

Activity Areas of Female Long-eared Myotis in Coniferous Forests in Western Oregon

Abstract

Spatial relationships among locations of day-roosts, activity areas, and water are poorly understood for forest-dwelling bats. We used radiotelemetry to investigate temporal patterns of activity, characteristics of activity areas, and the spatial relationships among activity areas, day-roosts, and water of female long-eared myotis (*Myotis evotis*). We tracked 12 adult female long-eared myotis for 23 nights from June to August, 1996 and 1997, on the western slope of the Cascade Mountains in Oregon. Activity areas of nine bats ($n = 11$ nights) averaged 38.3 ha and were centered an average of 518 m from the day-roost ($SE = 60$ m) and 73 m from water ($SE = 10$ m); centers of activity were significantly closer to water than random points ($P < 0.001$). Odds of an area being used decreased with distance to available water ($P = 0.0001$). Activity areas typically encompassed water but did not include the day-roost. Activity areas did not significantly differ in forest composition from randomly selected circular plots. Bodies of open water appear to function as important centers of activity for long-eared myotis. We contend that management of habitats for bats should consider spatial relationships among activity areas, day-roosts, and water.

Introduction

Spatial relationships of day-roosts, activity areas (defined as the area used by a bat between emergence from and return to a day-roost), and available water are poorly understood. Foraging bouts can account for the largest proportion of a bat's daily energy budget (Kurta et al. 1989a) and roosting close to foraging areas with adequate prey may minimize energetic costs of commuting between roosts and activity areas (Tuttle 1976). Knowledge of spatial relationships among resources that are important to bats would provide a foundation for the conservation of bats through informed management of roosts, water sites, and riparian zones.

In forests of the Pacific Northwest, bats are thought to roost primarily in older forests and travel elsewhere to forage (Thomas 1988, Barclay and Brigham 1996). In coniferous forests, most species of bats generally roost in upland areas in large conifer snags (Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Betts 1998, Ormsbee and McComb 1998, Waldien et al. 2000). In addition to large conifer snags, the long-eared myotis (*Myotis evotis*) roosts in conifer trees, hardwood trees and snags, conifer stumps, and

logs (Manning and Jones 1989; Vonhof and Barclay 1996, 1997; Waldien et al. 2000). Although bats often roost in older forests (Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Betts 1998, Ormsbee and McComb 1998), some species of bats will roost in younger forests if roost structures are available (Vonhof and Barclay 1997, Waldien et al. 2000).

Bodies of open water and riparian areas are often assumed to function as foraging areas or drinking sites for bats (Caire et al. 1984, Lunde and Harestad 1986, Thomas 1988, Barclay 1991, Brigham et al. 1992, Grindal et al. 1999). Higher levels of bat activity are more often detected over or near water sites compared to terrestrial habitats (Geggie and Fenton 1985, Lunde and Harestad 1986, Furlonger et al. 1987, Grindal et al. 1999) and many species forage within 100 m of water (Tuttle 1976, Fenton and Bell 1979, Racey and Swift 1985, von Frenckell and Barclay 1987, Brigham et al. 1992, Wilkinson and Barclay 1997). The extensive use of water and riparian habitat as foraging sites may be related to an abundant prey-base in close proximity to a ready source of water (Grindal et al. 1999).

Although water may be important as drinking and foraging sites for some species, water sites may be less important for long-eared myotis and species that primarily forage over terrestrial habitats. The long-eared myotis is a substrate-gleaner (Faure and Barclay 1992, 1994) that specializes

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on moths (Lepidoptera; Whitaker et al. 1977, 1981) and typically forages in terrestrial habitats (Manning and Jones 1989, Barclay 1991). Recent telemetry work has shown that day-roosts of the long-eared myotis (Waldien et al. 2000), long-legged myotis (*M. volans*; Ormsbee and McComb 1998), and the silver-haired bat (*Lasionycteris noctivagans*; Mattson et al. 1996, Betts 1998) were not associated with water, suggesting that proximity of roosts to water may not be critical for some species.

Current understanding of how bats use resources in an area (e.g., water, day-roosts, and night-roosts) often is inferred from captures (Kunz 1973, Reith 1980), use of chemiluminescent light tags (Caire et al. 1984, Racey and Swift 1985, Barclay 1991, Brigham et al. 1992), or ultrasonic detectors (von Frenckell and Barclay 1987, Thomas 1988, Hayes 1997, Grindal and Brigham 1998, Humes et al. 1999, Zielinski and Gellman 1999). These methods provide valuable information on activity of bats at specific sites but do not provide information on patterns of use of resources by individual bats across their home range. Assessment of activity areas with radiotelemetry provides the opportunity to gather more detailed information concerning spatial relationships of habitat use. However, because of methodological difficulties, use of radiotelemetry to achieve this end has been restricted to relatively few species (e.g., big brown bat [*Eptesicus fuscus*], Brigham and Fenton 1986, Brigham 1991, Hamilton and Barclay 1994, Wilkinson and Barclay 1997; brown big-eared bat [*Plecotus auritus*], Entwistle et al. 1996; Townsend's big-eared bat [*Corynorhinus townsendii*], Clark et al. 1993, Adam et al. 1994, Dobkin et al. 1995, Wethington et al. 1996) and relatively few habitats. As a result, little is known about the characteristics of activity areas of bats and their spatial relationship with day-roosts and water sites in coniferous forests.

Our objectives were to characterize activity areas of female long-eared myotis and to examine spatial relationships among activity areas, day-roosts, and water. Specifically, we tested whether characteristics of activity areas and randomly available areas differed, and whether activity areas were closer than random areas to available water.

Methods

We conducted our study on the west slope of the Cascade Mountains in Lane County, Oregon, be-

tween 44°30' and 43°58' north latitude and 123°50' and 122°30' west longitude. Climate in the study area is mild with average minimum temperatures of -2 to -5°C in January and average maximum temperatures of 24 to 29°C in July (Franklin and Dyrness 1973). Study sites were located in Douglas-fir forests in the western hemlock (*Tsuga heterophylla*) zone (Franklin and Dyrness 1973) and ranged from 350 to 700 m in elevation.

The study area encompasses a diversity of habitats in three major drainage systems: Fall Creek, Little Fall Creek, and South McKenzie River. Douglas-fir (*Pseudotsuga menziesii*) is the dominant overstory species in all three areas; western hemlock and western redcedar (*Thuja plicata*) are minor components in many forest stands. Clear-cuts are generally replanted with Douglas-fir following harvest. The Fall Creek watershed has a history of relatively little timber harvest and is generally characterized by large blocks of forests >80 yr in age. The Little Fall Creek watershed and the South McKenzie River area are primarily under private ownership with a history of high-yield timber management; these areas are generally dominated by forests <80 yr in age with few, small areas of older forests remaining.

Capture and Transmitter Attachment

We captured bats using mist nets, harp traps, hoop nets (Kunz and Kurta 1988), and H-nets (Waldien and Hayes 1999) under bridges used as night-roosts and over ponds and streams from June through August in 1996 and 1997. Captured bats were identified to species, sex, age class (adult or juvenile; Anthony 1988), and reproductive condition (Racey 1988).

We attached a 0.51 g radio transmitter (model LB2, Holohil Systems Ltd., Carp, Ontario, Canada) to adult female long-eared myotis that weighed ≥ 6.5 g and were not in a late stage of pregnancy. We trimmed a small patch of fur from between the scapulae and glued the transmitter to the trimmed area using Skin-Bond (Smith and Nephew United, Inc., Largo, FL). Transmitters were held in place for ca. 2 min and bats were retained in a container for an additional 20-30 min to allow the adhesive to set. Instrumented bats were released at the capture site within 1 hr of capture.

Transmitters weighed 5.7-7.7% of the mass of the bat, an amount similar to relative weights

reported for several studies of roost-selection (e.g., Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Ormsbee and McComb 1998) and habitat use (e.g., Adam et al. 1994, Dobkin et al. 1995, Entwistle et al. 1996, Wethington 1996). Transmitters that comprised 6.4-9.5% of the bats mass did not influence the maximum distance brown long-eared bats traveled from the roost or the time bats spent within 0.5 km of the roost (Entwistle et al. 1996). Based on behavioral patterns we observed in the field, we are unaware of any impacts of transmitters on the behavior of telemetered bats in our study, although we were unable to examine this directly.

Radiotelemetry and Activity Areas

We used TRX-1000S (Wildlife Materials, Inc.; Carbondale, Illinois) and TR-2 (Telonics, Telemetry-Electronic Consultants; Mesa, Arizona) receivers and hand-held 4- and 6-element yagi antennas to track female long-eared myotis throughout the night. We used direct observation and fluctuation in signal strength to determine the time female long-eared myotis departed from day-roosts, whether instrumented bats were mobile, and the time they returned to a day-roost. Hand-held and citizen band radios were used to coordinate simultaneous bearings at 10-minute intervals among three mobile telemetry stations. Rugged topography, location of roads, and movement patterns of bats required that telemetry stations be moved periodically in an effort to ensure optimal angles between telemetry stations; maximum detection distance of transmitters in the study area was ca. 3 km although most bats were tracked at distances <1.2 km. We successfully tracked bats for which we defined activity areas for an average of 94% of the night. Temporary transmitter failure for one bat on one night and another bat periodically returning to a roost during the night, where we could not typically receive a radio-signal, resulted in our inability to determine a bat's status for an average of 6% of the night. Locations of telemetry stations were identified using a geographical positioning system (TrimbleNavigation, Ltd., Sunnyvale, California).

We identified locations of instrumented bats by triangulation of bearings using XYLOG (Dodge and Steiner 1986). Locations with < 3 bearings were excluded. We examined error associated with bearings by conducting blind tests using station-

ary transmitters placed along roads within areas used by instrumented bats. Transmitters placed on or near the ground were often screened from telemetry stations by topography and forest stands to simulate conditions frequently encountered while tracking bats. We examined bearings from blind tests and instrumented bats for undue influence of angles between stations, topography, and distance the bat or transmitter was from telemetry stations. Locations resulting from nearly parallel bearings were excluded.

We used the adaptive kernel method (Worton 1989, 1995) with least squares cross-validation to estimate nightly activity areas. We used CALHOME (Kie et al. 1996) to calculate 95% utilization distributions (nightly activity areas) for bats that were active for at least 4 hr (approximately 50% of the night) and for which we obtained locations for $\geq 50\%$ of the time the bat was active. Polygons of activity areas were imported into a Geographical Information System (GIS, ArcInfo, Environmental Systems Research Institute, Redlands, California, USA).

We used GIS to define available habitat at each capture site. Polygons of available habitat were defined by combining 2.4-km radius circles circumscribing each day-roost of all bats captured at the same capture site ($n = 5$ polygons). This radius was the maximum distance any instrumented bat was detected from a day-roost (Waldien 1998). We randomly selected 50 points in each of the five polygons and established 500-m radius circular plots (78 ha) around each point to estimate available habitat (random areas). We determined the proportion of 0-12, 13-35, 36-80, or >80 years-old forest in each activity area (area within the 95% utilization distribution polygon) and random area. We also determined the proportion of each activity area and random area composed of riparian habitat; riparian habitat was defined as the area within 20 m of intermittent and small streams (average annual flow ≤ 0.04 m³), 50 m of medium streams (average annual flow > 0.04 m³ and < 0.2 m³) and ponds, and 100 m of large streams (average annual flow ≥ 0.2 m³). All other areas were classified as uplands. We defined available water as medium streams, large streams, and ponds; small streams in our study area are almost entirely covered by vegetation and generally do not offer pools from which bats could drink. We used GIS to determine distance from each random point

and from the geometric center of each activity area to the nearest available water, the day-roost from which the bat departed, and the site at which the bat was captured.

Statistical Analyses

We used stepwise logistic regression (PROC GENMOD, SAS Institute 1997) to compare characteristics of activity areas and randomly available areas and to test for differences in patterns of use among landscapes. We conducted logistic regression analyses for habitat variables, distances between centers of activity areas and available water, and all variables combined. Variables were considered statistically significant and included in the models at $P \leq 0.05$. Odds ratios were calculated by taking the antilogarithm of the parameter estimate (Ramsay and Schafer 1997); examples of calculations for odds ratios are presented in the results. We used the Mann-Whitney U-test to test for differences in habitat characteristics and distance of activity areas from available water between used and random areas. We also used Mann-Whitney U-tests to test for differences among characteristics of activity areas in different landscapes.

Results

We tracked 12 female long-eared myotis (1 non-parous, 4 pregnant, 5 lactating, and 2 post-lactating) on 23 nights (1 to 4 nights each); seven bats were tracked on more than one night. We collected sufficient data to identify 11 activity areas for nine bats (1 non-parous, 2 pregnant, 5 lactating, and 1 post-lactating); four of these bats (five nights) were captured at ponds and five (six nights)

were captured at bridges used as night-roosts. All bats used the same general activity area at a capture site and females tracked on more than one night repeatedly used the same general area.

Activity Areas

Activity areas averaged 38.3 ha (SE = 7.3 ha; n = 11 nights) and were centered 100 m from capture sites (SE = 12 m). Centers of activity areas averaged over 500 m from the day-roost but <100 m from available water (Table 1). Activity areas were significantly closer than random areas to available water and comprised a greater proportion of riparian habitat than random areas, but did not differ significantly with respect to proportion of forest in different age classes (Table 1). No differences among females differing in reproductive condition were evident, although small sample sizes precluded meaningful statistical analysis.

Of the 11 activity areas determined, nine encompassed open water. Patterns of use were similar for four activity areas from bats that we tracked for the entire night but had insufficient locations to delineate specific activity areas. Most female long-eared myotis had activity areas that encompassed available water but not the day-roost (n = 7 activity areas); all bats captured at upland ponds exhibited this pattern. Bats captured at bridges exhibited greater variability in patterns of use; two activity areas did not encompass open water whereas four did.

The distance an activity area was from available water was the only variable that entered any model ($P = 0.0001$) and the odds of an area being used by female long-eared myotis decreased with increasing distance from available water (model

TABLE 1. Comparison of characteristics of activity areas (n = 11) of nine female long-eared myotis and random areas (n = 249) in the Cascade Range of western Oregon, 1996 and 1997.

Variable ¹	Activity Areas		Random Areas		P ²
	mean	SE	mean	SE	
Distance to day-roost (m)	518.2	60.0	—	—	—
Distance to available water (m)	72.7	10.4	562.5	23.8	<0.001
Riparian habitat (%)	19.0	4.9	11.4	0.7	0.05
Forest 0-12 years old (%)	7.2	3.8	10.5	0.9	0.22
Forest 13-35 years old (%)	24.6	7.8	22.4	1.8	0.69
Forest 36-80 years old (%)	26.0	6.8	39.9	1.9	0.12
Forest >80 years old (%)	22.8	9.2	15.4	1.3	0.91

¹Distance variables were measured from geometric centers of activity areas and random areas.

²P-values are the result of Mann-Whitney U-tests comparing used and random areas.

= -0.0684 - 0.0166 (Distance to water); 95% CI Intercept = -1.168 to 1.076, Distance to water = -0.008 to -0.029). For example, an area centered 72.7 m from available water (Table 1) was 3.4 times more likely to be used as an activity area than an area centered twice as far (145.4 m) from available water ($72.7 - 145.4 = -72.7$; $0.9835^{-72.7} = 3.4$; 95% CI = 1.8 to 8.1).

Temporal Patterns of Activity

Female long-eared myotis departed day-roosts an average of 19.6 min after sunset, (SE = 2.1 min; n = 28) and returned to day-roosts an average of 2 hr 16 min before sunrise (SE = 23.3 min; n = 16). Bats were active for approximately half of the night ($\bar{x} = 52.7\%$; SE = 4.5%) and exhibited an average of 4.2 periods of activity (SE = 0.4) punctuated by relatively short periods of inactivity (generally <20 min in length).

Discussion

Our research provides evidence that water sites and riparian areas play an important role in determining activity areas of female long-eared myotis and that water sites can be focal points for terrestrial foraging bats (Szewczak et al. 1998). The association between water and activity areas of long-eared myotis is particularly noteworthy because the long-eared myotis forages primarily over terrestrial habitats (Manning and Jones 1989; Barclay 1991; Faure and Barclay 1992, 1994). Our observations indicate that female long-eared myotis rarely occur over water, but frequently use terrestrial habitats or riparian areas immediately adjacent to water. Bats are adapted to exploit patchy food sources and increase their foraging efficiency by feeding on concentrations of insects that are often encountered near water (Fenton and Morris 1976, Bell 1980, Geggie and Fenton 1985, Furlonger et al. 1987).

We postulate that activity areas of female long-eared myotis are associated with water sites because of increased foraging efficiency and access to water for drinking. Female bats may spend little time foraging near day-roosts and fly to more productive foraging areas near water or along forest-edges (Brigham et al. 1992, Wilkinson and Barclay 1997, Grindal and Brigham 1998, Grindal et al. 1999), only returning to the day-roost during the night to nurse young (Anthony et al. 1981, Racey and Swift 1985, Adam et al. 1994). Al-

though selection of roost sites is not strongly influenced by commuting costs to foraging areas (Mattson et al. 1996, Fenton et al. 1985, Brigham 1991), activity areas near water and day-roosts can reduce energetic costs associated with commuting between areas (Tuttle 1976) during periods when energy requirements are high because of reproductive demands (Kurta et al. 1989a). Further, many species of bats require water in excess of that obtained from their diet (Kurta et al. 1989b, 1990; Webb et al. 1993; McLean and Speakman 1999) and having activity areas close to water would facilitate meeting this need.

Spatial patterns in the availability of resources can influence the distances bats fly among roosts, water, and activity areas. Mean distances that female long-eared myotis commuted to activity areas is similar to those reported for the gray bat (*Myotis grisescens*, Tuttle 1976) but shorter than those reported for larger species in other habitats (i.e., big brown bat, Brigham and Fenton 1986, Brigham 1991; Townsend's big-eared bat, Clark et al. 1993, Adam et al. 1994, Wethington et al. 1996). Although the distance bats fly to foraging areas can vary with region, reproduction, sex, and age (Tuttle 1976, Brigham 1991, Adam et al. 1994, Entwistle et al. 1996), we suspect that relatively short commuting distances are typical of small species of bats in forested habitats. However, our findings may be a function of availability and proximity of potential roosts to water in our study area.

Studies of the roosting ecology of bats in forest often focus on characteristics of roost structures (e.g., Vonhof and Barclay 1996, 1997; Brigham et al. 1997; Crampton and Barclay 1998; Kalcounis and Brigham 1998), with proximity of roosts to water or other habitat features rarely being considered (e.g., Campbell et al. 1996, Betts 1998, Ormsbee and McComb 1998, Waldien et al. 2000). While many species of bats in temperate forests exhibit low fidelity to specific roost structures (Lewis 1995, Vonhof and Barclay 1996, Brigham et al. 1997, Betts 1998, Ormsbee and McComb 1998, Waldien et al. 2000), they exhibit higher fidelity to foraging areas (Racey and Swift 1985, Brigham 1991, Entwistle et al. 1996, Wilkinson and Barclay 1997). Water resources function as important focal points for populations of bats (Szewczak et al. 1998), including species that forage over terrestrial habitats, and provide important drinking and foraging sites (Racey and

Swift 1985, Brigham et al. 1992, Wilkinson and Barclay 1997). Our data suggest that managing for roosts between 0.5-1.0 km from open water will be most beneficial for bats in forested habitats. Creating ponds with open water that are free of vegetation in upland habitats where roosts are available will provide foraging and drinking sites, and ultimately will improve the quality and suitability of habitat in that area for bats.

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