*, *Lasiurus blossevillii*, *Lasiurus cinereus*, and *Pipistrellus hesperus*).

Site Fidelity

Although site fidelity to maternity roosts has been well documented for a number of species (see Kunz 1982 for a review), little evidence has accumulated for night roosts, particularly those that are geographically separate from day roosts. Kunz (1982) states that bats are opportunistic in their choice of night roosts, thus implying that site fidelity would be low. Lewis (1994) has recently reported night-to-night and year-to-year fidelity to night roosts in a two-year study of *A. pallidus*. In the present study, year-to-year night roost fidelity for *A. pallidus*, *E. fuscus*, *M. volans*, and *M. yumanensis* was observed over varied periods up to four years.

The decreasing proportion of unbanded adult *M. yumanensis* (Figure 3) with each year after 1992 suggests that a single late-season, mass capture per year in a night roost is sufficient to band a large proportion of young (i.e., most individuals in the population are present in the night roost after midnight on an arbitrarily chosen night in August) and that movement of adults from other unmarked night roosts (known to occur within a few km) is infrequent.

Advantages and Limitations of Bridge Roost Surveys

The comparative ease with which night roosts, especially bridges, can be identified and sampled has not been explicitly acknowledged in the literature. The method is simple, requiring only hand nets and lights. Bats are not tangled in nets, so handling time, and presumably stress, is generally lower than for netting. The association of night roosts with roads typically allows convenient access. Also, when roads follow rivers, bridge surveys can provide a distributed series of sampling stations along an altitudinal habitat transect.

The evidence of within-year and between-year fidelity to night roosts for several species means that night roost aggregations offer a convenient alternative to more disturbance-sensitive maternity roosts for long-term monitoring of many aspects of reproduction and demography. In a forested setting, where day roosts may be both relatively inaccessible (i.e., over 10 m high inside a tree cavity) and occupied for short intervals, night roosts could offer the best opportunity for following a population over time. Particularly in landscape with extensive, ongoing timber harvest, bridge night roost sites probably persist over longer intervals than do day roosts.

The primary limitation of the bridge roost surveys is that they only sample a subset of the species present in the community (in this study, nine of 17). Adequate bat community inventory requires a combination of techniques. Also, fortunately, some areas still lack both roads and bridges.

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