Long Foraging Distances in Two Uncommon Bat Species (*Euderma maculatum* and *Eumops perotis*) in Northern Arizona

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Abstract. The Kaibab Plateau of north-central Arizona is a high elevation, limestone plateau on the northern edge of the Grand Canyon. We used radio telemetry to determine foraging areas for seven lactating female spotted bats (*Euderma maculatum*) and located roosts for four of these bats. We also captured greater western mastiff bats (*Eumops perotis*) and located a single roost for this species. Roosts for both spotted and mastiff bats were in xeric cliffs in or near Grand Canyon National Park (GCNP) at approximately 650 to 1040 m elevation. Distances from capture location to maternity roosts ranged from approximately 28 to 42 km. Capture sites and foraging areas were located at approximately 2600 m elevation for spotted bats and 1900 m for mastiff bats. We caught 18 bat species during mist net surveys conducted from 1994 through 1998. The high species diversity that we observed may be due to the proximity of the Kaibab Plateau to the Grand Canyon, and the great range of elevations and habitats available from the floor of GCNP (600 m elevation, desert) to the meadows (2600 m elevation, subalpine) on the Kaibab Plateau.

Key words: foraging, western mastiff bats, *Eumops perotis*, spotted bats, *Euderma maculatum*, Kaibab Plateau, Arizona, Grand Canyon National Park, surveys

INTRODUCTION

Once thought to be extremely rare, spotted bats (*Euderma maculatum*) are widely distributed throughout western North America and probably have a discontinuous, patchy distribution (Fenton et al. 1987, Nagorsen and Brigham 1993). Much of what is known of spotted bat behavior and ecology has been gained from three locations where they are relatively common: the Okanagan Valley in southern British Columbia, Canada (Leonard and Fenton 1983), Big Bend National Park in southern Texas (Easterla 1970), and Fort Pierce Wash on the Utah-Arizona border (Ruffner et al. 1979). High cliffs were nearby in all three of these locations. Radio tracking of three spotted bats in British Columbia (Wai-Ping and Fenton 1989) found that bats foraged all night and did not travel farther than 10 km from cliff day roosts. Preferred foraging habitat appears to be open areas surrounded by ponderosa pines (Woodsworth et al. 1981, Leonard and Fenton 1983, Wai-Ping and Fenton 1989).

Roost sites for greater western mastiff bats (*Eumops perotis*) were not known from the state of Arizona since the 1970s, and was not known north of the Grand Canyon until we captured eight lactating females in 1995. These captures were a range expansion for the species (Castner et al. 1996). Roost sites have been described for California (Cockrum 1960, Dalquist 1946, Howell and Little 1924), Texas (Ohlendorf 1972) and Arizona (Cox 1965). In general greater western mastiff bats live in high, dry places, and roosts are in locations that allow the bat to drop >3 m to launch into flight (Freeman 1981). In the southwestern United States, roosts are typically found in rugged rocky canyons and cliffs (Barbour and Davis 1969, Dalquest 1946). Little is known about the foraging habitat for this species. The purpose of this study was to locate day roosts and foraging areas used by spotted and mastiff bats on the North Kaibab Ranger District (NKRD) of the Kaibab National Forest, in northern Arizona.

METHODS

During July - August 1995, July 1996, July - August 1997, and August 1998 we caught bats with mist nets set across small ponds (ca. 15 to 35 m across) in subalpine meadows on the NKRD, north of Grand Canyon National Park (GCNP). Spotted bats were captured in meadows from approximately 2400 to 2650 m in elevation that were linked across the landscape to form a series of meadow systems. These meadows were surrounded by ponderosa pine (*Pinus ponderosa*) forests that included Douglas-fir (*Pseudotsuga menziezii*), white fir (*Abies concolor*), and patches of aspen (*Populus tremuloides*) Mastiff bats were captured in similar meadows from approximately 1900 to 2400 m elevation.

We attached radio transmitters to captured spotted and mastiff bats with surgical glue, and followed them to day roosts. We placed transmitters (0.68 g, BD2, Holohil Inc., Ontario, Canada) on six (1 male, 4 lactating females, 1 post lactating female) spotted bats in 1995, six (four lactating and two non-reproductive adult females) spotted bats in 1996 and seven (all lactating adult females) spotted bats in 1997. We also placed 1.28g transmitters on six (all lactating female) mastiff bats in 1995, one (non-reproductive adult female) mastiff bat in 1997, and one (lactating adult female) mastiff bat in 1998. Radio telemetry was conducted through a combination of vehicle pursuit, stationary positions, and airplane.

RESULTS

The presence of many audible (low-frequency) spotted bat echolocation calls and feeding buzzes (increased rates of echolocation calls associated with insect detection and pursuit; Griffin et al. 1960) in the meadows indicated that spotted bats were locally common and that the meadow systems were heavily used as foraging areas. Over 13 weeks, during four summers, we caught 25 spotted bats and 18 mastiff bats in 44 nights of netting, and we heard many spotted bat and mastiff bat calls. We caught other bats that also used the meadows for foraging (big free-tail, *Nyctinomops macrotis*; Mexican free-tail, *Tadarida braziliensis*; and Allen's big-eared bat, *Idionycteris phyllotis*), but spotted bat and mastiff bat calls are distinctive (Fenton et al. 1987, Cockrum 1960) and we could distinguish their calls from the others. Although we primarily netted ponds within forested habitat on the NKRD, we rarely heard and never caught spotted or mastiff bats in forested areas.

Spotted Bats

Spotted bats are rapid flyers (Woodsworth et al. 1981, Wai-Ping and Fenton 1989) and the rugged topography and few roads on the NKRD made nighttime pursuit difficult. While radio tracking from the ground, foraging bats were rarely detectable >1.5 km due to effects of forest canopy and topography. When in open country or from lookout towers, we were sometimes able to detect the bats from greater distances.

Initial attempts to detect signals from roosting bats during daylight, even from aircraft, were unsuccessful. However, by using a combination of vehicle pursuit and hilltop radiotelemetry sites, several bats were relocated sufficiently to obtain general flight directions during early morning when bats left meadows and were presumably en route to day roosts.

In July 1996, we tracked one lactating female to a day roost in a remote area of GCNP, 38 km from the capture site (Rabe et al. 1998; Table 1). We located the roost from an airplane overflight after triangulating transmitter signals from the canyon rim in early morning. The day roost was at an elevation of ca. 700 m in a south-facing limestone cliff ca. 150 m above and 200 m from the Colorado River. The roost site was located in Sonoran Desert habitat with predominantly catclaw (*Acacia greggii*) and mesquite (*Prosopis glandulosa*) vegetation.

The bat followed a predictable pattern in its foraging movements. In four sequential nights of monitoring, we first detected the signal from the canyon rim (we could detect signals near the river 8 to 15 km distant) at 2010 h to 2030 h (170 to 190 minutes after sunset) each night the bat emerged from its cliff roost. It arrived in the same meadow system each night at about 2130 h, and foraged until ca. 2400 h to 0100 h, when it night-roosted in the same patch of aspen on the south face of a small ridge, 1 km east of the meadow. Radio signals indicated no movement during this night-roosting period, but the bat did not appear torpid. The bat was easily disturbed and would fly away if approached. Each night, the bat left the night roost between 0330 h and 0350 h (103 to 83 nimutes before sunrise) and flew directly towards the cliff roost, 38.5 km away. The animal did not seem to forage after night roosting and we lost the signal over the rim of the Grand Canyon 40 to 45 minutes after departing the night roost. This resulted in a flight speed of approximately 50 km/h.

Table 1. Spotted bat capture and roost site elevations and roost-to-capture-site distances.

Year	Bat	Capture Elevation (m)	Roost Elevation (m)	Elevation Change (m)	Distance (km)
1996	102	2499	700	1799	38.7
1997	216	2536	1024	1512	42.7
1997	246	2536	ca. 1000		
1997	275	2536	1036	1500	39.4
1997	301	2597	768	1829	41.3
1997	325	2597	ca. 1000		
1997	371	2524	1134	1390	38.2
1997	406	2597			

In July 1997, we tracked four additional lactating females to four day roosts in remote areas of GCNP and Kanab Creek Wilderness on the NKRD. Distances from the capture sites ranged from 38.2 km to 42.7 km (Table 1). We located the bat roosts from airplane overflights after triangulating transmitter signals from the canyon rims in early morning. Day roosts ranged in elevation from ca. 700 m to 1080 m. One roost was approximately 850 m from the Colorado River. The three roosts located within Kanab Creek canyon were all <100 m from Kanab Creek. Roost sites were located in Sonoran Desert habitat with predominantly catclaw (*Acacia greggii*) and mesquite (*Prosopis glandulosa*) vegetation. Because these roosts were located in very rugged, isolated desert country, we visited only one roost for an exit count. The Kanab Creek roost was visited on two occasions, 18 July and 24 July 1997. The exact roost site could not be determined during exit counts; however, the general location was on a cliff face, approximately 20 m from the base of the cliff, in the top one-third of the cliff. The bat exited the roost at approximately 2015 h (ca. 30 minutes after sunset) each night and returned to roost at approximately 0420 h. Based on audible echolocation calls and radio telemetry signals, this was the only bat to exit.

In 1996 and 1997, female spotted bats averaged three hours foraging in the high elevation meadows. With extensive radio telemetry on six lactating female spotted bats in 1997, there appeared to be an overlap of foraging territories (Fig. 1). In 1997, we again noticed night roosting behavior in some of the females; however, they also appeared to arrive in the meadow systems later and leave earlier than in 1996. Because we were tracking spotted bats slightly earlier in the season from 1996, we thought that perhaps the females could not leave younger offspring for long periods of time due to feeding demands. Bats arrived in the meadow systems at approximately 2300 h and left at approximately 0200 h. Again, bats flew straight lines back to their canyon day roosts and did not appear to forage on the return trip.

Greater Western Mastiff Bats

In 1995 we captured eight greater western mastiff bats, six of which where lactating females. Since all eight females were captured relatively early in the evening (60 to 100 minutes after sunset), we speculated that a roost site was nearby. We placed transmitters (BD-2, Holohil) on the six lactating females and attempted to follow them. Mastiffs are very rapid

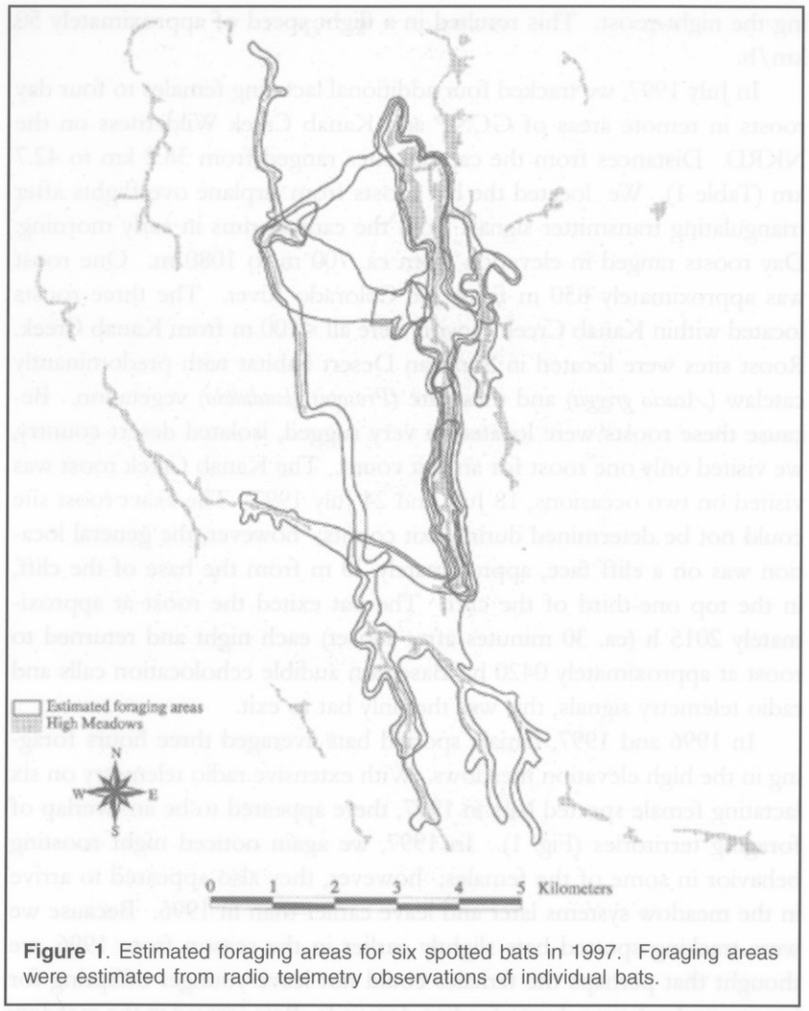

Figure 1. Estimated foraging areas for six spotted bats in 1997. Foraging areas were estimated from radio telemetry observations of individual bats.

fliers and we were able to follow them for only a short period that night. We detected only one faint signal the next day in a cliff a few miles south of the trap site, but quickly lost the signal. We detected no signals over the next few nights despite substantial effort.

In 1997 we captured several greater western mastiff bats at higher elevation meadow tanks. Because we assumed that the 1995 trap location was near the maternity roost, we waited to attach radios until we returned to that trap location. Although many mastiff bats were heard at the 1995 location at various times during the summer, we were only able

to capture one non-reproductive female in 1997. We held her until early morning (ca. 0400 h) when a plane we had arranged to be overhead arrived. Equipped with telemetry receiver and antenna, the plane was able to track her until just after sunrise, when she roosted in a tall ponderosa pine tree near the rim of the Grand Canyon, ca. 19.5 km from the trap site. Over six nights of telemetry from stationary points along the rim of the Grand Canyon, we were able to triangulate on a 20 km^2 area along the Colorado River (ca. 29 km from the trap site) where the bat appeared at ca. 2000 h and ca. 0500 h each day (Table 2). On day six, no signal was detected, and it was assumed that the bat dropped its transmitter at the roost. A plane made an overflight of the area two days later, but did not detect any radio signal.

Although we did not attempt to determine the foraging areas for the mastiff bat, it did return to the plateau and headed in the general direction of the trap site each night. Mastiff bats were also heard in several locations on the plateau in meadows, where they appeared to travel in groups. Hoffmeister (1986) suggested that these bats forage in groups, keeping contact with their roost mates.

In 1998, we again attempted to capture mastiff bats at several locations. It appeared to us that fewer feeding buzzes were detected at several locations compared to previous years. One lactating female was finally captured at the 1995 trap location and a radio transmitter attached. A general roost location was determined from three telemetry points along the rim of the Grand Canyon, very close to the 1997 location. An airplane overflight determined the exact roost location, which appeared to be near an overhang of an east-facing cliff in a side drainage approximately 1000 m from the Colorado River. The location was accessible only from the river, with no feasible overland route. We accompanied GCNP personnel to the site during a scheduled river trip on September 18, but could not determine if mastiff bats were in the area.

Distances from the capture sites to apparent roosts were approximately 28 km in 1997 and 29.1 km in 1998. The apparent day roost we

Table 2. Greater western mastiff bat capture and roost site elevations and roost-to-capture-site distances.

Year	Bat	Capture Elevation (m)	Roost Elevation (m)	Elevation Change (m)	Distance (km)
1997	015	1889	ca. 606-883		ca. 28
1998	155	1889	737	1152	28.7

located in 1998 was at 737 m elevation. The site was located in Sonoran Desert habitat, similar to the spotted bat roosts.

DISCUSSION

Female spotted and mastiff bats appear to forage long distances from their night roosts and use completely different roosting and foraging habitats. The differences between the foraging behaviors of spotted bats in British Columbia and the Kaibab Plateau may be explained by a lack of suitable high-cliff roost sites near the meadow systems on the Kaibab Plateau. In British Columbia, observed spotted bats (1) foraged in open areas 6 to 10 km from day roosts in cliffs, (2) foraged continuously while away from cliff roosts, and (3) flew at about 19 km/h while foraging (Wai-Ping and Fenton 1989). The night-roosting that we observed may be a response to the high energy demand of long distance flight. The faster flight speeds we report probably indicate that bats on the Kaibab Plateau were not foraging on their return flight and may approximate the actual flight speed capabilities of spotted bats.

The long distance traveled by spotted bats from roost to foraging habitat (77-86 km round trip) is substantially longer than previously reported distances for this species (Wai-Ping and Fenton 1989). Spotted bats have very low frequency echolocation calls that may enable them to detect insects at relatively long distances but probably limits them to resolving large (>10 mm) prey (Woodsworth et al. 1981, Leonard and Fenton 1984). Spotted bats may, therefore, prefer open foraging areas because uncluttered habitats allow detection of large prey items at relatively long distances.

Little has been described about the foraging habitat and habits of mastiff bats. Due to the timing of our first and last radio signals each day, we feel confident that the 1997 bat was roosting near the Colorado River in the Grand Canyon and may be the same roost as that found in 1998. This results in a relatively long distance traveled by this mastiff bat from roost to trap site (58 km round trip).

For both the spotted and mastiff bats to travel such distances, we suspect there may be an abundance of insect prey in the high meadow systems sufficiently valuable to justify the energy expenditure of such long flight distances. The large elevation and temperature differences between the low, hot desert cliff roost in GCNP and the high, cool subalpine meadows on the NKRD present an opportunity to forage in several habitat types, but high energetic demands of lactation (Racey 1982) should force lactating females to choose the most productive foraging habitat. Although we have not yet analyzed insect sampling data, large moths appeared abundant in meadows on the NKRD during July and August. Further research should document whether the long day-roost to foraging distance and night roosting behavior of these bats is typical of local spotted and mastiff bats and what insect species bats select in these meadows.

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