ROOST PREFERENCES OF LONG-LEGGED MYOTIS IN NORTHERN ARIZONA

MICHAEL J. HERDER, Bureau of Land Management, Arizona Strip Field Office, 345 East Riverside Drive, St. George, Utah 84790 USA

JENNIFER G. JACKSON, Bureau of Land Management, Arizona Strip Field Office, 345 East Riverside Drive, St. George, Utah 84790 USA

ABSTRACT: We used radiotelemetry to locate 59 roosts of long-legged myotis (*Myotis volans*) and other bat species at Mt. Trumbull in northwestern Arizona from May - August, 1997 - 1999. Of the 59 roosts located, 55 were found in ponderosa pine (*Pinus ponderosa*) snags. At least 15 of the radio-telemetered bats used more than one roost. Length of stay at a roost ranged from one to five days ($\bar{x}$ = 1.99 days). At least five of the tagged bats foraged more than 10 km from their day roosts. Roost snags were taller, found on shallower slopes, and were located closer to drainages than randomly selected snags that were not active roosts. Over 80% of the roost snags had loose, exfoliating bark. The forest surrounding roost snags was more open than randomly selected snags and had higher densities of larger diameter class trees and snags. Roost snags were more common in areas with evidence of recent fire. We used these habitat characteristics to develop a logistic regression model that correctly classified 79.2% of the roosts and 80.3% of the random snags. Nine of 12 habitat variables in our model support the theory that bats gain energetic benefits from selecting roosts in structures that receive high levels of solar radiation. Our study suggests that forest management practices that promote retention of old growth in open stands should increase available roosting habitat. We recommend leaving large diameter trees in open park-like areas, retaining snags, restoring a quasi-natural regime of low intensity fires to mimic natural processes, and to maintain these conditions in the long term.

2000 TRANSACTIONS OF THE WESTERN SECTION OF THE WILDLIFE SOCIETY 36:1-7

INTRODUCTION

Roosts are a vital habitat component for bats, affording protection from weather and predators, providing a place for giving birth, rearing young, mating, and hibernation (Kunz 1982, Altringham 1996). The availability of roosts may limit the number and distribution of some bat species (Humphrey 1975). Pregnant females of many North American species form maternity groups or colonies to rear their young (Barbour and Davis 1969, Kunz 1982, Altringham 1996). By roosting communally, clustering bats generate heat and increase the temperature in the roost (Kunz 1982, Altringham 1996). As a result, the thermal characteristics of the roost are important in the growth and development of the young and may be an important factor in roost selection (Kunz 1982, Racey 1982, Altringham 1996). Bats must select roosts that have insulating properties to minimize heat loss (Racey 1982, Kurta 1985).

Many bat species reside in forested environments and rely on trees and snags (dead standing trees) for their roosting sites (Barbour and Davis 1969, Kunz 1982, Altringham 1996). In coniferous forests across the western United States, bats are known to roost under bark, in cracks and crevices, and in hollows left by primary cavity excavators (Kunz 1982, Christy and West 1993, Altringham 1996). Long-legged myotis (*Myotis volans*) are one of 16 bat species found in the ponderosa pine (*Pinus ponderosa*) forests of Northern Arizona. Long-legged myotis and five other southwestern bats are considered sensitive species by the Bureau of Land Management (2000, unpublished species list). Habitat associations and roost selection criteria are poorly understood for most of these species (Christy and West 1993, Vonhof and Barclay 1996, Rabe et al. 1998, Ormsbee and McComb 1998). At present, baseline information on distribution and habitat requirements of most forest-dwelling species is not sufficient to formulate management strategies.

As urban and suburban communities continue to expand, demands on forest resources are increasing. Land management practices such as timber harvest, livestock grazing, and fire suppression have contributed to disruption of natural fire regimes, loss of understory vegetation, and development of dense stands of small diameter trees (Covington and Moore 1994, Dahms and Geils 1997). Forested lands in this condition are considered unhealthy and at extreme risk from high intensity fire (Covington and Moore 1994, Dahms and Geils 1997).

In 1995, the Bureau of Land Management (BLM) began a partnership with Northern Arizona University and the Arizona Game and Fish Department to restore unhealthy forests at Mt. Trumbull in northwestern Arizona. The Mt. Trumbull Ecosystem Restoration Project was initiated to reduce stand densities of ponderosa pines from $\geq$ 200 small diameter trees per ha to 8 - 20 trees per ha, to increase the understory from $\leq$5% to 30%, and to restore a quasi-natural fire regime (Waltz and Fule' unpublished report). Restoration treatments included thinning small diameter trees, raking organic material away from leave trees, and conducting low intensity prescribed burns followed by re-seeding with native species (Waltz and Fule' unpublished report).

The purpose of this study was to identify roost habitat preferences of long-legged myotis and other sensitive bat species in the ponderosa pine forest at Mt. Trumbull, Arizona. We developed a model of roost affinities to predict changes in the availability of suitable roosts following forest restoration treatments.

STUDY AREA

The study was conducted May through August of 1997 - 1999 at Mt. Trumbull (T 35 N, R 08 W, Gila and Salt River Meridian) in northwestern Arizona on public lands administered by the BLM. The forested area included approximately 5,400 ha located between 1600 m and 2100 m above mean sea level. Primary vegetation types present in the study area included ponderosa pine with Gambel oak (*Quercus gambelii*), pinyon-juniper woodlands (*Pinus monophylla* and *Juniperus osteosperma*), and sagebrush (*Artemesia tridentata*). Approximately 80% of the ponderosa pine forest includes dense stands of young trees ≤25 cm in diameter up to 200 trees per ha.

METHODS

We captured bats in mist nets at open water sources including wildlife catchments and stock ponds. For each bat captured we recorded the species, gender, reproductive status (Racey 1982), and weight to nearest 0.2 g. Most bats captured were released within five minutes following capture, except those selected for radiotelemetry. We attached radio transmitters (Holohil Systems Ltd., Ontario, Canada; and Titley Electronics, New South Wales, Australia) to the interscapular region using a non-toxic surgical glue. To ensure a good bond, we trimmed fur from the attachment site and allowed the glue to cure prior to release. For all individuals tagged, transmitter mass (≤0.46 g) was ≤10% of the mass of the bat (Aldridge and Brigham 1988). Transmitter life varied from 10 to 14 days.

We used radiotelemetry to locate day roosts of tagged individuals. We attempted to relocate each telemetered bat daily to determine if bats were switching roosts. We also tracked telemetered bats throughout the night to identify foraging areas and night roosts. When necessary, a fixed wing aircraft was used to expand the search area. Occasionally, roosts were located by examining large diameter trees or snags with excavated cavities, fissures, or loose bark. We used lights to check for bats under bark, tapped on the trunk and listened for vocalizations, and searched for guano piles. To confirm use of suspected roosts, we used night vision and infrared video to count bats as they exited at dusk (exit survey). Whenever possible, we identified exiting bats to species by recording vocalizations with an Anabat ultrasonic bat detector (Titley Electronics, New South Wales, Australia) and comparing the calls with those in our library of identified vocalizations.

We compared various characteristics of ponderosa pine roost snags with those of randomly selected snags to determine whether bats were selecting roosts based on specific characteristics or randomly choosing roosts from available snags. We focused on snags rather than live trees based upon past experience in this study area and results of similar studies in ponderosa pine systems (Rabe et al. 1998). Random snags were chosen by locating the closest snag to a random point generated by a Geographic Information System. Randomly selected snags were first checked for signs of an active roost. If bats were found, the snag was counted as a roost and attempts were made to determine the species present.

We characterized both roost and random snags by recording 27 habitat variables at two spatial scales: individual snag and surrounding forest. For all snags we recorded the species, location, diameter at breast height (dbh), elevation, percent slope, and height. We identified the position of the snag on the slope in 1/5th slope length increments. We classified snag decomposition based upon the degree of decay: 1-bark fully intact, 2-bark loose or exfoliating, 3-bark absent, 4-broken top, or 5-downed log. We also recorded distances from the roost to the nearest water, drainage, forest opening ≥0.5 ha, and forest treatment area (raking, thinning, controlled burning, or any combination of these). When possible, we identified the specific roosting location on the snag and classified it as under-bark, fissure, or cavity.

We characterized the forest surrounding the snag by measuring habitat variables in five non-overlapping 11.3 m radius plots (0.04 ha each) as described by Rabe et al. (1998). One plot was centered on the snag while the others were centered 23.2 m from the roost in each of the four cardinal directions. Habitat variables measured within plots included percentage canopy closure, number of trees and snags within each of four dbh classes (≤25 cm, 25 - 50 cm, 50 - 75 cm, ≥75), total basal area, and number of shrubs and shrub species present. We also noted the number of downed logs, evidence of grazing, and past or current treatment activities observed.

Statistical Analysis

We tested the hypothesis that habitat variables measured for roost snags and the surrounding forest would not differ from those of randomly selected snags without active roosts. Significant differences in habitat variables between roosts and random snags were interpreted as selection preferences by bats.

Statistical methods follow Rabe et al. (1998) and are summarized below. We used a backward elimination logistic regression (SPSS Regression Model, SPSS Inc., Chicago, Illinois) to determine which habitat variables best discriminated roosts from randomly selected snags. The backward elimination entered all 27 variables into the model and iteratively removed the least significant terms one at a time. Variables used in the final regression model were reviewed to ensure they made biological sense. To test the model for fit, we used the -2 LOG L and Hosmer and Lemeshow Goodness-of-Fit tests (Hosmer and Lemeshow 1989). Wald's chi-square statistic was used to assess the contribution of individual habitat variables to the model. We used the model to classify snags selected from the data set as roost or random snags using a logistic cut point of 0.5. In all other statistical tests performed, we considered $P \leq 0.05$ as the indicator of significance. A positive parameter coefficient in the regression equation indicated that as the value of the variable increased, the probability that the snag was a roost also increased.

RESULTS

We attached radio transmitters to 46 bats of four species, including 37 long-legged myotis, five fringed myotis (*Myotis thysanodes*), three Townsend's big-eared bats (*Corynorhinus townsendii*), and one Allen's lappet-browed bat (*Idionycteris phyllotis*). We tagged 26 female long-legged myotis (average body mass = 7.8 g) including six lactating, two post-lactating, and 18 not reproductively active. None of the eleven male long-legged myotis tagged (average body mass = 7.3 g) appeared reproductively active. We attached radio transmitters to two female (average body mass = 8.3 g) and three male fringed myotis (average body mass = 7.1 g), including one lactating and four apparently not reproductively active. All three Townsend's big-eared bats tagged were female (average body mass =9.1 g), including two lactating and one not reproductively active. The Allen's lappet-browed bat tagged was a lactating female (body mass =12.0 g).

In the days following release, we detected radio signals for 28 of the tagged bats, including 25 of 37 (68%) long-legged myotis, one fringed myotis, one Townsend's big-eared bat, and one Allen's lappet-browed bat. Transmitter signals were detected an average of 3.9 days following tagging (range 0-12 days). Migration of tagged animals from the area and transmitter failure likely accounted for the majority of signals not reacquired. Nine of the transmitters were recovered while still active from under bark on the roost or from the ground, suggesting the tag fell off or was removed by the bat.

We located 59 active bat roosts in trees or snags, including 55 in ponderosa pine snags, two in live ponderosa pine trees, and two in Gambel oak. Of those found in ponderosa pine snags, 38 were located by following radio-telemetered long-legged myotis and 17 were located by chance discovery. We were able to identify long-legged myotis from vocal signatures in the vicinity of nine of the 17 roosts (53%) located by chance. At three of these roosts we also identified big brown bats (*Eptesicus fuscus*) and at one we identified fringed myotis. We were unable to identify species using eight of the 17 roosts (47%) located by chance. Three snag roosts could not be relocated on subsequent visits to measure habitat variables. Eight roosts were found in rock outcroppings: five of long-legged myotis, two of fringed myotis, and one of a Townsend's big-eared bat. The Allen's lappet-browed bat was tracked to a 1 ha patch of aspen (*Populus tremuloides*), but the specific roost location could not be identified prior to transmitter failure.

At least 15 of the radio-telemetered long-legged myotis used more than one roost during the tracking period. Of these, four used three or more different roosts. Length of stay at any particular roost ranged from one to five days for tagged long-legged myotis ($\bar{x}$ = 1.99 days). Each time roost switching occurred, at least one exit survey was conducted at both the previous and the new roost location. No bats were counted exiting any previously used roost on the night following the roost change. However, six long-legged myotis returned to a previously used roost after staying two or more days at another roost. The average distance from the capture site to the first roost located following tagging was 3.2 km (range = 0.2 - 7.9 km). At least five of the tagged long-legged myotis foraged more than 10 km from their day roosts, well beyond the range of the radio telemetry equipment used.

Snags used by long-legged myotis and other unidentified bat species were taller and of larger diameter than were random snags (Table 1). The mean dbh of roost snags was 22.2% greater than that of randomly selected snags. Roost snags were found on shallower slopes than randomly selected snags. Thirty-six of 52 (69%) roosts were found in the lower two fifths of the slope or were on sites with no measurable slope. In contrast, only 23 of 61 (38%) randomly selected snags were found in the lower two fifths of the slope. Snags with loose, exfoliating bark (decay class 2) were more common among roosts than among random snags. Over 80% of roost snags examined (42 of 52) were decay class 2. Of the remaining roosts, six (12%) were found in recently dead trees with bark intact (decay class 1) and three (6%) were in snags with fissures but no bark (decay class 3). Decay class 2 snags were common among random snags as well (28 of 61 = 46%), but other decay classes were also well represented. Roost snags were located farther from water and closer to drainages, forest openings $\geq$0.5 ha, and areas where restoration treatments were underway or completed than were randomly selected snags. Seventeen of 52 (32.7%) roost snags were located within restoration treatment areas.

The canopy cover was less dense in the forest surrounding roost snags than the area surrounding randomly selected snags (Table 1). Roost snags had fewer small diameter trees and snags (25 - 50 cm dbh) and more large diameter trees and snags (≥ 50 cm dbh) in the forest surrounding the roost than did random snags.

Twelve habitat variables significantly discriminated between roost and random snags in the final logistic regression model (Table 2). The model estimated a positive parameter coefficient for dbh, distance to drainage, number of trees ≤25 cm dbh, number of trees 50 - 75 cm dbh, number of trees ≥75 cm dbh, number of snags 50 - 75 cm dbh, basal area, and evidence of recent burning. An increase in the value of any of these habitat variables increases the probability that a particular snag is a roost. The model estimated negative parameter coefficients for percent slope, number of shrubs, percent canopy cover, and number of snags ≤25 cm dbh. Increases in any of these variables increases the probability that the a particular snag is not a roost. The model correctly classified 79.2% of the roosts and 80.3% of the random snags. The -2 LOG L test chi-square statistic of 86.93 (df=12, P=0.0001) and the Hosmer-Lemeshow test statistic of 8.39 (df=8, P=.396) indicated a good fit to the logistic regression model.

DISCUSSION

Roosting habits of bats are variable and likely influenced by reproductive status, environmental or microclimatic conditions, proximity to watering and foraging areas, parasite load, level of predation, and social organization (Kunz 1982, Altringham 1996, Ormsbee and McComb 1998). A number of previous studies have documented that forest dwelling bats preferentially select tall, large diameter trees and snags from open mature stands (Christy and West 1993, Betts 1996, Lutch 1996, Vonhof 1996, Vonhof and Barclay 1996, Ormsbee and McComb 1998, Rabe et al. 1998).

Table 1. Characteristics of ponderosa pine roosts of bats using snag and surrounding forest habitat at Mt. Trumbull, Arizona, May - August, 1997-1999.

	Roost Snags (n=52)		Random Snags (n=61)	
SNAG	$\bar{x}$	SE	$\bar{x}$	SE
Dbh (cm)	79.9	3.0	62.2	4.0
Snag Height (m)	21.1	1.0	16.1	1.2
Percent Slope	4.0	0.7	6.1	0.7
Elevation (m)	2068	22.0	2093	12.7
Position on Slope	4.0	0.2	3.2	0.2
Distance to Drainage	322.4	84.6	183.3	49.2
Distance to Water	1032	57.3	770	64.0
Distance to Forest Opening	90.0	38.2	51.1	27.0
Distance to Treatment	734	136.8	1246	178.1
SURROUNDING FOREST	$\bar{x}$	SE	$\bar{x}$	SE
Ave. No. Shrubs	1.9	0.2	1.5	0.1
Ave. No. Shrub Species	32.7	10.0	30.8	10.0
Ave. % Canopy Cover	55.2	2.7	64.2	2.2
Ave. No. Downed Logs	0.8	0.1	0.8	0.1
Ave. Basal Area (cm2)	13,245	881	12,621	615
No. Trees 0-10 dbh (cm)	96.8	14.6	80.2	9.0
No. Trees 10-20 dbh (cm)	3.8	0.4	5.7	0.4
No. Trees 20-30 dbh (cm)	0.6	0.1	0.4	0.1
No. Trees >30 dbh (cm)	0.2	0.04	0.1	0.02
No. Snags 0-10 dbh (cm)	6.1	1.2	6.5	0.9
No. Snags 10-20 dbh (cm)	0.1	0.02	0.1	0.03
No. Snags 0-10 dbh (cm)	0.1	0.02	0.1	0.05
No. Snags 10-20 dbh (cm)	0.1	0.02	0.1	0.01

Roost trees or snags located in open areas or that are taller than the surrounding forest canopy receive greater solar exposure throughout the day than those in closed stands (Betts 1996). Warmer roost temperatures may provide thermoregulatory benefits to bats as they seek optimum temperatures by moving within the roost (Kunz 1982, Altringham 1996, Rabe et al. 1998). The high energetic demands of neonates and lactating females in maternity colonies are reduced in warmer, well insulated roosts (Kunz 1982, Racey 1982, Kurta 1985). Additional benefits from larger trees and snags include an increase in available roosting area as diameter increases (Ormsbee and McComb 1998). Tall trees and snags are also more likely to be detected by echolocating bats as they return to the roost (Ormsbee and McComb 1998). Vonhof (1996) found either height or dbh, or both variables, discriminated well between roosts and random snags and concluded that overall tree size is a more appropriate selection factor for bats choosing a roost than the particular measure used to determine snag size.

That bats gain energetic benefits from selecting roosts in snags receiving greater solar radiation is supported by nine of the twelve habitat variables included in our logistic regression model. The greatest amount of solar radiation would be afforded to roosts in large diameter ponderosa pine snags in open areas, surrounded by relatively few shrubs and large diameter trees and snags. Snags found in dense thickets of small diameter trees (≤25 cm dbh), a common situation within the study area, must be taller than the surrounding forest canopy to receive sufficient solar radiation to provide a suitable roost. This may account for the inclusion of trees ≤25 cm dbh in the logistic regression model. Forest patches that have burned would also allow for increased solar radiation, though fire poses a substantial risk to snags.

In addition to thermoregulatory benefits, an open canopy indicates a less cluttered environment, minimizing navigational hazards when entering and leaving the roost (Ormsbee and McComb 1998). A more open canopy also provides fewer perches for predators waiting near the roost entrance (Vonhof 1996, Ormsbee and McComb 1998).

Other studies have reported roost snags are more common on steeper slopes (Betts 1996, Lutch 1996, Rabe et al. 1998). In managed forests, areas of high snag density are typically limited to slopes too steep for commercial logging operations. A few small-scale logging operations occurred within the study area at Mt. Trumbull in the early 1900s, but the area was generally considered to be too small to be commercially viable. Most of the steeper slopes have burned several times since the 1870's (Waltz and Fule' unpublished report), removing snags and promoting conditions for dense stands of smaller diameter trees.

Roost switching among forest bat species has been reported from a number of previous studies (Lewis 1995, Betts 1996, Lutch 1996, Vonhof 1996, Vonhof and Barclay 1996, Ormsbee and McComb 1998, Rabe et al. 1998). Roost fidelity is partially based on the number of potential roosts available and their permanence in the local environment

Table 2. Analysis of maximum likelihood estimates for habitat variables included in the backward elimination logistic regression model for discriminating between roosts and random snags at Mt. Trumbull, Arizona, May - August, 1997 - 1999.

	Parameter Coefficient	SE	Wald Chi-Square	*P*
Intercept	-1.904	1.641	1.346	0.246
Dbh	0.060	0.020	8.477	0.004
Percent Slope	-0.176	0.073	5.831	0.016
Distance to Drainage	0.002	0.001	6.932	0.008
Number Shrubs	-0.024	0.012	4.165	0.041
Canopy Cover	-0.167	0.045	13.996	<0.001
Trees <25 cm dbh	0.020	0.007	8.773	0.003
Trees 50-75 cm dbh	2.026	0.824	6.047	0.014
Trees >75 cm dbh	4.316	1.644	6.893	0.009
Snags <25 cm dbh	-0.128	0.056	0.022	0.022
Snags 50-75 cm dbh	6.355	3.091	4.227	0.040
Basal Area	0.0004	0.0001	7.446	0.006
Evidence of Burning	5.203	1.747	8.870	0.003

(Kunz 1982, Lewis 1995, Altringham 1996). Bats may switch roosts in response to disturbance or threat of predation, to introduce young to new roost locations, to seek locations closer to foraging areas, or to reduce parasite loads (Kunz 1982, Lewis 1995, Brigham 1991, O'Shea and Vaughn 1977).

Our study design was based on the assumption that randomly selected snags were not used as roosts due to some unsuitable or undesirable characteristics. Some of the random snags may have been roosts that were unoccupied at the time of the survey. We noted several female long-legged myotis switched roosts up to four times, eventually returning to re-occupy a previously used roost. We also noted roosts that were abandoned and remained unoccupied for the remainder of the season. While this may have introduced bias to our study, the model correctly discriminated between roosts and random snags in over 80% of the cases. Field validation of the model should reduce this bias and increase the sensitivity of classification. Rabe et al. (1998) noted that roost switching introduces an additional bias because individuals may select similar habitat characteristics in subsequent roosts. However, their comparisons of roost characteristics of bats that switched with those that did not were statistically indistinguishable. We followed Rabe et al. (1998) by including multiple roosts in our analysis.

MANAGEMENT IMPLICATIONS

Dead standing and downed wood is a vital component of forest ecosystems for a wide variety of wildlife species including cavity nesting birds, rodents, bats, and numerous invertebrates (Bull et al. 1997). Our study and those studies conducted by Rabe et al. (1998) and Ormsbee and McComb (1998) suggest that ecosystem restoration projects that open the forest canopy may provide more roosting habitat for bats such as long-legged myotis, provided that large diameter snags are retained. Park-like forest stands with moderate understory vegetation promote better solar heating, provide easier access to roost snags (Betts 1996, Vonhof and Barclay 1996, Ormsbee and McComb 1998, Rabe et al. 1998), and may reduce the risk that snags will be lost to fire (Covington and Moore 1994, Dahms and Geils 1997). While some snags will likely be burned as a result of re-establishing a fire regime, loss of deadwood features can be minimized by raking duff away, building protective fire lines, removing adjacent heavy fuels, and pre-treatment with water and/or foam (Covington and Moore 1994, Waltz and Fule' unpublished report). Ideally, the number of trees killed in each prescribed burn should equal the number of snags consumed by the fire. Trees identified for snag replacement should be approximately equal in size to the snags they are replacing. In addition, studies should be established to monitor the decomposition rate of snags.

ACKNOWLEDGMENTS

Funding for this project was provided by the National Fish and Wildlife Foundation, the Arizona Game and Fish Department, and Bat Conservation International. Their assistance in making this study possible is gratefully acknowledged. We wish to thank the following people for their contributions of time, energy, and humor: T. Arial, J. Check, B. Coleman, S. Davis, K. Day, M. Doty, D. Emmons, B. Ferrell, C. Geiselman, G. Grasso, M. Herder, R. Herder, K. Hinman, A. Holycross, M. Kreighbaum, J. Leckie, K. McDonald, Y.R. Mensing, C. Peterson, L.X. Poppystone, M. Ramsey, G. Ritter, T. Snow, D. Solick, H. Straga, S. Thome, J. Thurau, K. Wallace, T. Weller and E. Zylstra. We are especially grateful to K. Yasuda for voluntarily spending part of his vacation with the field crews. We are indebted to L. DeFalco and M. Rabe for their assistance with the statistical analysis.

LITERATURE CITED

Altringham, J.D. 1996. Bats: biology and behavior. Oxford University Press, Oxford, Great Britain. 262 p.

Aldridge, H.D. and R.M. Brigham. 1988. Load carrying and maneuverability in an insectivorous bat: a test of the 5% "rule" of radio telemetry. Journal of Mammalogy 69:379-382.

Barbour, R.W. and W.H. Davis. 1969. Bats of America. The University of Kentucky Press, Lexington, Kentucky, USA.

Betts, B.J. 1996. Roosting behavior of silver-haired bats (*Lasionycteris noctivagans*) and big brown bats (*Eptesicus fuscus*) in northeast Oregon. Pages 55-61 in Barclay, R. M. R. and R. M. Brigham, editors. Bats and forests symposium. British Columbia Ministry of Forests, Victoria, British Columbia, Canada.

Brigham, R.M.R. 1991. Flexibility in foraging and roosting behavior by the big brown bat (*Eptesicus fuscus*). Canadian Journal of Zoology 69:117-121.

Bull, E., C. Parks, and T. Torolf. 1997. Trees and logs important to wildlife in the interior Columbia River Basin. General Technical Report PNW-GTR-391. USDA Forest Service, LeGrande, Oregon, USA. 83 p.

Christy, R.E. and S.D. West. 1993. Biology of bats in Douglas-fir forests. General Technical Report PNW-308. USDA Forest Service, Portland, Oregon, USA. 28 p.

Covington, W.W., and M. Moore. 1994. Southwest ponderosa pine forest structure: changes since Euro-American settlement. Journal of Forestry 92:39-47.

Dahms, C.W. and B.W. Geils, editors. 1997. An assessment of forest ecosystem health in the Southwest. General Technical Report RM-GTR-295. USDA Forest Service, Fort Collins, Colorado, USA. 97 p.

Hosmer, D.W. Jr., and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons, New York, New York, USA. 307 p.

Humphrey, S.R. 1975. Nursery roosts and community diversity of nearctic bats. Journal of Mammalogy 56:321-346.

Kunz, T.H. 1982. Roosting ecology of bats. Pages 1-55 *in* Ecology of bats. T.H. Kunz, editor. Plenum Press, New York, New York.

Kurta, A. 1985. External insulation available to a non-nesting mammal, the little brown bat (*Myotis lucifigus*). Comparative Biochemistry and Physiology 82A:413-420.

Lewis, S.E. 1995. Roost fidelity in bats: a review. Journal of Mammalogy 76:481-496.

Lutch, D.J. 1996. Maternity roost characteristics and habitat selection of three forest-dwelling bat species in Arizona. Thesis. Arizona State University, Tempe, Arizona, USA.

Ormsbee, P.C. and W.C. McComb. 1998. Selection of day roosts by female long-legged myotis in the Central Oregon Cascade Range. Journal of Wildlife Management 62:596-603.

O'Shea, T.J., and T.A. Vaughn. 1977. Nocturnal and seasonal activities of the pallid bat, *Antrozous pallidus*. Journal of Mammalogy 58:269-284.

Rabe, M.J., T.E. Morrell, H. Green, J.C. DeVos Jr., and C.R. Miller. 1998. Characteristics of ponderosa pine snag roosts used by reproductive bats in Northern Arizona. Journal of Wildlife Management 62:612-621.

Racey, P.A. 1982. Ecology of bat reproduction. Pages 57-104 *in* T.H. Kunz editor. Ecology of bats. Plenum Press, New York, New York, USA

Vonhof, M.J. 1996. Roost-site preferences of big brown bats (*Eptesicus fuscus*) and silver-haired bats (*Lasionycteris noctivagans*) in the Pend d'Oreille Valley in southern British Columbia. Pages 62-80 *in* Barclay, R. M. R. and R. M. Brigham, editors. Bats and forests symposium. British Columbia Ministry of Forests, Victoria, British Columbia, Canada.

Vonhof, M.J. and R.M.R. Barclay. 1996. Roost-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. Canadian Journal of Zoology. 74:1797-1805.