Distribution and Ecology of the Big-Eared Bat, *Corynorhinus* (=*Plecotus*) *Townsendii* in California

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EXECUTIVE SUMMARY

This study had two primary objectives: to conduct roost surveys for *C. townsendii* in two parts of California where distributional information was most limited or lacking, and to obtain information on roosting and foraging ecology in two distinctly different habitats. This project was urgently needed because 1) recent California Department of Fish and Game surveys (conducted in 1987-1991) documented significant population declines in most surveyed areas, 2) distribution was still unknown in areas with suitable roosting habitat, and 3) the impact of various land management practices (e.g. prescribed fire, timber harvest, agriculture, and grazing) on foraging behavior was unknown.

A total of 95 abandoned mines, 18 caves, 11 man-made water tunnels, and 7 buildings were surveyed for bats. Twenty-one structures (twelve caves and nine mines) showed significant use by *C. townsendii*. Eleven are located in the western Sierra Nevada foothills, and ten in the Trinity Mountain area. Six maternity colonies, ranging in size from 48 to about 250 adult females, were identified. Three were in caves, and three were in mines.

Distribution for this species is somewhat patchy, and appears to be limited by the availability of roosting habitat. Historic and recent records would suggest that populations are concentrated in areas with abundant caves (especially the large lava flows in the northeastern portion of the state and karstic regions in the Sierra Nevada and Trinity Alps) or extensive abandoned mine workings (particularly in the desert regions to the east and southeast of the Sierra Nevada).

Radiotracking studies were conducted in two different habitats: 1) coastal forest (California bay, Douglas fir, and redwood) and grazed grassland at Pt. Reyes National Seashore, and 2) a mixture of scrub (with juniper and mountain mahogany) and ponderosa pine forest at Lava Beds National Monument. At Point Reyes the study colony resided in an abandoned ranch house, and at Lava Beds in a lava tube. In both settings the animals showed considerable loyalty to their roost sites even though the study was conducted after the nursery season had ended; females traveled greater distances than males to forage; and all the animals foraged in close association with vegetation -- in the vegetated gullies and redwood forest at Pt. Reyes, and in the vegetated lava trenches, near juniper or mountain mahogany, and with the stands of ponderosa pine at Lava Beds.

Genetic variation was preliminarily examined for three populations using mitochondrial DNA and microsatellites -- two populations within the zone of intergradation between the two subspecies, *C. t. townsendii* and *C. t.*

pallescens, and one population from the range of *C. t. pallescens*. These three populations were sufficiently distinct genetically to suggest that these techniques would be appropriate for addressing a wide range of questions for this species, including population differentiation, gene flow and mating systems.

Most maternity populations appear to be declining in numbers, and many historic colonies no longer exist. The primary threat to this species appears to be human disturbance at roost sites, particularly recreational caving, renewed mining in old mining districts, and reclamation of abandoned mines for hazard abatement.

1.0 INTRODUCTION

1.1. BACKGROUND INFORMATION

Recent status surveys conducted by California Department of Fish and Game (CDFG) revisited areas of known historic distribution, and documented serious population declines for Townsend's big-eared bat (*Corynorhinus townsendii*) in California (Pierson and Rainey 1996). While these surveys identified a number of important colonies, they focused on areas with historic records (i.e., primarily the coast, the southern deserts, the Owens Valley, the karst areas of the Mother Lode, and the lava flows in Shasta and Siskiyou Counties). Incidental observations of bats in other parts of California suggested that the big-eared bat was present in areas which had not been surveyed, particularly the southern Trinity Alps and lower elevations on the western slope of the central Sierra Nevada.

1.2. SYSTEMATICS AND POPULATION GENETICS

The taxon treated here as *Corynorhinus*, and originally described by that name (see Hall 1981 for prior taxonomic history), was known as *Plecotus* for nearly forty years based on Handley's (1959) revision . In this treatment, Handley subsumed three lineages in *Plecotus*:

1. the Palearctic taxa previously known as *Plecotus*,

2. the North American taxa previously known as *Corynorhinus*,

3. the monotypic western North American lineage now known as *Idionycteris*.

He retained these former genera as subgenera. *Idionycteris* was subsequently reevaluated and restored to generic status (Williams et al. 1970), a change which has been generally accepted (e.g., Koopman 1993). More recently, two phylogenetic studies have reviewed relationships among plecotine genera (Frost and Timm 1992; Tumlison and Douglas 1992). They derived significantly different relationships among the genera and differ in some taxonomic recommendations (e.g., one proposed synonomizing *Idionycteris* with *Euderma*), but were consistent in recognizing *Corynorhinus* (= North American *Plecotus*) as distinct at the generic level from Palearctic *Plecotus*. These suggested revisions post-date the closing publication date for Koopman (1993), and Koopman (in litt.) subsequently agreed that *Corynorhinus* should be recognized as a separate genus.

Within *Corynorhinus townsendii*, Handley (1959) identified two western subspecies, *C. t. townsendii* and *C. t. pallescens*, both occurring in California. His range map showed *C. t. townsendii* as occurring in a narrow band along the Pacific coast, and *C. t. pallescens* as covering a far more extensive range inland. However, he also described extensive subspecific intergradation in California, Nevada, Idaho, Oregon and Washington. In California, the area of intergradation includes virtually all of the state west of 118°W longitude.

In the zone of intergradation, individual specimens and series were not readily assignable to either subspecies and the morphological features which typified the subspecies did not change concordantly. Handley (1959) indicated that full spectrum of characteristics for both subspecies can be seen within a single population:

> "Within this zone of intergradation there is considerable individual variation in dorsal coloration. . . Tone is very variable throughout the zone, the range in some samples almost bridging the gap between the pale and dark extremes of the northwestern coast and the pallid belt (p. 192). . . Similarly, there is intergradation between the pale-colored and dark-colored populations in cranial characteristics. This is best seen in the relative stoutness of the rostrum (normally stout in dark-colored northwestern coast populations, normally less stout in pale-colored interior populations). Within the zone of intergradation, stoutness of the rostrum can not be correlated with coloration: some pale-colored individuals have the rostrum very stout; some dark-colored individuals have the rostrum rather frail (p. 193). . . Allocation of specimens, especially in inadequate series, from much of this [zone of intergradation] to one race or the other is largely a matter of personal opinion. As a result, various authors have disagreed on just where the artificial boundary between the ranges of *townsendii* and *pallescens* should be set (p. 199)."

Hall (1981) redrew Handley's map, eliminating indications of intergradation , and the resulting simplified subspecific geography has inevitably been widely used as the best available template for management planning for this species. The two western subspecies are currently considered a Federal Species of Concern (formerly a Category 2 candidate) by the U.S. Fish and Wildlife Service.

To evaluate the potential of genetic markers for clarifying relationships and examining gene flow among extant populations of *C. townsendii*, we are collaborating with T. Burland who has examined variation in several genetic marker systems within and among colonies of the related species *Plecotus* *auritus* in Scotland (Burland et al.1988, Burland, unpubl.). Successful amplification of DNA from a few California *C. townsendii* using *P. auritus* microsatellite primers (Burland et al.1988) prompted an expanded trial screening of samples from three colonies.

1.3. ECOLOGY

1.3.1. Roosting Ecology

C. townsendii is primarily a cavern-dwelling species. Whereas many bat species roost cryptically, concealing themselves in crevices or small hollows, *C. townsendii* roosts on open surfaces where it is extremely vulnerable to detection and disturbance. For this species, as for many others, the most significant roosts are summer maternity sites (occupied by adult females and their young) and winter hibernacula (where males and females roost together). Animals may also be encountered during the summer roosting by day singly or in very small groups (generally adult males or nonreproductive females) or by night in shelters that are used for resting or digesting food. *C. townsendii* does not form large night roosting aggregations as do some other species. Instead, they appear in small numbers (generally singly) in caves, rock shelters, open buildings, mines, and sometimes bridges (Brown et al. 1994, Burford and Lacki 1998, Dalquest 1947, Graham 1966, Lacki et al. 1993, Perkins and Levesque 1987, Perlmeter 1996, Rainey and Pierson 1996). Larger aggregations may be encountered in the spring or fall at sites that are close to, but not the same as, either the maternity or hibernating sites. The purpose of these roosts is not well known, but they may have an important sociobiological function. Fall roosts have been shown to be important mating sites for other species (Berry and Brown 1995). Spring roosts may serve as "staging" sites for the formation of maternity colonies (Perkins 1995), and/or be convenient to foraging areas (Dobkin et al. 1995).

1.3.1.1. <u>Maternity Roosts</u>

Prior to recent surveys, caves, abandoned mines, and buildings had all been reported as roost sites for *C. townsendii* in California (Barbour and Davis 1969, Dalquest 1947, Graham 1966, Marcot 1984, Pearson et al. 1952). Of the 54 maternity roosts recently documented in California, 43% were in caves and 39% were in abandoned mines (Pierson and Rainey 1996). The remainder were in anthropogenic structures (buildings, bridges, water diversion tunnels), each of which offered a cave-like roosting space (e.g., an enclosed attic or an open-ended box beam). While colony size seems to vary somewhat regionally (Idaho State Conservation Effort 1995), in California, nursery aggregations vary from ca. 30-400 adult females. A number of factors seem to play a role in roost selection, including temperature, dimensions, light quality and air flow (Clark et al. 1996, Lacki et al. 1994, Pearson et al. 1952, Perkins et al. 1994, Pierson et al. 1991, Pierson and Rainey 1996, Tipton 1984). Recorded temperatures in maternity roosts throughout California vary between 19°C in the cooler regions to 30°C in the warmer southern regions. This species also prefers a relatively spacious roost. The majority examined in California are at least 30 m in length, with the roosting area located at least 2 m above the ground. Maternity clusters are often located in ceiling pockets or along the walls just inside the roost entrance, within the twilight zone. This species generally shows a high degree of roost fidelity, with up to 77% of the adult females returning to the same site every year (Pearson et al. 1952). Yet colonies may sometimes change roost sites, either in response to disturbance or seasonal shifts in temperature (e.g., seeking cooler sites during early pregnancy and warmer sites in late pregnancy and after the young are born).

1.3.1.2. Hibernacula

Winter roosting behavior for *C. townsendii* varies considerably throughout its range. Whereas the eastern subspecies, *C. townsendii virginianus*, forms very large hibernating aggregations of up to 6,000 (Rippy and Harvey 1965, Stihler and Hall 1993) and the western subspecies, *C. townsendii pallescens*, can form aggregations up to several thousand in some areas of the West (Idaho State Conservation Effort 1995), the largest known wintering aggregation in California is <500 animals (C. Barat pers. comm.). In California, hibernating behavior seems to vary with altitude and latitude. The only sizable aggregations (>100 animals) occur in areas that experience prolonged periods of subfreezing ambient temperature. West of the Sierra Nevada crest no aggregations larger than a few animals are known below 39°N latitude (Lake County). Aggregations of >50 animals also have recently been identified at > 2,000 m elevation in the White and Inyo Mountains (Szewczak et al. 1998). Throughout areas that experience moderate, mostly above freezing winter temperatures, however, the animals appear to roost singly or in small groups, move roost sites frequently, and forage on warmer nights (Pearson et al. 1952, Pierson et al. 1991). Although certain sites are used reliably year to year, individual animals appear to move within and between roosts even in areas that experience prolonged winter conditions (Clark and Clark 1997, Humphrey and Kunz 1976, Pearson et al. 1952). *C. townsendii* appears to select hibernating roosts with stable cold temperatures and moderate air flow (Humphrey and Kunz 1976, Kunz and Martin 1982). Temperatures below 10°C are preferred (Humphrey and Kunz 1976, Genter 1986, Pearson et al. 1952, Perkins et al. 1994, Pierson et al. 1991, Pierson and Rainey 1996, Twente 1955). In California, the only sizable winter colonies have been found in caves or mines, with smaller groups (generally <10) being found occasionally in buildings (Barbour and Davis 1969, Dalquest 1947, G. Fellers pers. obs., Marcot 1984, Pearson et al. 1952, Pierson and Rainey 1996).

1.3.2. Foraging Ecology

Recent radiotracking and light-tagging studies have found *C. townsendii* foraging in a variety of habitats. The eastern subspecies have been detected foraging over open pasture, corn and alfalfa fields, and around the crowns of trees in Virginia (Dalton et al. 1989), along the edges of intermittent streams (Clark 1991, Clark et al. 1993), over pasture/rangeland, in the forest, and along the forest edge (Wethington et al. 1996) in Oklahoma, along canyon walls and cliff faces (Adam et al. 1994, Burford and Lacki 1995, Caire at al. 1984) and over small old fields (Burford and Lacki 1995) in Kentucky and Oklahoma. The western subspecies have been radiotracked foraging in native oak and ironwood forest on Santa Cruz island in California (Brown et al. 1994), and in sagebrush steppe and open ponderosa pine parkland in central Oregon (Dobkin et al. 1995).

The diet of *C. townsendii* consists of >90% moths (Dalton et al. 1986, Ross 1967, Sample and Whitmore 1993, Whitaker et al. 1977 & 1981). Studies in Kentucky have found noctuid and sphingid moths to dominate the diet (Burford and Lacki 1998, Shoemaker and Lacki 1993). Geometrids and notodontids are also consumed, and arctiids avoided (Shoemaker and Lacki 1993). Studies in both Kentucky and West Virginia have shown *C. townsendii* feeding selectively on forest-associated moths (Burford and Lacki 1998, Sample and Whitmore 1993). Small quantities of other taxa are also consumed, particularly coleopterans and dipterans (Dalton et al. 1986, Ross 1967, Sample and Whitmore 1993). Hemiptera, Hymenoptera, Homoptera, Neuroptera, Tricoptera, and Plecoptera have also been found occasionally (Dalton et al. 1986, Whitaker et al. 1977).

1.4. LIFE HISTORY

Most of what we know regarding reproduction in *C. townsendii* derives from the comprehensive studies of Pearson et al. (1952) in California. They found mating took place primarily in the hibernacula from October to February, although some females were likely inseminated earlier in the fall. Females may breed as early as their first winter, whereas males are not reproductively active until their second year. As in other temperate zone vespertilionid species, the female stores sperm in the uterine lining until the spring when ovulation and fertilization occur. Gestation length varies with climatic conditions, but generally lasts from 56 to 100 days.

The timing of maternity colony formation and parturition varies with climate and latitude. In California, colonies will form in March in the desert and along the central coastal, but and not until June in interior northern California. A single young, weighing ca. 25 % of mother's postpartum mass, is born sometime between May and July (Easterla 1973, Pearson et al. 1952, Twente 1955). Young bats are capable of flight at 2.5 to 3 weeks of age and are fully weaned at 6 weeks (Pearson et al. 1952). Nursery colonies start to disperse after the young are weaned, and break up altogether in September and October (Pearson et al 1952, Tipton 1983).

In the absence of disturbance, year to year survivorship is likely ca. 50 % for the young, and 80 % for adults (Pearson et al. 1952). Band recoveries have yielded longevity records of 16 years, 5 months (Paradiso and Greenhall 1967) and 21 years, 2 months (Perkins 1994).

1.5. STUDY OBJECTIVES

This study had two primary objectives: to conduct roost surveys for *C. townsendii* in two parts of California where distributional information was most limited or lacking, and to obtain information on roosting and foraging ecology in two distinctly different habitats. This project was urgently needed because 1) recent California Department of Fish and Game surveys (conducted in 1987-1991) documented significant population declines in most surveyed areas (Pierson and Rainey 1996), 2) distribution was still unknown in areas with suitable roosting habitat, and 3) the impact of various land management practices (e.g. prescribed fire, timber harvest, agriculture, and grazing) on foraging behavior was unknown.

2.0 MATERIALS AND METHODS

2.1. ROOST SURVEYS

Roost surveys focused on caves and abandoned mines in two areas of known historical distribution for which current information was lacking -- lower elevations in the Trinity Alps (western Shasta, western Siskiyou and Trinity counties) in the northwestern portion of the state and the lower elevation western slope of the central Sierra Nevada (Mariposa, Tulare and Tuolumne counties). Sites were selected either because historical records existed for the area, or because the area contained a high density of mines or caves that had not been surveyed for bats. All work was conducted in collaboration with the Bureau of Land Management, the Forest Service, or the

National Park Service.

Trained field technicians conducted surveys according to a standardized protocol (see Riddle 1995). For those mines that could be entered, investigators noted the presence or absence of bats, the presence or absence of bat sign (guano, culled insect parts or urine stains on the ceiling), and measured a number of parameters for the roost site (including dimensions of the entrance, distance of the roost site from the entrance, height of roost above the ground, roost temperature) and the surrounding habitat (dominant vegetation, ambient temperature, distance to nearest water source). Mines and caves that could not be entered for safety reasons were monitored at emergence time using night vision equipment. The guano of *C. townsendii*, if intact, is distinctive (a golden-brown and spiral shaped), thus facilitating the identification of roosts being used by this species.

All summer surveys were conducted between late May and early October 1997. Limited winter surveys were conducted in between January and March 1998. A few significant sites were revisited in the spring or summer of 1998.

2.2. RADIOTELEMETRY

Radiotelemetry was used to investigate roosting and foraging behavior for two significant populations of Townsend's big-eared bat, one at Point Reyes National Seashore along the central California coast and the other at Lava Beds National Monument, close to the Oregon border. Both sites had abundant native habitat (coastal mixed conifer/hardwood and montane conifer forests respectively) in the vicinity of known *C. townsendii* roosts. Yet, at Point Reyes there was active grazing adjacent to the roost, and at Lava Beds, a prescribed burn had recently been conducted in the vicinity of one roost. Some of the forest within a few kilometers of a this roost, under the jurisdiction of Modoc National Forest, was scheduled for timber harvest and geothermal development. Thus, both of these sites offered opportunities to investigate potential impacts of various land uses on foraging behavior of *C. townsendii.*

At both sites, radiotelemetry was used to locate alternate roost sites and determine the foraging range of post-lactating or non-reproductive females and selected adult males. Animals were captured in harp traps or mist nets at roost entrances. The heaviest individuals were selected for telemetry, outfitted with 0.44 g radiotransmitters (Model LB-2, Holohil Systems Ltd., Carp, Ontario), and followed for 10 days and nights. The transmitters weighed between 3.5 and 4.7 % body mass, less than the 5 % recommended maximum (Aldridge and Brigham 1988). Transmitters were attached to bats by trimming midline dorsal hair over the scapulae and applying SkinBond® surgical adhesive to the under side of the transmitter.

At both sites we established 2-4 fixed stations. These investigators were constantly monitoring for transmittered bats, scrolling through the frequencies in sequence. With 15-17 animals carrying transmitters, it was only possible to sample each frequency once every 30 to 60 minutes. At both study sites, 2-4 investigators were mobile and assigned the task of following particular individuals or searching areas that were out of reach for fixed stations. All stationary and roving investigators were equipped with a hand-held walkie-talkie or a CB radio, and reported regularly to one station that served as radio central and coordinated the activities of the roving investigators. Efforts focused on qualitative characterization of the geographical pattern of foraging activity and broad habitat associations (e.g., forest versus grassland at Point Reyes, and forest versus scrub at Lava Beds National Monument). Movements were often rapid and of large scale (several km in minutes) and simultaneous bearings from two or more observers were frequently not available, although it was still possible to determine direction of movement or the general area where the bat occurred. During the day, roost sites of animals with active radio transmitters were identified using telemetry receivers and handheld antennas carried by one or two member observer teams.

2.3. GENETIC STUDIES

Three populations of *C. townsendii* (minimum map distance> 300km) were selected for screening relatively large scale geographical patterns of genetic variation. According to the subspecific distribution map of Handley (1959):

1. One colony (Pt. Reyes National Seashore, Marin County) is coastal *C. t. townsendii* within the zone of intergradation with *C. t. pallescens,*

2.The second (vicinity of Mt. Shasta, Siskiyou County) is also in the intergradation zone, but is separated from the coast by the Klamath Mountains,

3. and the third (China Lake area, Inyo County) is *C. t. pallescens* from east of the Sierra Nevada, potentially a major geographical barrier.

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). T. Burland conducted the laboratory investigations and provided the data analysis summarized below. DNA was extracted by a saltingout/chloroform method. When two wing punches were available for an individual, both punches were used. DNA from ten females per site was amplified with primers for six microsatellite loci which were highly polymorphic in *P. auritus* and scored via polyacrylamide gel electrophoresis (see Burland et al. 1998 for methods, primer sequences, and allele nomenclature). In a smaller test of mitochondrial DNA variation, both the 3' and 5' ends of the control region of two individuals per population were also sequenced.

Given the difficulties in distinguishing between the two western subspecies, and the fact that California Department of Fish and Game considers the entire species to be a Species of Special Concern, for the purposes of this study, the two subspecies are considered as a single taxonomic unit.

3.0 RESULTS AND DISCUSSION

3.1. GENETIC VARIATION

3.1.1. Microsatellites

Two loci were monomorphic for all individuals tested and thus were not informative regarding genetic variation. No clear banding pattern could be obtained at two other loci, and thus could not be scored. Two loci (Paur03 and Paur05) gave a clear banding pattern and were polymorphic (>1 allele). All individuals were scored for locus Paur03, whereas three individuals did not amplify for locus Paur05. As the individuals that did not amplify were three of the individuals for which only one wing punch was available, it appears likely that reliably resolving this locus demands higher concentrations of DNA.

Five alleles were identified for locus Paur03, of which one was only found in the Inyo population. Paur05 was more polymorphic, with a total of 14 alleles identified. Unique alleles were identified for all three populations, although Inyo had more unique alleles than the other two (Fig. 1).

A preliminary measure of genetic differentiation among populations was calculated with the program GENEPOP using Weir and Cockerham's estimate of F_{st}. Low mean genetic differentiation was observed with locus Paur03, but much greater differentiation was identified with locus Paur05 (Fig. 1). A qualitative summary of these data is that the Inyo population is the most distinct of the three, and that Marin and Inyo are the most different pair. While the results strongly suggest microsatellites will offer valuable insight into geographic variation in *C. townsendii*, data from five or more loci are required for a permutation test to evaluate if the apparent differentiation is significantly different from zero.

3.1.2. Mitochondrial DNA

All individuals yielded sequence data from both ends of the control region. In the following results, only the variable sites of each sequence are shown. A '.' indicates the base is the same as in the top sequence, whereas a '-' indicates a proposed indel site.

3.1.2.1. *C. townsendii* control region, 3' end

A total of 390 bp sequence was obtained, containing five variable sites (4 transitions and 1 indel). From this, four haplotypes were identified (3' A - D). Haplotypes A and B differed by a single transition. Haplotypes C and D were more divergent, but differed from one another by only two transitions. Haplotype A was shared between Marin and Inyo.

Individual	(location)	Variable sites	3' Haplotype
43.01	(Marin)	GTATT	A
45.13	(Marin)	...C.	B
B53	(Siskiyou)	A-G..	C
B65	(Siskiyou)	A-..C	D
JM2	(Inyo)	.....	A
JM14	(Inyo)	.....	A

3.1.2.2. *C. townsendii* control region, 5' end

A total of 331 bp sequence was obtained, containing 34 variable sites (32 transitions, 1 tranversion and 1 indel). From this, five haplotypes were identified (5' A - E). Sequence divergence among all haplotypes was high, although haplotypes C and D appeared particularly distinct. No haplotypes were shared among geographical locations.

Individual	Variable sites	5' Haplotype
43.01	GCCGAAGCTAGTCTCGATACAGATCGTCCACTAC	A
45.13	.............C.....T.......T.GTC..	B
B53	GG..G..T....TCT.G.G...G.TAC...T...	C
B65	-.TAGGA.C.ACTC.A.C..GA.C..C...T...	D
JM2	.........CG...C...........C.T.T.GT	E
JM14	.........CG...C...........C.T.T.GT	E

3.1.3. Implications of Genetic Data

The mtDNA data are consistent with the microsatellite data in suggesting that the three populations are sufficiently distinct genetically to make a more extensive survey very informative. Both ends of the control region indicate that the Marin and Inyo county samples are more similar to one another than either is to the Siskiyou county sample. This apparent difference from the preliminary microsatellite data could result from a combination of several factors, including the very small samples and differences between the uniparental inheritance of mtDNA and the biparental inheritance of microsatellite markers. Both individuals from Inyo have the same haplotype at both control region ends, suggesting close matrilineal relationship and raising questions about population size and possible prior bottlenecks. Analysis by the same methods of larger samples from these sites and additional localities (maternity colonies, including mother -young pairs, isolated males, and hibernating populations) over a range of geographical distances would offer considerable insight into population differentiation, mating systems, geographical patterns of gene exchange and inferences about recent population history.

3.2. DISTRIBUTION OF *C. TOWNSENDII* IN CALIFORNIA -- ROOST STUDIES

3.2.1. Background Information

There are records for *C. townsendii* throughout much of California, although there is a notable absence of records from the Central Valley (Fig. 2). Although the majority of records are from low to moderate elevations, the species has been found from sea level to > 3,000 m. It occurs in a wide variety of habitat types -- coastal redwood forest, oak savannah, mixed conifer forest, pinyon-juniper, and all the desert habitats (Sonoran, Mojave, and Great Basin). Maternity colonies have been found up to 1,600 m in the Sierra Nevada (E.D. Pierson pers. obs.) and 1,700 m in the White and Inyo Mountains (Szewczak et al. 1998), and hibernating sites occur as high as 3,188 m in the White Mountains (Szewczak et al. 1998).

Distribution is, however, somewhat patchy, and appears to be limited by the availability of roosting habitat. Historic and recent records would suggest that populations are concentrated in areas with abundant caves (especially the large lava flows in the northeastern portion of the state and karstic regions in the Sierra Nevada and Trinity Alps) or extensive abandoned mine workings (particularly in the desert regions to the east and southeast of the Sierra Nevada). Also, fifty years ago a number of significant populations were known along the coast, in the redwood belt from the Monterey Peninsula northward (Pearson et al. 1952; M. J. Koford, MVZ field notes; A.K. Pearson, MVZ field notes), and on Santa Cruz Island in the south.

A status survey was conducted in the late 1980s and early 1990s by California Department of Fish and Game (Pierson and Rainey 1996). In this study, the status of 46 historically known maternity colonies (based on records dating from the late 1940s to the 1960s) was investigated. Twenty-four of these colonies could no longer be found either at the original roost site or within a 15 km radius, suggesting a 52% decline in the number of colonies over a 40-50 year period. Twenty-one of these colonies were located, an additional one was reported to still exist, and approximately 20 additional colonies were identified. Thus based on the results of this study, a total of 39 colonies were known to exist in the late 1980s and/or early 1990s, with unconfirmed but reliable reports of four others.

3.2.2. This Study

One purpose of the current study was to investigate some areas not covered by the California Department of Fish and Game survey. Since much of the previous effort in northern California and the western Sierras had focused on caves, this study placed a particular emphasis on abandoned mines. The Fish and Game study had found severe population declines at historically important roosts in limestone caves in the Mother Lode country of the central Sierra Nevada. One possibility, not investigated at the time, was that the colonies no longer occupying particular caves had moved to abandoned mines. Also, in the northwestern part of the state, some of the lava and limestone areas had been intensively investigated, whereas others had not (particularly one remote portion of Trinity County). Also, abandoned mines had been essentially overlooked in this area as potential roosting habitat for *C. townsendii.*

3.2.2.1. **Roost Use by Structural Type**

A total of 95 abandoned mines, 18 caves, 11 man-made water tunnels, and 7 buildings were surveyed for bats (Table 1). Fig. 3 is a bar graph depicting use by bats for each of structural type. While these results clearly demonstrate that both caves and mines provide extremely important roost sites for *C. townsendii*, they are not indicative of the relative importance of the various structural types. The surveyed sites were not selected at random. Because time was limited we gave preference to sites we thought had a high likelihood of being used by bats. Every surveyed cave was visited because there was reason to think (based on historic records or recent reports by agency personnel or local cavers) that it was being used by bats. There was also some pre-selection of mine sites. In one area (Whiskeytown National Recreation Area and BLM land in Shasta County) trained technicians pre-screened the mines, and identified, based on external surveys, those that warranted further investigation. On all Federal lands we worked with local agency staff, and often relied upon their knowledge for selecting mines or caves to survey. Thus the usage rates indicated in Fig. 3 likely over-represent the extent to which these structural types are actually used on a regional basis.

Of the 95 mines surveyed, 63 (66 %) had evidence of some use by bats; 35 (37 %) were being used by *C. townsendii*; 24 (25 %) had one or more *C. townsendii* resident at the time of survey (Table 1). Four mines (4 %) had maternity aggregations present at the time of survey, although these likely represented three colonies since two mines were close to each other (and thus were likely being used by the same colony). Thirteen of the mines that had no use (39 %) were prospects <10 m in total length, whereas only six of the mines used by bats (10%) were <10 m in length. All were night roosts, and only one was used by *C. townsendii*.

Seventeen of the 18 surveyed caves showed evidence of use by bats; 14 by *C. townsendii*. Twelve caves had significant use, and maternity colonies were resident in five (representing three colonies) at the time of survey.

Eleven water tunnels associated with Hetch Hetchy Reservoir in Tuolumne County were surveyed. Seven showed some use by bats, three by *C. townsendii*. A single *C. townsendii* was resident in two structures at the time of survey. None showed significant use. All seven buildings showed some sign of use by bats, with one being a day and night roost for the yuma myotis, *Myotis yumanensis*. Four showed some evidence of use by *C. townsendii*, and one or two individuals were resident in three structures at the time of survey.

3.2.2.2. Maternity Colonies and Other Significant Roosts

Twenty-one structures (twelve caves and nine mines) showed significant use by *C. townsendii* (Table 1). Eleven are located in the western Sierra Nevada foothills, and ten in the Trinity Mountain area. The Forest Service has jurisdiction over nine sites; the National Park Service over four; and BLM over five. Three are privately owned.

Six maternity colonies, ranging in size from 48 to about 250 adult females, were identified. Three were in caves, and three were in mines One colony, the Greenview Mine was unknown prior to this study. The other five were expected based on prior information. One colony (Murphys Cave) had been documented in late August 1988 during the CDFG surveys (Pierson and Rainey 1996). The Hyampom and Hayfork caves had been reported as *C. townsendii* sites by Graham (1966) and/or Marcot (1984), but their significance as nursery sites was unknown prior to these surveys. The presence of a bat colony in the Indian Creek mines had been documented by BLM several years ago (K. Hughes pers. comm.), and identified as a *C. townsendii* colony in June 1996 (P. Brown pers. comm.). Yosemite National Park had unconfirmed reports of bats using the Barium mines (L. Chow pers. comm.).

Three of these colonies (Hayfork, Hyampom and Indian Creek) appeared to use more than one structure. In each case a pair of structures (located within one kilometer of each other) was identified, and while one may have been favored, both were used at some point. The reasons for roost switching are not known. The most likely explanations are seasonal shifts in roost needs or human disturbance to the roosting site.

Seven other caves and five mines had significant accumulations of *C. townsendii* guano. Although the roosts did not contain more than a few animals (zero to four) at the time of survey, the large relatively fresh guano deposits suggested these sites were important roosts at some other time of year, most likely earlier in the maternity season. Use of multiple nursery sites has been documented for *C. townsendii*, with females using a cooler site during early pregnancy, and a warmer site in late pregnancy and after the young are born (Pierson et al. 1991; V. Dalton pers. comm.). Most of these surveys were conducted mid-to-late season. Two sites (Bower Cave and Clough Cave) were known to be important nursery sites in the past (Graham 1966), but currently receive very high recreational use. Clough Cave, although located within Sequoia National Park and gated, is subject to recurring acts of vandalism. These two sites have been monitored irregularly in recent years. They always show use by *C. townsendii*, but a colony has never been encountered at the time of survey.

Although the sites surveyed ranged in elevation from 250-2,536 m, all the significant sites were found in a rather narrow elevation band from 488-1,140 m, whereas those sites occupied by small numbers of animals or used as night roosts ranged in elevation from 250-2,463 m. Although lower elevation sites are more common, some of the largest concentrations of *C. townsendii* in California, found in the lava caves in north central Siskiyou County, are at elevations of ca. 1,200-1,500 m. There is also one maternity colony known at 1,600 m in the Sierra Nevada (E.D. Pierson pers. obs.), and colonies at 1,380-1,710 m in the White and Inyo Mountains (Szewczak et al. 1998). The temperature conditions within all surveyed mines and caves ranged from 8°-47°C, whereas those that received significant usage had a more restricted temperature range of 15°-28°C (comparable to that previously reported for *C. townsendii* roosts in California [Pierson et al. 1991]). All surveyed sites were located in stream or river drainages, ca. one kilometer or less from permanent water. The size of the roost opening varied greatly for the significant roosts, with openings being 0.3-30 m high and 0.2-15 m wide. The smallest opening (Murphys Cave) was 0.7 by 0.2 m.

Most of the significant cave sites are currently subject to considerable human disturbance. One cave on National Park Service land has not been discovered by the public. All others are heavily used for recreational purposes. Attempts at management for two caves (Bower and Clough) have largely failed. Although recommendation for the protection of Bower Cave were submitted to the Forest Service in October 1991, no effective protection measures have been implemented. The Park Service has made repeated efforts over a number of years to protect Clough Cave, but every gate installation has been breached and the cave repeatedly vandalized. The mines appear to receive considerably less recreational traffic. The Barium Mine, under the jurisdiction of Yosemite National Park, is protected by a sturdy cyclone fence and is not disturbed. BLM has plans to gate the most important of the two Indian Creek mines. The presence of a possible nursery roost at Greenview was only recently discovered (May 1998). In a repeat survey in June 1998, an active campsite was located outside the mine and only two bats were present.

Information was obtained collaterally regarding four other important maternity populations -- two in limestone caves on Lake Shasta in Shasta County and two in lava caves in Siskiyou County. These colonies are monitored irregularly on a volunteer basis by the Shasta Area Grotto, in cooperation with the Klamath and Shasta-Trinity National Forests (R. Miller pers. comm., L. Wolff pers. comm.). Although three of these sites are discussed in the CDFG survey report (Pierson and Rainey 1996), a considerable amount of information has been gathered since the field work for that survey was completed in 1991.

These four sites are discussed below:

Samwell Cave, Shasta County

Graham (1966) had identified Samwell Cave, located in a limestone formation on the McCloud arm of Lake Shasta (Whiskeytown-Shasta-Trinity National Recreation Area), as a significant *C. townsendii* maternity site. Due to heavy recreational use, and the installation of an inappropriate gate, this cave was abandoned by *C. townsendii* many years ago. Despite recent replacement of the gate, the colony has not returned to this cave, since the gate does not protect the chamber where visitors congregate and the bats prefer to roost. Also, the Forest Service continues to issue keys on request to recreational users. A substantial colony of *C. townsendii* was located in 1996 at a cave nearby (location undisclosed) (L. Wolff pers. comm.) and is likely the same population that once occupied Samwell Cave. This new cave, also under the jurisdiction of the U.S. Forest Service, has been subjected to frequent visitation for mapping and cave inventory.
Since the colony moves in response to disturbance, their presence there is unpredictable. Ten bats were observed by us in an exit count during our only site visit on 10 April 1996. Seven bats were observed on 15 May 1997 (L. Wolff pers. comm.).

Lake Shasta, Cave # 2, Shasta County

There is a second pair of caves located on the McCloud arm of Lake Shasta, ca. 15 km air distance from Samwell. We have not visited either of these sites, but they are reported by reliable observers in the Shasta Area Grotto to have a colony of 50-100 *C. townsendii* (L. Wolff pers. comm.).

Bat Cave, Siskiyou County

Bat Cave had been known since the 1970s as a significant *C. townsendii* roost, serving as both a maternity and hibernating site. Monitoring of this cave by the Shasta Area Grotto over several years documented that recreational use of the cave was very high, and that the bat population fluctuated in response to human disturbance. On 11 May 1997 the Forest Service installed a "bat friendly" gate, and within two months the bat population in the cave began to increase. Both the summer and winter populations have responded positively to the gate. Forty-two bats were found in the cave in May 1997, just prior to the gate installation. Although they abandoned the cave in response to the noise and confusion of gate construction, the population had climbed to 69 by July (as compared to only a few animals present in July 1994). In May 1998, after a full year of gate protection, the May population had almost doubled to

76 bats. Likewise only seven bats were found hibernating in this cave in January 1997, prior to gate installation, and 66 were found there in December 1997. Since >200 animals have been seen in this cave on occasion (generally in late summer), it is considered to be an important colony.

Pluto Lava Flow, Siskiyou County

There are at least five caves in the Pluto Lava Flow that are important to a substantial population of *C. townsendii*. Local movement among sites is not well understood, so it is not known how many colonies are involved (although it is likely at least two). Two adjacent caves are on private land -- one (Pluto Lava Flow #6) which serves as a maternity site for ca. 150 females (Pierson and Rainey 1996) and the other (Pluto Lava Flow #5) as a hibernating site for comparable numbers of animals (see Section 3.2.2.3. below). The remainder of the caves are now under the jurisdiction of the Klamath National Forest, which is currently preparing a management plan that includes proposals to gate several of the caves. The most significant cave, which receives intense recreational use, was used historically as a maternity site, and in recent years has been an important hibernating site. Due to multiple large openings along a collapse trench, protecting the bats from human disturbance presents formidable management challenges. A fourth cave that receives frequent visitation is a very important hibernating cave (Pierson and Rainey 1996), and a fifth cave supports a small maternity cluster (R. Miller pers. comm.).

3.2.2.3. Hibernating Roosts

Large wintering aggregations of *C. townsendii* in California are known to occur primarily in the lava cave country of Shasta and Siskiyou counties (Pearson et al. 1952, Pierson and Rainey 1996), and above 2,000 m in the White and Inyo Mountains (Szewczak et al. 1998), with smaller aggregations being known historically as far south as Lake and Napa counties, just north of the San Francisco Bay area (Pearson et al. 1952).

Eleven caves were surveyed for hibernating populations between 20 January and 10 March 1998 -- six in the Pluto Lava Flow of Siskiyou County (see Section 3.2.2.2. above), two in the vicinity of Bat Cave (Siskiyou County), and three in the Sierra Nevada foothills of Mariposa County: Merced Cave #1, Merced Cave #2, and Bower Cave (Table 2). Substantial hibernating aggregations were found in three of the Pluto Lava Flow caves. Pluto Lava Flow #1 had 102 animals in January 1988 (Pierson and Rainey 1996), 55 in February 1995 (R. Miller pers. comm.), had 85 *C. townsendii* on 3 February 1998. (The decline in 1995 may have resulted from disturbance a year or two prior to this date when school children removed a number of hibernating bats from this cave and released them in a local store). Pluto Lava Flow #5, which had 170 *C. townsendii* on 20 January, had only one on 1 March, while Pluto Lava Flow #4 had 140 *C. townsendii* on 1 March. Bat Cave had 66 hibernating *C. townsendii* in December 1997. This cave, used as both a maternity and hibernating site, showed a marked increase in the number of bats using the cave following the installation of a protective gate in May 1997. Although known to have large numbers of hibernating bats in the 1970's, this cave had only 7 bats in January 1997 prior to the gate installation. None of the caves in the Sierra Nevada foothills had more than a few bats in early March.

Of the caves surveyed, five had sign of recent human disturbance -- foot traffic in three, a recent fire in one, 3 groups of 9 people were encountered at another, and evidence that permanent climbing routes had been established was found in another.

Our intention to resurvey the caves visited by Marcot (1984) was thwarted by extremely severe winter conditions.

3.2.2.4. Roosts by Region

3.2.2.4.1. Trinity Mountains (Shasta, Siskiyou and Trinity Counties)

Fifty-six mines were surveyed in this region, and 21 (38 %) had evidence of use by *C. townsendii.* In most cases evidence suggested use by only a few animals. Two mines (part of the same complex and only 100 meters from each other) were used as maternity roosts (with a collective population of 200-300 females). Another mine had a small colony (likely the beginnings of a maternity roost) in late May 1998. Four caves known to be used by *C. townsendii* in the winter (Marcot 1984), and suspected to be summer maternity sites based on historical data (Graham 1966) did, in fact, contain maternity colonies. These caves were all located in a limestone area of southern Trinity County. Their location in relationship to each other (two caves close to each other in one drainage, and two others close to each other in another drainage) suggest that these sites are occupied by two colonies of ca. 70-75 adult females each. Individual *C. townsendii* were also found using four buildings located on Park Service land.

Shasta County

Thirty-four mines were surveyed in western Shasta County. The majority were located in an old mining district west of Redding, on either BLM land (in the vicinity of French Gulch) or in Whiskeytown National Recreation Area. Twenty-two mines (65 %) had some bat use; 9 (26 %) had evidence of use by *C.*

townsendii; 8 (24 %) had between one and four *C. townsendii* resident in the daytime.

Five buildings located on the Whiskeytown National Recreation Area were also surveyed. All showed evidence of use by bats, 4 by C. *townsendii*, and one to two animals were present in three of the buildings at the time of survey.

No new previously unknown maternity colonies were found in Shasta County. A total of 15 *C. townsendii* were observed. The presence of one to several *C. townsendii* in a high percentage of the sites surveyed suggests that there is likely a maternity colony in the vicinity of Whiskeytown National Recreation Area. Two very important maternity colonies (the only two currently known for the county) occupy limestone caves on Lake Shasta (see Section 3.2.2. above). Neither of these colonies, both under the jurisdiction of the Shasta Trinity National Forest, is adequately protected at this time.

Siskiyou County

Eleven mines were surveyed in western Siskiyou County, three on BLM land, and eight on the Klamath National Forest. Ten mines (91%) had some bat use; seven (64 %) were being used by *C. townsendii*. One of the mines, which had only one bat present when first surveyed in early October 1997, had what is presumed to be a small nursery roost (48 bats) when revisited in late May 1998. The colony was not present in June 1998, however, likely because of human disturbance (an active campsite) in the vicinity of the roost. Six other mines had between one and six animals each for a total of 14 *C. townsendii*.

Siskiyou County has some of the most significant limestone and lava caves in the state -- cave systems which support extremely important *C. townsendii* populations. The status of most of these caves is reviewed in the CDFG study (Pierson and Rainey 1996). A few are privately owned, but the majority are on public land (either Lava Beds National Monument or the Klamath and Shasta-Trinity national forests). Many caves on Forest Service land are being monitored on a volunteer basis by the Shasta Area Grotto (R.M. Miller pers. comm.); those at Lava Beds National Monument by National Park Service staff.

To summarize, there are maternity colonies (generally >200 females) in limestone caves on private land near Gazelle (an unsubstantiated, but reliable report) and on the Klamath National Forest near Cecilville, in a man-made structure on private land near Somes Bar, and in two or more lava caves in the Pluto Lava Flow near Weed (Klamath National Forest and private land) (see Section 3.2.3 above), in Bat Cave (recently closed by gating by the Shasta-

Trinity National Forest) (see Section 3.2.3 above), a cave near Tennant (Klamath National Forest), and multiple caves at Lava Beds National Monument (where three apparently separate colonies occur within a few kilometers of each other). Of these ten significant colonies, only four are currently provided with adequate protection from human disturbance (the three at Lava Beds National Monument and Bat Cave on the Shasta-Trinity National Forest). A management plan for some of the caves in the Pluto Cave lava flow is currently in preparation.

Trinity County

Eleven mines in Trinity County were surveyed, the majority under the jurisdiction of BLM or the Forest Service. Five mines were being used by *C. townsendii.* Three mines had one individual each. Two, located very close to each other, served as a maternity roost for > of 200 adult females. One of these mines had 260 bats on June 26 and about 200 on July 22. The neighboring mine had 3 bats on June 26 and 140 on July 22. The increased numbers in July likely reflect the entrance of volant juveniles into the population.

Trinity County has significant limestone formations in the vicinity of Hyampom, Forest Glenn, and Wildwood. Four caves in this area were surveyed for hibernating bats in the 1980s (Marcot 1984). All were found to have hibernating *C. townsendii.* Attempts to locate these caves at the time of the CDFG survey had not been successful. Consequently these sites and three others mentioned by Graham (1966) were given high priority in this study. Five of the seven caves (two pairs of which were close to each other and thus likely served as alternate roosts for the same colony) were successfully surveyed. Four contained maternity colonies (Hayfork#1, Hayfork #2, Hyampom #1 and Hyampom #2); one (Hall City) contained no evidence of use by *C. townsendii*; one could not be located; and one was designated off-limits by the Forest Service due to the presence of an active raptor nest (although reliable reports from cavers indicate no bat colony has ever been found at this cave -- B. Rogers pers. comm.).

3.2.2.4.2. Western Slope of the Central Sierra Nevada (Calaveras, Mariposa, Tulare and Tuolumne Counties)

Thirty-nine mines were surveyed; 25 (64 %) had evidence of use by bats; 15 (38 %) by *C. townsendii*, although only one appeared to be used as a maternity site. Additionally, 11 tunnels associated with Hetch Hetchy Reservoir were surveyed. Seven showed evidence of use by bats, three were being used by small numbers of *C. townsendii.* Eleven caves with known or expected bat use were surveyed, and ten had evidence of use by *C. townsendii.* Although a maternity colony was actually located at only one site, substantial guano accumulation suggested that seven other sites are used by colonies at some point in the annual cycle.

Mariposa County

Fifteen mines were surveyed. Nine (60 %) had some indication of bat use, 7 (47 %) by *C. townsendii.* Three mines had one or two *C. townsendii* each, for a total of 4 bats. Another mine complex under the jurisdiction of Yosemite National Park is a *C. townsendii* maternity roost. Emergence counts at the 5 portals on August 25 yielded 62 bats (54 from one portal, 2 from another, and 6 from a third).

Four caves were surveyed, three in the Merced River drainage on the Sierra National Forest, and one on the Stanislaus National Forest. All showed sign of use by *C. townsendii*; three had one to four bats present for a total of seven bats. Three caves had extensive guano deposits suggesting use by significant colonies at some other time of year. The cave on the Stanislaus National Forest (Bower Cave) was an historically important nursery site for *C. townsendii* (Graham 1966). This cave experiences extensive recreational use, and current management practices do not provide adequate protection for the bats. Merced Cave #1 and Merced Cave # 2 (plus Miller Gulch Mine #2) are all in close proximity to each other and thus likely serve as alternate roosts for the same colony.

Tulare County

Five caves, all in Sequoia National Park were surveyed. Four had evidence of use by *C. townsendii*; two had small numbers (1-3) of *C. townsendii* present. Although no caves had more than a few bats present at the time of survey, two had extensive guano piles indicating significant use at some other time during the year. Although persistent disturbance has precluded occupation of Clough Cave by *C. townsendii* for many years, individuals continue to visit this historically important roost site. This cave would likely be reoccupied if adequate protection could be provided.

Tuolumne (and portion of Calaveras) Counties

Twenty-four mines were surveyed. Sixteen (67 %) showed some use by bats, eight (33 %) by *C. townsendii.* Two had one *C. townsendii* each present at the time of survey; another had six *C. townsendii* emerge at an exit count. Also surveyed were eleven tunnels associated with the water pipes of the Hetch

Hetchy Reservoir system. As indicated above, seven showed use by bats, three by *C. townsendii.* Two buildings on Hetch Hetchy Reservoir property had extensive night use by a *Myotis* species, but no use by *C. townsendii.*

Two caves were surveyed, one on private land in the Stanislaus River drainage (Murphys Cave -- just across the county line in Calaveras County), and the other on the Stanislaus National Forest in the Clavey River drainage. The cave on the Stanislaus River housed a large maternity roost (>500 bats) on August 23; the other cave had one *C. townsendii* present of August 24, but extensive guano piles suggested this cave is also used as a maternity roost at some time during the season. The Stanislaus River colony is one of two in this area that was known historically (Graham 1966, Pierson and Rainey 1996). This area experiences intensive recreational caving and this colony appears to move around among several caves, both seasonally and in response to disturbance. Repeated attempts during the CDFG surveys to document a colony larger than ca. 20 animals were unsuccessful, although local cavers repeatedly report seeing large clusters of bats in one or more of these caves. In late August 1998 this cave had ca. 500 animals (likely about 250 adult females and their young), thus confirming that a large colony still persists in this area.

3.3. RADIOTELEMETRY AND LIGHT-TAGGING STUDIES

3.3.1. Point Reyes National Seashore

3.3.1.1. Study Objectives

The Point Reyes area supports two of the largest colonies of *C. townsendii* along the coast of California (Pearson et al. 1952; Pierson and Rainey 1996). The largest and best known colony has occupied an abandoned house in the Olema Valley along Highway 1.

The purpose of the study was to investigate the foraging behavior of bats in the Olema Valley, evaluate habitat usage, and to locate alternate day roost sites. Habitat use was of particular interest because much of the east side of the valley is grazed by beef cattle and questions have been raised about how this might affect wildlife, including rare bats.

3.3.1.2. Study Area

The study area is located in a 348 km^2 area managed by Point Reyes National Seashore in western Marin County, California (Fig. 2). The study colony roosts in the attic of an abandoned, two-story ranch house, the last building remaining from the original dairy ranch complex which originally included several out buildings, a dairy barn, and a creamery. The house and other structures were built in 1880, and the dairy operated until the early 1960s when the area reverted to beef cattle. The house has been vacant since 1974. It is located in the center of the Olema Valley, less than 100 m from a year-round water source, Olema Creek, which runs for the length of the valley. Additional water is available from a number of ponds within the valley and several large reservoirs < 10 km to the east.

The Olema Valley is an area that has been subject to a number of perturbations, including beef cattle ranching (since the 1840s), dairy ranching (1850s-1960), periodic fires (most notably 1945), and clear cut logging operations (1945 -1952). Nonetheless, much of the native habitat has either persisted or regrown so today the area is a combination of grazed grasslands and second growth Douglas fir, redwood, California bay, and riparian.

The habitat is somewhat varied. The east side of the valley is mostly grazed grassland, though historically there were several dairy ranches. Now, there is beef cattle grazing along most of the east side of the valley. The slopes are bisected by numerous small drainages with intermittent streams that support small woodlands composed of riparian vegetation and California bay (*Umbellularia californica*). Beyond the valley to the east is second growth redwood (*Sequoia sempervirens*) forest growing on lands protected by the Marin Municipal Water District which operates several large reservoirs used primarily for drinking water. The habitat was extensively modified due to the combined effects of a large wild fire in 1945 and a clear-cut logging operation from 1945-1952.

The west side of the valley is mostly second growth Douglas fir (*Pseudotsuga menziesii*), with California bay in the moister areas, mostly in the canyon bottoms. Photographs form the mid-1800s show that the west side of the valley looked the same as it does today. Though there was some selective hand logging in the late 1800s, the forest persisted well into this century. An extensive, mechanized logging operation in the 1950s removed most of the larger Douglas fir trees from the valley, though a few seed trees testify to the nature of the forest in years past. Beyond the valley to the west is a mosaic of fir and coastal scrub which extends down the slope to the Pacific Ocean.

3.3.1.3. Specific Methods

3.3.1.3.1. Light Tagging

On September 27, 1989 we captured 21 bats at Point Reyes National Seashore at the same maternity roost which was used for the radiotelemetry study in 1997. Each bat was outfitted with a light tag (Buchler 1976). The tags were made by one of the authors (GF) by blowing glass balls from a small diameter glass tube. The final tag ranged from 5 to 9 mm in diameter and had a 4 mm long stem which was filled with silicone rubber. The tags were filled with activated fluid from a cylume flare which resulted in a yellow-green light which glowed for 6-8 hours. The resulting tag weighed from 2.5 to 4.5 g, well within the 5% weight limit used in telemetry studies.

Tags were attached to the back of bats in a fashion similar to that of transmitters except that the fur was not clipped and only a small amount of adhesive was used so that the tag would fall off within 1 - 2 days.

Tags were visible to the unaided eye over distances exceeding 100 m. The tags were particularly obvious when bats were moving. Observers occasionally used either binoculars or night vision equipment to facilitate behavioral observations.

Each observer had a two-way radio and was in constant contact with a permanent base station and most other observers. A cassette tape recorder at the base station made a permanent record of all radio transmissions from all observers. The resulting tapes were transcribed into a computer file for later printing and analysis.

3.3.1.3.2. Radiotelemetry

Thirteen post-lactating females, one non-reproductive adult female and three adult males were captured in mist nets and a harp trap as bats exited the farm house roost during the evening of September 15, 1997.

The ranch house was visited each day to determine which bats had returned to the roost. We tried to locate any bats which were not present at the main day roost site. This was done by driving Highway 1 (a narrow, two-lane road) through Olema Valley, driving dirt roads along adjacent ridges, and by searching from small aircraft. When a signal was detected for a missing bat, an attempt was made to locate the exact roost site by hiking toward the signal.

Each evening for 10 days, observers were stationed at various high points throughout the Olema Valley and adjacent ridge tops. Several sites were used each night while others were occupied for only one or two nights in an attempt to determine whether bats were in the vicinity. A total of 16 sites were used as observation posts during the study.

Each night, some observers were assigned the task of following certain bats regardless of where they went. Success in following a bat depended on a combination of observer ability in tracking, how far and fast the bat moved, and whether there were roads or trails in the vicinity of the bat's activity.

3.3.1.4. Foraging Behavior

3.3.1.4.1. Habitat Preference and Foraging Areas

The majority of the animals returned repeatedly to the main roost in the abandoned ranch house. Several animals, particularly the males, day roosted and night roosted in tree hollows. These were basal hollows in large diameter redwoods and California bay.

Individual bats traveled up to 10.5 km from the day roost to forage, and tended to return to the same areas to forage night after night. All the bats foraged primarily in vegetated gullies, frequently following small stream courses, and appeared to avoid open grassland, both when foraging and when traveling between the roost and foraging areas.

3.3.1.4.2. Flight over open county

From our observations of light-tagged bats, we found the animals spend the majority of their time in close proximity to shrubs or bushes. On a number of occasions bats were observed as they crossed open grassland. In these situations, the flight was always fast. This was in contrast to flight patterns in and around vegetation where the bats were presumably foraging. When crossing open grassland, bats consistently dropped down to the ground and flew at a height of about 1 m. This initial movement down was quite distinctive and would be described as either a vertical plunge or a sharp drop. Flight across the open grassland was usually in a straight line, but occasionally had an erratic or jerky pattern. Presumably this type of flight would make it more difficult for predators (e.g., owls).

From the radiotelemetry data, we know that bats often dispersed several miles. While we could not track bats over those distances with light tags, we were able to watch bats disperse over shorter distances. These flights were clearly distinct from the foraging activity described elsewhere.

Dispersal flights typically followed the edge of the forest along riparian zones where the vegetation was predominantly Douglas fir, California bay trees, and occasionally willows (*Salix* sp.). Bats flew somewhere between mid-canopy to near the top of the canopy (10-30 m). Bats clearly reduced their time in open areas. They followed streams up valleys, but they hugged the tree canopy rather then flying out in the open. Like movements over grassland, flight was fast and direct.

3.3.1.4.3. Foraging Activity

Light-tagged bats mostly foraged around the perimeter of trees, with a slow, leisurely flight pattern. While bats were occasionally observed flying amongst the outer-most limbs, they were most often right at the edge of the vegetation.

The flight was always slow and leisurely, often appearing rather methodical. Several patterns were observed. Most often, there were large, almost perfectly horizontal sweeps back and forth. After one or two sweeps, the bat would move up 0.5-1 m and continue with more sweeps. Less commonly, the bat would move down in successive sweeps. The extent of horizontal movement varied from 3-10 m depending on whether the bat was flying around a single tree or a clump of trees. Sometimes the sweeps were not entirely level so that the bat followed a horizontal figure eight pattern.

Less commonly observed behavior included bats flying under the lower branches of a tree, and bats which used slow vertical movements rather than horizontal sweeps. One bat dipped in and out of openings in the vegetation as it flew along a mostly horizontal path.

When bats foraged around bushes, their flight pattern followed the contour of the vegetation, similar to what was observed around trees.

3.3.1.4.4. Feeding patterns

Figure 4 shows all the areas where bats were found during the 11 days of radiotracking. It is clear that bats favored riparian habitat along the streams and smaller tributaries. Only occasionally were bats found in more open habitats, and when they were, the bats were typically in close association with the few scattered trees or large shrubs. This trend was consistently true for both male and female bats.

Observations of light tagged bats strongly suggest that *C. townsendii* are not gleaning insects from the surface of vegetation. Bats flew slowly along the edge of the vegetation, but did not hover or obviously pause as would be expected if they were gleaning. The flight patterns were more consistent with the idea that bats were feeding on insects (presumably moths) which were flying close to the vegetation.

Other observations indicated that *C. townsendii* feed on oak moths (Dioptidae). A light-tagged bat was observed capturing these moths at the edge of a coast live oak (*Quercus agrifolia*) as the bat flew around and slightly within the perimeter of the oak canopy. These observations are in contrast to the general presumption that *C. townsendii* are gleaners because they have such large ears.

3.3.1.4.5. Distance to Forage

There was a significant difference in how far female bats traveled to forage compared with males. The center of activity for females was 3.2 (+0.5) km from the roost site while the mean for males was 1.3 (+0.2) km ($p = 0.33$, df = 13) (Table 3). The relative lack of movement by males is typified by the male #583 for which we have the most extensive observations. He never moved further than 1.7 km from the original capture site, and most of his activities were within 1.0 km.

These observations are similar to our findings at Lava Beds National Monument in northern California (see Section 3.4.2.below). While both the roosting and most commonly used foraging habitats were strikingly different from those at Point Reyes, male bats in the Lava Beds study did not travel nearly as far from the day roost as did females. Hence, the more local activity of males is consistent across several habitats and over a geographic distance of > 425 km.

3.3.1.4.6. Activity Periods

Though it was not the primary goal of our work, we did obtain some data on activity periods of several bats. In particular, we were able to track one male bat (#583) nearly continuously for the early portion of two nights (Table 4).

On Sept. 17, Bat #583 left the roost at 1950. With the exception of one 73 min gap (2034 - 2247 hr), we were able to track the bat continuously until 0252 in the morning. During the time that we tracked the bat, it was flying (presumably foraging) 67% of the time. During the balance of the time, the bat roosted. While the exact roost site was not located, the bat was in a woodland with both bay trees and Douglas fir. No man-made structures were in the immediate area.

On Sept. 18, our data for Bat #583 is much less complete, but it is clear that the pattern of activity was somewhat different. The bat flew most of the first hour, moving between various areas as it had the night before, but by 2042 it roosted for a short period before resuming its flight. The bat was not tracked continuously, but was found roosting at the ranch house roost during all the checks through 0330 in the morning. Hence, there was a much shorter period of flight on the second night.

Bat #777 was the only female which we tracked for a nearly continuous period (Table 4). On Sept 18, she flew continuously from emergence at 2007 until 2214 when she began roosting back at the ranch house.

Based on these two bats and less detailed observations of the others, it appears that there is a period of about an hour when the bats fly continuously, or nearly so. After that, the behavior is highly variable, both between bats and for given bats on consecutive nights.

3.3.1.5. Roosts

3.3.1.5.1. Primary Colonial Roost Site

The primary roost site in an abandoned ranch house has been occupied by *C. townsendii* for more than 12 years and contains approximately 200 females which occupy to house for 8 - 10 months each year. The nearest roost is 6.6 km to the SW where a another colony of nearly 200 females occupies the attic of an old barn-like building.

3.3.1.5.2. Roost Fidelity

Only four of the 17 bats with transmitters returned to the original day roost each day for seven consecutive days. Some of this behavior might be due to the disturbance of bats during initial capture and handling. Also, mid-September is about the time that *C. townsendii* begin to disperse from the main roost, and hence an unusual disturbance might cause them depart somewhat earlier than normal. Overall, there was fairly strong roost fidelity (Fig. 5) , especially considering the disturbance to the colony created by the capture of bats and the handling of bats outfitted with radiotransmitters.

Of the 17 bats, only 47% (1 of 3 males, 7 of 14 females) returned to the original roost the second day after tagging. By contrast, four bats (all female) were found in the roost each of the next seven days. At the other extreme, one male bat did not return at all to the original day roost during the seven day period and one female was found there only during the sixth day after tagging. In general, there seemed to be fairly strong roost fidelity, especially considering that the colony would normally be diminishing at that time of year.

3.3.1.5.3. Alternate Day Roosts

Bats were found at six alternate day roosts. Only one of these roost sites was in a man-made structure. That roost was an old storage building which was part of an active ranch complex. The building was one-story and approximately 8 x 10 m in size. It had several openings on the side through which a bat could easily fly.

The other roosts were all in basal tree hollows, one in California bay and the others in redwoods. The bay tree was in a riparian zone, 0.9 km from the original capture site. The tree was the largest bay in the area, clearly standing out as the matriarch tree. The hollow was formed when the base of the tree rotted out. Though the hollow was moderately dark, it was much lighter than the redwood tree hollows.

The five redwood tree roosts were on the eastern slope of the eastern ridge, and were located 2.3 - 2.6 km from the original capture site. The redwoods were part of a second growth redwood forest which had been logged 50 years prior to the study. The hillside had a NE orientation. The roost trees ranged from 1.15 to 1.94 m diameter at breast height (DBH) and were generally amongst the larger trees in that part of the forest, but not dramatically so.

The redwood basal hollows used by the bats had all been created by fire, presumably the large 1945 fire which burned much of the watershed east of the Olema Valley. On average, the openings faced toward the west (249°) and were 2.6 m high by 0.7 m wide. The inside hollow averaged 3.0 m high and 0.9 m wide, hence the hollow extended up into the tree higher than the external opening. This is typical of fire scars on redwoods. The interiors were conspicuously dark, largely due to the charred wood which remained blackened. With the exception of one of the redwood tree hollows, all the alternate day roosts were used by males.

3.3.2. Lava Beds National Monument

3.3.2.1. Study Objectives

The lava flow area of northern California supports one of the most significant concentrations of *C. townsendii* in the state (Pearson et al. 1952; Pierson and Rainey 1996). In Lava Beds National Monument, a 188 km2 area honeycombed with lava caves, three maternity colonies containing >200 females each are known within a few km of each other.

The purpose of this study was to investigate both the roosting and foraging behavior of the Lava Beds National Monument population for which several management concerns had been identified. The colony that was the focus of this investigation roosts in a cave system (Cave Loop) that is one the primary areas visited by tourists. Although several years ago the Park instituted a policy of voluntary closure for caves used by the Cave Loop colony, we were interested in finding alternate roosting sites.

Also, in the fall of 1996 (after the nursery roost had disbanded), the Park, in consultation with bat biologists, had conducted a controlled burn of one half of the Cave Loop area. Since control burns are a frequently used management tool, it seemed relevant to determine whether foraging bats treated the burned areas any differently from the unburned areas.

Additionally, all the known nursery colonies roost in caves towards the southern end of the park, within a few km of the Modoc National Forest, where potential impacts of timber harvest on foraging habitat had not been considered. Several studies conducted on the diet of the eastern subspecies of *C. townsendii* suggest that they feed predominantly on forest-associated Lepidoptera (Burford and Lacki 1998; Sample and Whitmore 1993), yet some radiotracking studies on these same subspecies have suggested that they forage over open fields and in edge habitat as well as in the forest (Burford and Lacki 1995; Clark et al. 1993; Dalton et al. 1989; Wethington et al. 1996). In the west, this species had been radiotracked foraging in oak and ironwood forest in southern California (Brown et al. 1994) and in both sagebrush steppe and open ponderosa pine woodland in the lava flow country of central Oregon (Dobkin et al. 1995). A primary goal was to determine the extent to which this population foraged in the forest. A sharp demarcation between forested and scrub habitats, convenient monitoring stations offered by the buttes, plus a network of Forest Service roads made this an ideal setting for evaluating relative use of these two markedly different habitats.

Also of interest was where the animals went to drink. The closest surface water is Tule Lake, located outside the Park, ca. 15 km northeast of the roost sites in an agricultural area subjected to heavy applications of pesticides. Finally, there was a question whether geothermal development, proposed for an area ca. 10 km southwest of the park could affect this population in any way.

3.3.2.2. Study Area

Lava Beds National Monument lies in the northeastern corner of California, just south of the Oregon border (Fig. 2). Basaltic lava flows in the monument belong to the northern slope of the Medicine Lake volcano, a huge Hawaiian (shield) type volcano nearly 33 kms in diameter and over 2,400 m high. Most of the exposed lava is younger than 11,000 years old and displays excellently preserved volcanic features such as flows, lava tube caves, collapse trenches, lava lakes, and cinder cones. The primary habitat in the park is high elevation desert scrub, dominated by bunchgrasses, sagebrush (*Artemesia* spp.), and golden rabbitbrush (*Haplopappus bloomeri*) (Erhardt 1979). The known maternity roosts for *C. townsendii* occur in Cave Loop or within a few kilometers of Cave Loop, in the southern portion of the park where the habitat is more varied, at an elevation of ca. 1,500 m. Cave Loop is bounded by cinder cones (e.g., Schonchin, Crescent, Hippo, Red and Caldwell Buttes), the north/northeast exposures of which are vegetated with mountain mahogany (*Cercocarpus montanus*) and western juniper (*Juniperus occidentalis*). The trench systems within Cave Loop and elsewhere, although sparsely vegetated, support primarily fernbush or desert sweet (*Chamaebatiaria millefolium*) and purple or desert sage (*Salvia* spp.) (Erhardt 1979). Just 2 km south of Cave Loop the terrain begins to rise in elevation, and the habitat undergoes an abrupt transition to conifer forest dominated by Ponderosa pine (*Pinus ponderosa*). This transition is marked by a kilometer long trench called Hidden Valley, the floor of which supports an open ponderosa pine parkland, mixed with antelope bitterbrush (*Purshia tridentata*), greenleaf manzanita (*Arctostaphylos patula*) and mountain mahogany (*Cercocarpus montanus*).

3.3.2.3. Specific Methods

Eight post-lactating females, three non-reproductive adult females and four adult males were captured in the Cave Loop area on 3 September 1997. Four males and one non-reproductive female, found roosting alone in various locations in Cave Loop, were captured by hand or in hand nets in late afternoon, outfitted with transmitters (see Section 2.2 above), and released at dusk. All other individuals were captured at evening emergence in mist nets set in the trench system near several entrances to the known nursery cave.

Cave Loop was visited each day to determine which bats were roosting there. Attempts were also made to locate any animals roosting elsewhere. Once cross-bearings were obtained from high points, investigators attempted to localize the signal, generally by hiking cross-country in very challenging terrain, often in areas with no trails. Foraging behavior was followed using both stationary and roving investigators. Animals were followed for nine nights (September 3-11) for a total of 281 observer hours. A station on Crescent Butte served as Radio Central, with Hippo Butte and Schonchin Butte as the other most consistently used fixed stations. Natural Bridges (in Cave Loop), Red Butte, Caldwell Butte, Caldwell Minor, Gillem Bluff, Hardin Butte, and the western rim of Hidden Valley also sometimes served as fixed monitoring stations. Roving investigators traveled by car from Captain Jack's Stronghold on the shores of Tule Lake in the North to 6 km south of the park boundary in the Modoc National Forest, and on foot as far east as Captain Jack's Ice Cave (Fig. 6).

3.3.2.4. <u>Roosts</u>

3.3.2.4.1. <u>Day Roosts</u>

The majority of radio-tagged bats that were captured in Cave Loop continued to roost in that area. Although three alternate day roosting sites were found, no new colonial sites were located. No bat from Cave Loop was ever located in a known roost site of either of the other colonies. All alternate roost sites that were located were relatively small rock shelters that appeared to be used by a single animal. It is possible, however, that two roost sites that were not located (towards Captain Jacks and Three Sisters), and one that was localized but inaccessible without ropes (on a the side of the Hidden Valley trench) were colonial roost sites.

Males were more loyal to their day roost sites than were the nulliparous and post-lactating females. Three of the four males roosted every day in the Cave Loop area at or close to where they were captured (Figs. 7, 8, 9). One male (#306) could not be located for 6 of the nine days, although bearings obtained at night suggested he had moved to the northeast, in an area of the Park with very limited access (Fig. 10).

Four of the eight post-lactating females (#431, 454, 472, and 495) roosted consistently in Cave Loop at or close to the known nursery colony site (Figs. 11, 12, 14, 16). The four others (#465, 481, 513, and 549) used alternate roosts at least part of the time (Figs. 13, 15, 17, 18). Bat #513 roosted in Cave Loop six days, and two days in the Hidden Valley area (roost not located). Bat #481 was located on the second day in a small rock shelter cave (Crane Fly Hole), just east of Caldwell Butte, and was missing for all subsequent days. When Crane Fly Hole was monitored at emergence, only the radiotagged bat emerged. The other two bats (#465 and #549) roosted primarily towards the Northeast, #465 toward Captain Jacks Ice Cave, and #549 towards the Three Sisters. Despite concerted efforts neither of these roosts could be found by ground searching. Signals that could be obtained from high points were lost as investigators followed the bearings.

The one nulliparous female (#282) that was captured roosting alone during the day remained loyal to roost sites in Cave Loop (Fig. 19). The other two nulliparous females, apparently associated with the nursery colony, used alternate roosts at some point during the study. One (#413) roosted in Cave

Loop every day except the first day after capture, when she used a small rock shelter located in the Fleaners Chimney area, ca. 7 km northwest of Cave Loop (Fig. 21). The other (#349) moved around considerably, roosting for the first two days after capture in a rock shelter on the canyon wall in Hidden Valley, the next day back in Cave Loop, the fourth day on a bearing to the northeast (roost not located), the fifth and sixth days back at the Hidden Valley site, the seventh and eighth days back in Cave Loop (Fig. 20).

3.3.2.4.2. Night Roosts

Three night roosts, all small caves or rock shelters, were located in the course of the study, one near Fleaners Chimney (nulliparous female #413 -- Fig. 21), one near the campground (post-lactating female #549 -- Fig. 18), and one 1.5 km south of Mammoth Crater (post-lactating female #513 -- Fig. 17). Female #413 also used another night roost, not specifically located, on the cliff face below Devil's Homestead Overlook at the base of Gillem Bluff.

3.3.2.5. Foraging Behavior

There were marked differences between the males and females in distance traveled (compare Figs. 7-10 with Figs. 11-21). Three of the four males foraged exclusively within the Cave Loop area (within a 3.0 km radius of the roost area), and their individual patterns were highly predictable night to night (Figs. 7-10). The fourth male (#306) fed frequently in Cave Loop and in the area between Schonchin Butte and the campground, but was detectable only 59% of the time and often disappeared on a bearing to the northeast (Fig. 10). In general, the females moved much greater distances than the males, and were detected up to 14 km away. Some likely traveled farther. Maps depicting activity patterns illustrate the large areas covered by many of the animals (Figs. 11-21).

The bats foraged in three distinctly different habitats: the sparsely vegetated lava trenches; wooded areas dominated by western juniper and/or mountain mahogany; and the higher elevation, predominantly ponderosa pine forest. Three of the four males were highly predictable and fed almost exclusively in the Cave Loop area, predominantly in areas dominated by mountain mahogany. The foraging patterns of the females were more complex. Those that roosted in Cave Loop frequently foraged for the first 30-60 minutes in the Cave Loop area. Cross-bearings strongly suggest they favored areas dominated by mountain mahogany, western juniper, or ponderosa pine rather than scrub habitat. Animals were also observed, however, with night vision equipment, actually foraging within the lava trenches where large numbers of moths could be observed flying in association with the sparse vegetation (dominated by fern bush and purple sage). Several females also foraged frequently near the headquarters area, and one was observed foraging around the canopy of juniper and mountain mahogany.

Twelve of the fifteen bats were detected foraging near one of the buttes (Schonchin, Crescent, Caldwell or Hippo), almost always in association with western juniper/mountain mahogany habitat that tends to be concentrated on the north and northeast sides of the buttes. One bat (#431) fed almost exclusively around the base of Schonchin Butte for one and a half nights (September 9 and 10) and was followed continually (Fig. 11).

A rather sharp demarcation line between the low contour scrub habitat within the park boundary and upland forest to the south allowed us to estimate the amount of time the animals spent in forested, predominantly ponderosa pine habitat. Only one male ventured to the south, and this was only on one evening, when he appeared to be foraging in the vicinity of Hidden Valley. Ten of the eleven females, however, foraged at some point in this upland forest habitat. The amount of time they spent there varied from 5 to 79 % of the time they were followed (with an average of 21%, n=11). This is likely an underestimate of time spent in the forest since tracking the animals in this habitat was difficult, and several disappeared on bearings that would have taken them into this forested area. Two animals (Bat #454 and Bat #513) that could be closely followed spent > 50% of their time there (Figs. 12 and 17). The one animal never detected in upland forest may nevertheless have spent the majority of her time in forested habitat. Intermittent detections were generally in the vicinity of a heavily forested draw on the west side of Caldwell Butte, and she seemed to disappear to the southeast, towards ponderosa pine and juniper habitats. Additionally, it is worth noting that those bats that tended to move among habitats generally went to the forest within the first three hours after emergence, during prime foraging time. Bat #513, the bat that was followed most consistently and was detected in the upland forest habitat 79 % of the time, fed in both the forest and within a rather sparsely vegetated small crater south of Mammoth Crater. She was detected as far as 9 km south of her roost.

There was a tendency for the females to travel north later in the evening (generally after mid-night), with cross-bearings indicating that they were generally on the Schonchin Lava Flow, an area dominated by lava trenches, and sparsely vegetated with squaw currant, fern bush and purple sage. The activity pattern typically exhibited by the bats was to forage actively for the first two to four hours after emergence, and then to alternate between brief (10 to 30 minutes) bouts of foraging and night roosting until just prior to dawn when they would emerge for another foraging bout. All night roosts that were located were small rock shelters, structures that are abundant in the Schonchin Lava

Flow.

The majority of animals had somewhat predictable foraging patterns night to night. For example, bat #549 foraged predominantly on the southeastern side of the Schonchin Lava Flow and on a bearing towards the Three Sisters (Fig. 18); Bat #431 foraged predominantly near the campground and around the base of Schonchin Butte (Fig. 11); Bat # 513 foraged predominantly in the Hidden Valley and Mammoth Crater area (Fig. 17). Nevertheless, foraging activity also appeared to be somewhat responsive to some other factors. For example, more animals foraged in the forest early in the week, and more in the Schonchin Lava Flow later in the week. Why this was so is not immediately obvious, but is likely related to either local insect abundance, and/or some environmental factors (e.g., temperature, wind, cloud cover, phase of the moon).

There was no evidence that the controlled burn conducted in the fall of 1996 at Cave Loop affected the foraging behavior of this species. Bats were detected with comparable frequencies in the burned and unburned areas. All individuals that remained resident in Cave Loop foraged in the vicinity of the Loop (and area bounded by Hidden Valley, and Caldwell, Crescent, Hippo and Red Buttes), particularly early in the evening (the first 30-60 minutes after emergence) and again just prior to dawn.

3.3.2.6. Drinking Behavior

Another important management question for this population was where the animals went to drink. The closest surface water is Tule Lake, ca. 15 km to the northeast, in an agricultural area subjected to very heavy pesticide treatment. While it is possible animals occasionally travel as far as Tule Lake and may drink there, this study suggested that many bats, including this species, drink from the water that accumulates on the ice surface inside ice caves. The earliest bearings each evening for the majority of animals were consistent with visitation to one of the 12 ice caves located within ca. 4 km of their roost (see Fig. 6). Four ice caves were monitored for the first three to four hours after emergence on 8 September 1997. All caves were visited by bats, although Heppe Ice Cave received by far the most significant on the night monitored (see Table 6).

4.0 SPECIES STATUS IN CALIFORNIA

4.1. POPULATION STATUS

The California Department of Fish and Game surveys in the late 1980s and early 1990s identified 39 maternity colonies with an estimated total population of 4,250 adult females (Pierson and Rainey 1996). By using historic records it was possible to document that over a 40 year period there had been a 52 % decline in the number of maternity colonies, a 44 % decline in the number of available roosts, and a 55 % decline in the number of animals in the areas surveyed. The current survey identified six maternity roosts with a total population of ca. 700 adult females.

There are still some areas of the state that have not been systematically surveyed (e.g., mining districts in the coast range south of the San Francisco Bay area). Also, new colonies continue to be identified by various researchers -- e.g., P. Brown (pers. comm.) has found a few more colonies in mines in the Owens Valley and southeastern desert areas; K. Miner (pers. comm.) recently located a nursery colony in a bridge in San Diego County; a small colony was recently located in Mendocino County (P. Winters pers. comm.) close to the location of an historic roost site which no longer exists (CDFG surveys found that this cave roost had been mined away for highway rip-rap (Pierson and Rainey 1996). Nevertheless, it seems likely that the majority of relatively large roosts are known. It is somewhat alarming that extensive surveys in areas of highly suitable habitat (e.g., mining districts in the Trinity Mountains; caves in the southcentral Sierra Nevada) revealed so few previously unknown nursery roosts.

Combining the results of this survey with those conducted in the late 1980s and early 1990s (Pierson and Rainey 1996), and information provided by other researchers, we estimate that the total number of adult females found in the currently known roosts is approximately 5,500-6,000.

Of the nine roost sites used by the six maternity colonies identified during the current survey, eight showed signs of significant human intrusion (footprints, beer/soda cans or other trash, signs of recent campfires, climbing apparatus). Likewise, six of the eight roosts that had significant amounts of *C. townsendii* guano but few or no bats at the time of survey also showed signs of human disturbance. Of these seventeen sites, only three currently receive any sort of protection from human disturbance. Two are already gated or fenced and the location of a third is not disclosed to the public. Additionally, BLM has plans to gate another. Three of the most significant sites, two on Forest Service land and one on private land, receive no protection.

A recent evaluation of the conservation status of *C. townsendii* in the west (Idaho State Conservation Effort 1995) identified a number of threats for *C. townsendii*, which are summarized below (Section 4.2). Also, at a workshop sponsored by the Western Bat Working Group in Reno, Nevada in February 1998, *C. townsendii* emerged as the only species that occurred throughout the west and was also considered as imperiled or at high risk of imperilment throughout its range (Western Bat Working Group 1998).

4.2. IDENTIFIED THREATS

4.2.1. Loss of Roosting Habitat

4.2.1.1. Human Activity at Roosts

The intense recreational use of caves and mines in California provides the most likely explanation for why otherwise suitable, historically significant roosts are currently unoccupied. It is well documented that *C. townsendii* is so sensitive to human disturbance, that simple entry into a maternity roost can cause a colony to abandon or move to an alternate roost (Pearson, et al. 1952; Graham 1966; Stebbings 1966; Mohr 1972; Humphrey & Kunz 1976). Although evidence of vandalism has been observed at several roosts (Pierson and Rainey 1996), most disturbance may be inadvertent (e.g., well intentioned persons coming upon a colony of bats in the course of cave/mine exploration). Inappropriate behavior on the part of researchers (i.e., entry into maternity roosts, capture of animals in roosts) could also contribute to population declines. A serious concern is the increase in banding studies, since wing bands have been shown to cause serious injuries in *C. townsendii* (Pierson and Fellers 1994).

There is also accumulating evidence colonies respond positively, and numbers of animals often increase dramatically, when people are prevented from entering roost sites -- generally through installation of "bat friendly" gates (P. Bradley pers. comm., R.M. Miller pers. comm., M. Perkins pers. comm., Pierson et al. 1991, Riddle 1995, R. Sherwin pers. comm., Stihler and Hall 1993).

4.2.1.2. Closure of Abandoned Mines

Abandoned underground mines provide significant roosting habitat for a number of bat species, particularly *C. townsendii* (Altenbach and Pierson 1995, Belwood and Waugh 1991, Brown et al. 1993, Pierson et al. 1991). Safety considerations have led to extensive mine closure programs in western states, particularly on public lands, often without consideration for the biological values of old mines. If closures are done at the wrong time of year, or without prior biological survey (Altenbach 1995, Navo 1995, Rainey 1995), they can result in the entrapment, and thus elimination of entire bat colonies.

4.2.1.3. Renewed Mining in Historic Mining Districts

The resurgence of gold mining in the west potentially threatens cavern-dwelling bat species (Brown and Berry 1991, Brown et al. 1993, Brown 1995). Since open pits, created by current mining practices, are often located in historic mining districts, old mine workings are frequently demolished as part of the ore extraction process. While effective mitigation is possible (Brown et al. 1995, Pierson et al. 1991), there is currently no legal mandate requiring that existing populations be protected.

4.2.1.4. Deterioration/conversion of building roosts

Most known building roosts are abandoned structures that are generally in a poor state of repair. Even if maintained such structures have a limited life expectancy relative to cave roosts. With increasing suburbanization, many historically known building roosts have been demolished or subject to renovation. For example, the abandoned ranch house used by the Pt. Reyes colony was scheduled for demolition when the colony was first discovered. To protect this colony the park canceled plans for demolition and have conducted repairs to insure the persistence of the structure. The previous roost for this colony was likely a privately owned deteriorating building in the town of Olema from which a *C. townsendii* colony was excluded in the 1970's when renovations converted it to an upscale bed and breakfast inn.

4.2.1.5. Timber harvest

Research conducted at Point Reyes has demonstrated that large hollow trees, particularly fire-scarred redwoods and large California bay trees with basal hollows are used by *C. townsendii*. This species has been found in these trees both summer and winter. In fact, known colonies of *C. townsendii* along the north and central coast are all in close proximity to residual patches of redwood forest, and *C. townsendii* appears extirpated from areas of former distribution that no longer have redwood forests. While this linkage is not well substantiated at this time, it seems possible that redwood forests are critical to the survival of coastal populations, and that historically, along the coast where caves are few, this species roosted predominantly in very large hollow redwoods.

4.2.1.6. <u>Water impoundments/roost inundation</u>

The majority of reservoirs in California occur at low elevation on rivers draining the Sierra Nevada, Klamath and Trinity Mountains, at the same elevations favored by this species for nursery sites. Many of the known caves occur in river drainages and/or along the shores of current reservoirs (e.g., the two *C. townsendii* colonies known to occur on Lake Shasta and discussed in Section 3.3.2 above). At least one formerly significant cave roost (along the Stanislaus River) is known to have been inundated by the formation of a reservoir (New Melones) (Pierson and Rainey 1996). Proposals currently under review to raise the water level in Lake Success, a reservoir on the Tule River, will impact *C. townsendii* roost sites.

4.2.1.7. <u>Behavioral Ecology/ Population Biology</u>

The tendency for *C. townsendii* to roost in highly visible clusters on open surfaces, near roost entrances, makes them highly vulnerable to disturbance. Additionally, low reproductive potential and high roost fidelity increase the risks for the species.

4.2.2. Loss of Foraging Habitat

4.2.2.1. <u>Loss of riparian habitat</u>

The radiotracking and light-tagging studies conducted at Pt. Reyes National Seashore demonstrated that in coastal California riparian woodland is extremely important foraging habitat for *C. townsendii*. Conversion of the cottonwood riparian to agriculture along the lower Colorado River provides the most likely explanation for observed declines in *C. townsendii* and other bat species in this area. Foraging areas adjacent to water sources may be essential for desert populations (P. Brown pers. comm.). The wide invasion of tamarisk in desert areas also has contributed to the drying of water sources and consequent loss of native riparian vegetation.

4.2.2.2. <u>Grazing practices</u>

It is possible that grazing reduces foraging habitat for *C. townsendii*. While this species is reported to forage over old fields and agricultural fields in the East (Burford and Lacki 1995, Dalton et al. 1989, Wethington et al. 1996), we saw no evidence in either light-tagging or radiotracking studies that this species foraged over grazed grasslands. Since our study area did not include any areas of ungrazed grassland we cannot determine whether the foraging patterns we observed could best be explained by a preference for forested gullies and by an avoidance of grazed areas.

4.2.2.3. Timber harvest

The effects of timber harvest on the prey base and foraging habitat of *C. townsendii* is not known, although it appears virtually certain there is some impact. Several studies in the East have now shown a preference by this species for forest-associated Lepidoptera (Burford and Lacki 1998, Sample and Whitmore 1993). Additionally, our study at Lava Beds National Monument showed that this species fed extensively in association with trees. Prime foraging time was spent either in the upland ponderosa pine forest or in juniper and mountain mahogany habitat.

4.2.2.4. Toxic impoundments

The use of cyanide in the ore extraction process has caused wildlife deaths at a number of mine sites in the West. Although bats comprise 33.7 % of documented wildlife fatalities (Clark and Hothem 1991), they frequently are not considered in assessment of cyanide risks (Nevada Mining Assoc. et al. 1990). Renewed mining is known to account for the loss of one substantial colony in the California desert (P. Brown pers. comm.).

4.2.2.5. Pesticide spraying

Forest management activities, particularly timber harvest and spraying for non-target lepidopteran species may alter the prey base for *C. townsendii* (Sample et al. 1993, Sample and Whitmore 1993). Perkins and Schommer (1991) suggest that *Bt* (*Bacillus thuringiensis*) sprays may suppress Tussock moth and spruce budworm reproduction enough to suppress reproduction in resident *C. townsendii* for one or two years.

4.2.2.6. Geothermal development

Extensive development of geothermal resources is proposed for the area just south of Lava Beds National Monument, in an area used for foraging by the Lava Beds population. This project could result in net loss of foraging habitat, disturbance to the animals from the noise of operation, loss of critical water resources from drawdown, chemical alteration, or contamination of the water table.

4.2.3. Inadequate Protective Measures

Without legal protection under the Endangered Species Act, there is relatively little incentive for public land managers or private landowners to protect this species or mitigate for loss of habitat. While public agencies have generally been far more responsive than have private landowners, without federal protection this species is likely to continue to be subjected to the numerous threats outlined above. Without leverage to protect critical roost sites, this species is likely to continue to decline.

4.2.3.1. Management Policies on Public Lands

There are 22 colonies known in California with adult female populations >100 animals. Of these, 14 are on public lands. While the National Park Service and California State Parks have made substantial commitments to protecting known roosts, the Forest Service has been generally reluctant to recognize the biological significance of cave and mine roosts. The decision makers within this agency continue, often against the advice of their own biologists, to give first priority to recreational interests, despite the documented incompatibility between recreational caving and cave roosting bat populations. Likewise, BLM biologists, concerned for the status of *C. townsendii* populations located in mines or caves on their land, frequently report they are unable to obtain support from superiors for site protection.

4.2.3.2. Opportunities for Protection on Private Land

While there are numerous opportunities for private landowners of provide protection for this species -- and protection would often be relatively simple and inexpensive (e.g., the installation of a "bat friendly" gate) -- in the absence of a legal mandate such measures are rarely taken.

5.0 CONCLUSIONS

The results of this study and the California Department of Fish and Game surveys demonstrate the extreme importance of both caves and abandoned mines as roosting habitat for *C. townsendii*. The lava flow country in the northern part of the state, and concentrations of limestone in both the Trinity Mountains and Sierra Nevada are particularly important. Abandoned mines appear critical in the desert regions, but also provide significant roosts in other mining districts.

The greatest threat to *C. townsendii* populations is human disturbance of roost sites. The exclusion of humans from several roost sites in California (e.g., a building roost at Pt. Reyes National Seashore, Bat Cave on the Shasta-Trinity National Forest, the Homestake Mine in Napa County) has demonstrated here, as elsewhere, that populations respond favorably to protection (Pierson et al. 1991, R.M. Miller pers. comm., Stihler and Hall 1993).

The two radiotracking studies demonstrated a generally high degree of loyalty to chosen nursery sites. Although the foraging habitat differed markedly between the two sites, at neither site did the animals show a tendency to forage in the open. At Pt. Reyes they followed densely vegetated gullies, and spent the majority of their time within a forested habitat. While they clearly used edge habitat, they appeared to avoid the grazed grasslands. At Lava Beds National Monument, animals foraged either within the protection of lava trenches or in association with juniper/mountain mahogany or ponderosa pine habitat.

Data from the radiotracking study at Pt. Reyes National Seashore suggest an association between this species and large diameter hollow redwood trees along the coast. Although all known coastal maternity colonies now roost in old buildings, their proximity to remnant redwood forest suggests this habitat may be important for foraging or in providing winter refugia.

Preliminary genetic studies showed that three populations that were widely separated geographically were also distinct genetically. This indicates that the techniques used here (mitochondrial DNA and microsatellites) would be appropriate for addressing a wide range of questions for this species, including population differentiation, gene flow and mating systems.

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Table 1. All sites surveyed for presence of bats or bat sign.

Locality Name	County	T/R/Sec	Structure	Jurisdiction	Elev (m)	Date	Species	# Bats	Bat Sign
Significant Use by C. townsendii - Colony Present at Time of One or More Surveys									
Murphys Cave	Calaveras	NE 1/4 T3N,R14E	Cave	Private	561	8/23/97	*C. townsendii*	~500	Yes
Barium North	Mariposa	NW 1/4 T3S,R19E	Mine	Yosemite NP	594 to 655	8/25/97	*C. townsendii*	54	Yes
Greenview Mine Lower	Siskiyou	NW 1/4 T43N,R9W	Mine	BLM	1023	9/30/97	*C. townsendii*	1	No
Greenview Mine Lower	Siskiyou	NW 1/4 T43N,R9W	Mine	BLM	1023	5/27/98	*C. townsendii*	48	Yes
Greenview Mine Lower	Siskiyou	NW 1/4 T43N,R9W	Mine	BLM	1023	6/26/98	*C. townsendii*	2	Yes
Indian Creek #1	Trinity	SE 1/4 T32N,R9W	Mine	BLM	805	6/26/97	*C. townsendii*	~260	Yes
Indian Creek #2	Trinity	NE 1/4 T32N,R9W	Mine	BLM	846	6/25/97	*C. townsendii*	0	Yes
Indian Creek #1	Trinity	SE 1/4 T32N,R9W	Mine	BLM	805	7/22/97	*C. townsendii*	~200	Yes
Indian Creek #2	Trinity	NE 1/4 T32N,R9W	Mine	BLM	846	7/22/97	*C. townsendii*	140	Yes
Indian Creek #1	Trinity	SE 1/4 T32N,R9W	Mine	BLM	805	7/11/98	*C. townsendii*	~200	Yes
Indian Creek #2	Trinity	NE 1/4 T32N,R9W	Mine	BLM	846	7/11/98	*C. townsendii*	0	Yes
Hyampom # 1	Trinity	NW 1/4 T2N,R7E	Cave	Trinity NF	520	7/10/97	*C. townsendii*	35	Yes
Hyampom #2	Trinity	NW 1/4 T2N,R7E	Cave	Trinity NF	490	7/12/97	*C. townsendii*	135	Yes
Hyampom # 1	Trinity	NW 1/4 T2N,R7E	Cave	Trinity NF	520	6/23/98	*C. townsendii*	0	Yes
Hyampom #2	Trinity	NW 1/4 T2N,R7E	Cave	Trinity NF	490	6/23/98	*C. townsendii*	~130	Yes
Hayfork #1	Trinity	SW 1/4 T31N,R11W	Cave	Trinity NF	889	7/28/97	*C. townsendii*	1	Yes
Hayfork #2	Trinity	SW 1/4 T31N,R11W	Cave	Trinity NF	889	7/29/97	*C. townsendii*	140+	Yes
Hayfork #1	Trinity	SW 1/4 T31N,R11W	Cave	Trinity NF	889	6/24/98	*C. townsendii*	~145	Yes
Hayfork #2	Trinity	SW 1/4 T31N,R11W	Cave	Trinity NF	889	6/24/98	*C. townsendii*	0	Yes
Significant Use by C. townsendii -- Colony not Present at Time of Survey									
Bower Cave	Mariposa	SW 1/4 T2S,R18E	Cave	Stanislaus NF	732	8/12/97	*C. townsendii, E. fuscus*	1	Yes
Merced Cave #1	Mariposa	NW 1/4 T3S,R19E	Cave	Sierra NF	640	9/18/97	*C. townsendii*	4	Yes
Merced Cave #2	Mariposa	NW 1/4 T3S,R19E	Cave	Private	488	9/19/97	*C. townsendii*	2	Yes
Miller Gulch #2	Mariposa	NW 1/4 T3S,R19E	Mine	Private	472	9/19/97	*C. townsendii*	0	Yes
Scorpion Complex#1	Shasta	NW 1/4 T33N,R7W	Mine	BLM	1020	10/21/97	*C. townsendii*	0	Yes
Greenview Mine Upper	Siskiyou	NW 1/4 T43N,R9W	Mine	BLM	1071	9/30/97	*C. townsendii*	6	Yes
Greenview Mine Upper	Siskiyou	NW 1/4 T43N,R9W	Mine	BLM	1023	5/27/98	*C. townsendii*	0	No
Greenview Mine Upper	Siskiyou	NW 1/4 T43N,R9W	Mine	BLM	1023	6/26/98	*C. townsendii*	1	No
Tunnel Rock Campground	Trinity	SW1/4,T34N,R8W	Mine	Trinity NF	628	7/29/97	*C. townsendii*	1	Yes
Clough Cave	Tulare	NW 1/4 T18S R30E	Cave	Sequoia Kings Cyn NP	1140	8/7/97	*C. townsendii*	0	Yes
Kaweah Cave	Tulare	SE 1/4 T16S, R29E	Cave	Sequoia Kings Cyn NP	488	8/7/97	*C. townsendii*	3	Yes

Table 1. Cont'd.

Locality Name	County	T/R/Sec	Structure	Jurisdiction	Elev (m)	Date	Species	# Bats	Guano
Significant Use by C. townsendii -- Colony not Present at Time of Survey									
Walk Softly Cave	Tulare	SE 1/4 T16S, R29E	Cave	Sequoia Kings Cyn NP	762	8/8/97	*C. townsendii*	0	Yes
Eye of the Alligator Cave	Tuolumne	NE 1/4 T1S,R17E	Cave	Stanislaus NF	1014	8/24/97	*C. townsendii*	1	Yes
Lower N Mt. Prospect #3	Tuolumne	SE 1/4 T1N,R18E	Mine	Stanislaus NF	799	8/14/97	*C. townsendii*	6	Yes
Non-colonial Use by C. townsendii or Other Bat Species									
Last Chance Adit	Mariposa	T5S,R22E,Sec10	Mine	Sierra NF	2463	8/27/97	Unknown	0	Yes
Lindsey Mine #1	Mariposa	T3S,R19E,Sec 18	Mine	Sierra NF	518	8/28/97	*C. townsendii*	1	No (water)
Metzner Mine #1 & #4	Mariposa	T3S,R19E,Sec 18	Mine	Sierra NF	610	8/28/97	*C. townsendii* / *E. fuscus*	0	Yes
Metzner Mine #5	Mariposa	T3S,R19E,Sec 18	Mine	Sierra NF	732	8/28/97	*C. townsendii*	1	Yes
Miller Gulch #1	Mariposa	T3S,R19E,Sec 18	Mine	Private	488	9/19/97	*C. townsendii*	2	Yes
Munition Cave	Mariposa	T3S,R19E,Sec 18	Cave	Sierra NF	442	9/17/97	*C. townsendii*	0	Yes
Prospect Adit, Star Mine	Mariposa	T3S,R18E,Sec.18	Mine	Sierra NF	2548	9/17/97	Unknown	0	Yes
Star Mine Complex #3	Mariposa	T5S,R22E,Sec 10	Mine	Sierra NF	2438	9/17/97	*Myotis* sp.	0	Yes
1074 #2	Shasta	T32N,R5W Sec 30	Mine	BLM	265	9/25/97	Unknown	0	Yes
A1 Red Gulch	Shasta	T32N,R6W,Sec 9	Mine	Whiskeytown NRA	378	7/16/97	*Myotis* sp.	0	Yes
Ajax Mine #1	Shasta	T32N,R6W,Sec 6	Mine	Whiskeytown NRA	482	7/14/97	*C. townsendii*	1	Yes
Ajax Mine #2	Shasta	T32N,R7W,Sec1	Mine	Whiskeytown NRA	482	7/14/97	unknown	0	Yes
Building #503	Shasta	T32N,R7W,Sec 3	Building	Whiskeytown NRA	510	7/16/97	*C. townsendii*	0	Yes
Building #505	Shasta	T32N,R7W,Sec 3	Building	Whiskeytown NRA	510	7/16/97	*C. townsendii*	1	Yes
Building #507	Shasta	T32N,R7W,Sec 3	Building	Whiskeytown NRA	510	7/16/97	Unknown	0	Yes
Building #508 Barn	Shasta	T32N,R7W,Sec 3	Building	Whiskeytown NRA	510	7/16/97	*C. townsendii*	2	Yes
Davis Gulch (Three Amigos)	Shasta	T32N,R6W,Sec 20	Mine	Whiskeytown NRA	378	7/13/97	*Myotis* sp.	0	Yes
Eldorado Mine #1	Shasta	T32N,R7W,Sec 3	Mine	Whiskeytown NRA	518	7/4/97	*C. townsendii*	1	No
Franklin Mine #6	Shasta	T33N,R7W,Sec 16	Mine	Private	708	7/31/97	*C. townsendii*	1	Yes
Franklin #10	Shasta	T33N,R7W,Sec16	Mine	Private	630	7/31/97	Unknown	0	Yes
Gamin Adit #3	Shasta	T32N,R6W,Sec 5	Mine	Whiskeytown NRA	457	7/3/97	Unknown	0	Yes
Main House	Shasta	T32N,R7W,Sec 3	Building	Whiskeytown NRA	510	7/16/97	*C. townsendii*	1	Yes
Milkmaid #3	Shasta	T33N,R7W,Sec16	Mine	Private	580	7/24/97	Unknown	0	Yes
Modesty Gulch #1	Shasta	T32N,R7W,Sec1	Mine	Whiskeytown NRA	408	6/30/97	Unknown	0	Yes
NEED Camp - Upper Adit	Shasta	T32N,R6W,Sec34	Mine	Whiskeytown NRA	299	7/1/97	Unknown	0	Yes
North Star #2	Shasta	T32N,R6W,Sec 6	Mine	Whiskeytown NRA	680	7/15/97	*C. townsendii*	0	Yes
North Star Main	Shasta	T32N,R6W,Sec 6	Mine	Whiskeytown NRA	853	7/15/97	*C. townsendii*	1	No
Orus District #1	Shasta	T32N,R6W,Sec 34	Mine	Whiskeytown NRA	323	7/2/97	*C. townsendii*	1	Yes
Orus District #3	Shasta	T32N,R6W,Sec 34	Mine	Whiskeytown NRA	341	7/2/97	*C. townsendii*	1	Yes
Orus District #4	Shasta	T32N,R6W,Sec34	Mine	Whiskeytown NRA	347	7/3/97	Unknown	0	Yes
Orus District #5	Shasta	T32N,R6W,Sec34	Mine	Whiskeytown NRA	344	7/2/97	Unknown	0	Yes
Rock Creek Mine #7	Shasta	T32N,R6W,Sec.24	Mine	BLM	250	9/26/97	*C. townsendii*	1	Yes

Table 1. Cont'd.

Locality Name	County	T/R/Sec	Structure	Jurisdiction	Elev (m)	Date	Species	# Bats	Guano
Non-colonial Use by C. townsendii or Other Bat Species									
Scorpion Complex #2	Shasta	T33N,R7W,Sec 18	Mine	BLM	951	10/21/97	Unknown	0	Yes
Unnamed, Section 16	Shasta	T33N,R7W,Sec16	Mine	Unknown	591	7/25/97	Unknown	0	Yes
Bear Creek Rd. Mine	Siskiyou	T15N,R7W,Sec 7	Mine	Klamath NF	305	10/28/97	*C. townsendii*	4	Yes
Bear Creek Rd. Mine	Siskiyou	T15N,R7W,Sec 7	Mine	Klamath NF	305	4/9/98	*C. townsendii*	2	Yes
Black Bear Mine	Siskiyou	T39N,R11W,Sec 7	Mine	Klamath NF	1146	10/1/97	*C. townsendii*	0	Yes
Chan Jade Mine #1	Siskiyou	T17N,R6E,Sec 12	Mine	Klamath NF	561	10/29/97	*C. townsendii*	1	Yes
Cherry Hill #1	Siskiyou	T45N,R8W,Sec 27	Mine	Klamath NF	421	10/30/97	Unknown	0	Yes
Huey Mine #1	Siskiyou	T18N,R6E,Sec 24	Mine	Klamath NF	738	10/29/97	Unknown	0	Yes
Independence Creek Mine #2	Siskiyou	T15N,R6W, Sec. 31	Mine	Klamath NF	330	4/9/98	*C. townsendii* , *Myotis* sp.	0/2	Yes
Steiner Flat	Siskiyou	T38N,R10W,Sec 2	Mine	BLM	483	10/20/97	*Myotis* sp.	0	Yes
Hall City Cave	Trinity	T1N,R10W.Sec.31	Cave	Trinity NF	1240	6/24/98	*Myotis* sp.	0	Yes
Natural Bridge Main	Trinity	SW1/4 T13N,R11W	Cave	Trinity NF	889	7/11/97	*A. pallidus* /*E.fuscus*	0	Yes
Unnamed Indian Valley	Trinity	T2N,R7E,Sec 8	Cave	Trinity NF	540	7/12/97	Unknown	0	Yes
Venecia Mine #1	Trinity	T33N,R8W,Sec 3	Mine	BLM/Whiskeytown NRA	1025	10/20/97	*C. townsendii*	1	Yes
Venecia Mine #2	Trinity	T33N,R8W,Sec 3	Mine	BLM/Whiskeytown NRA	1036	10/20/97	*C. townsendii*	1	Yes
Crystal Cave	Tulare	T15S,R29E,Sec.27	Cave	Sequoia Kings Cyn NP	1396	8/6/97	*C. townsendii*	1	Yes
Adit 5/6 (Hetch Hetchy)	Tuolumne	T1S,R17E,Sec 25	Tunnel	Hetch Hetchy Water Dist	701	8/13/97	Unknown	0	Yes
Adit 8/9 (Hatch Hetchy)	Tuolumne	T1S,R17E,Sec 21	Tunnel	Hetch Hetchy Water Dist	671	8/13/97	Unknown	0	Yes
Cherry Lake Valve House	Tuolumne	T1N,R19E,Sec 5	Building	Hetch Hetchy Water Dist	1362	8/14/97	*Myotis* sp.	0	Yes
Devils Gate Adit #2	Tuolumne	T1N,R16E,Sec 32	Mine	Stanislaus NF	366	9/15/97	*C. townsendii*	1	Yes
Eagle Bluff Mine	Tuolumne	T1N,R16E,Sec 33	Mine	Stanislaus NF	350	8/10/97	*A. pallidus* ?	0	Yes
Early Intake Adit	Tuolumne	T1S,R18E,Sec 11	Tunnel	Hetch Hetchy Water Dist	719	8/14/97	Unknown	0	Yes
Ellen Winton Mine#1	Tuolumne	T1N,R16E,Sec 33	Mine	Stanislaus NF	320	9/13/97	*C. townsendii* , *Myotis* sp.	0	Yes
Ellen Winton Mine#2	Tuolumne	T1N,R16E,Sec 33	Mine	Stanislaus NF	305	9/13/97	*C. townsendii*	1	Yes
Fair Oaks #1	Tuolumne	T2N,R16E,Sec 22	Mine	Stanislaus NF	1201	9/4/97	Unknown	0	Yes
Indian Ck Adit	Tuolumne	T1S,R17E,Sec 6	Mine	Stanislaus NF	335	8/10/97	Unknown	0	Yes
Juniper Adit #2	Tuolumne	T3N,R16E,Sec 28	Mine	Stanislaus NF	1183	9/6/97	Unknown	0	Yes
Juniper Adit #1	Tuolumne	T3N,R16E,Sec 28	Mine	Stanislaus NF	1219	9/6/97	*Myotis* sp.	0	Yes
Lower N Mt. Tunnel #1	Tuolumne	T1N,R18E,Sec 36	Tunnel	Hetch Hetchy Water Dist	488	8/14/97	*C. townsendii* , *E. fuscus*	1	Yes
Lower N Mt. Tunnel #2	Tuolumne	T1N,R18E,Sec 36	Tunnel	Hetch Hetchy Water Dist	488	8/14/97	*C. townsendii*	1	Yes
Lower N Mt. Tunnel #4	Tuolumne	T1N,R18E,Sec 36	Tunnel	Hetch Hetchy Water Dist	799	8/21/97	*C. townsendii* , *E. fuscus*	0	Yes
Lucky Strike #1	Tuolumne	T2N,R16E,Sec14	Mine	Stanislaus NF	914	9/5/97	*Myotis* sp.	0	Yes
Mt. Lily Mine #1	Tuolumne	T3N,R15E,Sec 32	Mine	Stanislaus NF	497	9/22/97	*C. townsendii*	0	Yes
North Mountain Adit	Tuolumne	T1N,R19E,Sec 31	Tunnel	Hetch Hetchy Water Dist	1058	8/14/97	Unknown	0	Yes
Ora S. Cosby Rock Quarry #1	Tuolumne	T1s,R17E,Sec28	Mine	Stanislaus NF	902	8/11/97	Unknown	0	Yes
Playpen Adit #1	Tuolumne	T1N,R16E,Sec32	Mine	Stanislaus NF	290	9/14/97	*Myotis* sp.	0	Yes
Power House	Tuolumne	T1S,R17E,Sec 6	Building	Stanislaus NF	351	8/10/97	*Myotis* sp.	14/3	Yes
Riverbend Mine #1	Tuolumne	T1N,R16E,Sec 34	Mine	Stanislaus NF	335	9/13/97	*C. townsendii*	0	Yes

Table 1. Cont'd.

Locality Name	County	T/R/Sec	Structure	Jurisdiction	Elev (m)	Date	Species	# Bats	Guano
Non-colonial Use by C. townsendii or Other Bat Species									
Sarbo Mine	Tuolumne	T2N,R16E,Sec 13	Mine	Stanislaus NF	939	9/5/97	*C. townsendii*	0	Yes
Unnamed, near Stampmill	Tuolumne	T1N,R16E,Sec 32	Mine	Stanislaus NF	287	9/14/97	*C. townsendii* , *Myotis* sp.	0	Yes
No Evidence of Use by Bats									
Hwy 49 Mine #2	Mariposa	T3S,R17E,Sec19	Mine	BLM	655	8/9/97	None	0	No
Hwy 49 Mine #3	Mariposa	T3S,R17E,Sec19	Mine	BLM	663	8/9/97	None	0	No
Lindsay #3	Mariposa	T3S,R19E,Sec18	Mine	Sierra NF	479	8/28/97	None	0	No
Metzner Mine Complex #2	Mariposa	T3S,R19E,Sec18	Mine	Sierra NF	610	8/28/97	None	0	No
Metzner Mine Complex #3	Mariposa	T3S,R19E,Sec18	Mine	Sierra NF	640	8/28/97	None	0	No
Star Mine Main Adit #2	Mariposa	T5S,T22E,Sec 10	Mine	Sierra NF	2536	9/17/97	None	0	No
1071	Shasta	T32N,R5W,Sec 30	Mine	BLM	306	7/31/97	None	0	No
1074 #1	Shasta	T32N,R5W Sec 30	Mine	BLM	262	9/25/97	None	0	No
El Dorado Upper Adit #2	Shasta	T32N,R7W,Sec 3	Mine	Whiskeytown NRA		7/4/97	None	0	No
Gamin Adit #3	Shasta	T32N,R6W,Sec 5	Mine	Whiskeytown NRA	457	7/3/97	None	0	No
Gamin Shaft	Shasta	T32N,R6W,Sec 5	Mine	Whiskeytown NRA	457	7/16/97	None	0	No
Franklin #2	Shasta	T33N,R7W,Sec16	Mine	Private	633	7/26/97	None	0	No
Milkmaid #1	Shasta	T33N,R7W,Sec16	Mine	Private	597	7/24/97	None	0	No
Milkmaid #10	Shasta	T33N,R7W,Sec16	Mine	Private	607	7/25/97	None	0	No
Milkmaid #4	Shasta	T33N,R7W,Sec16	Mine	Private	580	7/25/97	None	0	No
Milkmaid #5	Shasta	T33N,R7W,Sec16	Mine	Private	580	7/25/97	None	0	No
Milkmaid #8	Shasta	T33N,R7W,Sec16	Mine	Private	553	7/25/97	None	0	No
Westend #1	Shasta	T32N,R6W,Sec15	Mine	Whiskeytown NRA	372	7/15/97	None	0	No
Independence Ck. Mine	Siskiyou	T15N, R6E,Sec.31	Mine	Klamath NF	329	4/8/98	None	0	No
Deer Horn	Trinity	T33N,R8W, Sec.33	Mine	BLM	1082	10/20/97	None	0	No
Dixie Queen Mine #1	Trinity	T32N,R9W,Sec 23	Mine	BLM	870	6/24/97	None	0	No
Dixie Queen Mine #3	Trinity	T32N,R9W,Sec 23	Mine	BLM	840	6/24/97	None	0	No
Unnamed Bully Choop #1	Trinity	T32N,R8W,Sec 9	Mine	BLM	1654	7/23/97	None	0	No
Unnamed Bully Choop #2	Trinity	T31N, R8W, Sec.4	Mine	BLM	1730	7/24/97	None	0	No
Unnamed Bully Choop #3	Trinity	T32N,R8W,Sec 9	Mine	BLM	1695	7/24/97	None	0	No
Cave, S Fork Kaweah	Tulare	T18S,R29E,Sec.24	Cave	Sequoia Kings Cyn NP	1036	8/7/97	None	0	No
Adit 3/4 (Hetch Hetchy)	Tuolumne	T1S,R18E,Sec 30	Tunnel	Hetch Hetchy Water Dist	701	8/13/97	None	0	No
Adit 4/5 (Hetch Hetchy)	Tuolumne	T1S,R18E,Sec 30	Tunnel	Hetch Hetchy Water Dist	686	8/13/97	None	0	No
Cherry Adit	Tuolumne	T1N,R19E,Sec 5	Tunnel	Hetch Hetchy Water Dist	1404	8/14/97	None	0	No
Devil's Gate Adit #1	Tuolumne	T1N,R16E,Sec 32	Mine	Stanislaus NF	312	9/15/97	None	0	No
O'Shaughnessy Adit	Tuolumne	T1N,R20E,Sec17	Tunnel	Hetch Hetchy Water Dist	1082	8/13/97	None	0	No
Riverbend Mine #2	Tuolumne	T1N,R16E,Sec 34	Mine	Stanislaus NF	366	9/13/97	None	0	No
Riverbend Mine #3	Tuolumne	T1N,R16E,Sec 34	Mine	Stanislaus NF	386	9/13/97	None	0	No

Table 1. Cont'd.

Locality Name	County	T/R/Sec	Structure	Jurisdiction	Elev (m)	Date	Species	# Bats	Guano
No Evidence of Use by Bats									
Russell Telegraph Adit #1	Tuolumne	T1S,R16E,Sec 6	Mine	Stanislaus NF	427	8/22/97	None	0	No
Russell Telegraph Adit #2	Tuolumne	T1S,R16E,Sec 6	Mine	Stanislaus NF	427	8/22/97	None	0	No
Tradewind Prospect	Tuolumne	T3N,R16E,Sec 36	Mine	Stanislaus NF	1390	9/4/97	None	0	No
Unnamed Adit #2	Tuolumne	T1N,R16E,Sec 32	Mine	Stanislaus NF	290	9/14/97	None	0	No
Wet Gulch Adit #1	Tuolumne	T2N,R1E,Sec1	Mine	Stanislaus NF	664	9/22/97	None	0	No

Table 2. Survey results for *C. townsendii* hibernating sites.

Locality Name	County	T/R/Sec	Structure	Jurisdiction	Elev (m)	Date	# *C. townsendii*
Merced Cave #1	Mariposa	NW1/4 T3S,R19E	Cave	Sierra NF	640	3/9/98	2
Merced Cave #2	Mariposa	NW1/4 T3S,R19E	Cave	Private	488	3/9/98	4
Bower Cave	Mariposa	SW1/4 T2S,R18E	Cave	Stanislaus NF	732	3/10/98	2
Bat Cave	Siskiyou	SE1/4T42N,R3E	Cave	Shasta-Trinity NF	1500	12/11/97	66
Bilibee Cave	Siskiyou	NW1/4 T41N,R3E	Cave	Shasta-Trinity NF	1370	1/22/98	0
Pluto Lava Flow #1	Siskiyou	SE1/4, T43N, R4W	Cave	Klamath NF	1100	2/3/98	85
Pluto Lava Flow #2	Siskiyou	SE1/4, T43N, R4W	Cave	Klamath NF	1120	2/3/98	4
Pluto Lava Flow #3	Siskiyou	SE1/4, T43N, R4W	Cave	Klamath NF	1120	2/3/98	0
Pluto Lava Flow #4	Siskiyou	NE1/4T43N, R4W	Cave	Klamath NF	1030	3/1/98	140
Pluto Lava Flow #5	Siskiyou	NW1/4 T43N,R4W	Cave	Private	950	1/20/98 3/4/98	170 1
Pluto Lava Flow #6	Siskiyou	NW1/4 T43N,R4W	Cave	Private	950	1/20/98 3/1/98	4 7

Table 3. Distances (in kilometers) that male and female bats traveled. Center = geographic center of foraging area. Max = maximum distance traveled from day roost.

Bat No.	Male/Female	Center	Max
583	M	1.0	1.7
816	M	1.1	1.9
621	M	1.7	9.2
665	F	5.6	9.6
936	F	8.1	9.2
917	F	2.3	5.1
615	F	3.4	4.9
566	F	1.5	2.7
706	F	2.6	4.3
674	F	1.0	2.3
857	F	1.8	7.8
806	F	2.2	3.3
777	F	2.0	11.2
744	F	1.9	9.0
896	F	2.7	4.8
957	F	6.2	10.3
645	F	4.0	6.3

Table 4. Activity of a male big-eared bat (583) which was tracked nearly continuously during selecting nights.

Sept. 17, 1997

Start	End	Activity
-	1950	Day roost
1950	2012	Foraging
2013	2034	Foraging
2034	2247	?
2247	2300	Foraging
2300	2302	Traveling
2302	0002	Roosted
0002	0009	Foraging
0009	00012	Traveling
0012	0019	Foraging
0019	0034	Foraging
0035	0114	Roosted
0114	0121	Foraging
0121	0227	Foraging
0227	0245	Roosted
0245	0252	Foraging
0252	0256	Foraging

Sept. 18, 1997

Start	End	Activity
-	1959	Day roost
1959	2005	Foraging
2005	2006	Traveling
2006	2013	Foraging
2013	2027	Foraging
2028	2029	Foraging
2029	2032	Foraging
2032	-	Traveling
2042	-	Roosting
2044	2048	Foraging
2048	2050	Foraging
2051	-	Foraging
2056	-	Roosting
2214	-	Roosting
2356	-	Roosting
0019	-	Roosting
0036	-	Roosting
0053	-	Roosting
0330	-	Roosting

Table 5. Activity of a female big-eared bat (777) which was tracked nearly continuously during one night.

Sept. 18, 1997

Start	End	Activity
-	2007	Day roost
2007	-	Flying
2014	-	Flying
2038	-	Flying
2052	-	Flying
2100	-	Flying
2102	2105	Foraging
2105	2106	Traveling
2106	2111	Foraging
2111	2130	Foraging
2130	2132	Foraging
2132	2134	Traveling
2134	2146	Foraging
2146	2202	Foraging
2203	2213	Foraging
2214	-	Roosting
0145	-	Foraging

Table 6. Activity level of bats at ice caves, Lava Beds National Monument, 8 Sept 1997. An hour is represented by four ten minute observation periods (one every 15 minutes).

Ice Cave	Total # passes	Total time (h)	# bat passes/h
Big Painted Cave	146	3	48.7
Cox's Well	56	3	18.7
Heppe	2314	4	578.5
Skull	15	3	5.0

Fig. 1. Genetic variation at two microsatellite loci from three widely separated *C. townsendii* populations. Samples (n = 10 females) are from maternity roosts in Marin, Siskiyou and Inyo counties.

F_{st} Estimates

Overall F_{st} values
for 3 populations

Locus	F_{st}
Paur03	0.0129
Paur05	0.1053
Combined	0.0612

Pairwise F_{st} estimates
for each locus

Paur03:

Population	Marin	Siskiyou
Siskiyou	-0.027	
Inyo	0.0455	0.0158

Paur05:

Population	Marin	Siskiyou
Siskiyou	0.0734	
Inyo	0.1352	0.0972

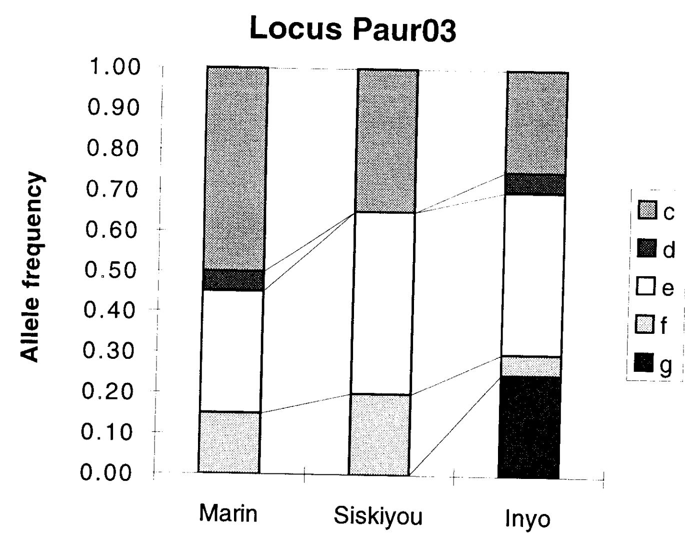
Pairwise F_{st} estimates
for loci combined

Population	Marin	Siskiyou
Siskiyou	0.0317	
Inyo	0.0968	0.0629

Allele frequencies by population

Paur03

Allele	Marin	Siskiyou	Inyo
c	0.5	0.35	0.25
d	0.05	0	0.05
e	0.3	0.45	0.4
f	0.15	0.2	0.05
g	0	0	0.25



Paur05

Allele	Marin	Siskiyou	Inyo
f	0	0	0.278
g	0	0.142	0.056
h	0.375	0	0
i	0	0	0.056
j	0	0.142	0
k	0.1875	0	0
m	0.125	0.285	0
n	0	0	0.222
p	0.25	0.142	0
q	0	0.285	0
r	0	0	0.056
u	0	0	0.111
x	0	0	0.111
y	0.0625	0	0.111

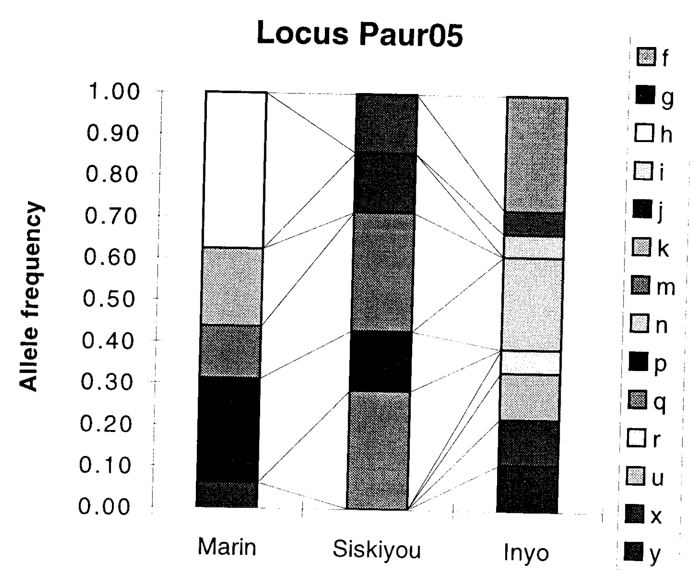
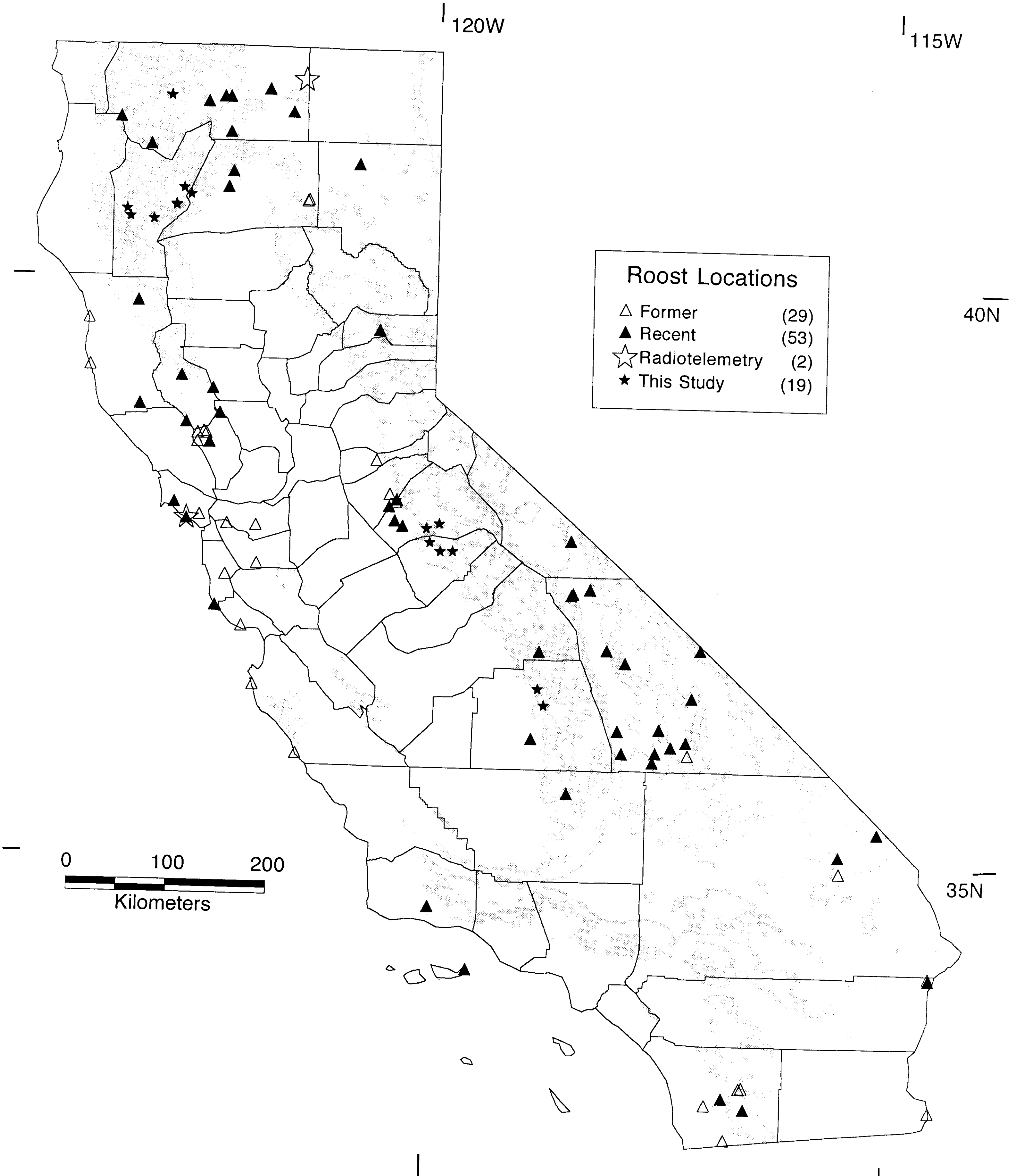


Fig. 2. A map of California (with 1,000 m contours and county lines indicated) showing the location and status of historically and currently known *C. townsendii* roosts. The two radiotracking localities, near the northern border, and along the central coast, are indicated by hollow stars. All localities indicated as "recent" have been surveyed within the last ten years (P. Brown(pers. comm., Pierson and Rainey 1996, and E.D. Pierson unpubl. data). Localities indicated as "former" are historic sites which were unoccupied or no longer existed when checked within the last ten years.



120W
115W
40N
35N
Roost Locations
Former (29)
Recent (53)
Radiotelemetry (2)
This Study (19)
0 100 200
Kilometers

Fig. 3. A bar graph showing categories of use by bats for the four types of structures surveyed.

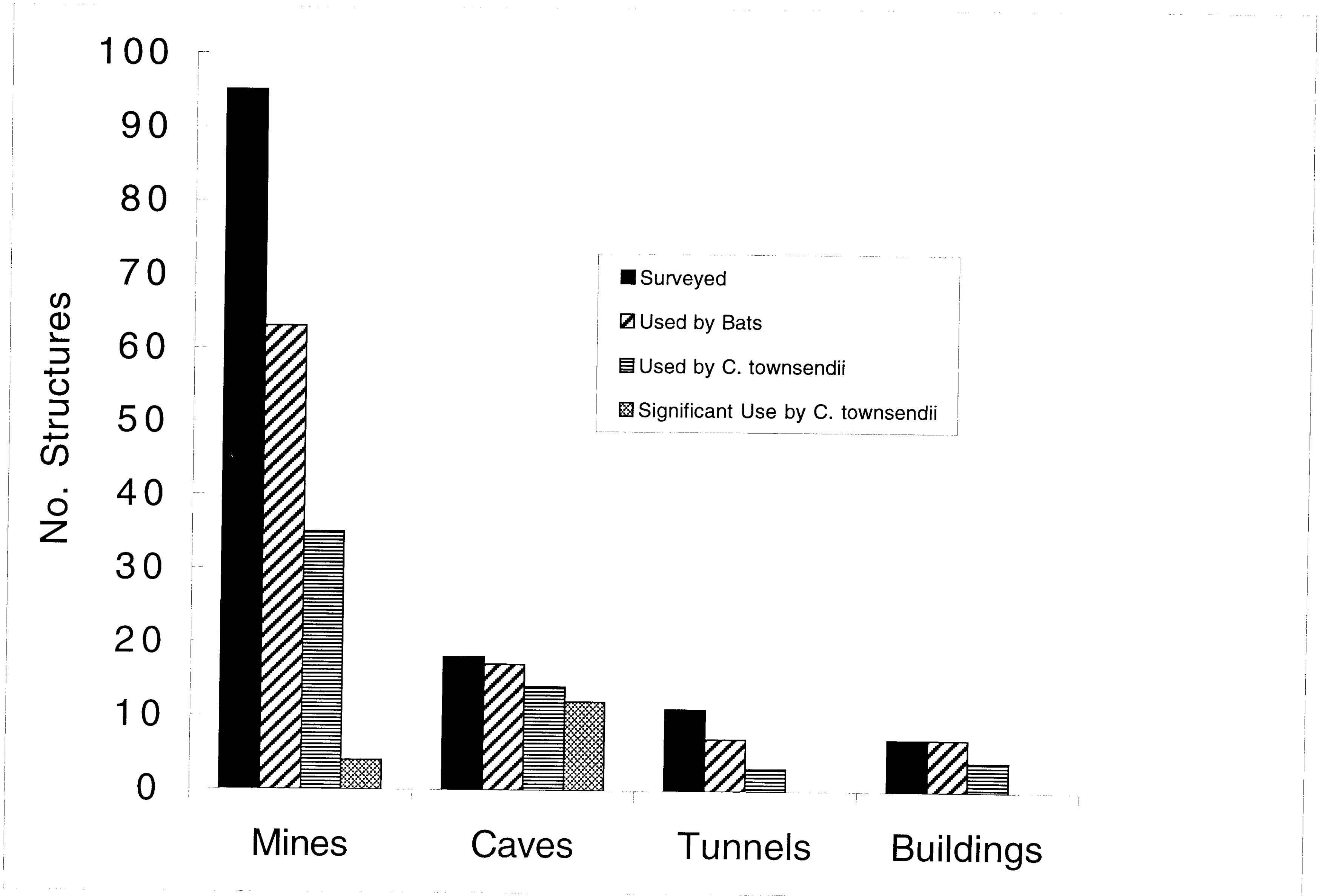

No. Structures
100
90
80
70
60
50
40
30
20
10
0
Surveyed
Used by Bats
Used by C. townsendii
Significant Use by C. townsendii
Mines
Caves
Tunnels
Buildings

Figure 4. Cumulative foraging areas for thirteen post-lactating females, one non-reproductive adult female and three adult male big-eared bats with radiotransmitters. Olema Valley, Marin County, CA. Heavy lines represent streams. Note the close association of foraging areas with riparian habitats along stream corridors.

Figure 5. Roost fidelity of big-eared bats at the Randall House, Olema Valley, Marin County, CA. The percentages represent the proportion of bats which returned to the Randall house each night after being outfitted with a transmitter on September 15, 1997.

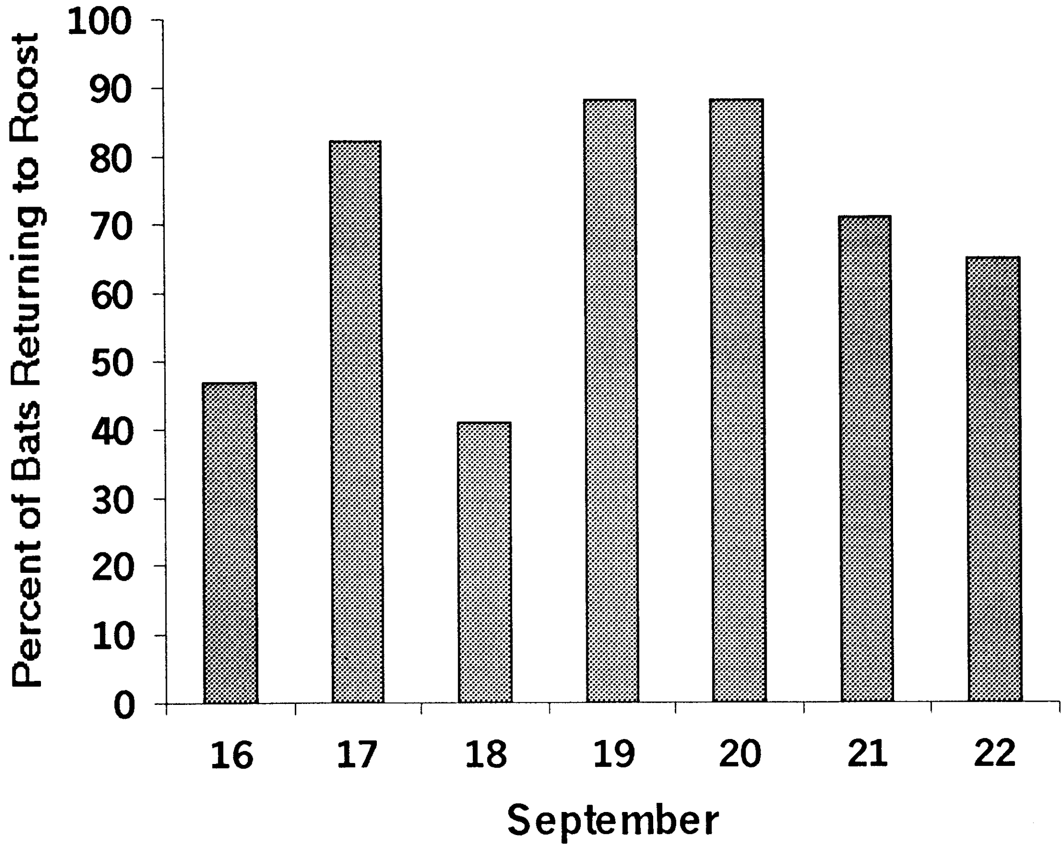
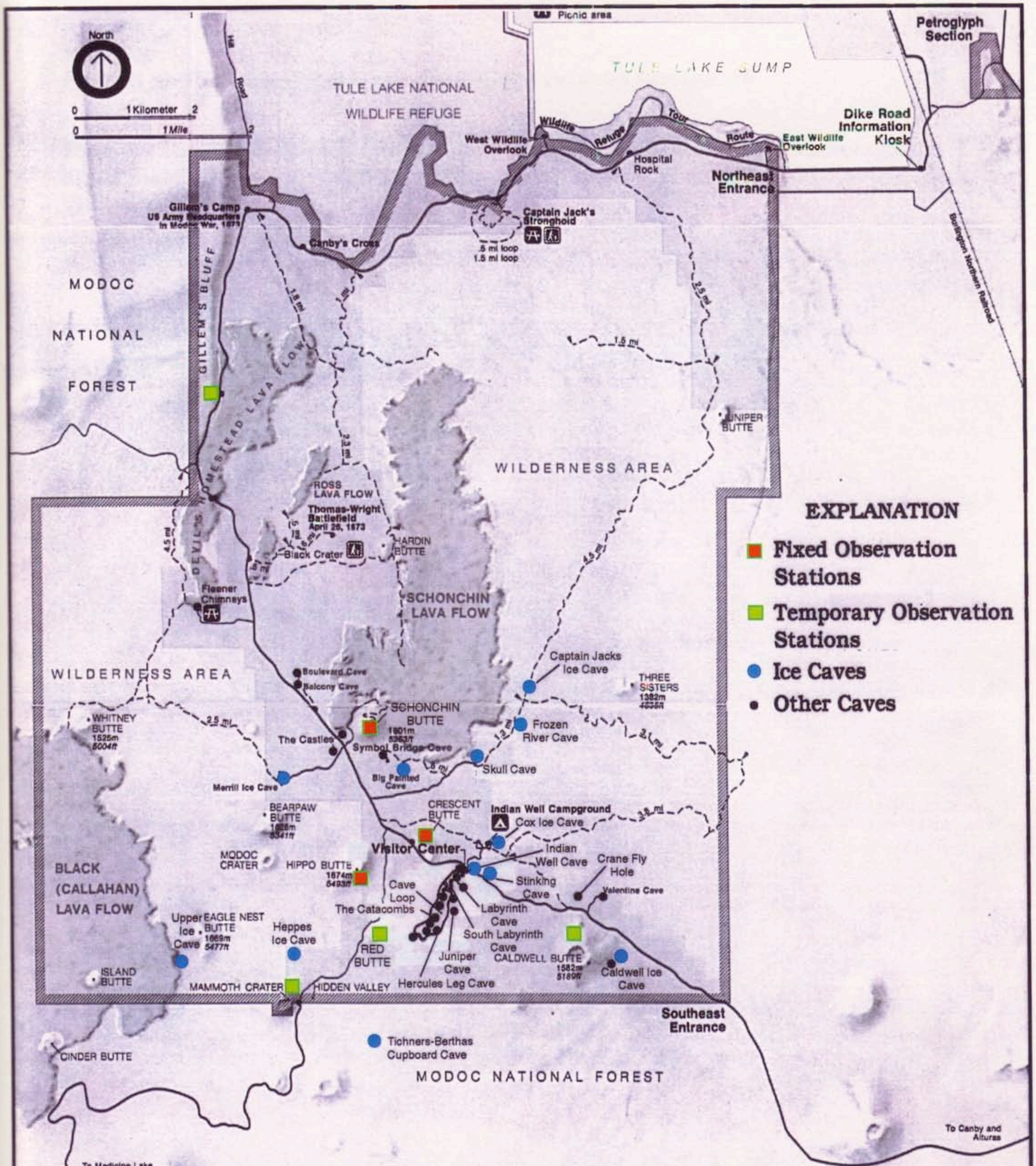
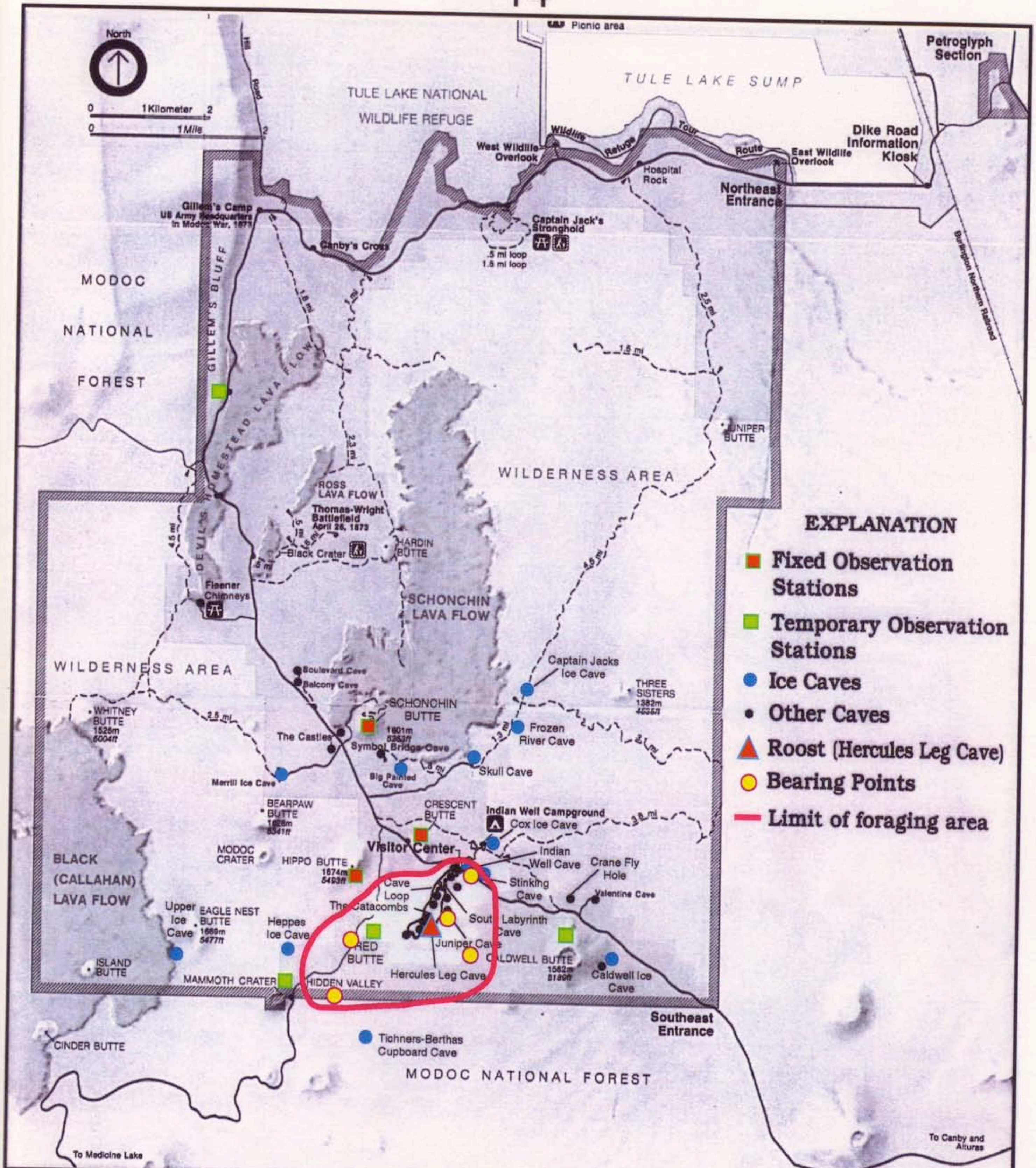

Percent of Bats Returning to Roost
100
90
80
70
60
50
40
30
20
10
0
16
17
18
19
20
21
22
September

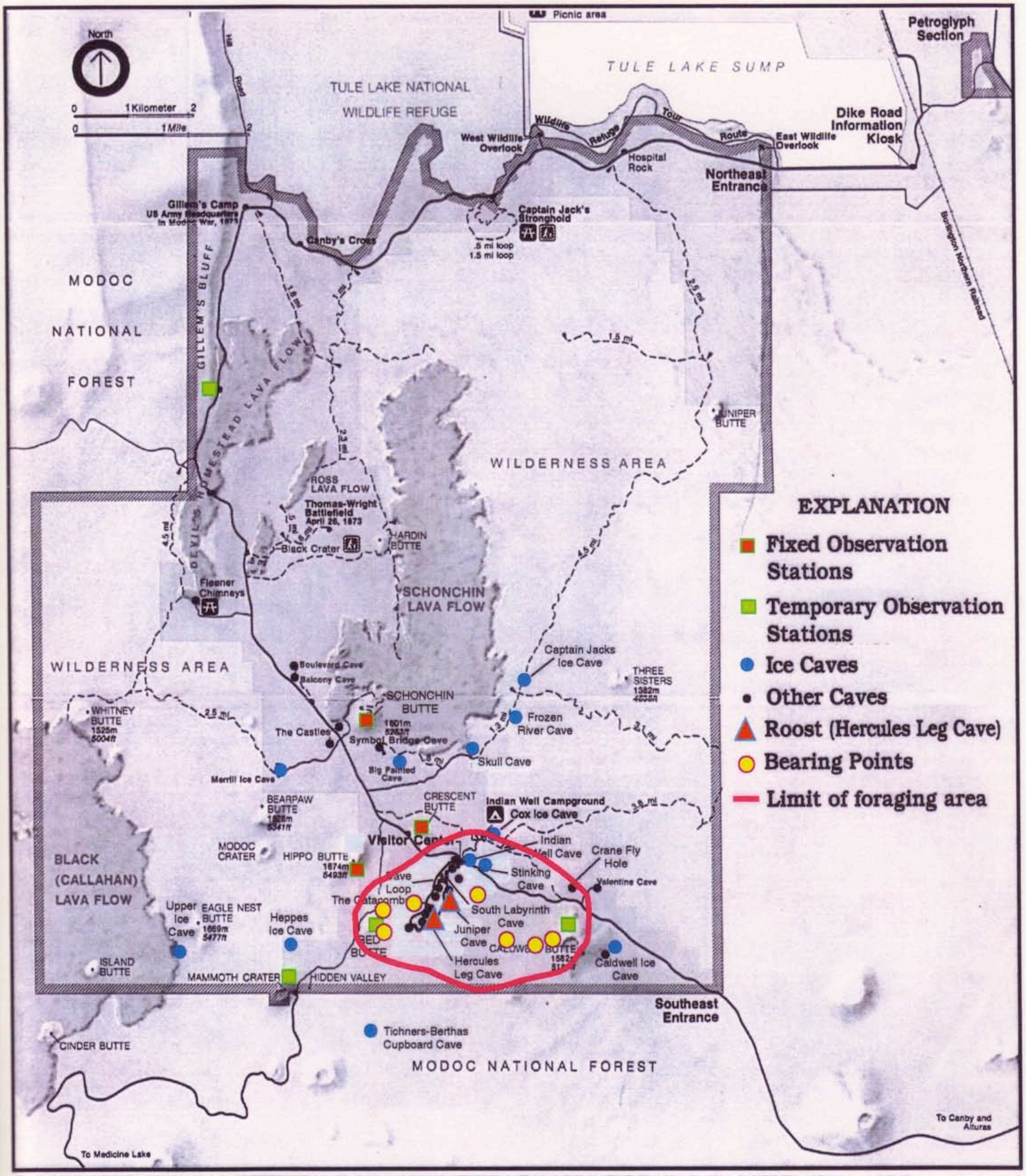
Figure 6. A map showing the study area at Lava Beds National Monument, the location of the ices caves, and the location of both the temporary and fixed observation stations used in the radiotracking study.

LAVA BEDS NATIONAL MONUMENT, CA

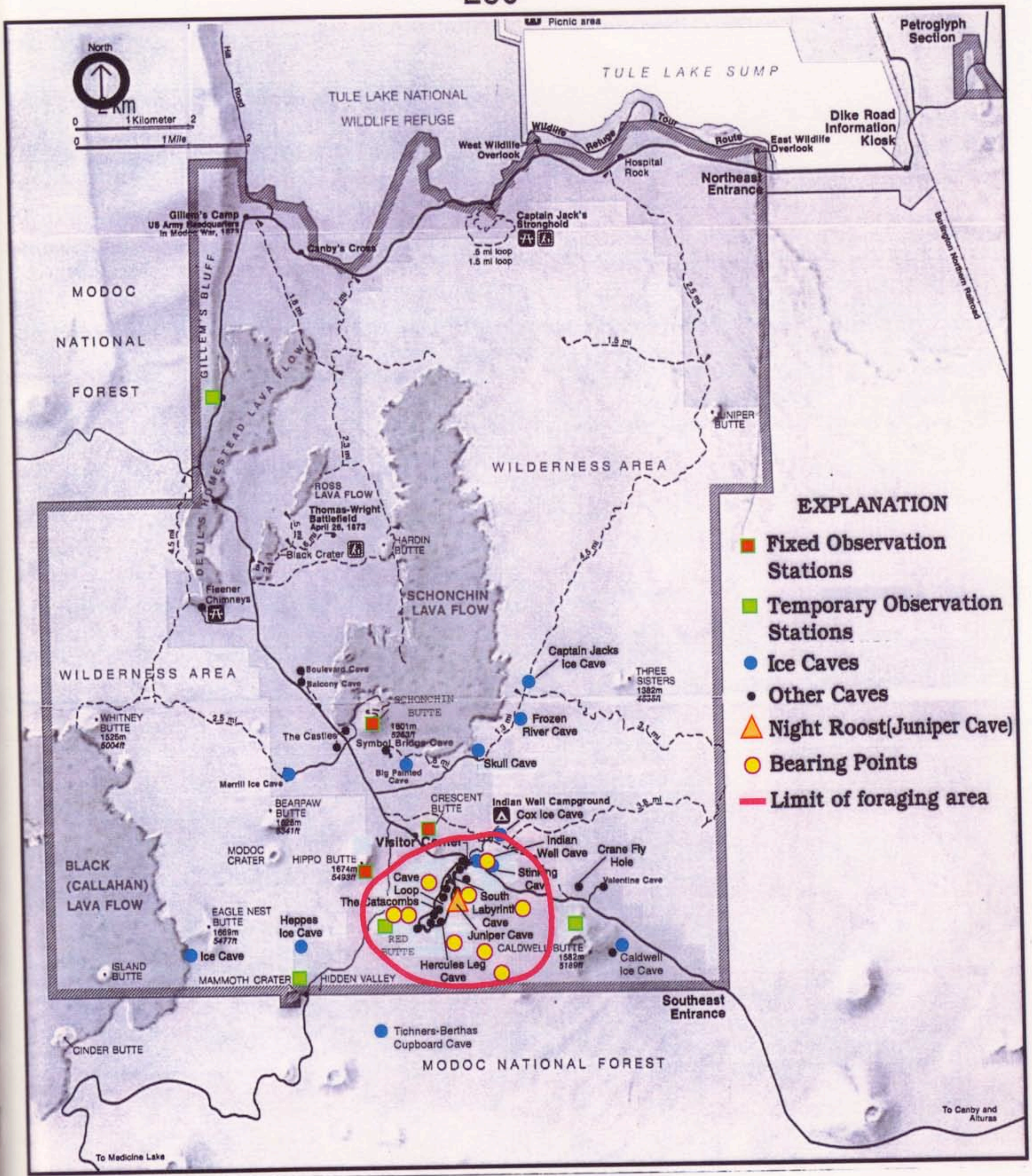


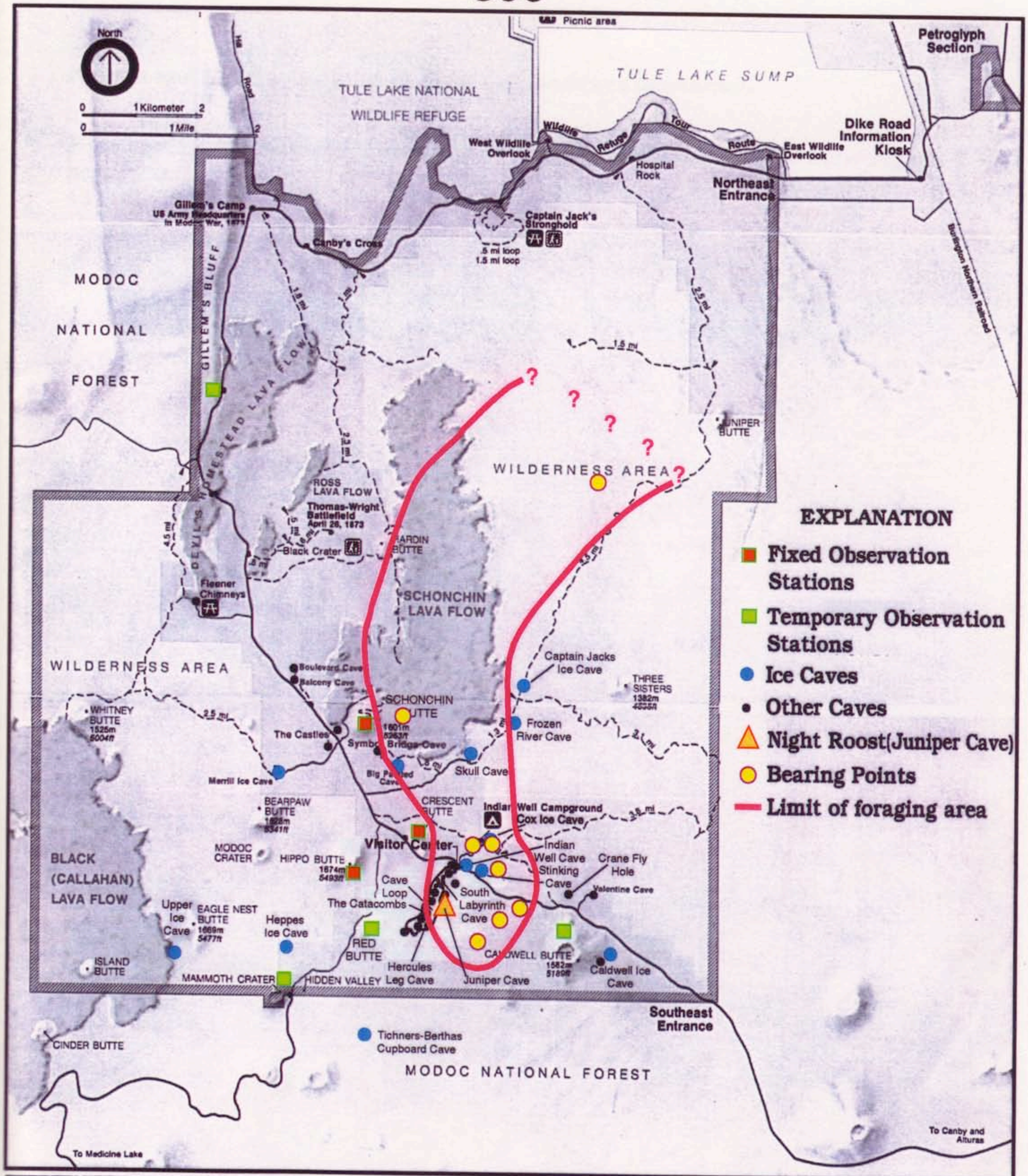
Figs. 7 - 10. These maps show the roosting and foraging areas for radiotagged adult male *C. townsendii* at Lava Beds National Monument (Bats 014, 046, 286, and 306).


North
0 1 Kilometer 2
0 1 Mile 2
Picnic area
TULE LAKE SUMP
Petroglyph Section
TULE LAKE NATIONAL WILDLIFE REFUGE
Wildlife Refuge Tour Route
West Wildlife Overlook
East Wildlife Overlook
Dike Road Information Kiosk
Hospital Rock
Northeast Entrance
Gillem's Camp US Army Headquarters in Modoc War, 1873
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
Canby's Cross
Burlington Northern Railroad
MODOC NATIONAL FOREST
GILLEM'S BLUFF
HOMESTEAD LAVA FLOW
JUNIPER BUTTE
WILDERNESS AREA
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
Black Crater
HARDIN BUTTE
DEVIL'S
Fleener Chimneys
SCHONCHIN LAVA FLOW
WILDERNESS AREA
Boulevard Cave
Balcony Cave
SCHONCHIN BUTTE
Captain Jacks Ice Cave
THREE SISTERS
WHITNEY BUTTE
The Castles
Symbol Bridge Cave
Frozen River Cave
Big Painted Cave
Skull Cave
Merrill Ice Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
Cox Ice Cave
MODOC CRATER
Visitor Center
HIPPO BUTTE
Indian Well Cave
Crane Fly Hole
BLACK (CALLAHAN) LAVA FLOW
Cave Loop
Stinking Cave
Valentine Cave
The Catacombs
Labyrinth Cave
Upper Ice Cave
EAGLE NEST BUTTE
Heppes Ice Cave
RED BUTTE
Juniper Cave
CALDWELL BUTTE
ISLAND BUTTE
Hercules Leg Cave
Caldwell Ice Cave
MAMMOTH CRATER
HIDDEN VALLEY
Southeast Entrance
CINDER BUTTE
Tichners-Berthas Cupboard Cave
MODOC NATIONAL FOREST
To Medicine Lake
To Canby and Alturas
EXPLANATION
Fixed Observation Stations
Temporary Observation Stations
Ice Caves
Other Caves
Roost (Hercules Leg Cave)
Bearing Points
Limit of foraging area



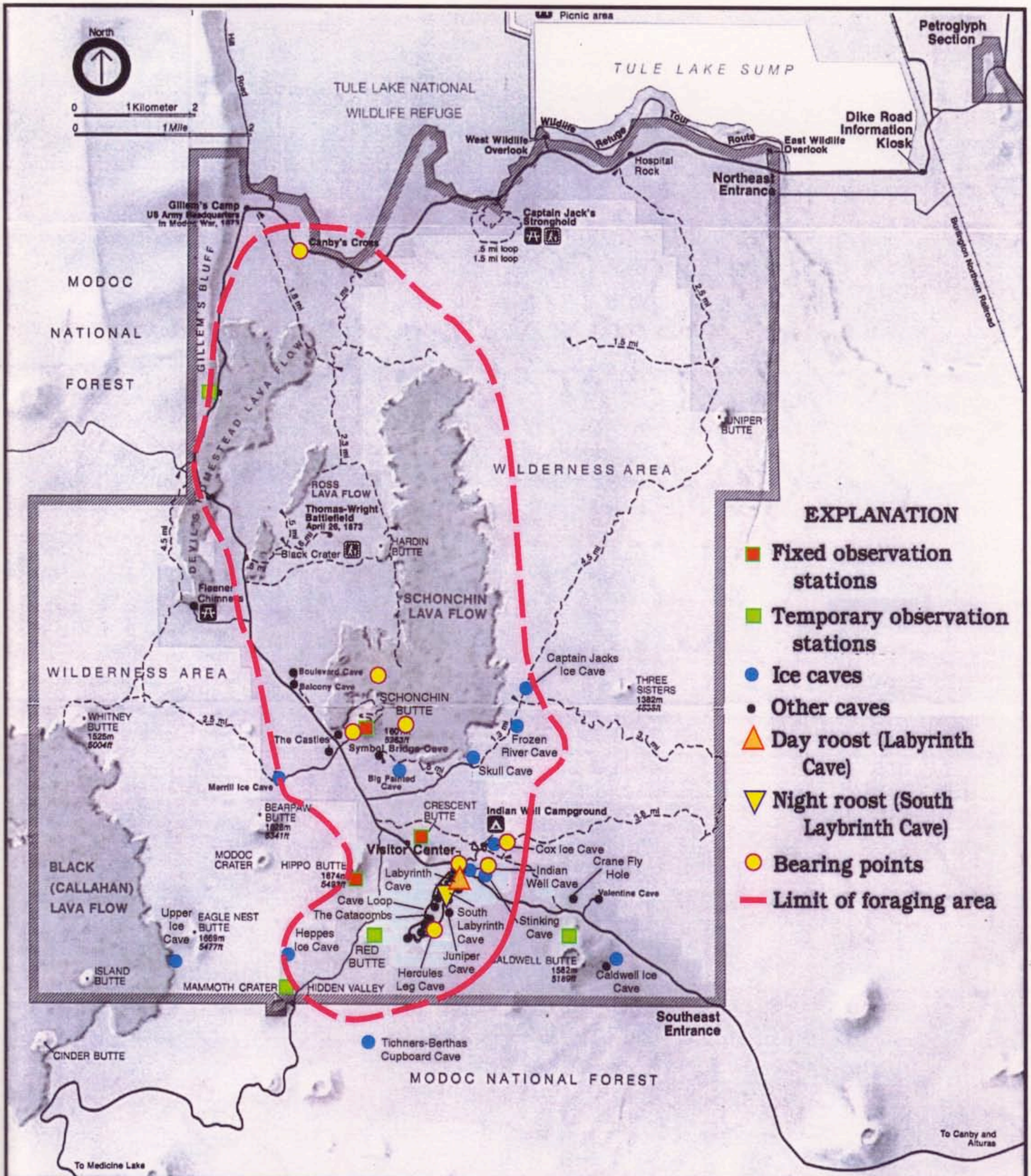
North
0 1 Kilometer 2
0 1 Mile 2
Picnic area
Petroglyph Section
TULE LAKE SUMP
TULE LAKE NATIONAL WILDLIFE REFUGE
Dike Road Information Kiosk
Wildlife Refuge Tour Route
West Wildlife Overlook
East Wildlife Overlook
Hospital Rock
Northeast Entrance
Gillem's Camp
Canby's Cross
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
Burlington Northern Railroad
MODOC NATIONAL FOREST
GILLEM'S BLUFF
HOMESTEAD LAVA FLOW
DEVIL'S HOMESTEAD LAVA FLOW
JUNIPER BUTTE
WILDERNESS AREA
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
Black Crater
HARDIN BUTTE
SCHONCHIN LAVA FLOW
Fleener Chimneys
WILDERNESS AREA
Boulevard Cave
Balcony Cave
SCHONCHIN BUTTE
Captain Jacks Ice Cave
THREE SISTERS 1382m
WHITNEY BUTTE 1525m 5004ft
The Castles
Symbol Bridge Cave
Frozen River Cave
Skull Cave
Big Painted Cave
Merrill Ice Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
Cox Ice Cave
MODOC CRATER
HIPPO BUTTE 1674m 5493ft
Visitor Center
Indian Well Cave
Crane Fly Hole
Stinking Cave
Valentine Cave
Cave Loop
The Catacombs
South Labyrinth Cave
Juniper Cave
Hercules Leg Cave
BLACK (CALLAHAN) LAVA FLOW
Upper Ice Cave
EAGLE NEST BUTTE 1669m 5477ft
Heppes Ice Cave
RED BUTTE
CALDWELL BUTTE
Caldwell Ice Cave
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Southeast Entrance
Tichners-Berthas Cupboard Cave
CINDER BUTTE
MODOC NATIONAL FOREST
To Canby and Alturas
To Medicine Lake
EXPLANATION
Fixed Observation Stations
Temporary Observation Stations
Ice Caves
Other Caves
Roost (Hercules Leg Cave)
Bearing Points
Limit of foraging area

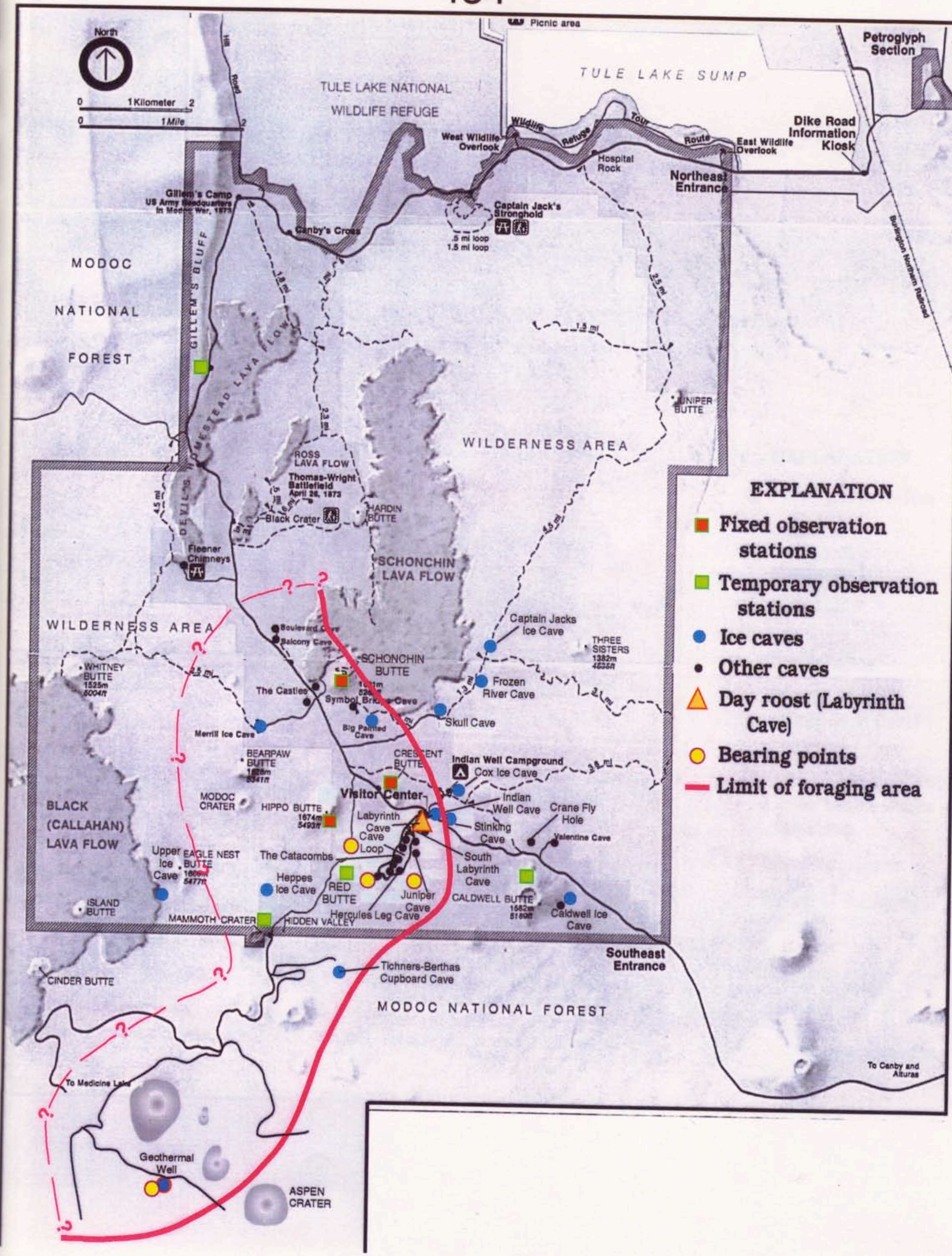

North
2 km
0 1 Kilometer 2
0 1 Mile
Picnic area
Petroglyph Section
TULE LAKE SUMP
TULE LAKE NATIONAL
WILDLIFE REFUGE
Wildlife Refuge Tour Route
West Wildlife Overlook
East Wildlife Overlook
Dike Road Information Kiosk
Hospital Rock
Northeast Entrance
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
Canby's Cross
US Army Headquarters in Modoc War, 1873
Burlington Northern Railroad
MODOC
NATIONAL
FOREST
GILLEM'S BLUFF
DEVIL'S HOMESTEAD LAVA FLOW
JUNIPER BUTTE
WILDERNESS AREA
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
Black Crater
HARDIN BUTTE
SCHONCHIN LAVA FLOW
Fleener Chimneys
WILDERNESS AREA
Boulevard Cave
Balcony Cave
SCHONCHIN BUTTE
1601m 5253ft
Captain Jacks Ice Cave
THREE SISTERS 1382m 4535ft
Frozen River Cave
WHITNEY BUTTE 1525m 5004ft
The Castles
Symbol Bridge Cave
Big Painted Cave
Skull Cave
Merrill Ice Cave
BEARPAW BUTTE 1626m 5341ft
CRESCENT BUTTE
Indian Well Campground
Cox Ice Cave
Visitor Center
Indian Well Cave
Crane Fly Hole
MODOC CRATER
HIPPO BUTTE 1674m 5493ft
Cave Loop
Stinking Cave
Valentine Cave
South Labyrinth Cave
The Catacombs
Juniper Cave
BLACK (CALLAHAN) LAVA FLOW
EAGLE NEST BUTTE 1669m 5477ft
Heppes Ice Cave
RED BUTTE
CALDWELL BUTTE 1582m 5189ft
Caldwell Ice Cave
Hercules Leg Cave
Ice Cave
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Southeast Entrance
Tichners-Berthas Cupboard Cave
CINDER BUTTE
MODOC NATIONAL FOREST
To Canby and Alturas
To Medicine Lake
EXPLANATION
Fixed Observation Stations
Temporary Observation Stations
Ice Caves
Other Caves
Night Roost(Juniper Cave)
Bearing Points
Limit of foraging area

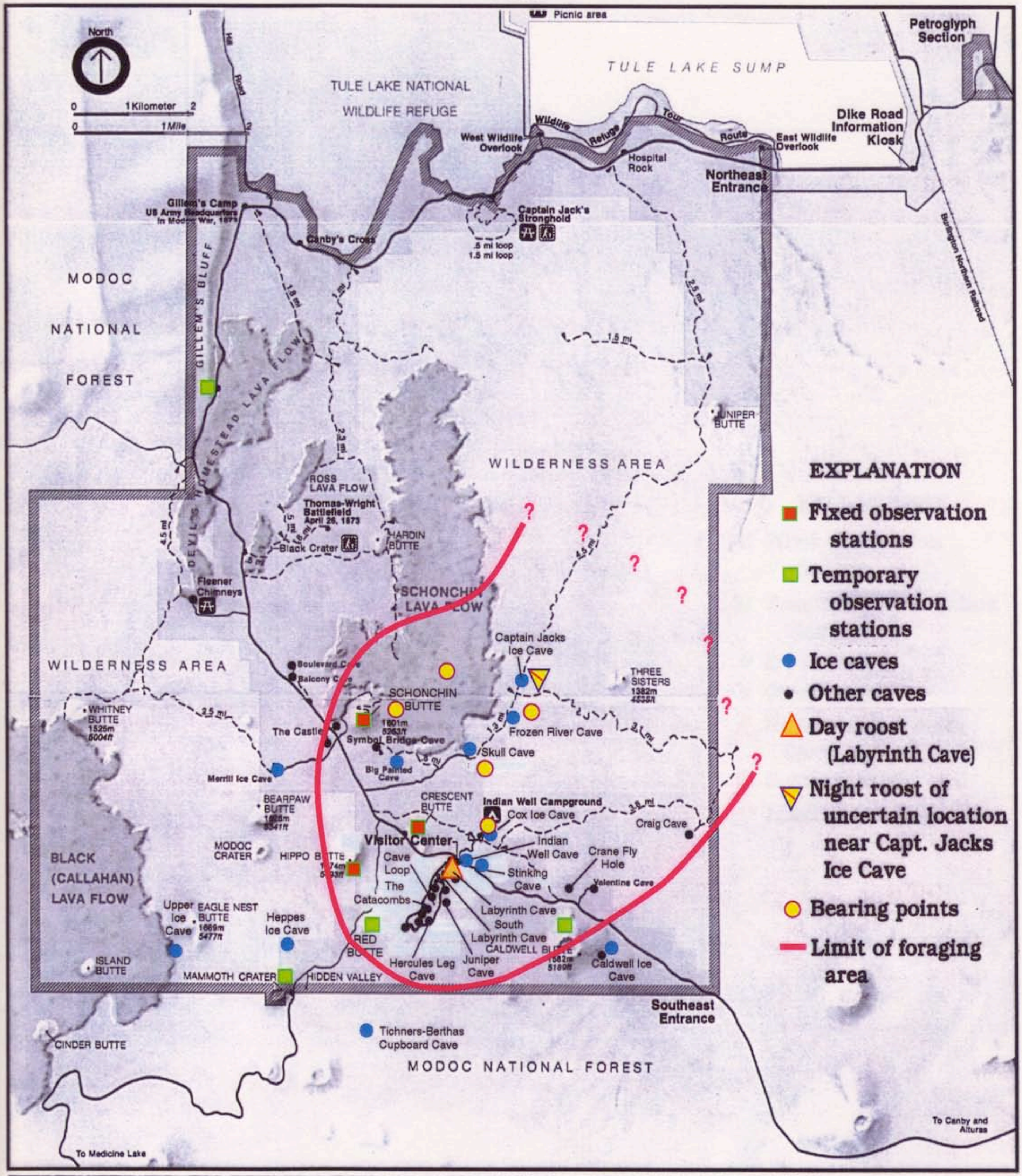


Picnic area
Petroglyph Section
TULE LAKE SUMP
TULE LAKE NATIONAL WILDLIFE REFUGE
North
0 1 Kilometer 2
0 1 Mile 2
Wildlife Refuge Tour Route
West Wildlife Overlook
East Wildlife Overlook
Dike Road Information Kiosk
Hospital Rock
Northeast Entrance
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
Canby's Cross
MODOC NATIONAL FOREST
GILLEM'S BLUFF
HOMESTEAD LAVA FLOW
DEVIL'S HOMESTEAD LAVA FLOW
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
Black Crater
HARDIN BUTTE
SCHONCHIN LAVA FLOW
WILDERNESS AREA
JUNIPER BUTTE
Fleener Chimneys
Boulevard Cave
Balcony Cave
SCHONCHIN BUTTE
The Castles
Symbol Bridge Cave
Big Painted Cave
Skull Cave
Captain Jacks Ice Cave
Frozen River Cave
THREE SISTERS
WHITNEY BUTTE
Merrill Ice Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
Cox Ice Cave
Visitor Center
Indian Well Cave
Stinking Cave
Crane Fly Hole
Valentine Cave
MODOC CRATER
HIPPO BUTTE
BLACK (CALLAHAN) LAVA FLOW
Cave Loop
The Catacombs
South Labyrinth Cave
Upper Ice Cave
EAGLE NEST BUTTE
Heppes Ice Cave
RED BUTTE
Hercules Leg Cave
Juniper Cave
CALDWELL BUTTE
Caldwell Ice Cave
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Southeast Entrance
CINDER BUTTE
Tichners-Berthas Cupboard Cave
MODOC NATIONAL FOREST
To Medicine Lake
To Canby and Alturas
EXPLANATION
Fixed Observation Stations
Temporary Observation Stations
Ice Caves
Other Caves
Night Roost(Juniper Cave)
Bearing Points
Limit of foraging area

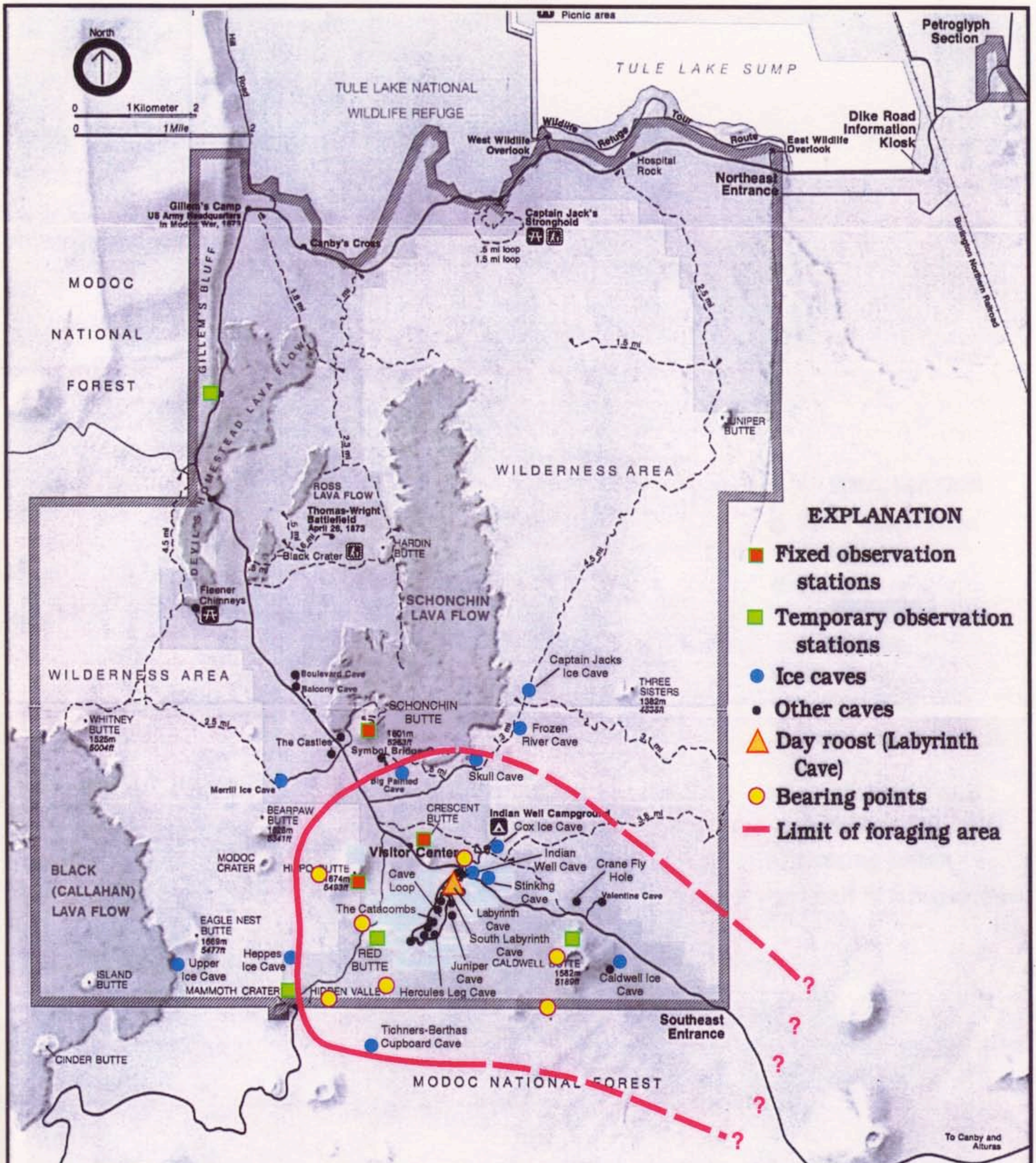
Figs. 11 - 18. These maps show the roosting and foraging areas for radiotagged post-lactating female *C. townsendii* at Lava Beds National Monument (Bats 431, 454, 465, 472,481, 495, 513, and 549).


North
0 1 Kilometer 2
0 1 Mile
TULE LAKE NATIONAL WILDLIFE REFUGE
TULE LAKE SUMP
Picnic area
Petroglyph Section
Dike Road Information Kiosk
East Wildlife Overlook
West Wildlife Overlook
Wildlife Refuge Tour Route
Hospital Rock
Northeast Entrance
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
Gillem's Camp
Canby's Cross
MODOC NATIONAL FOREST
GILLEM'S BLUFF
HOMESTEAD LAVA FLOW
DEVIL'S
JUNIPER BUTTE
WILDERNESS AREA
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
Black Crater
HARDIN BUTTE
SCHONCHIN LAVA FLOW
Fleener Chimneys
Boulevard Cave
Balcony Cave
SCHONCHIN BUTTE
Captain Jacks Ice Cave
THREE SISTERS 1382m 4535ft
WHITNEY BUTTE 1525m 5004ft
The Castles
Symbol Bridge Cave
Frozen River Cave
Skull Cave
Big Painted Cave
Merrill Ice Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
MODOC CRATER
HIPPO BUTTE
Visitor Center
Cox Ice Cave
Crane Fly Hole
Indian Well Cave
Valentine Cave
Labyrinth Cave
Cave Loop
The Catacombs
South Labyrinth Cave
Stinking Cave
BLACK (CALLAHAN) LAVA FLOW
Upper Ice Cave
EAGLE NEST BUTTE 1669m 5477ft
Heppes Ice Cave
RED BUTTE
Juniper Cave
Hercules Leg Cave
CALDWELL BUTTE 1582m 5189ft
Caldwell Ice Cave
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Southeast Entrance
Tichners-Berthas Cupboard Cave
CINDER BUTTE
MODOC NATIONAL FOREST
To Medicine Lake
To Canby and Alturas
EXPLANATION
Fixed observation stations
Temporary observation stations
Ice caves
Other caves
Day roost (Labyrinth Cave)
Night roost (South Laybrinth Cave)
Bearing points
Limit of foraging area

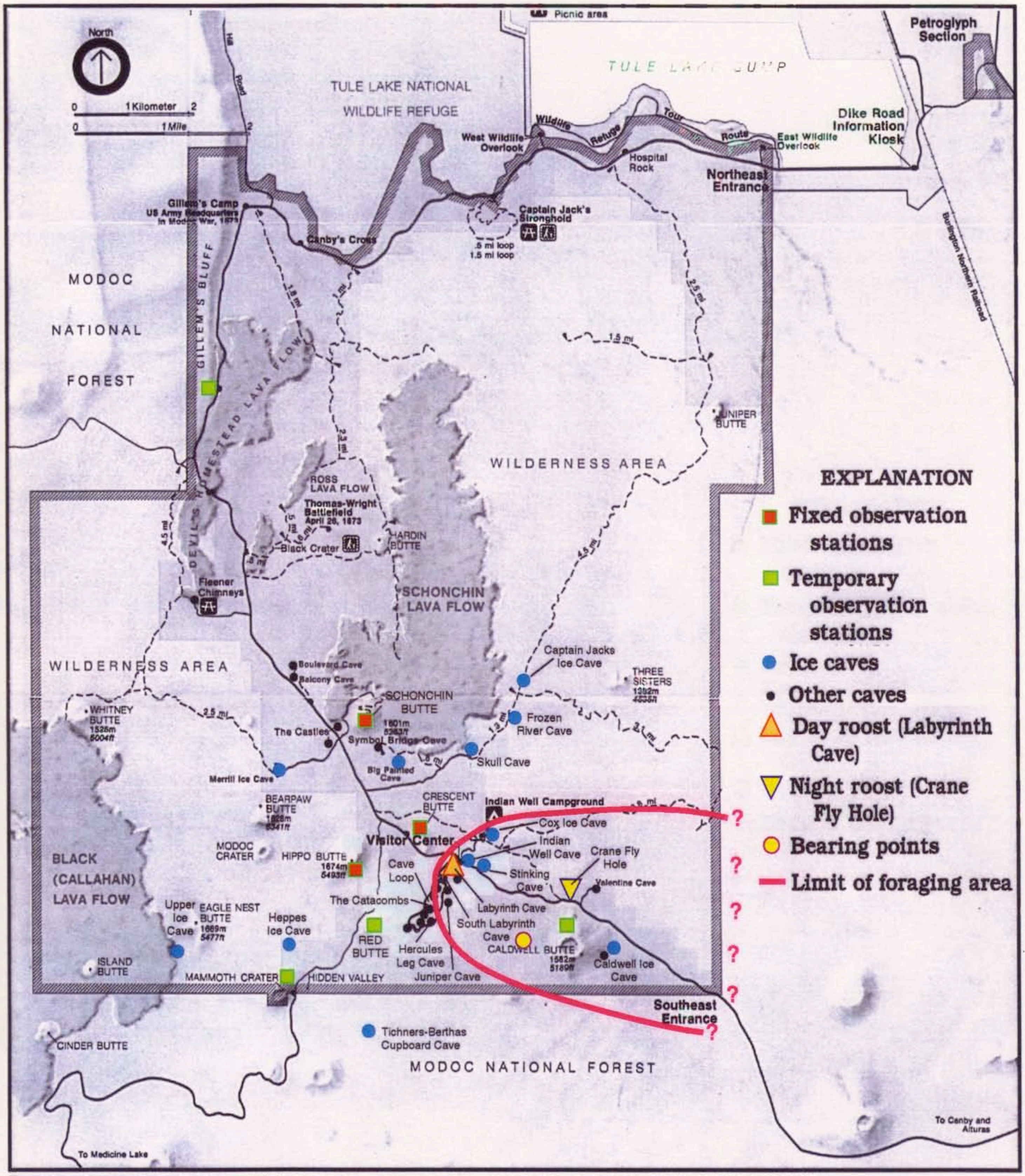

North
0 1 Kilometer 2
0 1 Mile 2
Picnic area
TULE LAKE SUMP
Petroglyph Section
TULE LAKE NATIONAL WILDLIFE REFUGE
West Wildlife Overlook
Wildlife Refuge Tour Route
East Wildlife Overlook
Dike Road Information Kiosk
Hospital Rock
Northeast Entrance
Gillem's Camp
Canby's Cross
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
Burlington Northern Railroad
MODOC NATIONAL FOREST
GILLEM'S BLUFF
DEVIL'S HOMESTEAD LAVA FLOW
JUNIPER BUTTE
WILDERNESS AREA
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
HARDIN BUTTE
Black Crater
Fleener Chimneys
SCHONCHIN LAVA FLOW
Boulevard Cave
Balcony Cave
SCHONCHIN BUTTE
WHITNEY BUTTE 1525m 5004ft
The Castles
Symbol Bridge Cave
Big Painted Cave
Skull Cave
Captain Jacks Ice Cave
THREE SISTERS 1382m 4535ft
Frozen River Cave
Merrill Ice Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
Cox Ice Cave
Visitor Center
Indian Well Cave
Crane Fly Hole
MODOC CRATER
HIPPO BUTTE 1674m 5493ft
Labyrinth Cave
Cave Loop
Stinking Cave
Valentine Cave
BLACK (CALLAHAN) LAVA FLOW
Upper Ice Cave
EAGLE NEST BUTTE
The Catacombs
South Labyrinth Cave
Heppes Ice Cave
RED BUTTE
Juniper Cave
CALDWELL BUTTE 1582m 5190ft
Caldwell Ice Cave
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Hercules Leg Cave
Southeast Entrance
Tichners-Berthas Cupboard Cave
CINDER BUTTE
MODOC NATIONAL FOREST
To Medicine Lake
To Canby and Alturas
Geothermal Well
ASPEN CRATER
EXPLANATION
Fixed observation stations
Temporary observation stations
Ice caves
Other caves
Day roost (Labyrinth Cave)
Bearing points
Limit of foraging area

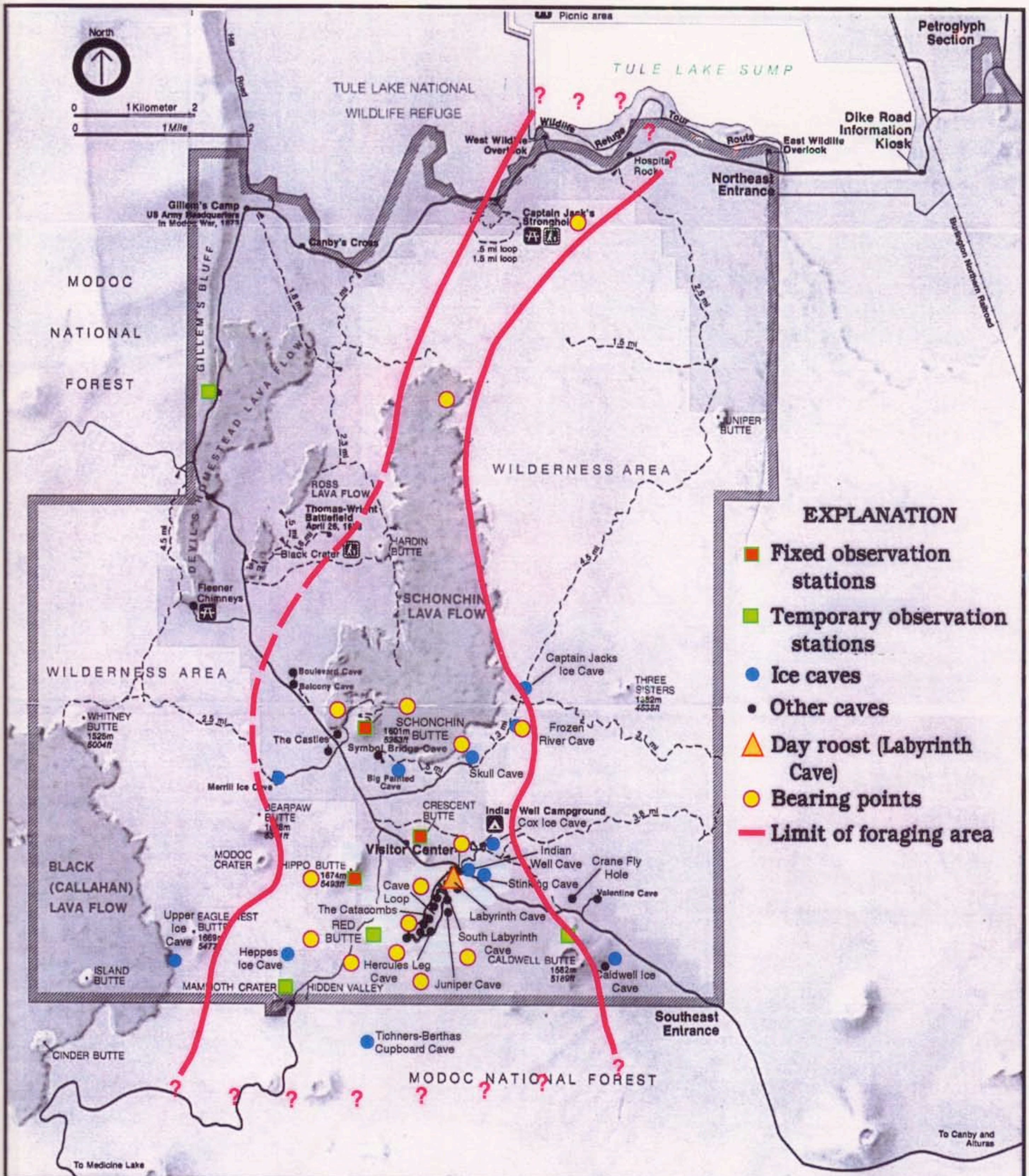


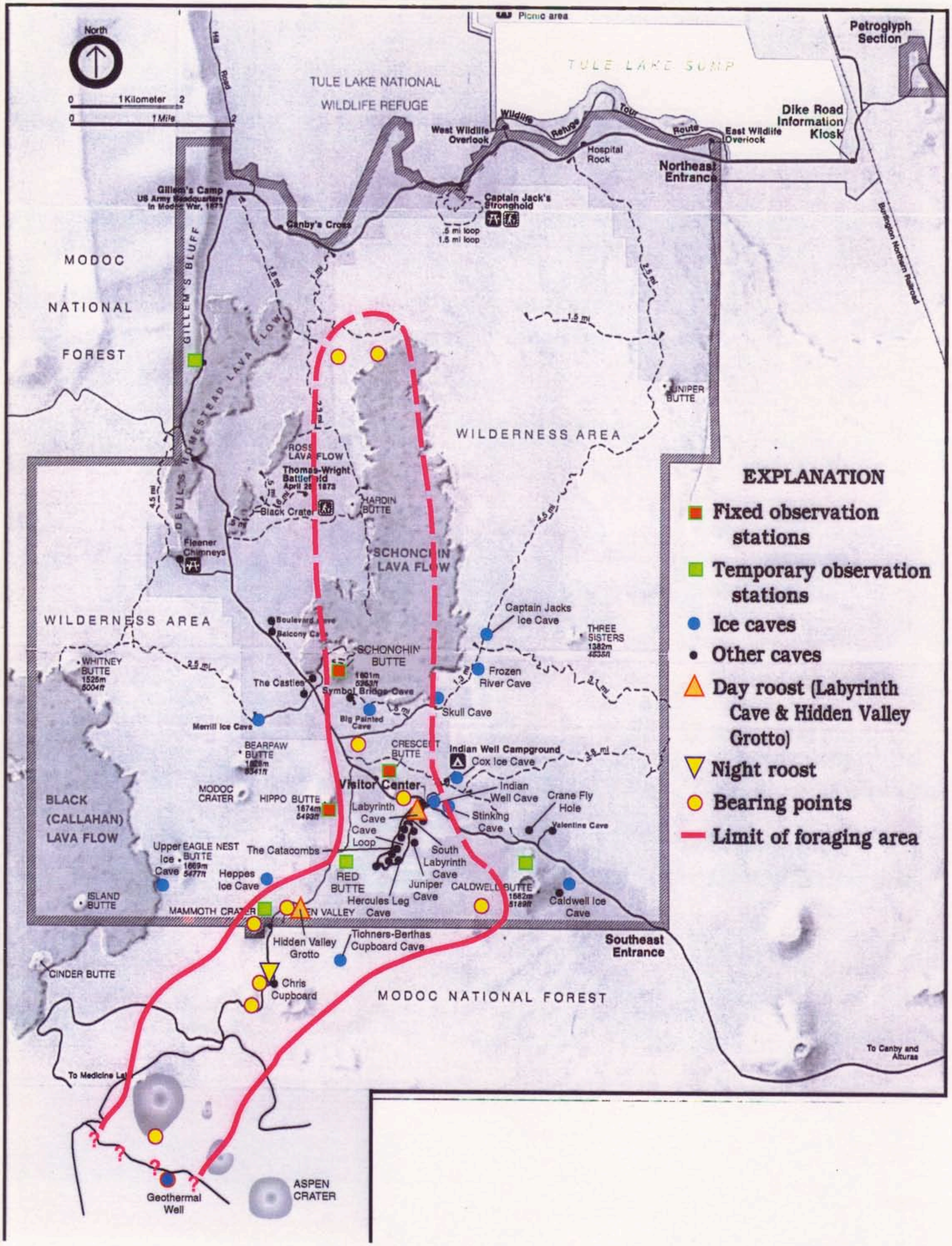
North
0 1 Kilometer 2
0 1 Mile 2
Picnic area
Petroglyph Section
TULE LAKE SUMP
TULE LAKE NATIONAL WILDLIFE REFUGE
Wildlife Refuge Tour Route
West Wildlife Overlook
East Wildlife Overlook
Dike Road Information Kiosk
Hospital Rock
Northeast Entrance
Gillem's Camp
Canby's Cross
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
MODOC NATIONAL FOREST
GILLEM'S BLUFF
HOMESTEAD LAVA FLOW
Hill Road
Burlington Northern Railroad
JUNIPER BUTTE
WILDERNESS AREA
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
Black Crater
HARDIN BUTTE
DEVILS HOMESTEAD
Fleener Chimneys
SCHONCHIN LAVA FLOW
Captain Jacks Ice Cave
THREE SISTERS
Boulevard Cave
Balcony Cave
SCHONCHIN BUTTE
WHITNEY BUTTE
The Castle
Symbol Bridge Cave
Frozen River Cave
Skull Cave
Big Painted Cave
Merrill Ice Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
Cox Ice Cave
Craig Cave
MODOC CRATER
HIPPO BUTTE
Visitor Center
Cave Loop
Indian Well Cave
Crane Fly Hole
Stinking Cave
Valentine Cave
BLACK (CALLAHAN) LAVA FLOW
The Catacombs
Labyrinth Cave
South Labyrinth Cave
Upper Ice Cave
EAGLE NEST BUTTE
Heppes Ice Cave
RED BUTTE
CALDWELL BUTTE
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Hercules Leg Cave
Juniper Cave
Caldwell Ice Cave
Southeast Entrance
Tichners-Berthas Cupboard Cave
CINDER BUTTE
MODOC NATIONAL FOREST
To Medicine Lake
To Canby and Alturas
EXPLANATION
Fixed observation stations
Temporary observation stations
Ice caves
Other caves
Day roost (Labyrinth Cave)
Night roost of uncertain location near Capt. Jacks Ice Cave
Bearing points
Limit of foraging area

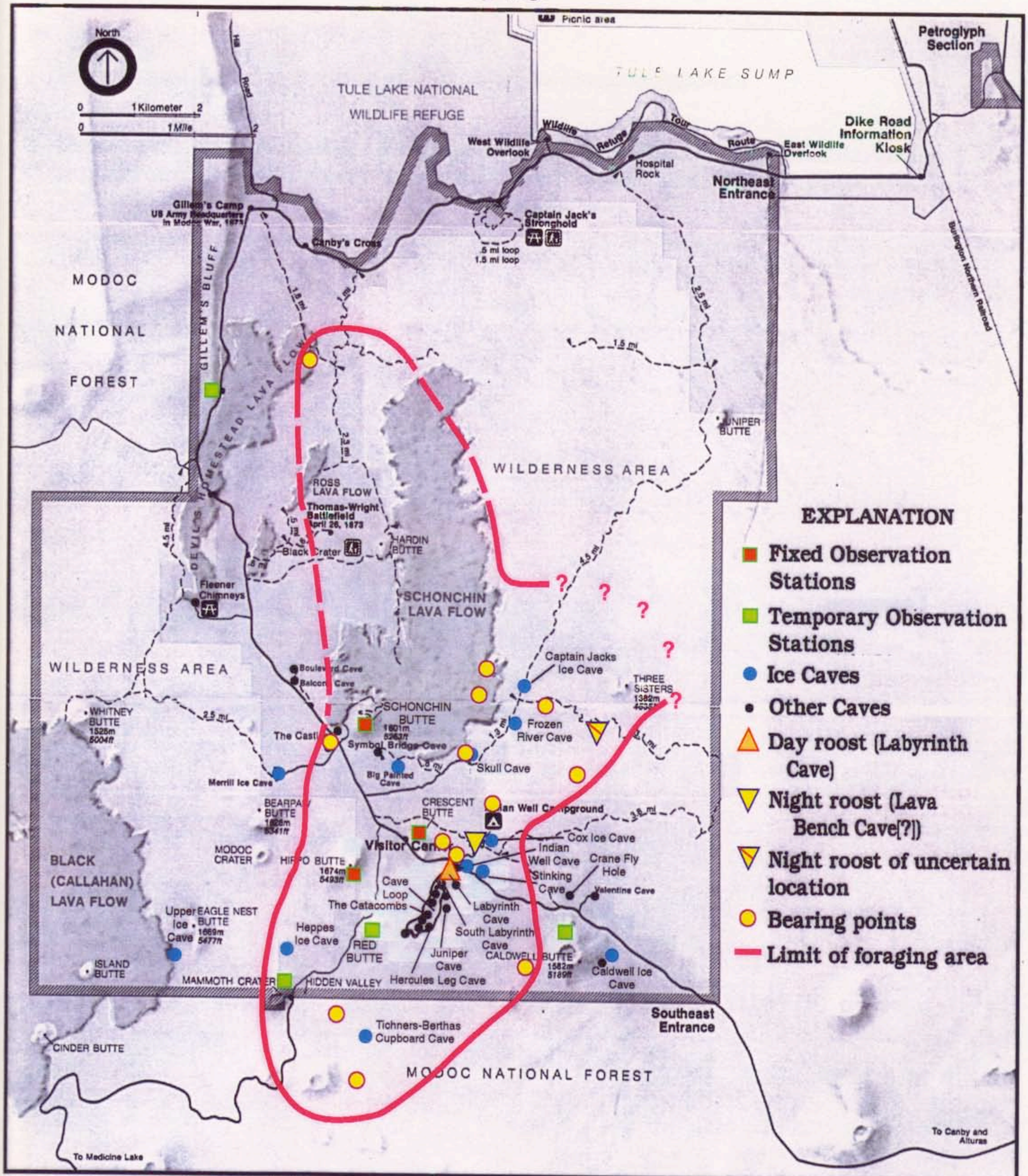


Picnic area
Petroglyph Section
TULE LAKE SUMP
TULE LAKE NATIONAL WILDLIFE REFUGE
North
0 1 Kilometer 2
0 1 Mile 2
Hill Road
West Wildlife Overlook
Wildlife Refuge Tour Route
East Wildlife Overlook
Dike Road Information Kiosk
Hospital Rock
Northeast Entrance
Gillem's Camp
Captain Jack's Stronghold
Canby's Cross
.5 mi loop
1.5 mi loop
Burlington Northern Railroad
MODOC
NATIONAL
FOREST
GILLEM'S BLUFF
HOMESTEAD LAVA FLOW
1.5 mi
JUNIPER BUTTE
WILDERNESS AREA
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
HARDIN BUTTE
Black Crater
DEVIL'S
Fleener Chimneys
SCHONCHIN LAVA FLOW
Captain Jacks Ice Cave
THREE SISTERS
WILDERNESS AREA
Boulevard Cave
Balcony Cave
SCHONCHIN BUTTE
WHITNEY BUTTE 1525m 5004ft
The Castles
Symbol Bridge
Frozen River Cave
Merrill Ice Cave
Big Painted Cave
Skull Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
Cox Ice Cave
MODOC CRATER
Visitor Center
Indian Well Cave
Crane Fly Hole
Valentine Cave
Stinking Cave
Cave Loop
BLACK (CALLAHAN) LAVA FLOW
The Catacombs
Labyrinth Cave
South Labyrinth Cave
EAGLE NEST BUTTE
RED BUTTE
Heppes Ice Cave
Upper Ice Cave
Juniper Cave
CALDWELL BUTTE
Caldwell Ice Cave
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Hercules Leg Cave
Southeast Entrance
Tichners-Berthas Cupboard Cave
CINDER BUTTE
MODOC NATIONAL FOREST
To Canby and Alturas
To Medicine Lake
EXPLANATION
Fixed observation stations
Temporary observation stations
Ice caves
Other caves
Day roost (Labyrinth Cave)
Bearing points
Limit of foraging area

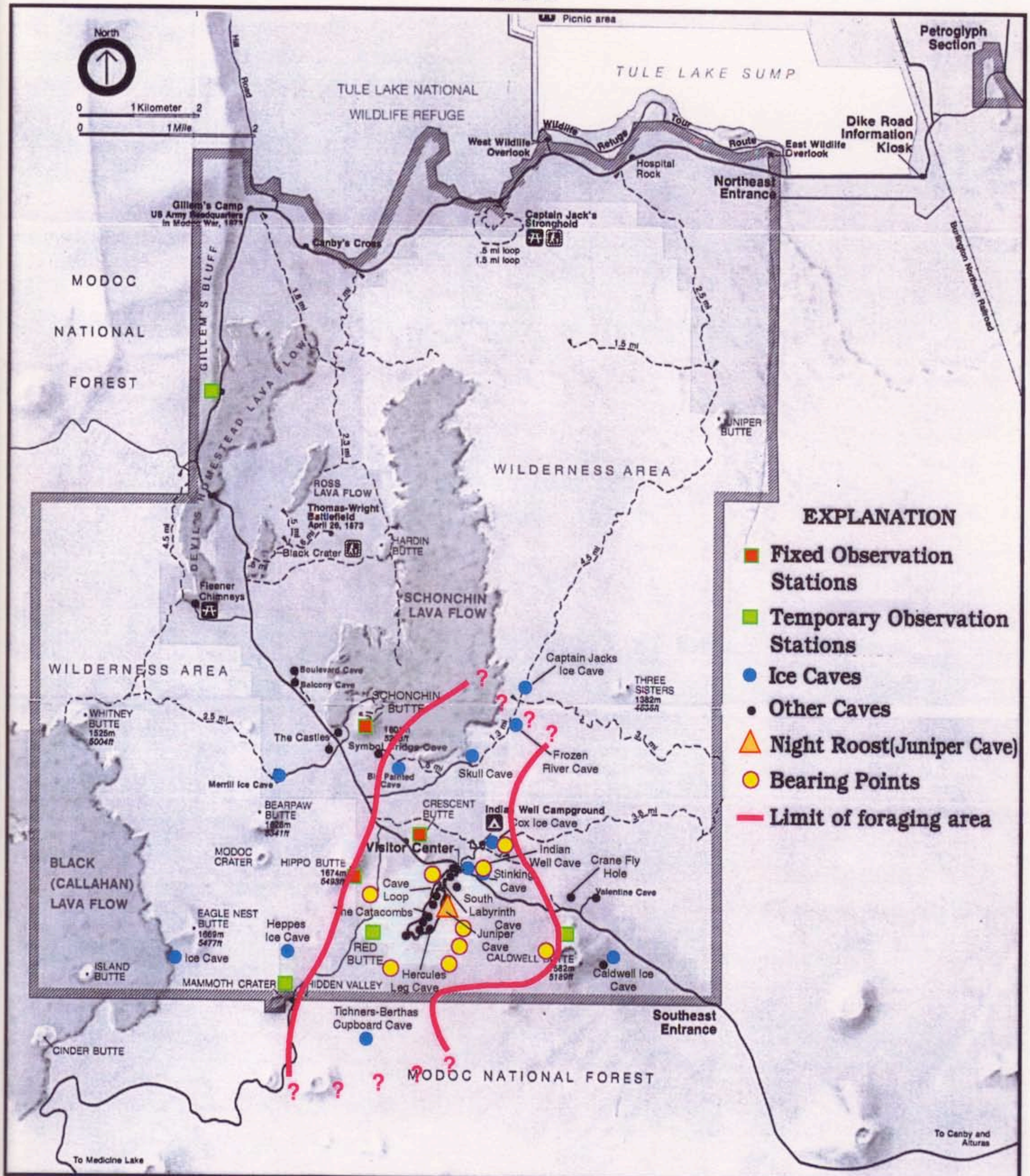

North
0 1 Kilometer 2
0 1 Mile 2
Picnic area
TULE LAKE NATIONAL WILDLIFE REFUGE
Petroglyph Section
Dike Road Information Kiosk
West Wildlife Overlook
Wildlife Refuge Tour Route
East Wildlife Overlook
Hospital Rock
Northeast Entrance
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
Canby's Cross
Burlington Northern Railroad
MODOC NATIONAL FOREST
GILLEM'S BLUFF
HOMESTEAD LAVA FLOW
JUNIPER BUTTE
WILDERNESS AREA
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
Black Crater
HARDIN BUTTE
DEVIL'S HOMESTEAD
Fleener Chimneys
SCHONCHIN LAVA FLOW
WILDERNESS AREA
Boulevard Cave
Balcony Cave
SCHONCHIN BUTTE
Captain Jacks Ice Cave
THREE SISTERS
WHITNEY BUTTE
The Castles
Symbol Bridge Cave
Frozen River Cave
Skull Cave
Big Painted Cave
Merrill Ice Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
Cox Ice Cave
Visitor Center
Indian Well Cave
Crane Fly Hole
Stinking Cave
Valentine Cave
MODOC CRATER
HIPPO BUTTE
Cave Loop
BLACK (CALLAHAN) LAVA FLOW
The Catacombs
Labyrinth Cave
South Labyrinth Cave
Upper Ice Cave
EAGLE NEST BUTTE
Heppes Ice Cave
RED BUTTE
Hercules Leg Cave
CALDWELL BUTTE
Caldwell Ice Cave
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Juniper Cave
Southeast Entrance
CINDER BUTTE
Tichners-Berthas Cupboard Cave
MODOC NATIONAL FOREST
To Canby and Alturas
To Medicine Lake
EXPLANATION
Fixed observation stations
Temporary observation stations
Ice caves
Other caves
Day roost (Labyrinth Cave)
Night roost (Crane Fly Hole)
Bearing points
Limit of foraging area

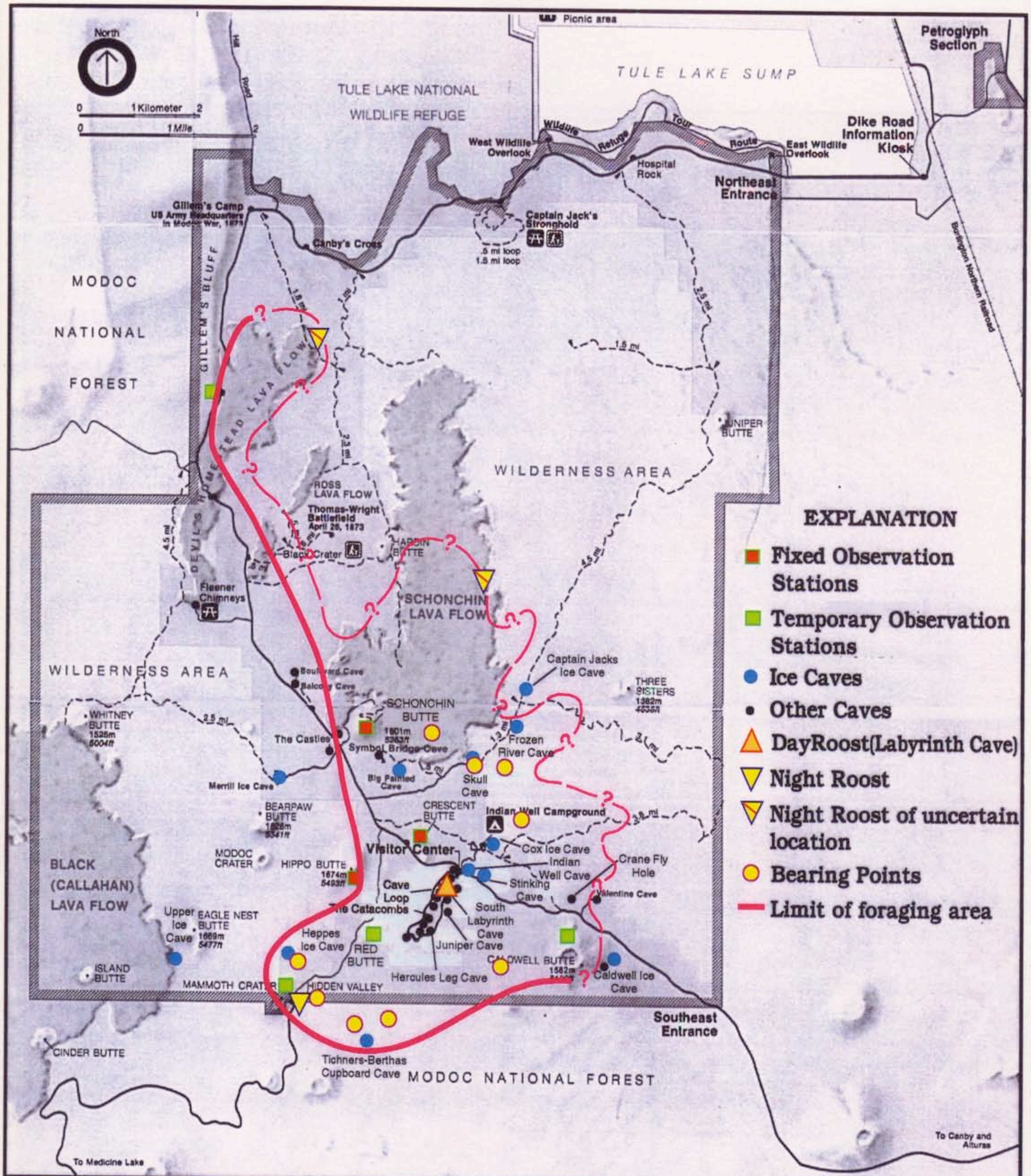

North
0 1 Kilometer 2
0 1 Mile 2
TULE LAKE NATIONAL WILDLIFE REFUGE
TULE LAKE SUMP
Picnic area
Petroglyph Section
Dike Road Information Kiosk
West Wildlife Overlook
East Wildlife Overlook
Wildlife Refuge Tour Route
Hospital Rock
Northeast Entrance
Gillem's Camp
Canby's Cross
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
Burlington Northern Railroad
MODOC NATIONAL FOREST
GILLEM'S BLUFF
HOMESTEAD LAVA FLOW
JUNIPER BUTTE
WILDERNESS AREA
ROSS LAVA FLOW
Thomas-Wright Battlefield
HARDIN BUTTE
Black Crater
DEVIL'S
Fleener Chimneys
SCHONCHIN LAVA FLOW
Boulevard Cave
Balcony Cave
Captain Jacks Ice Cave
THREE SISTERS
WHITNEY BUTTE
The Castles
SCHONCHIN BUTTE
Symbol Bridge Cave
Frozen River Cave
Skull Cave
Merrill Ice Cave
Big Painted Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
Cox Ice Cave
Visitor Center
Indian Well Cave
Crane Fly Hole
MODOC CRATER
HIPPO BUTTE
Stinking Cave
Valentine Cave
BLACK (CALLAHAN) LAVA FLOW
Cave Loop
The Catacombs
Labyrinth Cave
Upper Ice Cave
EAGLE NEST BUTTE
RED BUTTE
South Labyrinth Cave
Heppes Ice Cave
Hercules Leg Cave
CALDWELL BUTTE
Caldwell Ice Cave
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Juniper Cave
Southeast Entrance
Tichners-Berthas Cupboard Cave
CINDER BUTTE
MODOC NATIONAL FOREST
To Medicine Lake
To Canby and Alturas
EXPLANATION
Fixed observation stations
Temporary observation stations
Ice caves
Other caves
Day roost (Labyrinth Cave)
Bearing points
Limit of foraging area

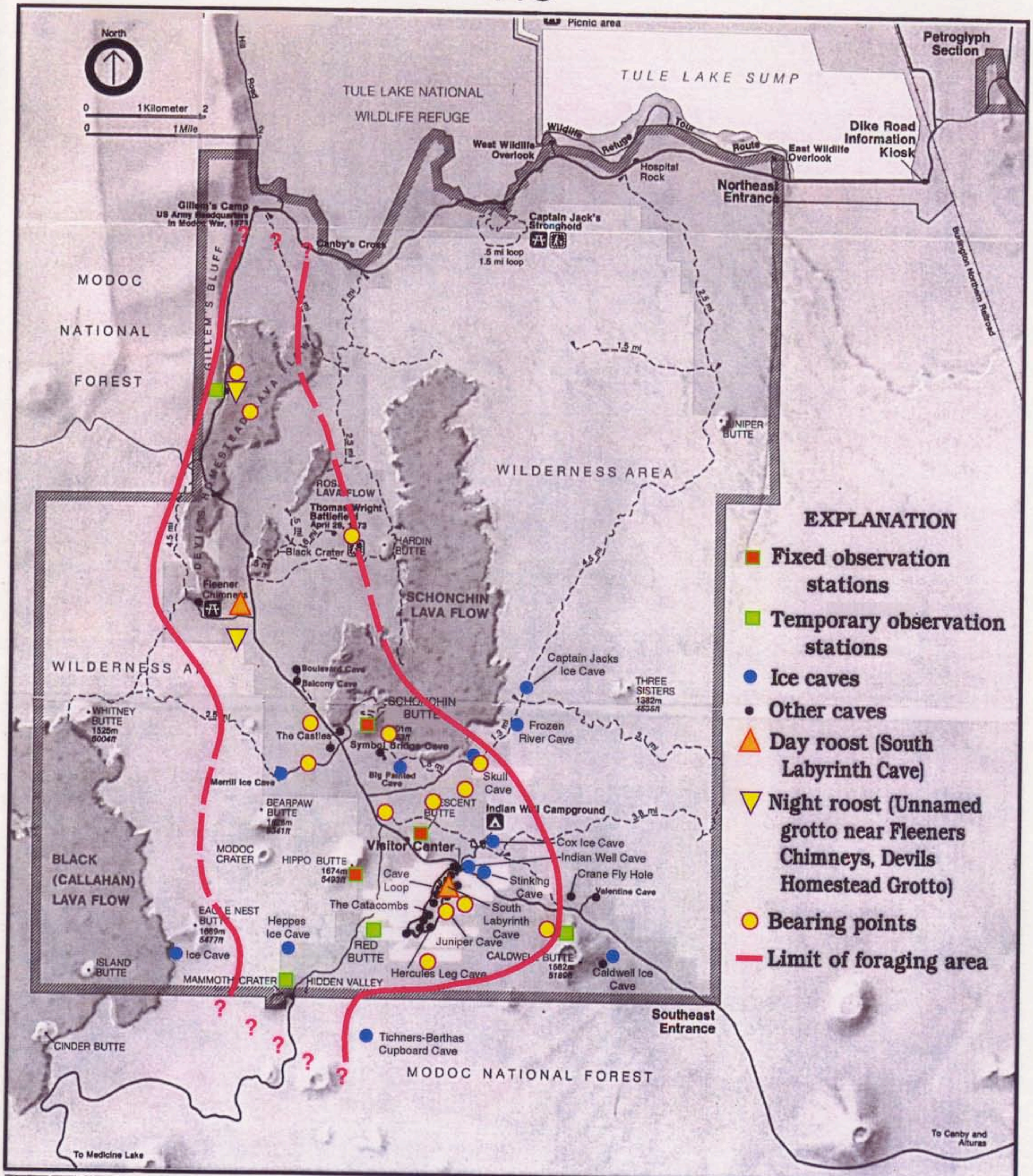

North
0 1 Kilometer 2
0 1 Mile 2
Picnic area
Petroglyph Section
TULE LAKE SUMP
TULE LAKE NATIONAL WILDLIFE REFUGE
Hill Road
West Wildlife Overlook
Wildlife Refuge Tour Route
East Wildlife Overlook
Dike Road Information Kiosk
Hospital Rock
Northeast Entrance
Gillem's Camp
Canby's Cross
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
Burlington Northern Railroad
MODOC NATIONAL FOREST
GILLEM'S BLUFF
HOMESTEAD LAVA FLOW
JUNIPER BUTTE
WILDERNESS AREA
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
HARDIN BUTTE
Black Crater
DEVIL'S HOMESTEAD
Fleener Chimneys
SCHONCHIN LAVA FLOW
WILDERNESS AREA
Boulevard Cave
Balcony Cave
Captain Jacks Ice Cave
THREE SISTERS 1382m 4535ft
WHITNEY BUTTE 1525m 5004ft
SCHONCHIN BUTTE 1601m 5253ft
Frozen River Cave
The Castles
Symbol Bridge Cave
Skull Cave
Merrill Ice Cave
Big Painted Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
Cox Ice Cave
MODOC CRATER
HIPPO BUTTE 1674m 5493ft
Visitor Center
Labyrinth Cave
Indian Well Cave
Crane Fly Hole
Stinking Cave
Valentine Cave
BLACK (CALLAHAN) LAVA FLOW
Cave Loop
South Labyrinth Cave
Upper Ice Cave
EAGLE NEST BUTTE 1669m 5477ft
The Catacombs
Heppes Ice Cave
RED BUTTE
Juniper Cave
Hercules Leg Cave
CALDWELL BUTTE 1582m 5189ft
Caldwell Ice Cave
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Hidden Valley Grotto
Tichners-Berthas Cupboard Cave
Southeast Entrance
CINDER BUTTE
Chris Cupboard
MODOC NATIONAL FOREST
To Canby and Alturas
To Medicine Lake
Geothermal Well
ASPEN CRATER
EXPLANATION
Fixed observation stations
Temporary observation stations
Ice caves
Other caves
Day roost (Labyrinth Cave & Hidden Valley Grotto)
Night roost
Bearing points
Limit of foraging area


North
0 1 Kilometer 2
0 1 Mile 2
Picnic area
TULE LAKE SUMP
TULE LAKE NATIONAL
WILDLIFE REFUGE
Petroglyph
Section
Dike Road
Information
Kiosk
West Wildlife
Overlook
Wildlife Refuge Tour Route
East Wildlife
Overlook
Hospital
Rock
Northeast
Entrance
Captain Jack's
Stronghold
.5 mi loop
1.5 mi loop
Canby's Cross
Burlington Northern Railroad
MODOC
NATIONAL
FOREST
GILLEM'S BLUFF
HOMESTEAD LAVA FLOW
DEVIL'S
JUNIPER
BUTTE
WILDERNESS AREA
ROSS
LAVA FLOW
Thomas-Wright
Battlefield
April 26, 1873
HARDIN
BUTTE
Black Crater
SCHONCHIN
LAVA FLOW
Fleener
Chimneys
WILDERNESS AREA
Boulevard Cave
Balcony Cave
Captain Jacks
Ice Cave
THREE
SISTERS
WHITNEY
BUTTE
1525m
5004ft
SCHONCHIN
BUTTE
1601m
5253ft
Frozen
River Cave
The Castle
Symbol Bridge Cave
Big Painted
Cave
Skull Cave
Merrill Ice Cave
BEARPAW
BUTTE
CRESCENT
BUTTE
Indian Well Campground
Cox Ice Cave
Visitor Center
Indian
Well Cave
Crane Fly
Hole
Stinking
Cave
Valentine Cave
BLACK
(CALLAHAN)
LAVA FLOW
MODOC
CRATER
HIPPO BUTTE
1674m
5493ft
Cave
Loop
The Catacombs
Labyrinth
Cave
South Labyrinth
Cave
Upper
Ice
Cave
EAGLE NEST
BUTTE
1669m
5477ft
Heppes
Ice Cave
RED
BUTTE
Juniper
Cave
CALDWELL BUTTE
1582m
5189ft
Caldwell Ice
Cave
ISLAND
BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Hercules Leg Cave
Southeast
Entrance
Tichners-Berthas
Cupboard Cave
CINDER BUTTE
MODOC NATIONAL FOREST
To Medicine Lake
To Canby and
Alturas
EXPLANATION
Fixed Observation
Stations
Temporary Observation
Stations
Ice Caves
Other Caves
Day roost (Labyrinth
Cave)
Night roost (Lava
Bench Cave[?])
Night roost of uncertain
location
Bearing points
Limit of foraging area

Figs. 19-21. These maps show the roosting and foraging areas for radiotagged nulliparous female *C. townsendii* at Lava Beds National Monument (Bats 282, 349, and 413).


North
0 1 Kilometer 2
0 1 Mile 2
Picnic area
Petroglyph Section
TULE LAKE SUMP
TULE LAKE NATIONAL WILDLIFE REFUGE
Wildlife Refuge Tour Route
West Wildlife Overlook
East Wildlife Overlook
Dike Road Information Kiosk
Hospital Rock
Northeast Entrance
Gillem's Camp
Canby's Cross
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
Burlington Northern Railroad
MODOC NATIONAL FOREST
GILLEM'S BLUFF
HOMESTEAD LAVA FLOW
Hill Road
WILDERNESS AREA
JUNIPER BUTTE
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
Black Crater
HARDIN BUTTE
SCHONCHIN LAVA FLOW
DEVIL'S
Fleener Chimneys
Boulevard Cave
Balcony Cave
SCHONCHIN BUTTE
The Castles
Symbol Bridge Cave
Big Painted Cave
Skull Cave
Captain Jacks Ice Cave
Frozen River Cave
THREE SISTERS 1382m 4535ft
WHITNEY BUTTE 1525m 5004ft
Merrill Ice Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
Cox Ice Cave
Visitor Center
Indian Well Cave
Crane Fly Hole
Stinking Cave
Valentine Cave
MODOC CRATER
HIPPO BUTTE
Cave Loop
South Labyrinth Cave
The Catacombs
Juniper Cave
BLACK (CALLAHAN) LAVA FLOW
EAGLE NEST BUTTE 1669m 5477ft
Heppes Ice Cave
Ice Cave
RED BUTTE
Hercules Leg Cave
CALDWELL BUTTE
Caldwell Ice Cave
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Tichners-Berthas Cupboard Cave
Southeast Entrance
CINDER BUTTE
MODOC NATIONAL FOREST
To Medicine Lake
To Canby and Alturas
EXPLANATION
Fixed Observation Stations
Temporary Observation Stations
Ice Caves
Other Caves
Night Roost(Juniper Cave)
Bearing Points
Limit of foraging area


EXPLANATION
Fixed Observation Stations
Temporary Observation Stations
Ice Caves
Other Caves
DayRoost(Labyrinth Cave)
Night Roost
Night Roost of uncertain location
Bearing Points
Limit of foraging area
TULE LAKE NATIONAL WILDLIFE REFUGE
TULE LAKE SUMP
MODOC NATIONAL FOREST
WILDERNESS AREA
SCHONCHIN LAVA FLOW
BLACK (CALLAHAN) LAVA FLOW
Visitor Center
Petroglyph Section
Dike Road Information Kiosk
Northeast Entrance
Southeast Entrance
Captain Jack's Stronghold
Captain Jacks Ice Cave
Frozen River Cave
Skull Cave
Indian Well Campground
Cox Ice Cave
Indian Well Cave
Stinking Cave
Crane Fly Hole
Valentine Cave
South Labyrinth Cave
Juniper Cave
Hercules Leg Cave
The Catacombs
Heppes Ice Cave
Caldwell Ice Cave
Tichners-Berthas Cupboard Cave
Merrill Ice Cave
The Castles
Symbol Bridge Cave
Upper Ice Cave
To Medicine Lake
To Canby and Alturas


North
0 1 Kilometer 2
0 1 Mile
TULE LAKE NATIONAL WILDLIFE REFUGE
TULE LAKE SUMP
Picnic area
Petroglyph Section
Dike Road Information Kiosk
West Wildlife Overlook
East Wildlife Overlook
Wildlife Refuge Tour Route
Hospital Rock
Northeast Entrance
Gillem's Camp
Canby's Cross
Captain Jack's Stronghold
.5 mi loop
1.5 mi loop
MODOC NATIONAL FOREST
GILLEM'S BLUFF
DEVILS HOMESTEAD LAVA FLOW
WILDERNESS AREA
JUNIPER BUTTE
Burlington Northern Railroad
ROSS LAVA FLOW
Thomas-Wright Battlefield April 26, 1873
Black Crater
HARDIN BUTTE
SCHONCHIN LAVA FLOW
Fleener Chimneys
Boulevard Cave
Balcony Cave
SCHONCHIN BUTTE
Captain Jacks Ice Cave
THREE SISTERS 1382m 4535ft
Frozen River Cave
WHITNEY BUTTE 1525m 5004ft
The Castles
Symbol Bridge Cave
Big Painted Cave
Skull Cave
Merrill Ice Cave
BEARPAW BUTTE
CRESCENT BUTTE
Indian Well Campground
Visitor Center
Cox Ice Cave
Indian Well Cave
MODOC CRATER
HIPPO BUTTE 1674m 5493ft
Cave Loop
Stinking Cave
Crane Fly Hole
Valentine Cave
BLACK (CALLAHAN) LAVA FLOW
The Catacombs
South Labyrinth Cave
EAGLE NEST BUTTE 1669m 5477ft
Heppes Ice Cave
RED BUTTE
Juniper Cave
CALDWELL BUTTE 1582m 5189ft
Caldwell Ice Cave
Ice Cave
ISLAND BUTTE
MAMMOTH CRATER
HIDDEN VALLEY
Hercules Leg Cave
Southeast Entrance
CINDER BUTTE
Tichners-Berthas Cupboard Cave
MODOC NATIONAL FOREST
To Medicine Lake
To Canby and Alturas
EXPLANATION
Fixed observation stations
Temporary observation stations
Ice caves
Other caves
Day roost (South Labyrinth Cave)
Night roost (Unnamed grotto near Fleeners Chimneys, Devils Homestead Grotto)
Bearing points
Limit of foraging area