AN ABSTRACT OF THE THESIS OF

David L. Waldien for the degree of Master of Science in Forest Science presented on August 25, 1998. Title: Characteristics and Spatial Relationships of Day-Roosts and Activity Areas of Female Long-eared Myotis (*Myotis evotis*) in Western Oregon.

Abstract approved:________________________________
John P. Hayes

Management of habitat for bats requires sound information on their habitat requirements. I used radio telemetry to identify 80 roosts for 24 long-eared myotis (*Myotis evotis*); 74 roosts were identified for 21 females and 6 roosts for 3 males. Females primarily used dead and defective conifer trees (n=22) and conifer stumps (n=41) though they also used 3 live conifer trees, 1 live and 5 dead hardwood trees, and 2 conifer logs. Males used one each of the following structures: dead conifer, dead hardwood, conifer log, conifer stump, slash pile, and rock crevice. Female long-eared myotis primarily roosted in conifer stumps in landscapes dominated by younger forests and used dead or defective conifer trees and stumps in landscapes characterized by older forests. Roosts generally were located in upland habitats. Odds of a dead or defective conifer being used as a roosts was associated with decay class, presence of snags, and distance to the edge of the stand. Odds of a conifer stump being used was associated with amount of species of stump, height of the stump on the downhill side, access, woody debris within 1 m, and slope (%).

Twelve female long-eared myotis were tracked on 23 nights to determine activity areas. Individuals had a mean nightly activity area of 39.5 ha which was centered 0.550 km from the day-roost and 0.16 km from available water; the maximum distance a bat was detected from a day-roost was 2.4 km. Odds of an area being used as an activity area was associated with distance to available water and percent of older forest conditions. Individual bats used the same general foraging area on different nights, suggesting that there are landscape features that function as centers of bat activity.

Management of habitats for bats should consider spatial relationships of day-roosts and activity areas. Maintenance of large dead and defective conifers within 1 km of available water should provide roosting and foraging habitat for long-eared myotis and other species of bats. Leaving tall stumps also may provide structures for roosting.

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Characteristics and Spatial Relationships of Day-Roosts and Activity Areas of Female Long-eared Myotis (*Myotis evotis*) in Western Oregon.

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented August 24, 1998
Commencement June, 1999

ACKNOWLEDGMENTS

Projects of this nature can not be completed without extensive support on numerous fronts. Three people have been instrumental in the initiation and completion of this project. I am deeply indebted to Dr. Steve Cross for exposing me to the field of bat biology and providing me an opportunity to work with this unique group of mammals. The opportunities and experience he gave me not only developed my interest in bats but provided me with the skills and attitude to accomplish this project. His professionalism, attention to detail, and dedication to our natural resources has been and continues to be an inspiration. I also thank Ed Arnett for his new found interest in bats, willingness to play a significant role in the initiation of this project, and the extensive time and energy he put forth in bringing together a diverse group of cooperators. His countless hours in the field and office have been an asset which helped make this a successful project. Our numerous discussions and his critical feedback helped to shape this project. Finally, I thank my major professor, Dr. John Hayes. In my opinion, few professors devote as much time and energy to the work of their graduate students. His expertise with and interest in bats always helped me to put forth that extra effort. This project and my learning experience has been greatly enhanced due to my association with him.

I would like to thank Dr. Bob Anthony, Dr. Bill Emmingham, Dr. Steve Hobbs, and Dr. Tim Righetti for their participation on my committee. Though our direct interactions may have been limited, I was accutely aware of their professionalism and association with quality research which helped me to focus on the question at hand and to question my methods and interpretation of results. I would also like to thank Lisa Ganio,

John Hayes, and Manuela Huso for providing statistical advice and Carol Berry for GIS support. I am deeply indebted to Manuela for often extending her office hours to accommodate my commuting life style.

During this project, numerous people have endured long hours in the field under all conditions. Their willing attitudes and skills helped bring this project to a successful completion. Discussions of our observations in the field often provided insight into the data and helped shape my interpretation of results. In particular, I would like to thank Jim Faulkner, Jeff Gruver, Ben Rinehart, Chris Smith, Brooks Stanfield, and Bryan Wright for your dedication to the project. Additionally, I would like to acknowledge several others who provided critical assistance in the field when logistics were tight: Mike Adam, Ed Arnett, Kat Beal, Dave Larsen, Lynn Larsen, Chris Oxley, Bob Schifferdecker, Greg Smith, and Melissa Souza.

Financial and logistical support was graciously provided by a diverse group of cooperators: Bat Conservation International, Bureau of Land Management (Eugene District), Forest and Rangeland Ecosystem Science Center, Oregon Chapter of The Wildlife Society, Oregon Department of Fish and Wildlife, Oregon State University (Department of Forest Science), U.S. Army Corp of Engineers, U.S. Fish and Wildlife Service, U.S. Forest Service (Willamette National Forest), Weyerhaeuser Company, and Willamette Industries. My thanks to the numerous people with these agencies and organizations for their contributions. In particular, I would like to thank Ed Arnett, Kat Beal, Carol Berry, Bruce Campbell, Bill Castillo, Mike Collopy, Larry Cooper, Brian Cox, Rebecca Goggins, John Hayes, Kirk Lunstrum, Greg Miller, Raul Morales, Logan

Norris, Tom O'Neil, Pat Ormsbee, Claire Puchey, Pam Whyte, and Frank Williams for thier assistance.

Finally, I would like to acknowledge the tremendous support I received from my wife and friend, Ginger Craig. The hours I have spent away from our home during this project far out numbered those spent at home. Through it all, I have felt her support and have appreciated her amazing tolerance of my consuming interest in my research. I would like to thank her for helping me to realize my dreams.

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CHAPTER 1: CHARACTERISTICS AND SPATIAL RELATIONSHIPS OF DAY-ROOSTS AND ACTIVITY AREAS OF FEMALE LONG-EARED MYOTIS (*MYOTIS EVOTIS*) IN WESTERN OREGON

Introduction

Successful implementation of management plans for bats requires sound ecological information concerning habitat requirements of bats. The lack of basic ecological information for many species of bats (Marshall et al. 1996) has contributed to a concern about impacts of management practices on their populations. Management practices (e.g., logging) that rapidly are modifying many landscapes may impact forest-dwelling bats negatively through loss of roosts, though the development of water sites in upland habitats may benefit bats by providing sources of water. Recently, research has focused on characteristics of day-roosts used by forest-dwelling bats (e.g., Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Callahan et al. 1997, Vonhof and Barclay 1997, Betts 1998, Ormsbee and McComb 1998, Rabe et al. 1998). However, there is a need for additional research on roosts used by forest-dwelling bats and their spatial relationship with activity areas (Barclay and Brigham 1996).

Spatial relationships of roosts and activity areas used by bats are poorly understood, particularly in forested habitats, and previously have not been researched in the Pacific Northwest. In addition, most information concerning use of managed forests by bats is inconclusive because data are anecdotal and based on limited sample sizes. Failure to provide adequate roost sites and associated foraging areas may decrease the size and viability of bat populations. Knowledge of structural characteristics and spatial patterns of roost sites and activity areas of bats would enable managers too more effectively manage habitats for forest-dwelling bat communities.

Fifteen species of bats are known to occur in Oregon (Maser and Cross 1981), 12 in Douglas-fir forests of the Pacific Northwest (Thomas 1988, Thomas and West 1991, Christy and West 1993). Ten of these, including the long-eared myotis (*Myotis evotis*), occur on the west-slope of the Cascades in central Oregon (Maser and Cross 1981). The long-eared myotis is a "species of concern" in Oregon (Marshall et al. 1996). Reasons for their present status in Oregon includes a lack of knowledge concerning the distribution, population trends, habitat requirements and preferences, hibernacula, maternity, and night roosts (Thomas et al. 1993, Marshall et al. 1996).

Long-eared myotis occur across a range of habitats (Nagorsen and Brigham 1993) and are thought to be associated with forested areas (Manning and Jones 1989). Information on habitat requirements for this species throughout its range is limited. Few studies specifically address habitat requirements of long-eared myotis (e.g., Vonhof and Barclay 1997), though Vonhof and Barclay (1996) characterized day-roosts for this and several others species. This project is the first to characterize roost structures and their spatial relationship with activity areas of long-eared myotis in managed forests.

My objectives were to characterize day-roosts, activity areas, and the spatial relationship between them for long-eared myotis. I tested hypotheses associated with selection of day-roost and activity areas by female long-eared myotis. I address day-roosts in Chapter 2 and activity areas and their spatial relationship with day-roosts in

Chapter 3. In Chapter 4, I summarize my results, and discuss management implications and recommendations, scope of inference, and research needs.

Study Area

The study was conducted on the west slope of the central Cascades in Lane County Oregon, between 44°30' and 43°58' north latitude and 123°50' and 122°30' west longitude, east of Springfield Oregon, from U.S. Highway 126 and the McKenzie River south to Fall Creek (Figure 1-1). The area encompasses a diversity of habitat conditions and is divided into three areas associated with major drainage systems: South McKenzie River, Little Fall Creek, and Fall Creek. The South McKenzie River and Little Fall Creek areas are dominated by younger seral forests resulting from a history of intensive timber harvest on private lands, though there are portions of these areas consisting of relatively older forest. The Fall Creek watershed is generally characterized by older forests resulting from a history of relatively lower levels of logging on U.S. Forest Service lands.

The study sites are located in the *Tsuga heterophylla* zone (Franklin and Dyrness 1973) and range in elevation from 364 to 686 m. Douglas-fir (*Pseudotsuga mensiezii*) is the dominant overstory species in the area, with minor components of western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*) present. Riparian zones also contained minor components of big-leaf maple (*Acer macrophyllum*), black cottonwood (*Populus trichocarpa*), and red alder (*Alnus rubra*). This area of the Cascades is characterized by a relatively mild climate with minimum average January temperatures around -2° to -5°C and average maximum temperatures in July of 24° to 29°C (Franklin and Dyrness 1973).

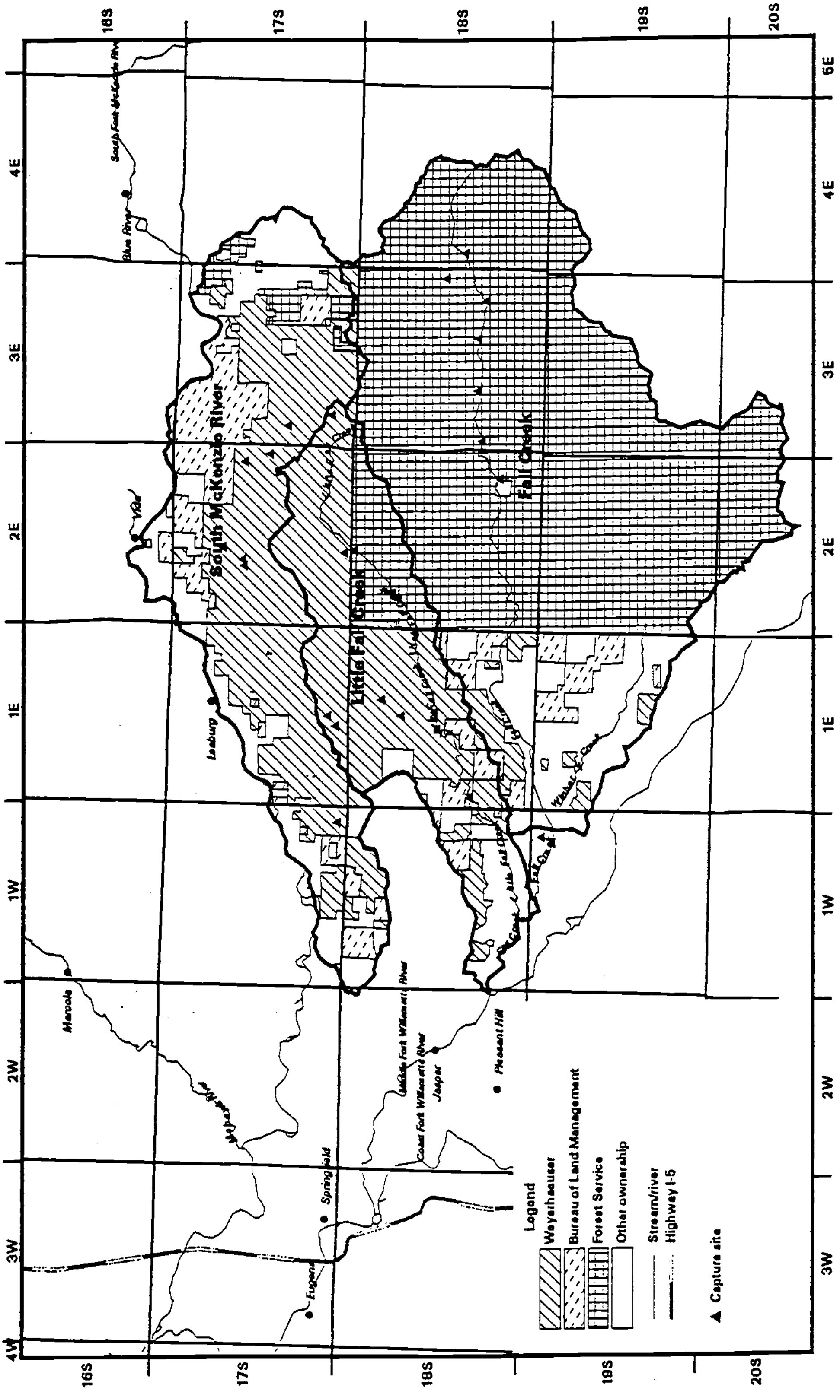

Figure 1-1. Map of study area and vicinity.

CHAPTER 2: CHARACTERISTICS OF DAY-ROOSTS USED BY FEMALE LONG-EARED MYOTIS (*MYOTIS EVOTIS*) IN WESTERN OREGON

Introduction

Many forests in the Pacific Northwest have been, and continue to be, intensively managed for timber production. Clear-cutting and other harvest systems traditionally remove dead and decadent trees which are thought to provide primary roosts used by forest-dwelling bats in the Pacific Northwest (Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Vonhof and Barclay 1997, Betts 1998, Ormsbee and McComb 1998). Removal of snags and trees with structural defects may be detrimental to bat communities and ultimately may limit distribution and reproductive success of species reliant on snags or similar types of structures. Roost structures are thought to provide bats physical protection (Humphrey 1975), favorable environments which help bats meet biological demands associated with reproduction and hibernation, and numerous other benefits (Kunz 1982).

Roosting ecology of forest-dwelling bats in the Pacific Northwest is poorly understood (Barclay and Brigham 1996) and information concerning selection of roost structures is limited, and is based largely on studies with limited sample sizes or inconclusive results. Often species-specific results are broadly, perhaps indiscriminately, applied to multiple species and extrapolated to broad geographical regions where differences in forest structure and environmental conditions may impact use and selection of habitats and roosts.

Few studies specifically address characteristics of roost structures used by long-eared myotis (e.g., Vonhof and Barclay 1997), though Vonhof and Barclay (1996) examined roost characteristics of long-eared myotis along with several other species. Anecdotal information and results of recent studies suggest that long-eared myotis use a variety of roost structures, including crevices and cavities in trees, snags, conifer stumps in clear-cuts, and rock outcrops, as well as caves, mines, and other man-made structures (Christy and West 1993, Vonhof and Barclay 1996, 1997). Recent work in British Columbia demonstrated that long-eared myotis roost in relatively large conifer snags (Vonhof and Barclay 1996) and that male and non-reproductive females may roost under exfoliating bark on conifer stumps in clear-cuts (Vonhof and Barclay 1997). However, characteristics of roost structures and their spatial relationship to other landscape features (e.g. water sites) are lacking for long-eared myotis.

My objectives were to characterize the types of structures used as day-roosts by female long-eared myotis at multiple spatial scales and compare them to randomly available structures. I also tested if reproductive condition of female long-eared myotis influenced the type of structure used as a day-roost and if females use different types of roosts in landscapes with different habitat characteristics. Specifically, I tested the following hypotheses: (1) characteristics of structures used as day-roosts will not differ from characteristics of randomly available structures; (2) habitat characteristics in the immediate vicinity of the day-roost will not differ from habitat characteristics around available structures; (3) bats will roost in stands proportional to their availability; (4) structures used as day-roosts will not exhibit random patterns of distribution within the landscape.

Methods

Capture Techniques

I used mist nets, harp traps, hoop nets (Kunz and Kurta 1988), and H-nets (Waldien and Hayes submitted) to capture bats over ponds and streams and at bridges used as night-roosts from May through August in 1996 and June through August in 1997. Sites were selected based on equipment limitations (e.g., size of mist nets) and access to the site by road or trail with most sites being trapped more than once to maximize opportunities to capture female long-eared myotis. Capture periods generally were initiated at sunset and lasted three to four hours depending on logistics and weather conditions. Captured bats were identified to species, sex, relative age (adult or juvenile) based on the degree of ossification in the epiphyseal growth plates (Anthony 1988), and reproductive condition (Racey 1988).

Radio Telemetry

I attached 0.51 g radio transmitters (model LB2, Holohil Systems Ltd.,112 John Cavanagh Road, Carp, Ontario, KOA 1L0, Canada) to 21 female and 3 male long-eared myotis during June, July, and August 1996 and 1997. I only attached transmitters to bats exceeding 6.5 g in weight that were not in a late stage of pregnancy. Transmitters weighed 6.7-7.8% of body mass. I trimmed a small patch of fur between the scapula and attached the transmitter to the bat using Skin-Bond (Smith and Nephew United, Inc., Largo, FL) and held the transmitters firmly in place for 1-2 minutes. I placed the bat in a container for 20-30 minutes to allow the adhesive to set and released the bat at the capture site .

I used Wildlife Materials TRX-1000S (Wildlife Materials, Inc.; Carbondale, Illinois) and Telonics TR-2 (Telonics, Telemetry-Electronic Consultants; Mesa, Arizona) receivers, and hand-held 4- and 6-element yagi antennas to track bats to roosts on a daily basis. I attempted to locate structures used for day-roosts by tracking instrumented bats to these sites. A structure was verified as a roost only if I confirmed that the instrumented bat had left the roost. This was accomplished by monitoring the radio signal and roosts at dusk. This protocol may have eliminated some structures used as day-roosts where a bat shed its transmitter, but minimized misclassification of structures where transmitters had been shed by bats flying over a structure or at night-roosts. Day-roosts were located on U.S.G.S. topographic maps and with a geographical positioning system (GPS; TrimbleNavigation, Ltd., Sunnyvale, California).

Habitat Sampling

I classified each roost used by female long-eared myotis into one of three categories: dead or defective conifer trees (completely dead trees and live trees with structural defects such as a dead top), conifer stumps (structures less than 3 m in height created by a conifer tree < 100 years old being cut), and all other roost structures (i.e., live conifers with no structural defects, logs, and hardwoods). Conifer trees and conifer stumps were classified according to stage of decay (Tables 2-1 and 2-2). I conducted statistical analyses only on dead or defective conifers and conifer stumps verified as roosts used by female long-eared myotis. Small sample sizes for males and other types of roosts precluded statistical analysis.

Table 2-1. Classification system used to identify decay stage of conifer trees and snags used as roost structures and available structures. Modified from Bull et al. (1997).

Class	Description
0	live; healthy; no obvious structural defects (e.g., dead or broken top)
1	live with structural defects (e.g., dead or broken top, cracks, or decay in bole) and recently dead trees with limited decay and the majority of limbs and needles present
2	dead; trees in intermediate stages of decay usually with a broken bole, branches, and missing bark
3	dead; remnant structure (<3 m tall) with most branches and bark lost

Table 2-2. Classification system used to identify decay stage of conifer stumps used as roost structures and available structures.

Class	Description
1	generally cut within the year; wood generally solid with minimal exfoliation of the bark; heart wood cavities formed prior to being cut
2	≥1 season since cut; variable levels of decay and exfoliation of bark
3	≥1 season since cut; extensive decay and wood generally spongy

I defined a stand to be an area of similar vegetative composition and structure. Topographic features (e.g., ridges and stream) were used to define boundaries of stands in areas with relatively large forest tracts of similar age or structure; resulting stand boundaries generally were consistent with management boundaries. I used a 1x1 cm grid and a random numbers table to randomly place 6 points in each stand where a dead or defective conifer or conifer stump used as a roosts were located. I navigated to these points with a U.S.G.S. topographic map and compass, and selected the structure nearest to the random point that was in the same category as the structure used in that stand (i.e., a dead or defective conifer tree or conifer stump).

I identified a total of 78 randomly available structures were selected (24 dead or defective conifer trees and 54 conifer stumps). For dead or defective conifer trees, I selected random trees in decay classes 1-3 and decay class 2 for conifer stumps. I excluded older stumps, stumps from previous harvests, and snags located in young-open or young-closed conditions because they were used infrequently and differed in many respects from the majority of the stumps or snags I observed being used by female long-eared myotis.

I collected data on characteristics of roosts and randomly selected structures at multiple spatial scales. For dead or defective conifer trees, data were collected on characteristics of structures (structure-scale) and habitat within 5-, 10-, 20-, and 50-meter radius concentric plots (plot-scale; Appendix A, Table A-1 and Appendix B). For conifer stumps, data were collected on characteristics of the structures (structure-scale) and habitat within 1-, 5-, 10-, and 20-meter radius concentric plots (plot-scale; Appendix A, Table A-2 and Appendix B). Data were also collected for spatial relationships with landscape features and other variables which did not naturally fit in either the structure- or plot-scales (larger-scale; Appendix A, Table A-1 and A-2).

I examined the spatial relationships between roosts and available water in the landscape by testing for differences in distance between roosts and random points in the landscape to available water. I defined available water as a pond or stream (medium or large) where bats could access water. I used GIS to define a arbitrary landscape of available habitat based on the maximum distance a female long-eared myotis was detected from a known roost by placing a 2.4 km radius buffer centered on each roost used by females and combined contiguous buffers into continuous polygons associated with each capture area. I used a random numbers generator in GIS to place 50 random points within each polygon and measured distance from each roost and random point to available water and stand condition at each roost and random point (Appendix B).

Data Analysis

I used a Fisher Exact test (PROC FREQ, SAS Institute 1990) to test for differences in the types of structures used as day-roosts between areas with different management histories and between females with different reproductive conditions; expected values were calculated using overall proportions of roost types used. I conducted a Chi-square test to compare stand conditions in which roosts were located and random points in the landscape by capture site and for the entire study area. A 2-sample t-test was used to test for differences in the distance of verified roosts and random points to available water and capture sites. To analyze characteristics of dead or defective conifer trees and conifer stumps used as roosts, I pooled data from bats (regardless of reproductive condition) instrumented over 2 years and throughout the study area which is a Design 2 approach from Thomas and Taylor (1990). Twenty dead or defective conifer trees and 38 conifer stumps were used in the statistical analysis. I calculated descriptive statistics of used and random structures using SAS statistical software.

I used stepwise logistic regression (PROC GENMOD, SAS Institute 1997) to compare roosts to randomly available structures and to test for differences among years, watersheds, capture sites, and stands. Logistic regression was used because it is distribution-free and can include both discrete and continuous variables (Ramsey and Schafer 1997, Steel et al. 1997). To examine the importance of habitat variables associated with different spatial scales, I conducted individual logistic regression analyses at structure-, plot-, and larger-scales for dead or defective conifers and for conifer stumps. As selection of roosts may be influenced by characteristics associated with habitat variables from different spatial scales I also conducted stepwise-logistic regression analyses using data from all spatial scales for dead or defective conifers and for conifer stumps. I used a 0.05 p-value for entering variables into a model, a 0.10 p-value to remove variables from a model.

Positive coefficient parameters in logistic regression models indicate that an increase in that variable results in an increase in the probability of the structure being used as a roost whereas a negative value indicates a decrease in the odds of use. Exponentiated parameter estimates identified using logistic regression are interpreted to be the odds ratio associated with habitat characteristics of that particular model (Ramsey and Schafer 1997, Steel et al. 1997). Standard errors associated with variables can not be used directly to interpret variable estimates due to the asymmetry of the log scale associated with logistic regression analysis, but can be used to estimate confidence intervals of exponentiated estimates (Ramsey and Schafer 1997, Steel et al. 1997).

Results

I captured 903 bats of which 47 were recaptures (Appendix C, Table C-1). Long-eared myotis comprised 10.2% (92 bats) of overall captures. I attached radio transmitters to 24 long-eared myotis and identified 80 roosts on 110 occasions. Twenty-one females were tracked to 74 roosts on 102 occasions and 3 males to 6 roosts on 8 occasions (Table 2-3). Individual females were located on 1-11 occasions (mean = 4.86, SE = 0.50) with an average of 3.52 roosts being identified for each female (SE = 0.37, range 1-8). Low

Table 2-3. Roost structures used by long-eared myotis through radio telemetry. Sample size (n) indicates the number of instrumented individuals.

	Female (n = 21)	Male (n = 3)
structure		
conifer tree (live)	3	0
conifer tree (dead or defective)	22	1
hardwood tree (live)	1	0
hardwood snag (dead)	5	1
conifer log	2	1
conifer stump	41	1
slash pile	0	1
rock crevice (abandoned quarry)	0	1
total	74	6

levels of roost fidelity were observed with females remaining in a roost for an average of 1.23 days (SE = 0.06; range 1-4). On only 6 occasions (4 bats) did females remain in a stump roost for more than 1 day (maximum = 3, range 1-3). Females which roosted in trees (i.e., conifers or hardwoods) consistently changed roosts the following day except on 8 occasions (7 bats) when they remained in the same roost for up to 4 days.

Reproductive condition did not appear to influence the type of structure a female long-eared myotis used ($p = 0.383$) though individuals appeared to differ in types of structures selected as day-roosts (Table 2-4). Eight (38%) of the 21 instrumented females were tracked only to conifer stumps and logs whereas 10 (48%) only used live, defective, or dead trees (i.e., conifers or hardwoods). Only 3 (14%) females used both categories of structures. One conifer snag was used as a day-roost during both years of this project

Table 2-4. Observed frequencies in types of roost structures used by female long-eared myotis in different reproductive conditions.

Variable	Stump/log	Tree	Both
reproductive condition			
non-reproductive	1	1	0
pregnant	0	3	1
lactating	3	5	1
post-lactating	4	1	1
total	8	10	3

(presumably by different individuals), though the actual roost crevice was located in different parts of the tree each year. Additionally, one conifer snag identified as a random structure in 1996 was subsequently used as a roost in 1997.

Female long-eared myotis used different types of roosts in landscapes characterized by different seral conditions ($p < 0.0001$; Table 2-5). They primarily roosted in conifer stumps in landscapes characterized by younger forests, though other types of structures (i.e., dead hardwoods, conifer trees, and conifer logs) were occasionally used. In landscapes dominated by older forests, female long-eared myotiS primarily roosted in dead or defective conifers and secondarily used conifer stumps, logs, and hardwood trees.

Table 2-5. Observed frequencies in types of roost-structures used by female long-eared myotis between landscapes characterized by different seral conditions. Capture sites in the Little Fall Creek and South McKenzie River landscapes were included in the "younger" seral category whereas those in Fall Creek were included in the "older" seral category.

Variable	Younger	Older
roost type		
conifer stumps	27	14
conifer trees	2	23
hardwood trees	5	1

Female long-eared myotis did not roost in stand proportional to what was expected ($\chi^2 = 82.01$, df = 3, $p < 0.001$; Table 2-6). Different types of roosts were associated with different stand categories. Twenty-one of the 22 dead or defective conifers were located in stands in mature or older stand categories whereas all of the stumps and logs used as roosts were located in stands <35 years old. Female long-eared myotis which roosted in conifer stumps and logs in dense young stands (young-closed category) selected roosts in gaps in the vegetation.

Table 2-6. Observed frequencies of roosts (all roost types combined) and random points by stand category for the entire study area.

Variable	Roost	Random
stand age		
young-open	34	30
young-closed	13	61
mid/mature	15	107
older	12	52

Only two roosts, one dead and one live conifer tree, were located within 100 m of large streams. The remainder of the roosts were located in upslope habitats, generally in the middle of the slope rather than on ridge tops. Mean distances from capture sites were 0.725 km (SE = 0.032 km) to stumps used as roosts and 0.617 km (SE = 0.039 km) to dead and defective conifer trees used as roosts. On average, structures used as roosts were located 0.59 km from "available" water. Roosts were not located significantly closer to "available" water than random points in the landscape (one-tailed p-value = 0.18), though they were significantly closer to captures sites (one-tailed p-value < 0.0001). Only one female long-eared myotis roosted beyond the topographic boundary of the watershed in which it was captured.

Dead or Defective Conifer Trees

Dead or defective conifer trees used as roosts had a mean height of 33.6 m (SE = 4.7 m), a mean diameter at breast height (DBH) of 93.3 cm (SE = 11.8 cm), retained the majority of the bark (mean = 82.7%, SE = 5.2%), and had a small percentage of the crown remaining (mean = 13.6%, SE = 6.5%). Dead or defective conifer trees used as roosts generally did not extend above the forest canopy, though all roost either extended into the upper canopy or were located on the edges of stands or in gaps; 18 roosts (86%) had broken tops. Douglas-fir was the predominant species of dead and defective tree identified as roosts (90%, n = 18); the remainder (10%, n = 2) were western hemlock. The majority of roosts were in decay class 2 (n = 13, 65.0%), with the remainder in decay classes 1 (n = 5, 25.0%) and 3 (n = 2, 10.0%). Descriptive statistics of habitat variables for dead or defective conifer tree roost and "available" trees are presented in Table 2-7.

Regression models were identified for each scale examined (Table 2-8). Snags in decay class 2 were approximately 29 times (95% CI = 4.3 to 343.1) more likely to be selected as a roost than structures in class 3 whereas conifers in decay class 1 were nearly twice as likely to be used (odds = 1.73, 95% CI = 0.30 to 14.0) as structures in class 3. A dead or defective conifer was 1.51 times (95% CI = 1.14 to 2.16) as likely to be used if there was another dead or defective conifer within 20 m after accounting for the watershed in which the structure was located. A dead or defective conifer with 5 snags within 20 m of it in the Fall Creek watershed is nearly 8.5 times (95% CI = 1 to 169.8) as likely to be selected as a roost as one with 5 snags in the South McKenzie area (Figure 2-1). Odds of a dead or defective conifer being selected as a roost is 1.05 times (95% CI =

0.22 to 4.61) if it was located 0.186 km (observed mean) from the edge of the stand whereas it is approximately 1.4 times (95% CI = 0.39 to 4.79) as likely if the structure is located 0.100 km from the stand edge (Figure 2-2). Care should be taken interpreting absolute values of the odds ratios due to small sample sizes and limited range of the data associated with some of the variables, especially if confidence intervals include 1.

Table 2-7. Habitat variables measured for dead and defective conifers used as roosts and random structures. Values for discrete variables are the number of observations whereas values for continuous variables are means and (SE).

Variable	Roost (n = 20)		Random (n = 24)	
decay class				
1	5		13	
2	13		2	
3	2		9	
top condition				
broken	17		15	
intact	3		9	
species				
Douglas-fir	18		21	
western hemlock	2		3	
height (m)	33.6	(4.7)	34.7	(4.1)
DBH (cm)	93.3	(11.8)	82.1	(10.5)
bark remaining (%)	82.7	(5.2)	93.4	(3.4)
crown (%)	13.6	(6.5)	36.0	(7.9)
slope (%)	45.0	(5.8)	42.2	(5.8)
aspect (°)				
elevation (m)	472.2	(20.4)	472.9	(21.8)
number of trees	38.5	(3.3)	35.9	(2.4)
number of snags	12.1	(1.6)	8.9	(0.9)
number of snags (decay 2)	3.7	(0.7)	1.5	(0.4)
maximum access, 0-8 m (%)	80.2	(4.8)	78.7	(5.0)
maximum access, 8-16 m (%)	93.7	(2.6)	87.0	(4.0)

Table 2-7. Continued.

Variable	Roost (n = 20)		Random (n = 24)	
maximum access, >16 m (%)	87.7	(4.8)	65.6	(9.7)
maximum access (%)	96.0	(1.5)	91.1	(2.3)
canopy cover, 20 m radius (%)	48.6	(4.6)	60.1	(4.2)
canopy cover, 50 m radius (%)	59.7	(3.7)	63.0	(3.5)
distance to nearest uphill tree ≥ in height (m)	6.6	(1.2)	7.1	(1.2)
distance to near downhill tree ≥ in height (m)	8.4	(1.4)	8.4	(1.3)
distance to capture site (km)	0.621	(0.038)	0.900	(1.160)
distance to road (km)	0.239	(0.038)	0.357	(0.083)
distance to edge of stand (km)	0.177	(0.032)	0.371	(0.069)
distance to large stream (km)	0.530	(0.052)	0.503	(0.081)

Table 2-8. Logistic regression models for dead or defective conifers. Odds ratios for decay class are relative to a decay class 3 reference condition. The combined scale was derived from a stepwise analysis using variables from the other 3 scales. Parameter estimates and 95% confidence intervals (CI) are on the natural log scale.

Scale	Variable	df	P	Parameter Estimate	Odds Ratio	95% CI Low	95% CI High
structure							
	intercept	1		-1.5041	0.22	-3.3849	-0.1482
	decay[a]	2	0.0002				
	class 1	1		0.5486	1.73	-1.2168	2.6392
	class 2	1		3.3759	29.25	1.4466	5.8380
	class 3	0		0.000			
plot							
	intercept	1		-2.992	0.05	-6.294	-0.811
	watershed[b]	1	0.0412				
	FCK	1		2.153	8.61	0.076	5.136
	SMK	0		0.000			
	# of snags[c]	1	0.0024	0.409	1.51	0.132	0.768
larger							
	intercept	1		0.619	1.86	-0.290	1.6116
	distance (km)[d]	1	0.0192	-3.061	0.05	-6.528	-0.447
combined							
	intercept	1		-1.5041	0.22	-3.3849	-0.1482
	decay[a]	2	0.0002				
	class 1	1		0.5486	1.73	-1.2168	2.6392
	class 2	1		3.3759	29.25	1.4466	5.8380
	class 3	0		0.000			

[a] Decay class of structures.

[b] Watersheds with roosts (FCK = Fall Creek, SMK = South McKenzie River).

[c] Number of snags in decay class 2.

[d] Distance to the edge of the stand (km).

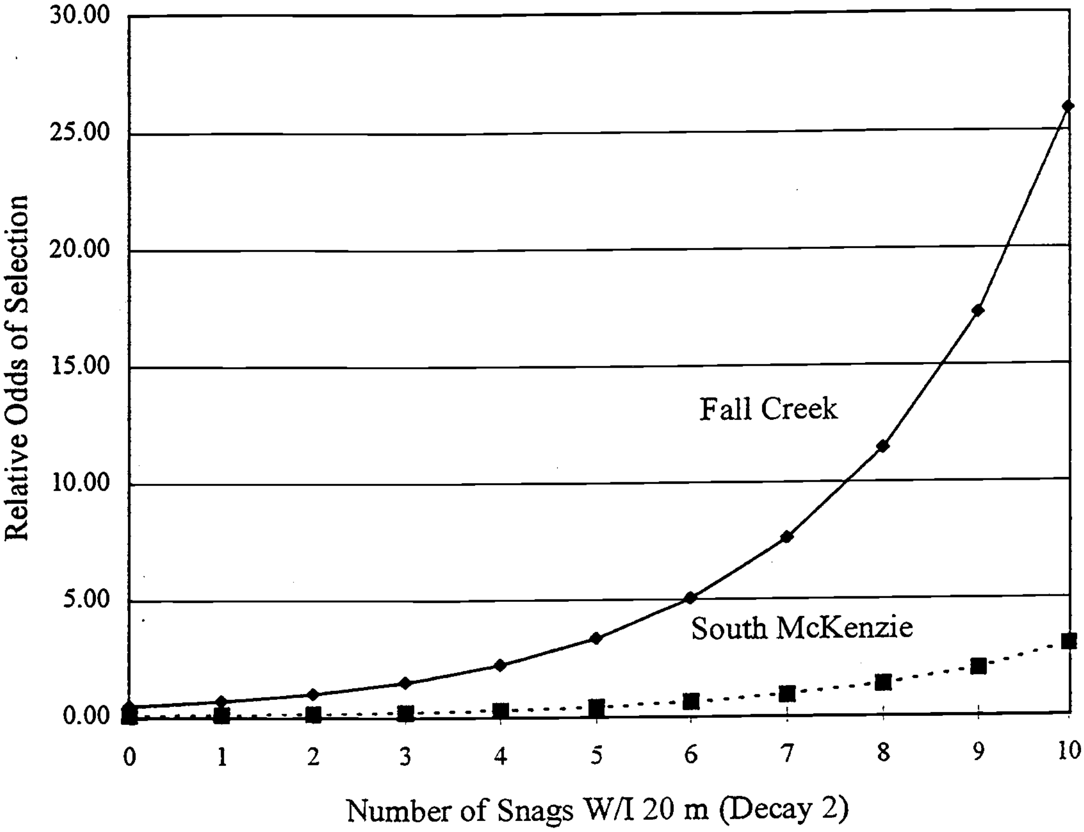

Figure 2-1. Probability of a conifer being selected as a day-roost by a female long-eared myotis relative to a change in the number of snags (decay 2) within 20 m of the central structure. Observations of number of snags within 20 m of the structure ranged from 0 to 10 for roost and random structures. Models: Fall Creek odds = exp(-2.992 + 2.153 + 0.409*snags); South McKenzie odds = exp(-2.992 + 0.409*snags).

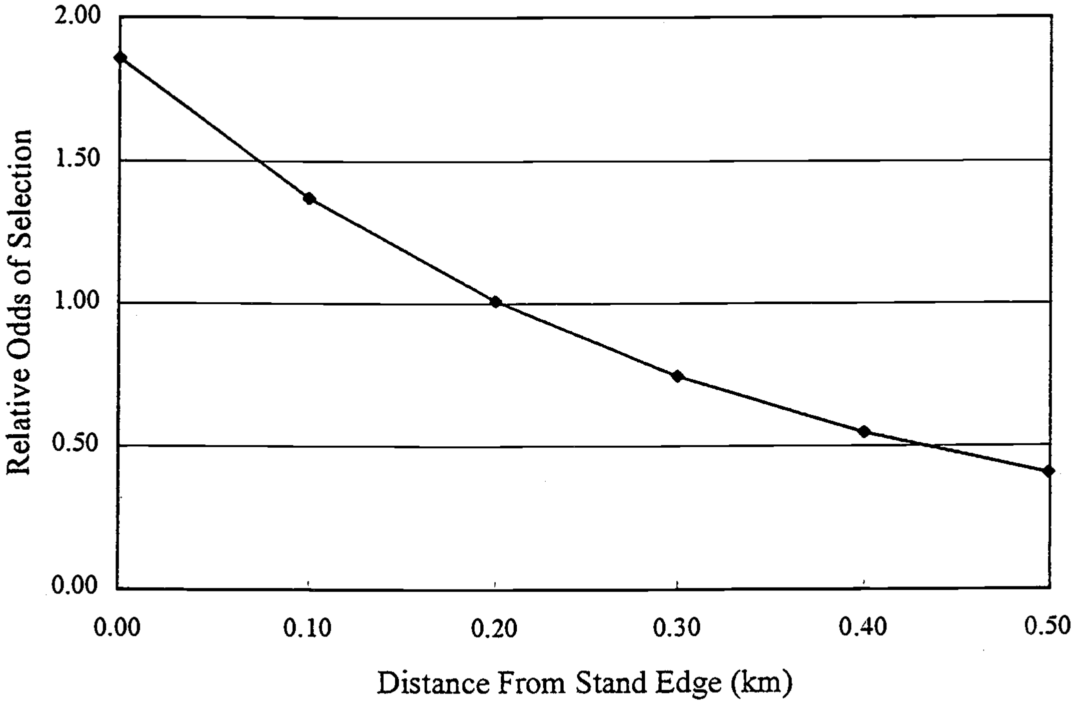

Figure 2-2. Probability of a conifer being selected as a day-roost by a female long-eared myotis relative to a change in the distance to the stand edge which ranged from 0.006 to 0.417 km for roosts and 0.024 to 1.185 for random structures. Model: Odds = exp(0.619 - 3.061*edge). Edge represents the distance of the structure from the edge of the stand (km).

Conifer Stumps

Conifer stumps used as roosts had a mean uphill height of 58.7 cm (SE = 5.8 cm), downhill height of 133.4 cm (SE = 9.1 cm), and diameter of 59.3 cm (SE = 3.5 cm). The majority of bark remained on stumps used as roosts (72.1%, SE = 3.5%). Western hemlock was the predominant species of stump used as roosts (61%, n = 23) with the remainder being Douglas-fir (34%, n = 13) and western redcedar (5%, n = 2). Descriptive statistics of habitat variables for stump-roost and "available" stumps are presented in Table 2-9.

Regression models were identified for each scale examined (Table 2-10). After accounting for percentage of potential crevice (crevice and crevice*crevice) and downhill height of the stump, female long-eared myotis were approximately 20 times (95% CI = 2.5 to 265.1) more likely to use Douglas-fir and nearly 9 times (95% CI = 1.4 to 90.5) more likely to use western hemlock as western redcedar. Additionally, female long-eared myotis were more likely to use stumps which were taller on the downhill side (Figure 2-3). Care should be taken interpreting absolute values of the odds ratios due to small sample sizes and limited range in the data associated with some of the variables, especially if confidence intervals include 1.

Table 2-9. Habitat variables measured for conifer stumps used as roosts and random structures. Values for discrete variables are the number of observations whereas values for continuous variables are means and (SE).

Variable	Roost (n = 38)		Random (n = 54)	
species				
Douglas-fir	13		18	
western hemlock	23		26	
western redcedar	2		10	
crevice, width (cm)	17.3	(1.2)	11.9	(1.8)
crevice, depth (cm)	49.3	(3.8)	21.9	(3.8)
crevice, opening depth (cm)	2.8	(0.3)	1.6	(0.2)
crevice, height (cm)	101.7	(6.7)	77.2	(9.3)
crevice, bark thickness (cm)	1.7	(0.2)	1.6	(0.2)
crevice, aspect (°)				
bark thickness, stump (cm)	1.7	(0.2)	1.5	(0.1)
height, uphill (cm)	58.7	(5.8)	54.4	(4.5)
height, downhill (cm)	133.4	(9.1)	109.6	(7.6)
diameter (cm)	59.3	(3.5)	57.7	(3.1)
bark remaining (%)	72.1	(3.5)	69.5	(4.1)
potential crevice (%)	34.2	(3.1)	15.5	(2.5)
slope (%)	66.3	(2.6)	56.2	(2.9)
aspect (°)				
elevation (m)	667	(25)	695	(22)
distance to capture site (m)	734	(32)	757	(40)
distance to available water (m)	711	(36)	724	(43)

Table 2-9. Continued.

Variable	Roost (n = 38)		Random (n = 54)	
small logs, 0-1 m	0.8	(0.2)	1.2	(0.2)
small logs, 0-5 m	6.2	(0.8)	7.0	(0.7)
large logs, 0-1 m	0.2	(0.1)	0.3	(0.1)
large logs, 0-5 m	1.4	(0.3)	1.6	(0.3)
large logs, 0-10 m	4.0	(0.6)	4.3	(0.5)
large logs, 0-20 m	10.9	(1.4)	11.5	(1.2)
stumps, 0-1 m	0.2	(0.1)	0.2	(0.1)
stumps, 0-5 m	2.8	(0.4)	2.0	(0.2)
stumps, 0-10 m	8.9	(0.8)	7.9	(0.7)
all wood, 0-1 m	1.2	(0.2)	1.8	(0.2)
large wood, 0-1 m	0.4	(0.1)	0.5	(0.1)
all wood, 0-5 m	4.7	(0.6)	3.8	(0.4)
large wood, 0-5 m	10.8	(1.1)	10.8	(0.8)
large wood, 0-10 m	13.7	(1.1)	13.1	(0.8)
saplings, 0-1 m	0.3	(0.1)	0.4	(0.1)
saplings, 0-5 m	8.9	(1.3)	11.7	(1.2)
saplings, 0-10 m	36.3	(5.6)	41.9	(4.0)
saplings, 5-10 m	27.4	(4.4)	30.1	(2.9)
trees, 0-20 m	3.6	(1.2)	3.4	(0.7)
overhead access, 5 m (%)	83.9	(4.7)	68.1	(5.2)
maximum access, 2 m (%)	91.7	(2.8)	74.5	(4.3)
maximum access, 5 m (%)	85.5	(3.1)	62.1	(4.8)

Table 2-10. Logistic regression models of habitat variables for conifer stumps. Odds ratios for species are relative to a reference condition of western redcedar. The combined scale was derived from a stepwise analysis using variables from the other 3 scales. Parameter estimates and 95% confidence intervals (CI) are on the natural log scale.

Scale	Variable	df	P	Parameter Estimate	Odds Ratio	95% CI	
						Low	High
structure							
	intercept	1		-6.766	0.001	-10.436	-3.889
	species[a]	2	0.0159				
	Douglas-fir	1		3.014	20.367	0.898	5.580
	hemlock	1		2.194	8.968	0.306	4.505
	redcedar	0					
	height[b]	1	0.0440	0.010	1.010	0.0003	0.020
	crevice[c]	1	0.0001	0.174	1.190	0.092	0.271
	crevice*crevice[c]	1	0.0065	-0.001	0.999	-0.002	-0.0004
plot							
	intercept	1		-2.397	0.091	-4.193	-0.973
	access[d]	1	0.0001	0.034	1.034	0.016	0.056
	wood[e]	1	0.0190	-0.355	0.701	-0.693	-0.056
larger							
	intercept	1		-2.077	0.125	-3.700	-0.633
	slope[f]	1	0.0132	0.028	1.028	0.006	0.053

Table 2-10. Continued.

Scale	Variable	df	P	Parameter Estimate	Odds Ratio	95% CI	
						Low	High
combined							
	intercept	1		-17.883	$1.712\text{x}10^{-8}$	-28.208	-10.600
	species[a]	2	0.0607				
	Douglas-fir	1		3.647	38.356	0.543	7.882
	hemlock	1		2.809	16.590	-0.134	6.821
	redcedar	0		0.000			
	crevice[c]	1	0.0001	0.233	1.262	0.125	0.373
	crevice*crevice[c]	1	0.0017	-0.002	0.998	-0.003	-0.0007
	access[d]	1	0.0021	0.045	1.046	0.015	0.081
	slope[e]	1	0.0002	0.082	1.085	0.035	0.142
	wood[f]	1	0.0010	-0.791	0.454	-1.397	-0.298
	area[g]	3	0.0260				
	SMK 1	1		3.314	27.503	0.733	6.420
	SMK 2	1		3.565	35.328	0.819	6.836
	FCK 1	1		4.254	70.393	1.280	7.912
	FCK 2	0		0.000			

[a] Species of stump (Douglas-fir, western hemlock, and western redcedar).

[b] Height of stump on downhill side (cm).

[c] Percent of stump circumference that has crevices which bats could use as roosts.

[d] Percent access at 5 m.

[e] Percent slope.

[f] Pieces of wood (all sizes) within 1 m of the stump.

[g] Capture site area.

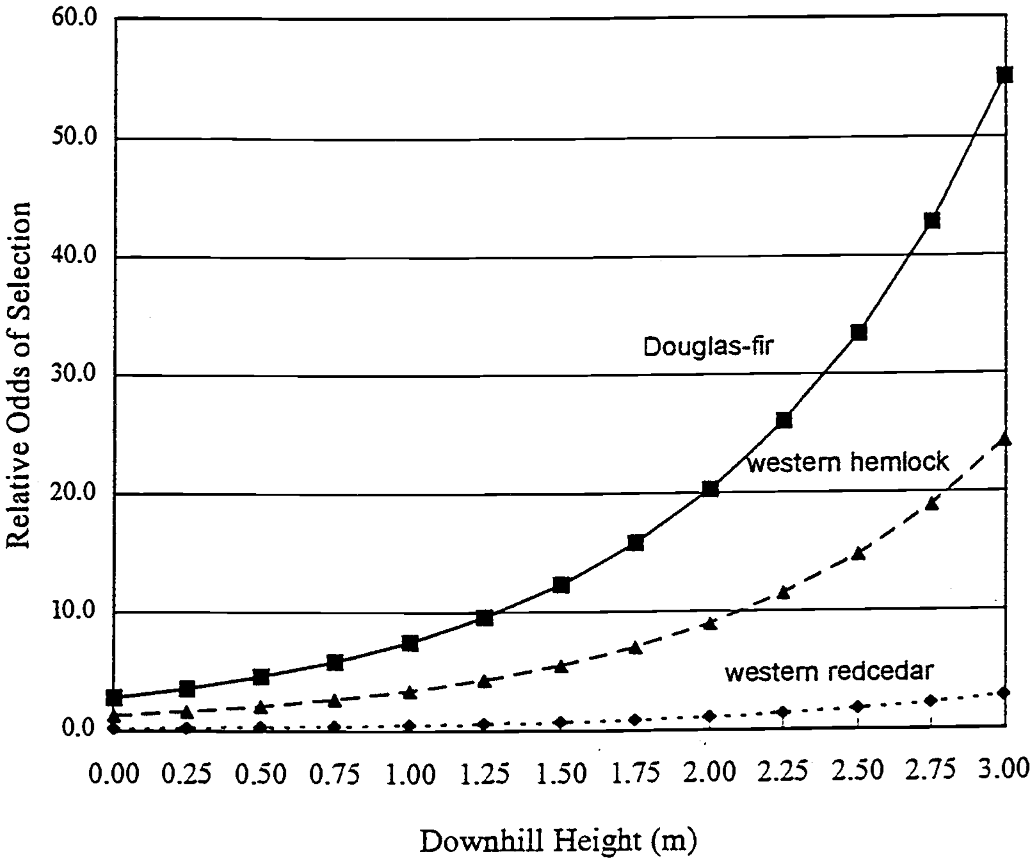

Figure 2-3. Probability of a conifer stump being selected as a day-roost by a female long-eared myotis relative to a change in the downhill height of the stump. Downhill heights of stumps range from 0.27 to 2.85 m for roosts and 0.43 to 3.23 m for random stumps. Percent crevice was held constant at 34%, the mean observed for roosts. Models: Douglas-fir odds = exp(-6.766 + 3.014 + 0.010*height + 0.174*crevice - 0.001*crevice^2) western hemlock odds = exp(-6.766 + 2.194 + 0.010*height + 0.174*crevice - 0.001*crevice^2); western redcedar odds = exp(-6.766 + 0.010*height + 0.174*crevice - 0.001*crevice^2).

Discussion

Roost Characteristics

Female long-eared myotis appear to be flexible in selection of roosts and use multiple types of structures as day-roosts. My observations that dead or defective conifer trees and conifer stumps were primary roost structures is consistent with previous observations of the species in the Pacific Northwest (Manning and Jones 1989, Christy and West 1993, Vonhof and Barclay 1996, Marshall et al. 1996, Vonhof and Barclay 1997). The ability of long-eared myotis to use multiple types of roosts may enable individuals to adapt to changes in abundance of different structures in the landscape. However, reproductive demands and other needs of female long-eared myotis may not be met in all roost types.

My observation that female long-eared myotis did not extensively use dead or defective conifers which extended above the forest canopy differs from previous results for long-eared myotis and several other species of forest-dwelling bats in the Pacific Northwest. Vonhof and Barclay (1996) concluded that several species of bats (big-brown bat, *Eptesicus fuscus*, silver-haired bat, *Lasionycteris noctivagans*, long-eared myotis, *Myotis evotis*, long-legged myotis, *M. volans*, and *Myotis* species), select large conifer snags which extend above the forest canopy. This has also been reported for California myotis (*M. californicus*, Brigham et al. 1997). Additional observations on long-legged myotis (Ormsbee and McComb 1998), and silver-haired bats (Campbell et al. 1996, Betts 1998) in different areas suggest that selection of roosts which extend above the forest canopy may apply to some species through out the Pacific Northwest. The consistency of the pattern across taxa has resulted in the inference that this pattern of use can be applied to bat communities of the Pacific Northwest. However, my data suggest that this extrapolation may be inappropriate for some species (e.g., long-eared myotis) or in areas having similar structures with other characteristics which may meet the needs of reproductive bats.

Emergent dead or defective conifers often are suggested to provide navigational cues, increased solar radiation, and increased access to bats (Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Callahan et al. 1997, Betts 1998, Ormsbee and McComb 1998). Dead or defective conifers which are located on edges of stands or in gaps and do not extend above the canopy may provide many of these same benefits. Many species of bats use gaps and edges in the forest canopy as foraging areas or as travel corridors (Kunz 1973, Fenton and Bell 1979, Barclay 1985, Lunde and Harestad 1986, Furlonger et al. 1987, von Frenckell and Barclay 1987, Crome and Richards 1988, Thomas 1988, Clark et al. 1993, Adam et al. 1994). Use of edges and gaps may increase the likelihood of bats locating roosts in these areas. In addition, emergent structures (e.g., dead or defective trees), roosts located on edges and in gaps, and roosts in stands located on south and west facing slopes generally receive relatively high levels of solar radiation. Snags receiving high levels of solar radiation acquire more heat than those that are shaded for a major portion of the day (Geiger 1957). This increased warmth has been hypothesized to benefit bats by facilitating fetal or juvenile development and by minimizing energy demands of reproductive females (Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Vonhof and Barclay 1997, Betts 1998, Ormsbee and McComb 1998).

Roosts in stumps also generally receive high levels of solar radiation due to the lack of overstory vegetation. The small size of stumps and lack of vegetative cover may also result in extreme temperatures in these structures. Bats which roost in stumps may benefit from warmer temperatures but risk exposure to extreme temperatures due to the small size of the structure. Bats have been observed to move within a roost, possibly as a means of coping with extreme temperatures. Yuma myotis (*M. yumanensis*), pallid bats (*Antrozous pallidus*), and Brazilian free-tailed bats (*Tadarida brasiliensis*) avoided the warmest temperatures in a roost by moving to areas with cooler temperatures (Licht and Leitner 1987). The relatively small size of crevices in stumps may prohibit bats from moving to more favorable temperatures within the roost.

Access may be particularly important in determining if a stump will be used. My finding that female long-eared myotis use highly accessible stumps is consistent with observations of long-eared myotis in British Columbia (Vonhof and Barclay 1997). Roosting opportunities in stumps may be ephemeral as vegetation often covers stumps in a relatively short period of time limiting access to them. Large stumps or stumps located on steep ground or in stands with minimal vegetation (i.e., low densities of seedlings, saplings, and shrubs) may remain accessible for relatively long periods. Additionally, newly created stumps generally do not provide crevices in which bats can roost. It is only after a period of time, probably several years, that the bark will have exfoliated sufficiently to allow bats to roost. Consequently, there may be a limited time in which most stumps can be effectively used as roosts by bats, beginning when the bark has exfoliated sufficiently to provide crevices for roosting and ending when vegetation in the stand has grown sufficiently to restrict access to stumps.

Vonhof and Barclay (1997) found that pines (*Pinus contorta*, *P. monticola*, *P. ponderosa*) received the highest levels of use by roosting long-eared myotis while western hemlock were selected against. In contrast, I found that western hemlock stumps were extensively used. This difference in use may be associated with the greater species richness of trees occurring in Vonhof and Barclay's study area. Furthermore, Vonhof and Barclay (1997) suggested that use of conifer stumps as day-roosts by long-eared myotis may be limited to males or nonreproductive females. In addition to males and nonreproductive females, I observed reproductive females and juveniles using stumps as day-roosts, indicating that, at least in my study area, use of stumps by long-eared myotis is not restricted by age, sex, or reproductive condition. The use of conifer stumps by bats appears to primarily be associated with long-eared myotis though I occasionally observed solitary Yuma myotis, California myotis, and fringed myotis (*M. thysanodes*) roosting in stumps (unpublished data). Vonhof and Barclay (1997) also found a single male Yuma myotis in a stump.

Landscape and Spatial Patterns

My finding that female long-eared myotis used roosts which were located predominantly in upslope habitats is consistent with findings for several species of bats in the Pacific Northwest (Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al.

1997, Vonhof and Barclay 1997, Betts 1998, Ormsbee and McComb 1998). Use of upslope habitats may promote warmer and more stable environments within roosts whereas environmental conditions associated with riparian areas may keep roosts cooler and not allow them to warm sufficiently. Roosts located on ridges may be highly exposed and subject to more environmental variability (e.g. extremes in temperatures through high levels of solar radiation) than roosts located on the middle of the slope. Additionally, bats that roost in structures on ridges may be subjected to periods of higher wind velocity which could negatively impact the ability of bats, particularly juveniles, to fly affectively in the area.

I observed that female long-eared myotis used day-roosts that were located relatively close to available water and were significantly closer to capture sites (i.e., ponds and bridges used as night-roosts). Close proximity between day-roosts and water may minimize energetic demands associated with travel between roosts and foraging areas. My data suggest that observed patterns of use within landscapes are associated with features in landscapes which are important to bats (e.g., water sources and night-roosts), features which researchers often use to capture bats.

Female long-eared myotis primarily used conifer stumps in intensively logged landscapes and dead or defective conifer trees in landscapes dominated by older forests. Intensively logged landscapes generally have few large dead or defective conifers (Neitro et al. 1985, Ohmann et al. 1994), and bats inhabiting these landscapes may be forced to use other types of structures (i.e, stumps and logs), compete with other bats and wildlife for roost sites in the few remaining large dead or defective trees, or disperse from the area. If large conifers that are dead or defective are preferred roosts of forest-dwelling bats, loss of these structures in a landscape may influence species composition, distribution, and population sizes in landscapes with low densities of these structures.

Roost Fidelity

Minimal roost fidelity was exhibited by female long-eared myotis regardless of type of structure used. Lewis (1995) hypothesized that roost fidelity is associated with disturbance and several other factors. Roosts located low to the ground (e.g., logs, rock crevices, stumps, trees) may be subject to higher levels of disturbance than those located higher in trees or on cliffs. Long-eared myotis that roosted in stumps often switched roosts on a daily basis. Activity near or in roosts may disturb a bat and cause it to change roosts. On several occasions, I flushed bats from stump used as roosts. These bats flew a short distance and found cover in another stump. On one occasion a rubber boa (*Charina bottae*) was observed in the roost crevice in a snag at the same time that at least four long-eared myotis (presumably a maternity colony and including the instrumented female) were present. The following day, no bats were observed in the crevice, the instrumented bat was roosting in a nearby snag, and a rubber boa (presumably the same snake) was again observed in the same crevice.

Though female long-eared myotis exhibit relatively low fidelity to individual roosts, they appear to have increased fidelity to areas in the landscape in which multiple roosts are located. Other researchers have observed similar patterns for big-brown bats (Vonhof and Barclay 1996), California myotis (Brigham et al. 1997), long-eared myotis

(Vonhof and Barclay 1996), long-legged myotis (Vonhof and Barclay 1996, Ormsbee and McComb 1998), and silver-haired bats, (Campbell et al. 1996, Vonhof and Barclay 1996, Betts 1998). Having multiple roosts in a relatively limited area may be beneficial because these roosts may offer similar environmental conditions and if a bat is disturbed at one roost, it could find refuge in a nearby structure with similar environmental conditions and minimal energy expenditure.

CHAPTER 3: NOCTURNAL ACTIVITY AREAS OF FEMALE LONG-EARED MYOTIS (*MYOTIS EVOTIS*) IN MANAGED FORESTS OF WESTERN OREGON

Introduction

Recently, research on habitat requirements of bats has focused on habitat characteristics of roost structures (see Barclay et al. 1988, Campbell et al. 1996, Mattson et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Callahan et al. 1997, Vonhof and Barclay 1997, Betts 1998, Ormsbee and McComb 1998, Rabe et al. 1998). This focus results from the perception that the loss of roosts may imperil bats during periods when they are susceptible to disturbance (i.e., maternity season, hibernation). Roost structures must be in close proximity to water and foraging areas for them to be energetically feasible for bats to use them.

Information on activity areas of forest-dwelling bats in the Pacific Northwest is limited. Available information often is anecdotal or is inferred from capture results (Kunz 1973, Reith 1980), research on individual species conducted in other regions (Brigham 1991, Clark et al. 1993, Adam et al. 1994, Wethington et al. 1996), or use of ultrasonic detectors (Lunde and Harestad 1986, Thomas 1988, Hayes 1997). Information on spatial relationships of roosts and activity areas in the Pacific Northwest is virtually nonexistent. In general, long-eared myotis and many other species of bats are thought to roost in forests and commute to foraging areas, which are generally considered to be associated with riparian areas (Thomas 1988).

The diversity of bats in the Pacific Northwest combined with the lack of information on foraging ecology of bats and concerns for the welfare of many of these species suggests that foraging ecology is a critical issue which should be investigated to provide a frame of reference for informed management of landscapes for bats. Managing roosts for bats without an understanding of their spatial relationship with foraging areas may result in ineffective or detrimental management to bat populations.

My objectives were to characterize areas used at night (activity areas) by female long-eared myotis and to examine their spatial relationship day-roosts, and available water in a landscape. I also examined patterns of activity exhibited by female long-eared myotis. Specifically, I tested the following hypotheses: (1) habitat characteristics of used activity areas will not differ from characteristics of available areas; (2) activity areas will be located closer to available water than random areas.

Methods

Radio Telemetry

I attached a 0.51 g radio transmitter (model LB2, Holohil Systems Ltd.,112 John Cavanagh Road, Carp, Ontario, KOA 1L0, Canada) to each of 12 female long-eared myotis during June, July, and August 1996 and 1997 (see methods section in Chapter 2 for details on capture and transmitter attachment methodology). I used TRX-1000S Wildlife Materials (Wildlife Materials, Inc.; Carbondale, Illinois) and TR-2 Telonics receivers (Telonics, Telemetry-Electronic Consultants; Mesa, Arizona) and hand-held 4-

and 6-element yagi antennas to track bats at night. I triangulated bearings obtained simultaneously from three telemetry stations to determine areas of activity (Wilkinson and Bradbury 1988).

Rugged topography, road patterns, and mobility of the bats required that telemetry stations be moved periodically in an effort to maintain contact with the bat and to ensure optimal triangulation angles. All telemetry stations were flagged, mapped onto U.S.G.S. topographic maps, and located using a geographical positioning system (GPS; TrimbleNavigation, Ltd., Sunnyvale, California). I attempted to follow one or two female long-eared myotis for an entire night, though logistical considerations, weather, and my ability to remain in contact with the bat often shortened the tracking time during a night; several bats were tracked on multiple nights. Hand-held and citizen band (CB) radios were used to facilitate obtaining simultaneous bearings at 10 minute intervals. Repeated bearings taken at short time periods may be serially correlated (Swihart and Slade 1985). However, patterns of activity observed suggested that the bats could and often did move from one end of their activity area within the 10 minute time period; thus I have assumed points to be independent for analytical purposes.

Triangulation of simultaneous bearings was accomplished using XYLOG (Dodge and Steiner 1986). I examined error associated with my bearings by conducting blind tests using stationary transmitters placed along roads within activity areas of instrumented bats. Transmitters were placed near the ground and were often screened by topography and dense forest stands, conditions frequently encountered while tracking bats at night. Bearings and points were analyzed for representativeness based on angle between stations, influence of topography, and the distance of the bat from the telemetry station. Bearings and triangulation points that were suspect due to the influence of any factors mentioned above were excluded in the blind tests and telemetry associated with individual bats. Blind tests resulted in a mean error of 12.5° associated with bearings, a rate that is substantially higher than error rates that have been reported for this type of telemetry work with bats (+/- 4°, Adam et al. 1994; +/-1.25°, Wethington et al. 1996) if error is even reported (Brigham 1991, Clark et al. 1993). The relatively high degree of error I encountered is probably associated with the topography in which the study was conducted. Radio signals can be strongly influenced by topography, vegetation, and distance from the telemetry station (Kufeld et al. 1987). Orientation of the animal may also influence signal quality and therefore bearing accuracy. Though the error is relatively large, I believe that activity areas calculated from these bearings are representative of actual activity areas because they appear to coincide with observations of bats in the field.

Telemetry and direct observation were used to determine time of departure from a roost and time that an individual returned to a roost. Fluctuation in strength of the radio signal during the night was used to determine if the bat was active.

Activity Area Calculation

I used CALHOME (Kie et al. 1996) to calculate 95% utilization distributions (activity areas) for individual bats on multiple nights using the adaptive kernel method (Whorton 1989, 1995). I also calculated activity areas for bats on individual nights. I used least squares cross-validation with a 0.75h smoothing factor to calculate activity areas. A 50x50 cell grid was used because preliminary examination of the data suggested that the data may have a bimodal distribution (Kie et al. 1996). I used 20 locations as the minimum number of points I would use to calculate activity areas based upon preliminary data analysis and previous work conducted by Adam et al. (1994) on Virginia big-eared bat (*Corynorhinus townsendii virginianus*). Resulting polygons of activity area were imported into GIS. I used GIS to randomly locate 50 points in polygons which represented available habitat in the study area (see methods section in Chapter 2). I established a 500 m radius (78 ha) buffer around each random point and used GIS to calculate the proportion of habitat types (Appendices A and B, Tables A-3 and B-1) in each activity area and random polygon. Distance to available water was measured from the geometric center of activity areas or random points using GIS and maps.

Data Analysis

To analyze characteristics of habitat used as foraging areas, I pooled data from bats instrumented over 2 years of the study, a Design 2 approach from Thomas and Taylor (1990). I analyzed data for individual bats over multiple nights (n = 11). I used stepwise logistic regression (PROC GENMOD, SAS Institute 1997) to compare activity areas and randomly available areas and to test for differences among years, watersheds, and capture sites. Logistic regression analysis is distribution-free and can include both discrete and continuous variables (Ramsey and Schafer 1997, Steel et al. 1997). To examine the importance of habitat variables and spatial data, I conducted individual logistic regression analyses for each. As selection of an activity area may be influenced by both habitat variables and spatial relationships with other features in a landscape, I also conducted stepwise-logistic regression analyses using data from both data sets. I used a 0.05 p-value for entering variables into a model, a 0.10 p-value to remove variables from a model. See Chapter 2 methods section for an explanation of interpreting parameters estimates identified from logistic regression.

Results

Activity Areas

I tracked 12 female long-eared myotis on 23 nights. Individuals were tracked for one to four nights, and individual bats had a mean nightly activity area of 39.5 ha (SE = 7.9 ha) though activity areas of individual bats identified over multiple nights tended to be somewhat larger (mean = 53.4 ha, SE = 9.2 ha). Instrumented bats tracked on a given night remained an average distance of 0.550 km (SE = 0.06 km) from the roost and 0.165 km (SE = 0.06 km) from available water (Table 3-1). The maximum distance an instrumented female long-eared myotis was detected from a roost was 2.4 km. Descriptive statistics are presented for habitat variables of activity areas defined for individual bats on individual nights (Table 3-1) and multiple nights (Table 3-2).

Nocturnal activity areas of bats instrumented in an area tended to overlap considerably, though individual activity areas generally were skewed towards the area where that individual roosted (Figure 3-1). Additionally, individual bats that were tracked on more than one night used the same general area every night (Figures 3-2 and 3-3). Activity areas defined from triangulations may not represent use of more distant areas due to my inability to adequately track bats at greater distances because of weak signals and less than optimum angles between stations that were associated with steep topography and limited road access.

Regression models were identified for each scale examined (Tables 3-3 and 3-4). Distance from available water entered all potential models and apparently is the primary measurement in determining if an area will be used by female long-eared myotis. Female long-eared myotis were more likely to use areas closer to available water (Figure 3-4). A site centered on available source of water is 330 times as likely to be used as an activity area than one centered 1 km away which has virtually no chance of being used. Care should be taken interpreting absolute values of the odds ratios due to small sample sizes and the limited range associated with data of some of the variables, especially if confidence intervals include 1.

Table 3-1. Habitat variables measured for areas used as activity areas (defined for individual nights) and random areas. Values for variables are means and (SE).

Variable	Used (n = 10)		Random (n = 199)	
young forest, open habitat	4.4	(2.7)	8.6	(0.90)
young forest, closed habitat	25.9	(8.6)	23.6	(2.05)
mature forest habitat	28.5	(6.9)	40.1	(2.17)
older forest habitat	21.5	(10.1)	15.0	(1.42)
riparian habitat	19.5	(5.4)	12.3	(0.82)
terrestrial habitat	80.5	(5.4)	87.7	(0.82)
distance to available water (km)	0.165	(0.06)	0.669	(0.032)
distance to roost (km)	0.55	(0.06)	-	-

Table 3-2. Habitat variables measured for areas used as activity areas (defined for individual bats over multiple nights) and random areas. Values for variables are means and (SE).

Variable	Used (n = 11)		Random (n = 249)	
young forest, open habitat	7.4	(3.8)	10.5	(0.9)
young forest, closed habitat	16.4	(6.8)	22.4	(1.9)
mature forest habitat	24.7	(7.3)	39.9	(1.9)
older forest habitat	33.3	(10.6)	15.4	(1.3)
riparian habitat	17.8	(4.8)	11.4	(0.7)
terrestrial habitat	82.2	(4.8)	88.6	(0.7)
distance to available water (km)	0.186	(0.06)	0.626	(0.03)

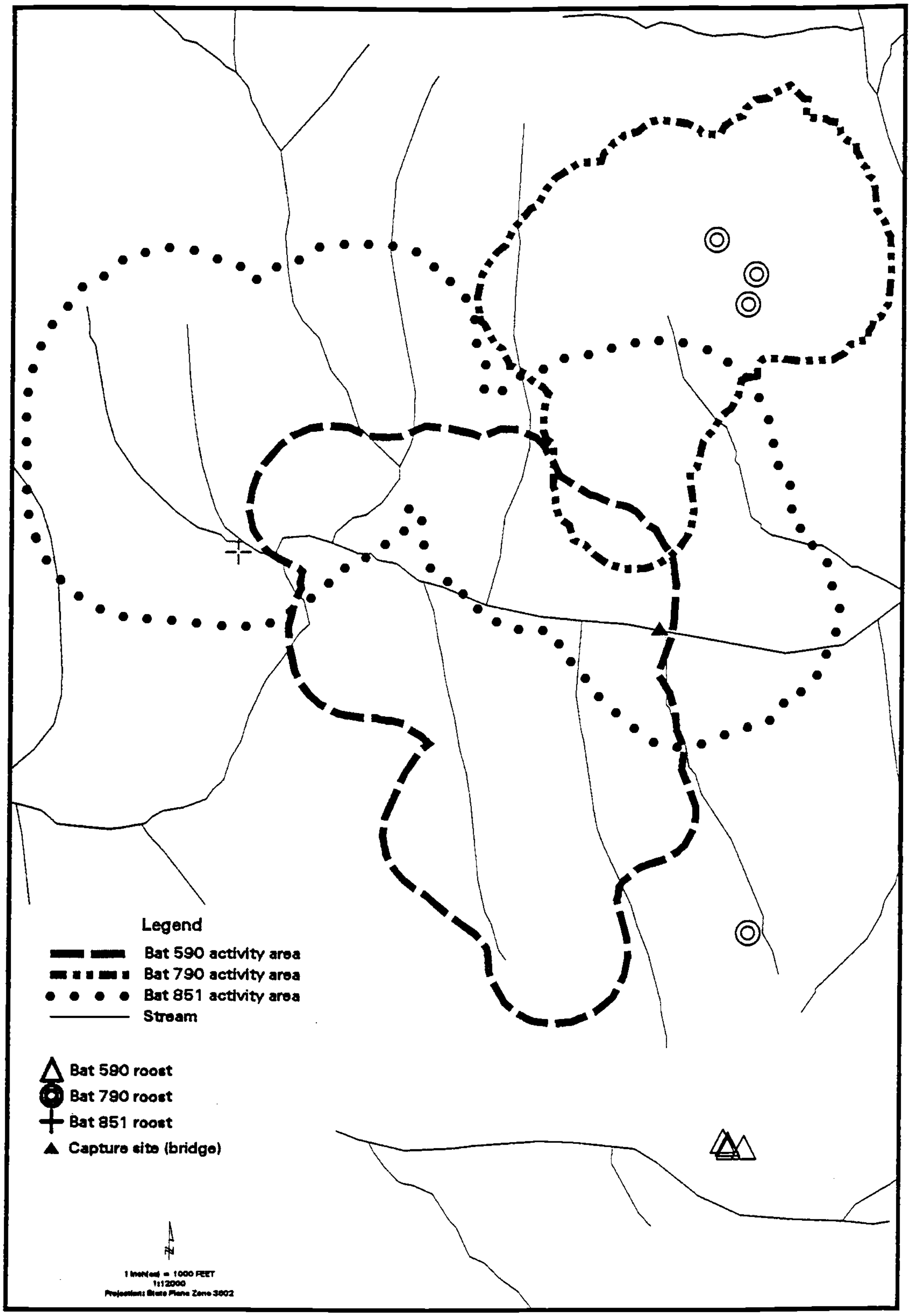

Figure 3-1. Activity areas of 3 female long-eared myotis captured at a bridge over Fall Creek.

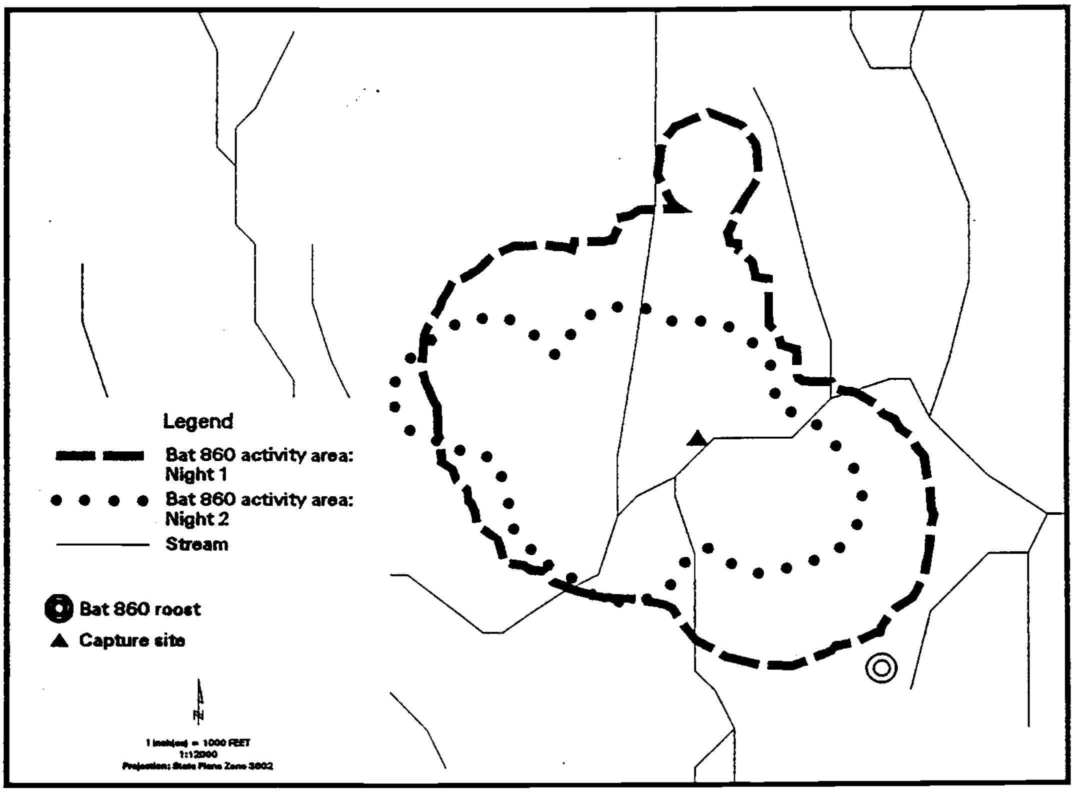

Figure 3-2. Activity areas from two nights for a female long-eared myotis captured at a bridge over Little Fall Creek.

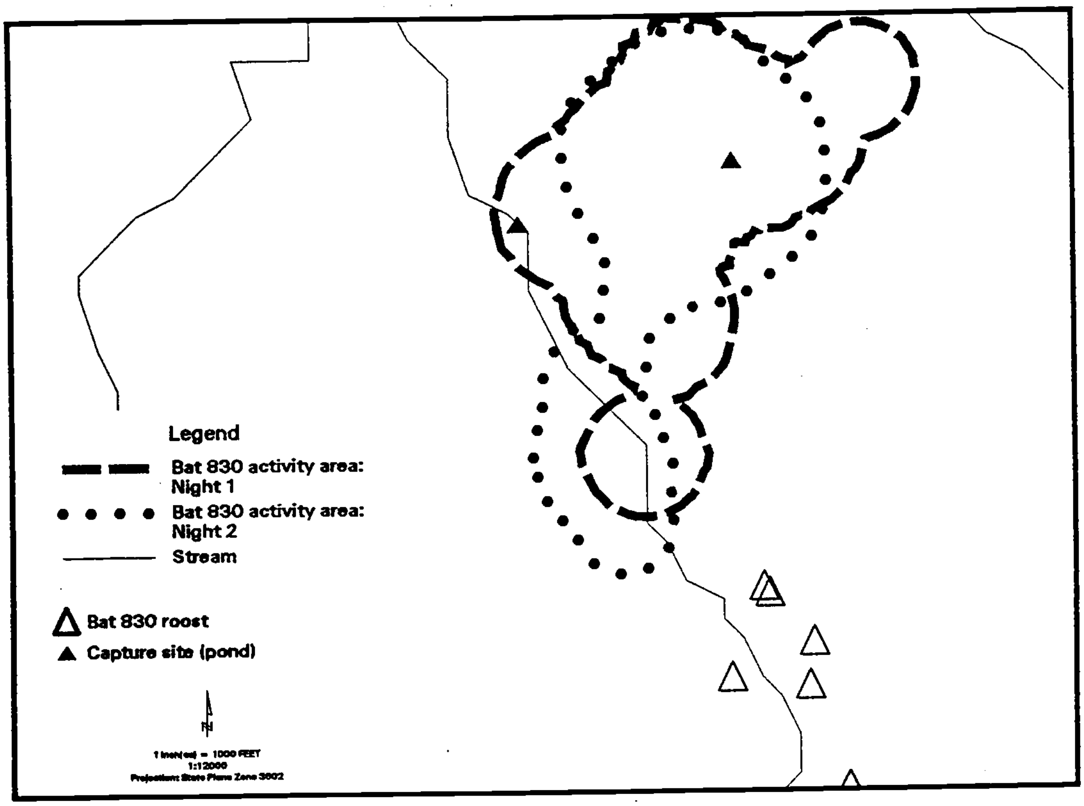

Figure 3-3. Activity areas from two nights for a female long-eared myotis captured at an upslope pond in the South McKenzie River area.

Table 3-3. Models selected using stepwise logistic regression from habitat and spatial variables for activity areas on individual nights. No model was identified for the habitat category.

Scale	Variable	df	P	Parameter Estimate	Odds Ratio	95% CI Low	95% CI High
Habitat							
	n/a						
Spatial							
	intercept	1		-1.0930	0.335	-2.1063	-0.1577
	distance[a]	1	0.0001	-5.6620	0.003	-10.3830	-2.4642
Combined							
	intercept	1		-1.8961	0.150	-3.0523	-0.6712
	distance[a]	1	0.0001	-5.6620	0.003	-10.3830	-2.4642

[a] Distance to available water in kilometers. Available water was defined as ponds, medium, and large streams.

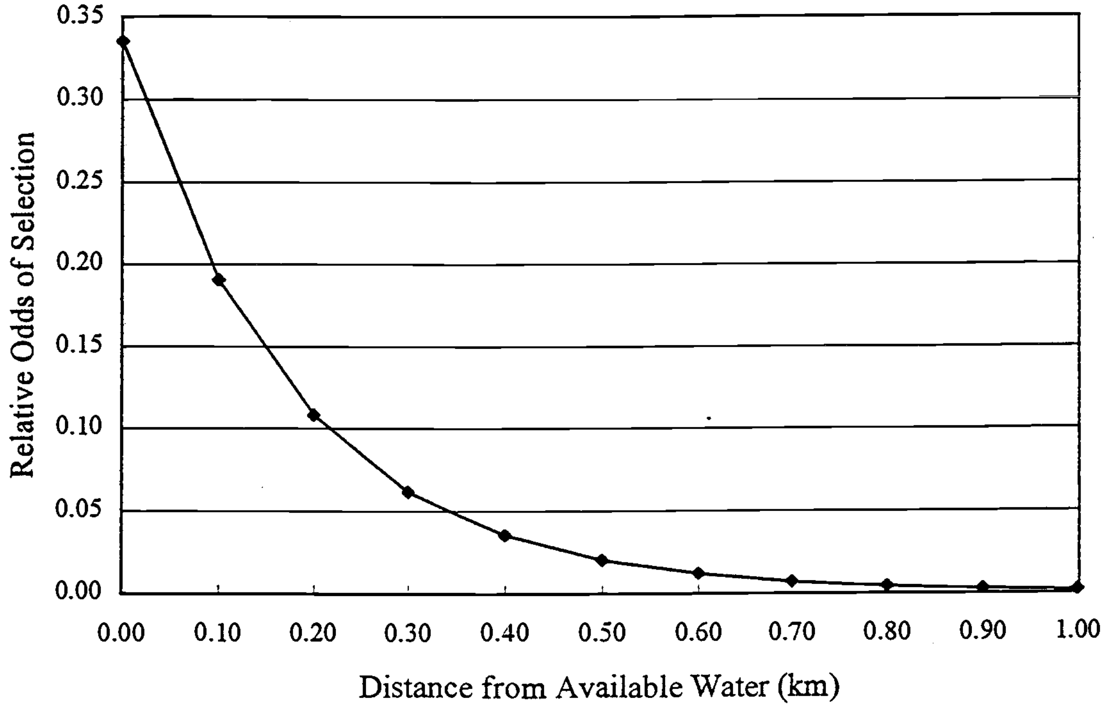

Figure 3-4. Probability of an area being selected as an activity area female long-eared myotis relative to a change in the distance to available water. Distance to available water range from 0.0 to 0.6 km for roosts and 0.0 to 2.1 km for random areas. Model: odds = exp(-1.0930 - 5.6620*distance).

Table 3-4. Models selected using stepwise logistic regression from habitat and spatial variables for activity areas on individual bats over multiple nights.

Scale	Variable	df	P	Parameter Estimate	Odds Ratio	95% CI	
						Low	High
Habitat							
	intercept	1		-3.7294	0.024	-4.7417	-2.9254
	older[a]	1	0.0201	2.6184	13.714	0.4408	4.6855
Spatial							
	intercept	1		-1.3325	0.264	-2.3170	-0.4325
	distance[b]	1	0.0001	-5.2376	0.005	-9.4001	-2.2747
Combined							
	intercept	1		-0.8637	0.422	-2.4044	0.5243
	distance[b]	1	0.0001	-11.9754	0.00001	-21.8327	-4.8644
	older[a]	1	0.8501	-0.3998	0.670	-4.5010	3.8337
	distance[b]*older[a]	1	0.0424	13.7230	911639.6	0.4699	28.1746

[a] Percent of activity area in older stand category.

[b] Distance to available water in kilometers. Available water was defined as ponds, medium, and large streams.

Patterns of Activity

On average, female long-eared myotis departed day-roosts nearly 22 minutes after civil sunset (SE = 2.5 minutes, range 6-52 minutes) and were active for approximately half of the night (mean = 52.7%, SE = 4.5%; range 19 to 81%). Bats exhibited a mean of 4.2 periods of activity (SE = 0.4) during the night and relatively short periods of inactivity (generally only 1 10 minute interval). Longer periods of inactivity appeared to be associated with inclement weather. One individual departed the roost nearly an hour after civil sunset (52 minutes) and only remained active for just over an hour (approximately 15% of the night). It is likely that this bat became active in order to change roosts from a conifer stump which probably exposed the bat to the rain, to a roost in a small snag under relatively dense canopy in a mature stand which offered more shelter. Additionally, individuals were observed to return to, and remain in the roost during the middle of the night on several occasions; this most frequently coincided with a drop in ambient temperatures or the onset of light rain. Temporary transmitter failures and bats flying beyond detection range resulted in my inability to determine a bat's status for approximately 6% of the night.

Direct observation and radio telemetry suggest that female long-eared myotis occasionally remain in the vicinity of a roost prior to flying to more distant areas such as a water site. However, on other occasions, instrumented bats were observed to immediately leave the roost area and fly toward areas with available water.

Discussion

Female long-eared myotis generally used activity areas in a manner which suggests there are features in landscapes (e.g., sources of water and night-roosts) that serve as focal points to their activity. Though I found no significant difference in the distance that bats roosted to available water (Chapter 2), they were observed to use areas as centers of activity which were relatively close to available water (mean = 0.165 km). The spatial relationship of features that are important to bats in a landscape (i.e., day-roosts, night-roosts, foraging areas, and water sources) likely influence how bats are distributed and use landscapes. Landscapes with isolated water sites may have populations of bats which are associated with those sites. Timber harvest near isolated water sites may have detrimental impacts on bats in the area through the loss of potential roosts. Smaller species of bats may not be capable of continuing to use a landscape because it is not energetically feasible for them to travel greater distances between day-roosts and activity areas. The impact to long-eared myotis may be minimal because long-eared myotis appears to be able to use other types structures as day-roosts (Chapter 2). However, other species which primarily use dead and defective trees as day-roosts (Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Callahan et al. 1997, Betts 1998, Ormsbee and McComb 1998) may be heavily impacted due to the loss of dead or defective conifers around an isolated water body.

The association of bats to features in landscapes (e.g., roosts) has been observed in other species of bats (Brigham and Fenton 1986, Brigham 1991, Clark et al. 1993, Adam et al. 1994, Wethington 1996), though species may exhibit different patterns in different areas. As noted by Brigham (1991) and Adam et al. (1994), different populations and subspecies appear to exhibit different behaviors in different regions. In British Columbia, big brown bats (*Eptesicus fuscus*) traveled an average of 1.8 km and a maximum of 4.4 km to foraging areas (Brigham 1991) though they only traveled an average of 0.9 km in Ontario (Brigham and Fenton 1986, Brigham 1991). Female Virginia big-eared bats (*Corynorhinus townsendii virginianus*; Adam et al. 1994) traveled an average of 0.74 km to foraging areas, whereas female Ozark big-eared bat (*C. townsendii ingens*) exhibited median distances of 1.0 to 4.2 km from the roost during the reproductive period (Clark et al. 1993) and 0.5 to 1.6 km during the post reproductive period (Wethington et al. 1996). I observed female long-eared myotis to use habitats associated with the area in which they were captured. Bats from capture sites which were isolated ponds in upland habitat generally restricted nightly movements to the area around the pond. However, two of the capture sites had large streams within 1.5 kilometer of ponds where a bat was captured. In one area, one female long-eared myotis restricted its nightly movements to the pond site whereas in the other area, bats consistently used the more distant stream.

Some research also suggests that for some species of bats, females in later stages of reproduction (i.e. lactating and post-lactating) travel further from roosts to forage (Clark et al. 1993, Adam et al. 1994), presumably to minimize competition with volant juveniles or in order to obtain sufficient prey. I did not observe an increase in the distance traveled to activity areas. Rather, the specific area in which a bat was instrumented and the environmental conditions at the time I tracked the bat appeared to be more important than reproductive condition in influencing observed patterns of behavior. The areas in which I tracked long-eared myotis may have sufficient day-roosts for female long-eared myotis in close proximity to foraging areas and water sites so that females did not have to fly further to forage once pups are volant. This may have enabled instrumented bats to use relatively small areas and to remain fairly close to the day-roost. The spatial relationship between water sites, foraging areas, and roosts may have been such that long-eared myotis were able to use the same general area throughout the summer.

Additionally, the research on other species which found that females traveled further during latter stages of reproduction was on species that formed relatively large maternity colonies in caves (Clark et al. 1993, Adam et al. 1994). In this study, female long-eared myotis appeared to roost singly or in small colonies (<20 individuals) in decadent trees, stumps, and various other types of structures (Chapter 2). These types of roosts may not provide focal points for bats in an area whereas caves used as day-roosts may attract local bats which may use the cave as a night-roost.

Though some species appear to travel greater distances to foraging areas (Clark et al. 1993, Adam et al. 1994), data from this study and several others suggest that female bats, regardless of their reproductive condition, generally are active in areas located relatively close to roosts (Brigham and Fenton 1986, Brigham 1991, Clark et al. 1993, Adam et al. 1994, Wethington et al. 1996). The use of areas relatively close to maternity roosts may be beneficial to reproductive females because shorter commuting distances help minimize energy demands and allow the bat to return to the roost several times during a night in order to nurse the pup, perhaps increasing the reproductive success of the individual.

CHAPTER 4: SUMMARY, MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS, SCOPE OF INFERENCE, INFLUENCE OF TRANSMITTERS, AND RESEARCH NEEDS

Summary

In landscapes generally dominated by younger forest and lower densities of conifer snags and with a history of intensive timber harvest, female long-eared myotis primarily roosted in conifer stumps, logs, defective hardwood and conifer trees. In contrast, landscapes characterized by older forests and with a history of less intensive timber harvest, female long-eared myotis were observed to use dead or defective conifers and, to a lesser degree, conifer stumps. Dead or defective conifers used as day-roosts were relatively large and were predominantly located in upslope habitats. Odds of use was associated with stage of decay, presence of other dead conifers within 20 m of the roost, and distance to the edge of the stand. Odds of use of conifer stumps was associated with habitat variables from multiple spatial scales, including height on the downhill-side, amount of woody debris within 1 m of the stump, maximum access at 5 m, and slope.

Patterns of use in landscapes suggest that there are features in the landscape which may serve as focal points to activity of long-eared myotis. Females used nightly activity areas that were an average of 0.165 km from available water and 0.550 km from day-roosts. The odds of an area being used was associated with distance to available water. Female long-eared myotis generally were active for the majority of a night though their activity appeared to be influenced by environmental conditions.

Management Implications and Recommendations

Management of habitat for bats should consider the characteristics and diversity in the types of roosts which are used. Female long-eared myotis used relatively large dead or defective conifers. The maintenance of these types of trees in landscapes is important because large diameter dead or defective conifers generally are rare in managed forests (Ohmann et al. 1994) and because large structures persist for longer periods of time than small dead and defective trees (Cline et al. 1980, Raphael and Morrison 1987). Though dead or defective trees can be created by various means (Carey and Sanderson 1981, Conner et al. 1981, Bull and Partridge 1986), there is a period of time prior to when woodpeckers have created cavities and the bark has exfoliated sufficiently to allow bats to roost in which there may be limited opportunities for bats to roost in created structures. I recommend that large dead or defective conifers be maintained in landscapes as legacy structures to serve as the primary type of roost structure for long-eared myotis, other species of bats, and other wildlife. This recommendation is consistent with those made by others who have studied roost selection for forest-dwelling bats in the Pacific Northwest (Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Vonhof and Barclay 1997, Betts 1998, Ormsbee and McComb 1998).

Longevity and accessability of dead or defective conifers over time are primary reasons why management of these structures should take precedence over management of conifer stumps as day-roosts for long-eared myotis. Additionally, anecdotal evidence suggests that rain or snow may limit the time frame during which stumps can be used in a season and that stumps are probably only available for use by bats for a few years before vegetation covers or screens stumps from bats. Moreover, whereas snags are extensively used by a variety of species of bats (Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Betts 1998, Ormsbee and McComb 1998, Rabe et al. 1998) and wildlife (Mannan et al. 1980, Neitro et al. 1985, Machmer and Steeger 1995, Bull et al. 1997), the use of conifer stumps as roosts has primarily been documented for long-eared myotis with only a few observations of other species of bats roosting in stumps (Vonhof and Barclay 1997).

However, conifer stumps are a prominent feature in many landscapes of the Pacific Northwest and they do provide important day-roosts for long-eared myotis. Creation of tall stumps may provide roosts for long-eared myotis, and perhaps other species of bats, where there may have been few, if any dead or defective conifers left after timber harvest. Tall stumps may be most beneficial if they are created in areas with natural gaps in vegetation and regeneration (e.g., rocky areas) to provide greater access by bats to the stumps for longer periods of time. Alternatively, small gaps can be created in the regeneration through adjustments in seedling placement and vegetation control.

In addition to managing roosts for bats, water sites, many of which have been created in upslope habitats as sources of water to fight fires, can be maintained to allow bats to use them. A pond that is overgrown by vegetation probably offers little or no opportunity for bats to use for water. Sources of water should be less than 1 km from potential roosts to minimize energy demands placed on bats by commuting greater distances to water or to foraging areas. This distance is likely to accommodate many species of forest-dwelling bats though shorter distances may be preferred for smaller species (i.e., California myotis and Yuma myotis).

In summary, I offer the following recommendations:

Dead or Defective Conifers

1. Maintain large dead or defective conifers in a range of decay stages throughout the landscape with emphasis on structures in early- or mid- stages of decay and located in upslope habitats. Target structures around 93 cm in DBH and 33 m in height.
2. Create snags within 175 m of the interface between young stands and mature forest stands.
3. Provide clusters of snags through maintenance of existing structures or creation of new snags.

Conifer Stumps

1. Create taller conifer stumps during harvest operations with an emphasis on Douglas-fir and western hemlock.
2. Adjust placement of seedlings relative to stumps during regeneration operations to maintain gaps around stumps which have potential as roost sites.
3. Remove debris and brush around high-cut stumps and stumps which have potential as roost sites during site preparation operations.
4. Create gaps around stumps which have potential as roost sites during pre-commercial thinning operations.

Available Water

1. Create new sources of water for bats in upslope habitats where abundant roosts are located within 1 km.
2. Maintain access to sites with available water by removing brush from over and around water sources.

Scope of Inference

Research on bats is often limited by small sample size. Conclusions based on few observations from both sexes and multiple species should be suspect in its application to the same species in other areas as well as other species in other areas. Extrapolation of data from this or other studies should be made only after considering the implications and limitations of each study. In the strictest sense, the results of this research is limited to female long-eared myotis in my study area in the western Oregon Cascades. However, I contend that aspects of my research are applicable to other regions and other species.

Large dead or defective conifers has consistently been documented as important to the roosting ecology of forest-dwelling bats in the Pacific Northwest. This pattern of use is probably consistent for other species and areas, though subtle area- and species-specific differences should be considered. Use of conifer stumps by long-eared myotis is likely widespread for the species though its application to other species of bats is probably inappropriate given the data. The use of activity areas which are relatively close to water by female long-eared myotis also may be applicable to other areas and other species. However, there may be species-specific differences in a species ability to commute a specified distance. Additionally, reproductive condition of bats in an area may influence how it will be able to utilize resources in a landscape.

Influence of Transmitters

Use of radio transmitters that exceed 5% of the weight of a bat has been a concern of telemetry studies on bats (Aldridge and Brigham 1988). However, strict adherence to the "5% rule" would preclude use of radio telemetry on long-eared myotis, and many other species of bats in the Pacific Northwest, due to their small size. The weight of the transmitters used in my study ranged from 6.7% to 7.7% of the mass of female long-eared myotis and was comparable to relative ratios in other studies (Brigham 1991, Adam et al. 1994, Campbell et al. 1996, Vonhof and Barclay 1996, Wethington 1996, Brigham et al. 1997, Betts 1998, Ormsbee and McComb 1998, Rabe et al. 1998). Although transmitters may have impacted the behavior of telemetered bats, I attempted to minimize this impact by using one of the lightest radio transmitters commercially available and by selecting a style with a reduced profile to minimize interference with crevice selection. Short retention time of transmitters (<14 days) and not putting radios on pregnant females which appeared to be small but met the weight requirement (presumably due to reproductive condition), also limited the impact of the transmitters.

Research Needs

Information on habitat requirements for many species of bats has been and continues to be fraught with limitations associated with inadequate resources and difficulties in studying nocturnal flying mammals. Research on habitat requirements of bat communities and interactions among species of bats and between bats and other species which are known to use structures in which bats roost (i.e., primary and secondary cavity-nesting birds) is warranted. The use of conifer stumps as day-roosts should be examined in greater detail to understand the role they play in the roosting ecology of long-eared myotis and if other species of bats roost in conifer stumps. Additional research is needed that examines not only the characteristics of roosts but their spatial relationship with foraging areas and other features in the landscape that are important to bats (e.g., night-roosts and water sources). Research on the impacts of timber harvest is warranted, specifically how timber harvest during the summer impacts maternity roosts in trees and how winter logging impacts hibernacula located in trees. Well replicated studies with experimental designs are needed to research the effectiveness of green-tree retention strategies, effectiveness of snag creation efforts in providing roosts for bats in a timely manner, and impacts of intensive timber harvest in landscapes.

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APPENDICES

APPENDIX A. DESCRIPTION OF HABITAT VARIABLES FOR DEAD OR DEFECTIVE CONIFER TREES AND CONIFER STUMPS USED AS DAY-ROOSTS AND RANDOMLY AVAILABLE STRUCTURES

Table A-1. Description of habitat variables measured for dead and defective conifers used as roosts and random structures.

Variable	Notes
year	Two categories were used, 1996 and 1997.
watershed	Two categories were used, Fall Creek and South McKenzie River.
area	Two categories were used corresponding to the capture site area, B1828 and Coopers.
stand	Five categories were used corresponding to the different stands in which snags used as roosts were located.
decay class	Three categories were used (Table 2-1).
edge	Two categories were used corresponding to whether or not the structure was located within 100 meters of the edge of a stand.
canopy layer	Three categories were used corresponding to the upper, middle or the lower canopy layers.
top condition	Two categories were used corresponding to whether the top was broken or intact.
species	Two categories were used: Douglas-fir and western hemlock.
height	Measured with a clinometer.
DBH	Measured with a D-tape.
bark remaining	Ocular estimate of the percentage of the bole having bark.
crown	Ocular estimate of the percentage of the crown remaining.

Table A-1. Continued.

Variable	Notes
slope	Measured with a clinometer.
aspect	Measured with a compass.
elevation	Obtained from GPS files.
number of trees	Total number of trees within 20 m of the focal structure. A tree is defined as a woody plant with a DBH ≥10 cm.
number of snags	Total number of snags (decay classes 1-3) within 20 m of the focal structure.
number of snags (decay 2)	Total number of snags (decay class 2) within 20 m of the focal structure.
maximum access (0-8 m)	The level of accessability to the structure for a bat was ocularly estimated in a 45° angles at 5 meters from the snag in the uphill, downhill, and sidehill directions. The highest level of accessability was used in the analysis. Accessability is measured as the lack of clutter in the 45° angle.
maximum access (8-16 m)	Same as above, except that it was measured in the 8-16 m range. No measurement was made if the snag was not this tall.
maximum access (>16 m)	Same as above, except that it was measured in the 8-16 m range. No measurement was made if the snag was not this tall.
maximum access	This was the highest level of accessability observed in any of the height classes.
canopy cover	Percent canopy within 20 m of the focal structure. Measured from aerial photographs.
canopy cover	Percent canopy within 50 m of the focal structure. Measured from aerial photographs.
distance to nearest uphill tree ≥ roost in height	Distance in meters to the nearest tree in the uphill direction that was equal to or greater in height to the roost or random structure.

Table A-1. Continued.

Variable	Notes
distance to nearest downhill tree ≥ roost in height	Distance in meters to the nearest tree in the downhill direction that was equal to or greater in height to the roost or random structure.
distance to capture site	Distance in meters of the focal structure to the capture site. Measured from GPS files, GIS, aerial photographs, and/or maps.
distance to road	Distance in meters of the focal structure to a road. Measured from GPS files, GIS, aerial photographs, and/or maps.
distance to edge	Distance in meters of the focal structure to the edge of the stand. Measured from GPS files, GIS, aerial photographs, and/or maps.
distance to stream	Distance in meters of the focal structure to a large stream. Measured from GPS files, GIS, aerial photographs, and/or maps.

Table A-2. Description of habitat variables measured for the analyses of conifer stumps used as roosts and random structures.

Variable	Notes
year	Two categories were used, 1996 and 1997.
watershed	Two categories were used, Fall Creek and South McKenzie River.
area	Four categories were used corresponding tp the capture site area, B1828, B1833, Coopers, and Wader.
stand	Nine categories were used corresponding to the different stands in which snags used as roosts were located.
species	Three categories were used: Douglas-fir, western hemlock, and western redcedar.
decay class	Three categories were used (Table 2-2).
crevice width	Measured in centimeters with a tape. The distance from one edge of the crevice to the other.
crevice depth	Measured in centimeters with a tape. The maximum distance that I estimated a bat could enter the crevice.
crevice, opening depth	Measured in centimeters with a tape. The distance between the inner edge of the bark and the outer edge of the wood. A representative portion of the crevice was used for this measurement.
crevice height	Measured in centimeters with a tape. The height of the crevice opening above the ground.
bark thickness, crevice	Measured in centimeters with a tape. A representative portion of the bark on the crevice was used for this measurement.
bark thickness, stump	Measured in centimeters with a tape. The average thickness was used from four measurements were taken in the four quadrants of the stump.
crevice aspect	Measured with a compass.
uphill height	Measured in centimeters with a tape.

Table A-2. Continued.

Variable	Notes
downhill height	Measured in centimeters with a tape.
diameter	Measured in centimeters with a tape. An average of two perpendicular measurements across the top of the stump.
bark remaining	Ocular estimates of the percentage of bark remaining on four quadrants of the stump.
potential crevice	Percentage of the circumference of the top of the stump which had crevices in which a bat could roost. A potential crevice was defined as a crevice approximately 5 cm in width, 15 cm deep, and had an opening depth of 1.5 cm.
slope	Measured with a clinometer.
aspect	Measured with a compass.
elevation	Obtained from GPS files.
distance to capture site	Distance in meters of the focal structure to the capture site. Measured from GPS files, GIS, aerial photographs, and/or maps.
distance to stream	Distance in meters of the focal structure to a large stream. Measured from GPS files, GIS, aerial photographs, and/or maps.
small logs (0-1 m)	Number of logs between 10 and 50 cm in diameter within 1 m of the focal structure. Diameter was measured at the largest point.
small logs (0-5 m)	Number of logs between 10 and 50 cm in diameter within 5 m of the focal structure. Diameter was measured at the largest point.
large logs (0-1 m)	Number of logs >50 cm in diameter within 1 m of the focal structure. Diameter was measured at the largest point.
large logs (0-5 m)	Number of logs >50 cm in diameter within 5 m of the focal structure. Diameter was measured at the largest point.

Table A-2. Continued.

Variable	Notes
large logs (0-10 m)	Number of logs >50 cm in diameter within 10 m of the focal structure. Diameter was measured at the largest point.
large logs (0-20 m)	Number of logs >50 cm in diameter within 20 m of the focal structure. Diameter was measured at the largest point.
stumps (0-1 m)	Number of stumps ≥ 10 cm (across the top) within 1 m of the focal structure and resulting from harvest practices. Structures that resulted from breakage were not considered a stump, but were decay class 3 snags.
stumps (0-5 m)	Number of stumps ≥ 10 cm (across the top) within 5 m of the focal structure and resulting from harvest practices.
stumps (0-10 m)	Number of stumps ≥ 10 cm (across the top) within 10 m of the focal structure and resulting from harvest practices.
all wood (0-1 m)	Number of pieces of wood within 1 m of the focal structure including small logs, large logs, stumps, and root wads.
large wood (0-1 m)	Number of pieces of wood within 1 m of the focal structure including large logs, stumps, and root wads.
all wood (0-5 m)	Number of pieces of wood within 5 m of the focal structure including small logs, large logs, stumps, and root wads.
large wood (0-5 m)	Number of pieces of wood within 5 m of the focal structure including large logs, stumps, and root wads.
large wood (0-10 m)	Number of pieces of wood within 10 m of the focal structure including large logs, stumps, and root wads.
saplings (0-1 m)	Number of coniferous or hardwood seedlings or saplings within 1 m of the focal structure with a diameter < 10 cm at 1.5 m in height.
saplings (0-5 m)	Number of coniferous or hardwood seedlings or saplings within 5 m of the focal structure with a diameter < 10 cm at 1.5 m in height.

Table A-2. Continued.

Variable	Notes
saplings (0-10 m)	Number of coniferous or hardwood seedlings or saplings within 10 m of the focal structure with a diameter < 10 cm at 1.5 m in height.
saplings (5-10 m)	Number of coniferous or hardwood seedlings or saplings between 5 and 10 m from the focal structure with a diameter < 10 cm at 1.5 m in height.
trees (0-20 m)	Number of coniferous or hardwood tree within 20 m of the focal structure with a diameter > 10 cm at 1.5 m in height.
overhead accessability	An ocular estimate of the ability of a bat to fly into the stump from above, estimated at ~5 m over the top of the stump. This is a measure of the amount of clutter in a 45° arc extending up from the stump as well as the location of the clutter and its potential to interfere with a bat being able to reach the stump.
maximum accessability (2 m)	An ocular estimate of the ability of a bat to fly into the stump from 2 m and was measured on 4 axis oriented to the slope (up, down, left, right). This is a measure of the amount of clutter in a 45° arc extending from the stump as well as the location of the clutter and its potential to interfere with a bat being able to reach the stump.
maximum accessability (5 m)	An ocular estimate of the ability of a bat to fly into the stump from 5 m and was measured on 4 axis oriented to the slope (up, down, left, right). This is a measure of the amount of clutter in a 45° arc extending from the stump as well as the location of the clutter and its potential to interfere with a bat being able to reach the stump.

Table A-3. Description of habitat variables measured for activity area analyses. Habitat was measured for activity areas defined from individual bats over multiple nights and from individual nights. See Appendix B for definitions of habitat types.

Variable	Notes
year	Two categories were used, 1996 and 1997.
watershed	Two categories were used, Fall Creek and South McKenzie River.
area	Six categories were used corresponding to capture sites: B1828, B1833, Coopers, LFC, Progeny, and Wader.
young forest, open habitat	Percentage of the activity area or random area in this condition. Measured from GIS.
young forest, closed habitat	Percentage of the activity area or random area in this condition. Measured from GIS.
mature forest habitat	Percentage of the activity area or random area in this condition. Measured from GIS.
older forest habitat	Percentage of the activity area or random area in this condition. Measured from GIS.
riparian habitat	Percentage of the activity area or random area in this condition. Measured from GIS.
terrestrial habitat	Percentage of the activity area or random area in this condition. Measured from GIS.
distance to available water	Distance in meters from the geometric center of activity areas or random areas to nearest available water (ponds, medium, or large streams). Measured from GIS maps.

APPENDIX B. DESCRIPTION OF THE SYSTEM I USED TO CLASSIFY HABITAT TYPES BASED ON STAND AGE, STREAM SIZE, AND OTHER WATER SOURCES

Habitat Classifications: Forest stands were classified in 1 of 4 categories based on age and structure. Stand classifications were overlaid with information on the presence or absence of riparian and stream habitat in the stand.

Young/Open: Age 0-12. These stands were generally cut in the past decade and primarily contains seedlings and saplings. Stands in this age range with closed canopies were bumped into the "closed" category because the stand may function in a different manner than the more open stand where potential roosts are accessible (i.e., stumps).

Young/Closed: Age 13-35. These stands have closed canopies and are generally in the stem exclusion stage. Stands are dense and have limited roosting opportunities. The stands are generally composed of saplings, poles, and small trees.

Mature: Age 36-80. These stands generally have several sizes of trees and are in the understory regeneration stage. Canopies are less dense with a relatively open understory.

Older: Age >80. These are more open stands with older trees and mature habitat conditions. The understory has reestablished due to more open canopy.

Riparian habitat: A portion of the landscape which was adjacent to a water source. Different types of water sources received different buffer widths based on their size.

Small and Intermittent Streams (20 m buffer): Small streams in this region generally have few, if any, open and calm areas of water which bats may access. They have different designations depending on ownership (i.e., class IV streams (though this is variable depending on the classification and use of the stream), 1st and 2nd order streams, intermittent streams, and small fish/non-fish bearing streams).

Medium Streams and Ponds (50 m buffer): Medium streams and ponds in this region tend to have open areas of water which bats can easily access. They were given a larger buffer area due the perception that their larger size had more of an influence in the surrounding area.

> Large streams (100 m buffer): Large streams in this region tend to have more open reaches of water which bats may access. They were given the largest buffer reasoning that their larger size have more of an influence in the immediate area.

Terrestrial habitat: Any portion of the landscape that was not included in a riparian buffer as described above.

APPENDIX C. CAPTURE RESULTS FROM SURVEY EFFORTS ASSOCIATED WITH THIS PROJECT DURING 1996 AND 1997

Table C-1. Capture data by species and sex for 2 years of surveys. Number of recaptures are enclosed in parentheses.

Species	Sex	Fall Creek		Little Fall Creek	South McKenzie River		Total	
Corynorhinus	F	2		0	0		2	
townsendii[a]	M	5	(1)	1	0		6	(1)
Eptesicus	F	7	(1)	25	71		103	(1)
fuscus[b]	M	88	(25)	11	39		138	(25)
	U	0		2	2		4	
Lasiurus	F	0		0	0		0	
cinereus[c]	M	0		1	0		1	
Lasionycteris	F	0		0	2		2	
noctivagans[d]	M	5		26	17		48	
Myotis	F	13		8	12		33	
californicus[e]	M	8		7	12	(1)	27	(1)
Myotis	F	23		6	19	(1)	48	(1)
evotis[f]	M	4		11	28		43	
	U	1		0	0		1	

Table C-1. Continued.

Species	Sex	Fall Creek		Little Fall Creek		South McKenzie River		Total	
Myotis	F	17		1		1		19	
lucifugus[g]	M	45	(1)	34	(2)	10	(1)	89	(4)
	U	1		0		0		1	
Myotis	F	13	(1)	0		0		13	(1)
thysonodes[h]	M	5		5		3		13	
Myotis	F	114	(3)	9		6		129	(3)
volans[i]	M	26		13	(1)	3		42	(1)
Myotis	F	6		6		1		13	
yumanensis[j]	M	66	(5)	52	(3)	8		126	(8)
	U	1		1	(1)	0		2	(1)
total		450	(38)	219	(7)	234	(3)	903	(47)

[a] Townsend's big-eared bat
[b] big brown bat
[c] hoary bat
[d] silver-haired bat
[e] California myotis
[f] long-eared myotis
[g] little brown myotis
[h] fringed myotis
[I] long-legged myotis
[j] Yuma myotis