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SELECTION OF DAY ROOSTS BY FEMALE LONG-LEGGED MYOTIS IN THE CENTRAL OREGON CASCADE RANGE

PATRICIA C. ORMSBEE,[1] Willamette National Forest, P.O. Box 10607, Eugene, OR 97404, USA
WILLIAM C. McCOMB, Department of Forestry and Wildlife Management, University of Massachusetts, Amherst, MA 01003, USA

Abstract: We radiotracked 16 female long-legged myotis (*Myotis volans*) in the central Oregon Cascade Range that used a total of 41 day roosts. Large Douglas-fir (*Pseudotsuga menziesii*) snags averaging 97 ± 7 (SE) cm diameter at breast height (dbh) and 38 ± 3 m in height were the most commonly used roost structures (88%). The odds that a snag was used as a day roost increased as snag height increased ($P < 0.001$); after snag height was accounted for, the odds of use decreased as stand height within 20 m of the snag increased ($P = 0.024$). The frequency of occurrence of roosts between young and late seral stands did not differ from that by chance in these 2 stand conditions ($P = 0.76$). Day roosts generally occurred in upland habitats associated with streams that contained night roosts. Management of large diameter, tall snags that extend above the canopy will provide 1 component of day-roost habitat for long-legged myotis in managed landscapes.

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Long-legged myotis are found in montane forests across the western United States and Canada and less frequently in arid rangeland (Warner and Czaplewski 1984, Nagorsen and Brigham 1993), and this species is 1 of 12 insectivorous bats that inhabit Douglas-fir forests of the Pacific Northwest. Habitat relations for these species are poorly understood (Christy and West 1993, U.S. Forest Service and Bureau of Land Management 1994); however, 11 of these species, including the long-legged myotis, were identified by the Forest Ecosystem Management Assessment Team (FEMAT) as being associated with old-growth forest, in need of further study, and of concern because of the reduced extent of old-growth habitat within

[1] E-mail: orms@rio.com

western Washington and Oregon, and northern California (U.S. Forest Service and Bureau of Land Management 1994).

Long-legged myotis use different habitat components for day roosts, maternity roosts, night roosts, hibernacula, and foraging areas (Christy and West 1993). The number and characteristics of habitat components required for persistence of this species are unknown, but use of a variety of roosts and foraging areas has been documented (Warner and Czaplewski 1984). Identifying characteristics of habitat used by long-legged myotis, such as day-roost habitat associated with reproductive females, may be key to ensuring the persistence of this species in managed landscapes and to testing assumptions about habitat associations attributed to this species.

Humphrey (1975) hypothesized that the distribution of Nearctic bat species was associated with availability of roost structures. His work indicated that presence or absence of different types of nursery roosts influences distribution and abundance of Nearctic bats. On a smaller scale, permanence and availability of roosts may influence roost fidelity of individuals or groups of bats (Kunz 1982). Long-legged myotis have been documented day-roosting in snags and under the bark of live trees, as well as in buildings, rock crevices, and fissures in the ground (Warner and Czaplewski 1984, Nagorsen and Brigham 1993).

An association between day roosts and old-growth stands has been found for numerous species of bats, including the long-legged myotis (Christy and West 1993, U.S. Forest Service and Bureau of Land Management 1994). Recorded bat calls indicated higher activity levels in old-growth Douglas-fir (Thomas 1988) and in aspen (*Populus* sp.)–mixed-wood forests (Crampton and Barclay 1996) than in young and mature stands. Large-diameter snags typically are more abundant in old than in young Douglas-fir and aspen–mixed-wood stands (Spies et al. 1988, Crampton and Barclay 1996), but formal testing via deterministic methods to identify specific characteristics of day roosts and associated stand attributes have not been done in the central Oregon Cascade Range for any species of forest-dwelling bat.

Several species of bats forage near or over water (Christy and West 1993), so day roosts located near water would seem to reduce travel time to foraging sites. Day roosts have consistently been found close to water for the Yuma myotis (*Myotis yumanensis*; Nagorsen and Brigham 1993), but this finding is not consistent for other species of bats that inhabit the central Oregon Cascade Range. Further, studies that document the proximity to water of day roosts used by bats in the central Oregon Cascade Range have not been completed. The central Oregon Cascade Range has a high density of streams when compared to more arid regions, and our study area included potential day roosts within and outside of riparian habitat. Having an array of potential roosts located varying distances from streams allowed us to test if day-roost selection by female long-legged myotis was influenced by proximity to water, without availability of potential roosts or availability of water being a limiting factor.

We designed our study to test the hypotheses that (1) female long-legged myotis select snags with distinctive structural attributes and microhabitat characteristics that differ from what is generally available, (2) they select old-growth stands disproportionate to what is available, and (3) day roosts are located closer to streams than expected by chance.

METHODS

Our study was conducted on the Willamette National Forest in the central Oregon Cascade Range, a region typified by mesic conditions and Douglas-fir–western hemlock (*Tsuga heterophylla*) plant associations between elevations of 500 and 1,500 m. We collected data in Lookout Creek drainage (6,391 ha), east of Blue River Reservoir, and we collected within the H. J. Andrews Experimental Forest, and in Quentin Creek drainage (3,258 ha), which is northeast of Blue River Reservoir. We selected these sites because they had accessible bridges that served as night roosts for female long-legged myotis, had a variety of potential day roosts (cliff faces, caves, snags, trees), and included natural stands and managed stands of a variety of ages, with and without residual snags and trees.

We captured 41 female long-legged myotis in 1993, 62 in 1994, and 10 in 1995 at 2 night roosts (bridges along Quentin and Lookout creek) between 0330 and 0430 during July and August. We radiomarked 15 pregnant or lactating females and 7 adult females of undetermined reproductive status (assumed in early stages of pregnancy) with 0.55–0.65-g Holohil BD-2B radiotransmitters (Holohil Institute, Woodlawn, Ontario, Canada). We attached radiotransmitters by clipping a patch of fur and adhering a transmitter between the scapulae via skin bond (Smith and Nephew United, Largo, Florida, USA), and we expected the transmitters to stay attached and functioning for a maximum of 3 weeks. The mass of a transmitter was 6–8% of the bats' body mass. We attempted to verify a day-roost structure for each radiomarked bat once every 24 hr during daylight hours by determining the tree, snag, or rock face from which the strongest signal was emitting. We mapped all verified roost structures.

Because of the increased physical stress to bats from carrying radiotransmitters, we wanted to minimize the number of bats radiomarked. We used the 1994 field data on roost dbh to determine a sample size (Ramsey and Schafer 1997) for analyzing snags. Our estimated sample size was 34 (to detect a biologically significant difference of 30 cm dbh), but because we were using logistic regression techniques for our analysis, we assumed a smaller sample size would be applicable (Ramsey et al. 1994). In 1995, we attempted to radiomark only the number of bats needed to approach our estimated sample size for analyzing snags.

Characteristics of Roost Snags

We tested the hypothesis that the odds of a snag being selected for a roost were associated with characteristics of the snag and the surrounding vegetation (within a 20-m radius) compared to what was available at random locations within the same stand (matched case–control study design). We measured the characteristics of habitat surrounding 33 roost snags (verified roosts that were snags) and 66 randomly selected snags (snags selected via random points located within the stand boundary where verified roosts occurred). Stand boundaries were identified by a Geographic Information System (GIS; K. Adee et al. 1991. Mature and overmature survey [MOMS] data dictionary, unpublished report. U.S. Forest Service, Eugene, Oregon, USA). Within each stand containing a day roost, we located 2 random points and walked in a spiral from each point until we found a snag between 30 and 200 cm dbh (within the dbh range of known roosts from data collected in 1994) and at least 3 m tall.

We measured the following physical characteristics of roost snags and randomly selected snags (n = 99): species, dbh (via diameter tape and laser relascope), height (laser relascope), decay class (modified from Neitro et al. [1985] to include partially live trees as decay class 0.5), percent branches (ocular estimate), percent bark (ocular estimate), and exposure of the snag to the sky (ocular estimate). Estimated diameters did not differ between use of a diameter tape and a laser relascope (2-tailed test: P = 0.43), and we had adequate power to detect a practical significant difference of 15 cm (n = 60).

We also measured several characteristics of the vegetation within a 10- and 20-m radius, nested circular plot centered on each roost or random snag: dbh, decay class, species, azimuth, and distance from the roost or random snag were measured for each green tree and snag ($\geq$15 cm dbh within a 10-m radius, and $\geq$25 cm dbh between 10- and 20-m radius) within the circular plot, adjacent stand height (estimated using the height of a dominant tree within 20 m of each roost or random snag; laser relascope), slope (laser relascope), and aspect (compass). We estimated canopy closure for vegetation >7 m tall (verticle projection grid; Vales and Bunnell 1985) and occurrence of canopy openings estimated to be at least 5 m^2 (ocular estimate; Spies et al. 1990). Mean estimates for all measurements were reported ± SE.

To test for redundancy in explanatory power among the habitat variables, we completed a correlation analysis to identify variables with moderate to high correlation ($r \geq 0.40$). We combined correlated variables where biologically reasonable to do so. For instance, average canopy closure within 10 m and average canopy closure between 10 and 20 m of a snag were strongly correlated ($r \geq 0.81$), so we averaged both variables to create 1 variable (average canopy closure within 20 m).

Using a matched case–control analysis including a stepwise process, we estimated an initial logistic model via a PHREG procedure (SAS Institute 1992). We used conditional likelihood functions to compare explanatory variables associated with roost snags and randomly selected snags (Hosmer and Lemeshow 1989). This type of analysis has its historical roots in cancer research (Breslow and Day 1980), and its application is relatively new to natural resource analyses. It is a statistically powerful design that can increase accuracy and lends itself well to comparative studies with a binary response (Ramsey et al. 1994).

We included the variable DBH (dbh of the roost or random snag) despite an associated P-value of 0.769 to control for the variability in the data attributed to DBH (Ramsey and Schafer 1997). Including the variable DBH is required for this type of analysis, but the parameter estimate and P-value have no real interpretive value because dbh was predetermined as a selection criterion for randomly located snags in the study design. We matched roost snags with randomly selected snags within stands, and we included a dummy variable, STAND, in the analysis to account for the matching (Ramsey and Schafer 1997).

Roost Stand Selection

We tested the null hypothesis that roost occurrence did not differ between late and early seral stands from that expected by chance. We compared the frequency of day roosts in early seral stands (predominate size class ranged from seedlings to trees $\leq$79 cm dbh) and late seral stands (dominated by trees >79 cm dbh) to the frequency that day roosts would be expected to occur within these 2 categories proportionate to their occurrence in each of the 2 drainages in our study. Using GIS, we identified and calculated the ratio of early and late seral stands in each drainage. We used these proportions to estimate the expected frequency of roosts in the 2 stand conditions and completed a chi-square analysis to test our hypothesis.

Stream Association

We tested the null hypothesis that bats selected roosts as close to Class I (largest stream), II, III, and IV (smallest stream) streams (Gregory and Ashkenas 1990), as would be expected by chance. We selected 3 random points for every known day roost (excluding roosts selected the morning a bat was radiomarked and released). Using GIS, we overlaid a grid with a cell size of 400 m^2 (the average distance between multiple roosts of individual bats) with a map of the study area, numbered the grid nodes, and entered the numbers in a random numbers generator to identify random points. We calculated the closest distance from each random point and known roost to Class I–IV streams via GIS. Using a 2-sample t-test, we determined if the distances differed between known roost locations and random locations for each stream class.

RESULTS

Radiotelemetry

We tracked 16 of 22 radiomarked bats to day roosts for an average of 8 $\pm$ 1 days/bat (range = 1–24 days). The other 6 bats left the study site, their radios failed, or their radio signal could not be located consistently within a 0.5-km^2 area. We tracked 15 of 22 bats for $\geq$4 days, and we tracked 13 bats to multiple day roosts. We located 41 day-roost structures of which 1 was a rock crevice, 4 were live trees, and 36 were snags.

Day Roost Characteristics

The mean height of all roost structures was 40 $\pm$ 3 m (range = 13–72 m). The mean dbh for all snags and trees used as day roosts was 100 $\pm$ 6 cm (range = 34–172 cm), and snags used as day roosts had a mean dbh of 97 $\pm$ 7 cm (95% CI = 83–110 cm; test for normality: P = 0.22) and mean height of 38 $\pm$ 3 m (95% CI = 33–44 m; test for normality: P = 0.38). Nearly half (47%) the snags used for roosts were Douglas-fir in decay class 1 or 2 and averaged 108 $\pm$ 7 cm dbh and 46 $\pm$ 3 m tall. Nine (25%) of the snags used as day roosts were Douglas-fir in decay class 3 or 4 and averaged 99 $\pm$ 10 cm dbh and 33 $\pm$ 6 m tall. The remaining snags were western hemlock snags (14%; n = 5) mostly in decay classes 1 and 2 (n = 4), and western redcedar (*Thuja plicata*) snags (11%; n = 4) in decay classes 0.5 (n = 3) and 2 (n = 1).

Roost Snag and Stand Selection

The odds that a snag would be selected as a day roost by female long-legged myotis increased 1.14 times (95% CI = 1.06–1.22, P < 0.001) for every meter increase in snag height. After snag height was accounted for, the odds of a snag being selected as a day roost decreased 0.94 times (95% CI = 0.89–0.99, P = 0.024) for every meter increase in stand height adjacent to the snag (Table 1). For example, the odds of a snag 38 m tall being selected as a day roost were 19 (38–15 = 23 and 1.137^{23} = 19) times that of a snag 15 m tall (95% CI = 17.91–20.53). Given snag height, the odds of a snag being selected where the mean stand height within 20 m of the roost was 48 m were 0.69 (48–42 = 6 and 0.9391^{6} = 0.69) times that of a snag where the mean stand height within 20 m of the roost was 42 m (95% CI = 0.65–0.72).

Table 1. Parameter estimates (log scale) and associated values resulting from a matched case–control analysis of 66 randomly selected snags and 33 snags selected as day roosts by female long-legged myotis in the central Oregon Cascade Range, 1993–95.

Variable	df	Parameter estimate	95% CI	$P > \chi^2$	Odds ratio
Dbh[a]	1	0.003524	−0.0202 to 0.0273	0.790	0.996
Height[b]	1	0.128426	0.0603 to 0.1965	0.0002	1.137
Canopy[c]	1	−0.063136	−0.1186 to −0.0076	0.0243	0.939

[a] Dbh of snags.
[b] Height of snags.
[c] Height of canopy within 20 m of snags.

The number of roosts in late seral stands compared to early seral stands (Fig. 1) did not differ from expected (1-tailed test: $P = 0.76$), given the proportion of these 2 stand conditions within the drainages we studied.

Stream Association

Day roosts were generally located in upland habitat and outside of riparian habitat yet were located closer to streams than randomly selected locations in both Lookout and Quentin creek drainages, with 1 exception (Class III streams in Lookout Drainage). In 3 cases, day roosts were exceptionately closer to streams than randomly selected locations ($P < 0.05$), and in all 3 cases, the streams were those where the known night roosts were located (Table 2).

DISCUSSION

Female long-legged myotis in our study tended to select as day-roost sites large snags as tall or taller than the surrounding canopy. Other studies have reported solar exposure as a component of day roosts selected by bats. Campbell (1993) found that all day roosts in her radiotelemetry study of silver-haired bats (*Lasionycteris noctivagans*) in eastern Washington were in snags or partially dead trees significantly taller and surrounded by sparser vegetation than other trees in the area. In northeastern Oregon, Betts (1996) found silver-haired and big brown bats (*Eptesicus fuscus*) day-roosting in large snags that received solar radiation throughout the day. Vonhof (1996) found that silver-haired bats and big brown bats in the southern interior of British Columbia selected roosts in tall trees surrounded by a low percentage of canopy closure, and Vonhoff and Barclay (1996) also found the same day-roost habitat associations true for female long-legged myotis and long-eared myotis (*Myotis evotis*) they studied in southern British Columbia.

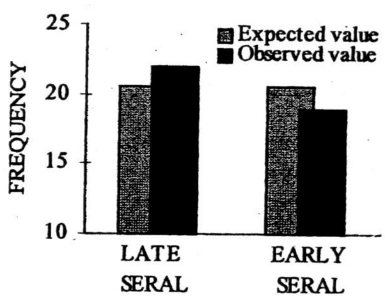

Fig. 1. Frequency distribution of 41 day roosts used by long-legged myotis between early and late seral conditions in the central Oregon Cascade Range, 1993–95. We used chi-square analysis (2-way contingency table) to compare the frequency with which roosts occurred in early seral stands and late seral stands, to the frequency with which roosts would be expected to occur within these 2 stand types as they were proportionately represented in the study area ($P = 0.76$).

Snags may be more easily detected by echolocating bats returning to roost if snags extend above the forest canopy, and these snags also may be warmer than snags into or obscured by forest canopy (Bakken and Kunz 1988). Measurements of heat retention in the boles of live trees and the heat reflection ability of green foliage indicate that a snag or a portion of a snag exposed to the sun will accumulate more heat than a snag shaded all day by forest canopy (Geiger 1957). If heat from solar exposure is retained in the roost beyond daylight hours, this heat could benefit neonates unable to thermoregulate and left alone at the roost for periods of time during the night (Kunz 1982, Racey 1982). Lactation is among the most energy-demanding periods in the annual cycle of reproductive female bats in temperate regions, and elevated roost temperatures reduce the metabolic demands on lactating females to endothermically produce heat for themselves and their altricial young (Racey 1982). Once pups can thermoregulate, energy demands remain high for females and their young as pups continue to grow, and both gain fat supplies to sustain them

Table 2. Comparison of distances (m) between known day roosts used by long-legged myotis and random locations from stream Classes I–IV in the central Oregon Cascade Range, 1993–95.

Stream class	Roost locations $\bar{x}$	Roost locations SE	Random locations $\bar{x}$	Random locations SE	P
Quentin Class I	2,152	365	2,950	211	0.018
Lookout Class I	2,372	383	3,418	221	0.030
Quentin Class II	754	94	797	54	0.686
Lookout Class II	490	123	947	71	0.003
Quentin Class III	259	53	347	31	0.063
Lookout Class III	778	151	676	87	0.633
Quentin Class IV	230	37	246	21	0.705
Lookout Class IV	352	85	357	49	0.956

through winter hibernation. Energy budgeting during this period is improved by warm roost temperatures (McNab 1982).

While relatively large diameter, tall, newly dead Douglas-fir snags dominated the type of day-roost structures selected by individual bats in our study, other types of day roosts also may be of value to this species. For instance, only a few western redcedar snags in decay class 0.5 were selected, and thus could be viewed as minor contributors to the pool of day roosts. Fire-hollowed western redcedar are relatively rare (9% of snags selected for known roosts, and 0% of snags selected for random roosts in this study) and provide sizable chambers or cavities that can house large numbers of bats (on 2 occasions, we observed >300 bats emerging from 1 such tree) when compared to cracks and crevices found in newly dead Douglas-fir snags. These rare trees may provide females and their altricial pups an opportunity to roost in relatively large groups, a strategy that could increase safety and energy conservation given that pups are unable to thermoregulate, echolocate, or fly. Once pups are more independent of their mothers, learning a variety of roosts and foraging sites in smaller, less competitive groups could increase a pup's chance of long-term survival.

We did not detect an association of day roosts used by female long-legged myotis with either early or late seral stands. This finding may seem inconsistent with Thomas's (1988) findings, but he used bat detectors to estimate bat activity levels associated with different seral conditions, a method that does not provide information specific to day-roosting habits of bats. While Crampton and Barclay (1996) used radiotelemetry to track little brown bats (*Myotis lucifugus*) and silver-haired bats (n = 27) to day roosts in large snags in old-growth stands in Alberta, large snags apparently were only present in old stands within their study area. Because our study used radiotracking to identify specific day-roost structures and was conducted in an area where potential roosts were available within an array of seral conditions, we conclude that large snags or hollow trees protruding above the adjacent canopy, regardless of the stands seral stage, have a high likelihood of providing day-roosting habitat for female long-legged myotis in the central Oregon Cascade Range.

The occurrence of day roosts in upland habitat also may augment warmer temperatures at the roost site by gaining more hours of solar exposure and avoiding cooler, moister conditions associated with riparian habitat. The proximity of day roosts to streams where night roosts were located may indicate that the relation between these 2 types of roosts and the stream itself is not entirely random.

MANAGEMENT IMPLICATIONS

Providing tall (>32 m), large diameter (>83 cm dbh) decay class 1 and 2 Douglas-fir snags distributed among seral stages in a watershed probably would provide 1 type of day-roost habitat for female long-legged myotis. Providing these types of snags throughout a rotation will require active management via periodic snag creation and removal of vegetation around snags to provide adequate exposure. Managing snags for a variety of wildlife species on commercial forest lands is common on most federal, state, and some private lands in the Pacific Northwest, and providing large, sound snags in harvest units over a rotation should be compatible with recommendations for other snag-dependent species. Although no other studies on use of day roosts by forest-dwelling bats have been completed for the central Oregon Cascade Range, studies in other areas of the Pacific

Northwest and British Columbia indicate a possibility that several of these species also may benefit from snags that receive solar exposure.

Roosts found in more uncommon structures such as hollow trees and rock outcrops may not be as easily replaced as snags and may provide rare but important roost habitat for bats, as well as other species. We recommend managing these sites to maintain roost habitat conditions. In many cases, ensuring roost exposure by reducing vegetation may create more suitable habitat for long-legged myotis than providing no-cut buffers around these roosts.

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