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Foraging Behavior of Townsend's Big-eared Bats (*Plecotus townsendii*) on Santa Cruz Island

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Abstract. A colony of Townsend's big-eared bats (*Plecotus townsendii*) roosts in the historic adobe ranch house at Scorpion Anchorage. A radio-telemetry study conducted in August 1992 showed that the bats did not forage among the lush nonnative vegetation near their day roost, but traveled up to 5 km to hunt for moths and other insects among the native oak and ironwood forest on north-facing slopes between 150 and 500 m above sea level. Depending on the weather, the bats foraged for about 3 hr after dark and then night-roosted in shallow caves nearby. At dawn, after another brief foraging period, the bats returned to the ranch building. The availability of large cave-like buildings altered the roosting behavior of Townsend's big-eared bats on Santa Cruz Island. However, they still prefer to forage among the native forests.

Keywords: Santa Cruz Island; bats; Townsend's big-eared bat; *Plecotus townsendii*; foraging behavior.

Introduction

Bats comprise more than half of the native mammalian species present on the California Channel Islands (Brown 1980). Santa Cruz Island, the largest and most diverse of the islands, has 11 of the 12 bat species recorded to date on the Channel Islands (Table 1). Since the 1978 Symposium Proceedings, a male fringed myotis (*Myotis thysanodes*) was captured over the stream near the University of California Research Station on 22 July 1988. The twelfth species, the western mastiff bat (*Eumops perotis*), was discovered foraging over the east end of Santa Cruz Island when its characteristic echolocation pulses were detected on 6 August 1992. As determined by the presence of lactating females, only 3 bat species apparently breed on the island: *Myotis californicus*, *Antrozous pallidus* and *Plecotus townsendii*. Only males of the other species have been captured.

When *Plecotus* was first discovered roosting in the attic of the historic 2-story ranch house at Prisoners Harbor in August 1939, the colony was estimated by von Bloeker to number "well over 300" (von Bloeker 1967). Von Bloeker and his colleagues took 111 specimens, in a ratio of 3.5 females to males, indicating a maternity colony. In September 1948, Pearson and Pitelka collected more specimens for the Museum of Vertebrate Zoology from a colony of approximately 200 bats. They also found 2 males roosting in a building at Christi Ranch. In 1964, collectors from the University of California at Santa Barbara brought the total number of *Plecotus* specimens taken from Prisoners Harbor to 246. This was about the time that the old ranch house was removed (M. Daily 1994, pers. comm.) In 1974, I did observe 4 *Plecotus* roosting at the roof peak of the brick building or magazine at Prisoners Harbor, and mist-netted a male over the stream in Canada del Medio. Despite extensive searching over the next 14 yr, no other *Plecotus* were seen until 2 lactating females and a male were mist-netted over the stream at the mouth of Canada del Medio in July 1988. In 1991, I became aware of a colony of *Plecotus* roosting in the old adobe building at Scorpion Anchorage (T. Green 1991, pers. comm.). This roost was unavailable to the bats prior to 1984 since the building had been closed (D. Owens 1992, pers. comm.). The colony currently at

Table 1. Bats of Santa Cruz Island.

Antrozous pallidus	Pallid bat
Myotis thysanodes	Fringed myotis
Myotis evotis	Big-eared myotis
Myotis californicus	California myotis
Eptesicus fuscus	Big brown bat
Plecotus townsendii	Townsend's big-eared bat
Lasiurus cinereus	Hoary bat
Lasiurus blossevillii	Red bat
Lasionycteris noctivagans	Silver-haired bat
Tadarida brasiliensis	Mexican free-tailed bat
Eumops perotis	Western mastiff bat

Scorpion may have migrated from Prisoners Harbor since 1984, or another population of *Plecotus* may still exist near Prisoners Harbor. Banding and radio-tracking studies of *Plecotus* in other locations have documented movements of up to 43 km (Pearson et al. 1952; Humphrey and Kunz 1976; Pierson and Rainey 1992). Several natural caves occur in the rock formations around Santa Cruz Island that were probably the traditional roosts prior to building construction.

Plecotus is a cave-roosting species that is very sensitive to human disturbance. If hibernating bats are aroused in the winter, they may deplete fat reserves and perish before spring. Disturbance of maternity colonies can cause desertion of the roost. In one case, the mothers were scared away, leaving the flightless young to starve (1988, pers. obs.). Cave exploration and vandalism by humans have driven bats to less-frequented cave-like roosts in old buildings and mines. Pierson and Rainey (1992) have documented more than a 50% decline in California *Plecotus* populations. A low tolerance for disturbance is a primary factor for the species designation as a Category 2 Candidate for Threatened or Endangered Status under the Federal Endangered Species Act. The roost at Scorpion Anchorage is vulnerable to disturbance and requires special protection.

Methods

Following an initial visit to the *Plecotus* colony at Scorpion Anchorage in July 1991, a radio-tracking study to determine foraging habitat was conducted from 31 July–7 August 1992. This was at the end of the maternity season when all the young of the year were volant and foraging on their own. On the evening of 31 July, prior to any disturbance of the roost, the bats were counted with the aid of night vision equipment and finger tallies as they left the roost at dusk. A mist net was spread near the roost entrance and the 6 heaviest bats captured (3 males and 3 females weighing 8.1 to 9.7 grams) had transmitters affixed to their backs with skin bond cement. The Holohil BD 2B transmitters weighed 0.7 grams and were tuned to individual frequencies in the 151 MHz band. The colored plastic bands placed on the forearms of the telemetered bats gave them a code name (i.e., blue, red, violet, green, yellow, and pink). The bats were held for 3 hr and then released in the roost. No tracking was attempted the first night.

For the next 5 nights, a team of 6 researchers followed the bats' movements from dusk until dawn. With 3 AVM receivers available, 2 pairs of researchers were stationed in fixed locations on high ridges, while another pair moved to locate the bats and triangulate the positions. When a signal was received in the field, researchers recorded their location, the time, bat color code name and the compass heading to maximum signal strength. Protocol was to tune in all frequencies at least once each 15 min all night long, and record either the presence or absence of the bats' signals. The transmitters were of such low power that all signals heard were assumed to be in line of sight with the receiver, and not over hills and ridges. Communications were usually maintained via portable walkie-talkies. On the seventh day of the study, those transmitters that had not already fallen off were removed from the bats after capturing them in the day roost.

The radio-telemetry data were entered into a custom-designed computer program written in Turbo Pascal for a personal computer. A digital elevation database for the study area was incorporated into the program to compute the nearest terrain obstruction to a line-of-sight compass heading. When the signal could only be detected by 1 receiver, the terrain model database was used to determine portions along the line-of-position that were in a terrain shadow to the other receiver positions. In this manner even the lack of signal constituted useful data in determining transmitter location. The computer program provided a map of the study area, onto which other information such as receiver positions, contour lines, drainages and vegetation types could be incorporated. The UTM grid could also be superimposed to aid in map orientation.

Results

The count of the outflight revealed 130 *Plecotus townsendii* using the west end or "bakery" of the 2-story ranch building. Guano and a mummified *Plecotus* were also found in the attic of the adjacent 1-story wood ranch house, although no live bats were present. The morning after the transmitters were attached, 5 of the 6 telemetered bats were missing from the roost, although a count of the evening outflight revealed that the rest of the bats (~145) were still present. A search of the surrounding hills failed to locate the signals of the missing bats. However, by the next morning, all of the bats were back in the "bakery." With the exception of 2 different bats on 2 separate nights, all of the bats returned to the bakery each dawn during the study. Those 2 bats were discovered in shallow rock caves within 3 km of the ranch. During the study, 3 transmitters fell off the bats—1 was located in the roost, 1 in a rock shelter about 3 km from the roost and another under an oak tree about 4 km (direct distance) away. The remaining 3 transmitters were removed from the bats after capturing them in the day roost on day 7. This disturbance to the whole colony caused the bats to temporarily desert the roost. The next day only 10 bats remained in the bakery, but 40 bats had moved into a shallow cave nearby. By the following evening, about 40 bats had returned to the bakery (J. Morgando 1992, pers. comm.).

The 6 bats with transmitters emerged between 2040 and 2050 hr and flew directly to foraging areas, heading west via the Scorpion drainage. By comparing the time

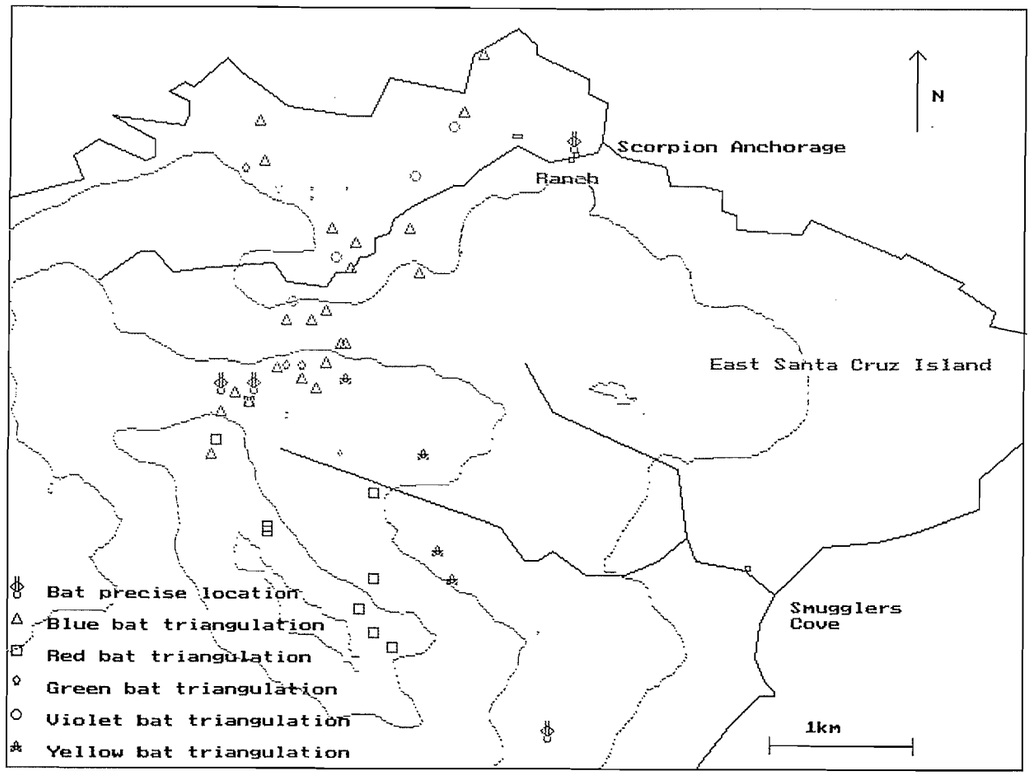

Figure 1. Foraging areas of individual *Plecotus townsendii* on East Santa Cruz Island as determined by radio-telemetry. The computer-generated map identifies the coastline and major drainages as bold lines. The elevational contour lines are fainter.

elapsed between changing triangulated positions, we determined that they flew at speeds of 30 km/hr. On 1 evening, researchers stationed at the water trough, recorded much bat activity there just after emergence and again in the half hour before dawn. Several *Plecotus* were captured in a mist net spread over the trough, including 1 of the bats with a transmitter.

Over the 5 nights, the bats were tracked for more than 45 hours. Figure 1 shows the triangulated positions of the foraging bats as well as the precise locations where bats were roosting or transmitters were recovered. Nearly continuous data were obtained from 2 bats that foraged along the north slope of the canyon 3 km west of the ranch. Three of the bats utilized areas southwest of the ranch, and their signals were received intermittently. The signal of the remaining bat was only received as it flew to and from the roost, and it is believed to have foraged more than 4 km to the south, out of range of the receivers. There was no apparent correlation between the sex of the bats and the foraging areas or distances travelled. The foraging areas where bats were detected were usually along north-facing slopes in the native vegetation (*Quercus dumosa* and *agrifolia*, *Lyonothamnus floribundus* and *Prunus ilicifolia*), 160 to 500 m above sea level. They did not appear to feed among the nonnative vegetation near the ranch. The bats would forage for approximately 3 hr after dark, and then night roost near their foraging areas. The canyons contained shallow rock caves. Frequently, a dense fog covered the higher elevations around midnight, making visual navigation for researchers (and probably echolocation for bats) difficult. During those periods, the bats remained stationary in night roosts. At dawn, the bats returned to the roost, after a short foraging period and a drink at the trough.

Discussion

The construction of buildings on Santa Cruz Island influenced the roosting behavior of some bat species. Townsend's big-eared bat traditionally roosted in caves, but now congregates in large numbers in buildings. This behavior increases their risk of disturbance by humans, since the bats roost in the open where they are visible and vulnerable. Visitors to Santa Cruz Island are attracted to

the historic structures. To prevent disturbance to the colony, human access to the bat roosting areas should be restricted. The construction of bat gates over mine entrances that allow bats to enter, but preclude people, has resulted in the increase in bat numbers in both maternity and hibernation colonies of *Plecotus* (Pierson et al. 1991; Saugey 1991; G. Fellers 1994; C. Stihler 1994, pers. comm.; P. Brown pers. obs.). A similar barrier could be installed at the entrance to the "bakery."

Pallid bats (*Antrozous pallidus*) also roost in buildings on Santa Cruz Island, but they tend to hide in crevices between the bricks and are less conspicuous and accessible. Radio-telemetry studies of *Antrozous* on the island have shown a different foraging and roosting behavior than is reported in the present paper for *Plecotus* (Brown 1978–1991, unpubl. data). Female *Antrozous* form a maternity colony in spring and summer in the cow barn at the Stanton Ranch, while males roost alone in rock crevices. Both sexes forage among oak woodlands and nonnative grasslands for large beetles and Jerusalem crickets (*Stenopelmatus fuscus*) that are captured on or near the ground. The increase of grasslands after European man developed the island may have enhanced foraging habitat for this bat species. Most individual pallid bats gather after foraging at the night roost on the second floor of the horse barn. For some males, the barn is 5 km from their foraging area and day roost, and the nightly commute is apparently for socialization.

In contrast, *Plecotus* commute several kilometers from the day roost to forage among native vegetation, and then night roost near their foraging areas. The signals of the night-roosting *Plecotus* were in different areas, signifying that they either roosted alone or in the company of non-telemetered bats. Although lush vegetation has been planted near the ranch, the bats did not feed in this area during the radio-telemetry study. Other research has shown that *Plecotus* feed primarily on moths (Dalton and Brack 1986). During some periods in summer, large numbers of moths appear near the ranch buildings, and the residents there report the area littered with moth wings in the morning (D. Owens 1992, pers. comm.). Probably these are the result of *Plecotus* opportunistically feeding closer to their roost. Studies conducted at different seasons on Santa Cruz Island could show different foraging strategies for *Plecotus*. The results of this radio-telemetry study do implicate the importance of native vegetation to this species and may have relevance to conservation and management issues in other geographic locations.

Conclusions

Plecotus townsendii on East Santa Cruz Island prefer to day roost as a large colony in a cave-like building, but use shallow rock caves for night roosting and can use them as day roosts if necessary. The construction of buildings on Santa Cruz Island has altered the bats' roosting behavior. In midsummer, *Plecotus* forage primarily among native vegetation along north-facing slopes of mountains, sometimes at distances of more than 4 km from their day roost, by-passing the lush nonnative plantings near the day roost.

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Delayed Breeding in the Santa Cruz Island Scrub Jay: Why Not Be Cooperative?

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Abstract. Passerine birds typically are reproductively competent and breed when they are 1 yr old. When suitable breeding habitat is saturated with breeding pairs, delayed reproduction and non-reproducing "floaters" can occur. In the endemic Santa Cruz Island scrub jay (*Aphelocoma coerulescens insularis*), 85% of young birds do not gain reproductive status until 3 yr of age or older. Unlike some other populations of this species, these jays do not exhibit cooperative breeding, and remain as long-term floaters until breeding status is achieved, forgoing any indirect component of inclusive fitness. The availability of marginal and undefended habitat facilitates this individualistic strategy.

Keywords: Santa Cruz Island; scrub jay; *Aphelocoma coerulescens*; *insularis*; cooperative breeding; survival; demography.

Introduction

Island populations offer unique opportunities to examine a number of evolutionary processes. Island bird populations have been previously shown to exhibit pronounced differences from their mainland counterparts in size and morphology (Murphy 1938; Grant 1965, 1967; Johnson 1972; Power 1980), reproductive behavior and demography (Blondel 1985), as well as population density and habitat utilization (MacArthur et al. 1972; Cox and Ricklefs 1977; Emlen 1979; Wright 1980; Blondel et al. 1989). Thus, study of the population biology and demography of the Santa Cruz Island scrub jay (*Aphelocoma coerulescens insularis*), a distinct population of the widespread North American scrub jay (A.O.U. 1983; Pitelka 1951), should be informative.

The Santa Cruz Island scrub jay is confined to Santa Cruz Island, the largest of the northern Channel Islands of coastal southern California (Philbrick 1967). It is the most highly differentiated element of the endemic Channel Islands avifauna, being distinctly brighter in coloration (Pitelka 1951) and larger (Pitelka 1951; Atwood 1978; Isitt 1989; pers. obs.) than adjacent mainland scrub jays. It has also been shown to be genetically distinct from other scrub jay populations (Peterson 1992).

Previous studies of the Santa Cruz Island scrub jay (Atwood 1978, 1980a, 1980b) have shown it to be sedentary, permanently territorial, monogamous and lacking the distinctive cooperative breeding system of the Florida scrub jay (*Aphelocoma coerulescens coerulescens*) (Woolfenden and Fitzpatrick 1984, 1990; Fitzpatrick and Woolfenden 1986). Annual survival of breeding adult Santa Cruz Island scrub jays is exceptionally high for a passerine bird (Atwood et al. 1990). Young birds show a delay of up to several years in the acquisition of territories and breeding status (Atwood 1980b; Atwood et al. 1990), which is not the case for mainland California scrub jays (Ritter 1972, 1983; Carmen 1988, M. J. Elpers 1993, pers. comm.) but which is typical of the cooperatively breeding Florida scrub jay (Woolfenden and Fitzpatrick 1984).

Herein we present additional data on the demography of the Santa Cruz Island scrub jay with special attention being given to the survival of pre-breeding individuals and the age of first breeding. The relation of these demographic parameters to the observed social system of the Santa Cruz Island scrub jay is also considered and comparisons made to both cooperative and non-cooperatively breeding mainland populations of scrub jays.

Methods

Santa Cruz Island, located 30 km off the coast of Santa Barbara, California, is the largest and most topographically diverse of the Channel Islands. It covers 249 km and rises to 753 m in elevation with 6 major vegetation zones (Philbrick 1967; Johnson et al. 1968; Minnich 1980). The study area, located in the island's dominant