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SELECTION OF DAY ROOSTS BY FEMALE LONG-LEGGED MYOTIS (*MYOTIS VOLANS*) IN FORESTS OF THE CENTRAL OREGON CASCADES

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Measuring habitat selection by bats is complicated by their intricate life cycle. Scaling habitat measurements to reflect a hierarchal habitat selection process can help to define habitat associations of bats. I assessed day roost habitat of female long-legged myotis at four scales: the roost structure, micro-habitat surrounding the roost, the stand level, and landscape level.

I radio-tracked 16 female long-legged myotis (*Myotis volans)* for an average of eight days per bat, July through August of 1993, 1994, and 1995 in two drainages in the central Oregon Cascades (Quentin Creek and Lookout Creek) to locate day roost structures. Forty-one day roost structures were identified, of which 1 was a rock face, 4 were green trees, and 36 were snags. The average height of all roost structures was 40 m (SE=2.5). The average dbh for all snags and trees used as day roosts was 100 cm (SE=6.1). Large snags including partially live, hollow western redcedar trees (*Thuja plicata)* averaging 97 cm dbh (SE=6.6) and 38 m (SE=2.8) high were the most commonly used roost structures.

Individuals radio-marked at the same night roost did not use one common day roost. Individual bats were found roosting in one roost for several days, or using multiple day roosts within discrete roost areas. The area which encompassed one night roost and all known day roosts covered 3,258 ha in the Quentin Creek drainage and 6,391 ha in Lookout Creek.

I compared physical characteristics and habitat within 20 meters of 33 roost snags with 66 randomly selected snags. The odds that a snag is used as a day roost is associated with roost height; given height, the odds of use is associated with the height of the stand within 20 meters of the snag. There is some indication that the presence of an open canopy around the snag, and the percentage of bark on the snag also could be factors that influence the selection of snags as day roosts.

The frequency of occurrence of roost structures within young and late seral stands did not differ from what was expected to occur by chance in these two stand conditions. Roosts did not occur in stands with a harvest history vs. stands without a harvest history disproportionate to availability.

I compared the distance to class I (largest) through class IV (smallest) streams between 34 day roosts and 102 randomly selected points. Day roosts were located closer to streams than randomly selected locations in both Lookout and Quentin Creek drainages with 1 exception (Lookout class III). In two cases day roosts were significantly closer to streams than randomly selected locations. Day roosts tended to be closer to streams where night roosts were located than did randomly selected points, regardless of stream class.

Maintaining large diameter, tall, solitary snags and patches of snags across all seral stages would be a reasonable step toward providing day roost habitat for long-legged myotis in managed landscapes. Managing for specific roost structures and the area around the roost structure may be desirable under some circumstances.

Further research and monitoring should include testing methods for aerial measurements of roost structure and canopy characteristics. More detailed analysis of roost structure characteristics such as bark, and stand characteristics such as numbers and types of snags present would increase the level of precision for characterizing day roost habitat. Further study of fidelity to roost areas and the influence of microclimatic conditions in and near different types of roosts would provide insight to the function of roosts and roost areas. Studies on the association of day roosts, night roosts, and foraging areas would provide a more complete picture of habitat utilization.

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Introduction

Ecosystem management is an approach to land management with the objective of sustaining ecological functions and systems while considering socially-defined benefits (USDI 1993). Implementation of ecosystem management requires an understanding of how components of the system function, interact with each other, and what elements and processes are critical to the system.

Despite the social and scientific recognition of the need to move forward with ecosystem management, basic information on the biology of many species is lacking. While habitat use by forest-dwelling bats has not been well studied, there is a growing concern over human-caused impacts on these species because of habitat removal, sensitivity of the species to large disturbances, and suspected declines in populations (USDI 1993).

Twelve species of insectivorous bats inhabit Douglas-fir (*Pseudotsuga menziesii)* forests of the Pacific Northwest. Little is known about the ecology of these bats (Christy and West 1993, USDI 1993). The long-legged myotis (*Myotis volans*) is one of these 12 species, which inhabits arid rangelands and montane forests across the western United States and Canada (Nagorsen and Brigham 1993). This species was identified by the Forest Ecosystem Management Assessment Team (FEMAT) as being associated with old-growth forest, in need of further study, and of concern because of the reduced extent of old-growth habitat within Western Washington and Oregon, and Northern California (USDI 1993). The long-legged myotis was federally listed in the U.S. as a Category 2 species in November, 1994 (USDI 1994).

As with many bat species, long-legged myotis have a complex life cycle. They are relatively small, heterothermic, volant mammals (Fenton 1983, Kunz 1982). The females are capable of storing sperm through hibernation so they can delay pregnancy until spring (Warner and Czaplewski 1984). Single young are born completely altricial, yet become self-sufficient within a few weeks of birth. Long-legged myotis are social animals and display some system of communication and interaction to successfully roost, hibernate, and forage in groups (Wilkinson 1992, Kunz 1982). This species is long-lived, with an estimated life span of 21 years (Warner and Czaplewski 1984). They use several differentiated habitats including day roosts, night roosts, hibernacula, maternity roosts, and foraging areas. Although the number and characteristics of these habitats that is required or preferred by this species is unknown, use of multiple roosts and foraging areas has been documented (Warner and Czaplewski 1984). Identifying characteristics of habitat used by long-legged myotis may be key to insuring the persistence of this species in managed landscapes.

Habitat selection by species with even simple life cycles and habitat associations is influenced by temporal, geographical, biological, social, and environmental factors. To complicate matters further, these factors can be addressed at different scales, or degrees of precision (Partridge 1978). For instance, temporal and geographical influences may span daily habitat use of a small patch or evolutionary shifts in habitat selection across the entire globe. The home range of a salamander is more likely to represent a smaller scale of biological influence than the breadth of biological factors associated with the breeding and wintering activity of long-distance migrants. The social context of habitat selection can include habitat use by an individual or an entire population. Studies of habitat selection can focus on a range of environmental conditions, from the specific characteristics of a den site to the structural diversity of habitat associated with entire populations.

Measuring physical characteristics of habitat to describe habitat selection by a species requires defining an appropriate scale of time and space, and known or assumed biological, social, and environmental factors that are relevant to the habitat association. Once these parameters have been identified, scaling habitat measurements that are representative of habitat selection along a conceptual continuum from grain (smallest scale of patch structure to which an organism responds) to extent (largest scale of patch heterogeneity to which an organism responds) serves to reflect the somewhat hierarchal nature of habitat selection (Johnson 1980, McGarigal 1993).

Understanding the ecological components associated with forest-dwelling bats includes investigations of habitats and biology related to day roosts, including maternity roosts. Humphrey (1975) hypothesized that the distribution of nearctic bat species was associated with the availability of roost structures. His work indicates that the presence or absence of different types of nursery roosts influence the distribution and abundance of neartic bats. On a smaller scale, permanence and availability of roosts may influence roost fidelity of individuals, or groups of bats (Kunz 1982).

No previous studies have been completed in the central Oregon Cascades that address use of day roosts by forest-dwelling bats. Information on the types of structures used for day roosting by forest-dwelling bats of the Pacific Northwest is limited. Campbell (1993) reported that all day roosts (n=13) in her radio telemetry study on silver-haired bats (*Lasionycteris noctivagans*) were in dead or partially dead trees averaging 47 cm dbh, with loose bark and extensive cracks or cavities. Hoary bats (*Lasiurus cinereus)* day roost primarily in the foliage of deciduous and coniferous trees (Christy and West 1993). Townsend's big-eared bats (*Plecotus townsendii*) almost exclusively day roost in secluded buildings, under bridges, or in caves (Howell et al. 1995). Brigham (1989) reported strong day roost fidelity by big brown bats (*Eptesicus fuscus)* for roost sites in buildings and rock crevices and significantly less site fidelity for tree cavities, while Betts (In press) found big brown bats and silver-haired bats day roosting mostly in large diameter snags. Yuma myotis (*M. yumanensis)* and fringed myotis (*M. thysanodes)* are most often associated with day roosts in buildings or caves (Nagorsen and Brigham 1993). The other myotis species found in the central Oregon Cascades usually day roost in buildings, under bridges, or in snags, trees, rock crevices and caves (Christy and West 1993).

I chose to study reproductive females because I wanted to characterize day roosting habitat used during the critical period of rearing young. The use of large snags for day roosts and an association with old-growth stands is a common finding or assumption in the literature for numerous species of bats, including the long-legged myotis (Thomas 1988, Christy and West 1993, USDI 1993, Crampton and Barclay in press). I designed my study to test the hypotheses that (1) female long-legged myotis select large snags with distinctive structural attributes and micro-habitat characteristics that differ from what is generally available, and (2) they select mature and old-growth stands disproportionate to what is available; and (3) that day roosts are located closer to small streams than expected by chance.

The scales of time and space defined for this study of female long-legged myotis fell within 3 summers in 2 drainages of the central Oregon Cascades. The average data set for each bat represented an 8-day period (SE=1.3, range=1-24 days). I limited my research to adult females assumed to be pregnant or rearing young. The environmental factors of the 2 drainages in the study included a matrix of different stand types, and various potential day roosting opportunities. I measured habitat characteristics associated with day roosts used by female long-legged myotis at 4 scales:

1) The roost structure

2) The micro-habitat within 20 meters of the roost structure

3) The stand level, comparing stand characteristics where roosts occurred to characteristics of all stands within the watershed; and

4) The landscape level, analyzing the distribution of roost structures for individual bats, measuring the distance of the day roosts to night roosts, and analyzing the relationship of day roosts to streams of different classes.

The four scales of measured characteristics for known roosts were compared to the same characteristics for random structures and locations to assess differences between what was known to be used and what was available.

Study Area

Study sites were located in the central Oregon Cascades on the Willamette National Forest. I collected data in 1993, 1994, and 1995 in Lookout Creek drainage which lies east of Blue River Reservoir and within the H.J. Andrews Experimental Forest; and in 1994, in Quentin Creek drainage which lies northeast of Blue River Reservoir. Both sites are northeast of the town of Blue River, Oregon which is on U.S. Highway 126 approximately 35 miles east of Springfield Oregon

I selected these sites for study because they had accessible bridges that served as night roosts for female long-legged myotis and because the drainages were relatively well roaded and accessible by foot. A variety of potential day roosts was present (cliff faces, caves, snags, and trees) over a matrix of varying stand conditions (natural seral stages and managed stands with and without residual snags and trees).

Methods and Materials

I captured female long-legged myotis at two bridge sites (Quentin Creek and Lookout Creek) between 0330 and 0430 hours during July and August. Priority was given to radio-marking lactating and pregnant females over females of unknown reproductive status. I radio-marked 22 bats with 0.55- to 0.65-g Holohil BD-2B radio transmitters (Holohil Inst. Co., Ontario, Canada). The weights of transmitters were 6 to 8% of the bats' body mass. A patch of fur between the scapulae was clipped where the radio transmitter was attached with skin bond (Smith and Nephew United, Inc., Largo, FL.). The fur was clipped away to insure a more secure bond, and to avoid rotation of the radio transmitter on the napless fur, which could impede flight. Slight pressure was applied to the radio for 1-3 minutes, and each bat was held for approximately 10 minutes before being released to ensure that the transmitter was attached correctly. One bat was radio-marked in both 1994 and 1995. Because it did not return to the same day roosts in 1995 as it had used in 1994, I treated the day roosts for each year as independent observations.

I attempted to map a location each day for individual radio-marked bats that stayed within the study area for the life of the radio or until it was shed. I walked into an area to verify the exact location of a roost structure when there were at least three compass bearings taken from different points of detection where the radio signal was precise and strong enough, that I could draw a line for each compass bearing on a topographic map that passed through the location of the receiver where the signal was detected and the vicinity where the signal was strongest. Once an area approximately 0.5 km^2 or smaller was identified, I attempted to verify an exact roost structure. I attempted to verify a day roost structure for each radio-marked bat once every 24 hours during daylight hours, by determining the tree, snag, or rock face from which the strongest signal was emitting (White and Garrott 1990). In some situations this involved a process of elimination so I could determine the strongest signal amongst more than one potential roost structure, or differentiate a radio signal bouncing off of a topographic feature such as a steep side slope, from a true signal location. In such cases, I systematically radiated towards and away from the area with the strongest signal which usually allowed me to determine the specific roost structure. I mapped verified roost structures using topographic maps, aerial photos, compasses, and altimeters. In some cases, I could not verify exact roost locations because of lack of time, or I could not isolate the radio signal to one roost structure. In these cases, I determined and mapped a location as a point within the center of the area from where the signal was generating, and only if the area could be restricted to 0.5 km^2 or less.

I identified stands where the roosts occurred on coverages within a geographical information system (GIS) and were defined as either a natural or artificially created plant community with enough homogeneity to differentiate it from it's surroundings. Stands were identified within the GIS using aerial photos and orthophoto quads at 1:15,840. No formal test of error has been conducted for the GIS stand delineation process (Adee 1991).

I selected two random points for every known roost structure within the stand containing the roost structure by entering the range of u.t.m. coordinates for the stand into a random numbers generator program in JMP software package (SAS Institute Inc., Cary N.C.). I located the random points in the field using map, compass, aerial photos, and an altimeter. I spiraled from the random point until I found a snag between 30 and 200 cm (within the dbh range of known roosts from data collected in 1993) dbh (diameter breast height) and that was at least 3 meters tall to use as a random structure. Roost structure characteristics for known and random points were measured, and vegetation data were collected within 10- and 20-meter radius, nested circular plots.

I determined dbh, height, decay class (Appendix A), percent branches, and percent bark for trees and snags used as roosts, as well as for randomly selected trees and snags. I took measurements of dbh with a metric tape or laser relascope. The error between the two methods was not significant (two-tailed p-value=0.43) and had adequate power to detect a practical significant difference of 15 cm between methods (see Appendix G for an example of the methodology I used for power testing) when tested with a two-sample t-test comparing measurements of 30 trees and snags taken with each method. Height was determined using a laser relascope. I estimated percent branches as the percentage of branches remaining from the assumed branching of a full, live crown using an ocular estimate. Percent bark was the proportion of area covered by bark in relation to the entire potential area that could be covered by bark using an ocular estimate.

I measured the height and width of rock faces using a metric tape and laser relascope, and the presence of crevices was documented. I estimated the dimensions of any interior chambers I could access, and the opening width of crevices using a metric tape, or if the crevice was inaccessible I used an ocular estimate.

I measured the height of the stand canopy within 20 meters of the snag using a laser relascope to take the height of a dominant tree that represented the overstory within 20 meters of the roost or random structure. Slope and aspect of the 20-meter plot were recorded using a laser relascope and compass. Canopy closure for all vegetation estimated to be over 7 m tall was measured using a moosehorn, which consists of a sighting tube approximately 35 cm long and 9 cm in diameter with a 16-celled, (equally sized) square grid etched in a circular plastic plate and attached to one end of the sighting tube. A bubble level is imbedded in the plastic plate, outside of the grid. A mirror is fixed inside the tube at a 45° angle at the other end of the tube from the grid, and a sighting hole and eye piece is placed on the outside of the tube above the mirror (Garrison 1949, Vales and Bunnell 1985, Stutzman et al. 1994). The observer recorded the number of the nine interior nodes where the grid cells intersected that were covered by canopy at least 7 m tall at 5, 10, 15, and 20 m distances from the roost or random structure in the four cardinal directions. This average ratio was used as an estimate of the percentage of canopy closure. Where the canopy was dense, an ocular estimate was used in combination with the moosehorn to determine the canopy cover over 7 m high. I mapped openings in the canopy, relative to the roost or random structure and within a 20 m radius, that I estimated to be at a height ≥ 7 m and at least 5 m^2 (Spies et al. 1990), I used an ocular estimate to determine whether the roost or random structure was exposed to the sky or enclosed by forest canopy.

The azimuth and distance from the roost or random structure to green trees and snags ($\geq$15 cm within 10 m radius, $\leq$25 cm between 10 and 20 m radius) were recorded using a compass, metric tape, and laser relascope. The dbh, decay class, and species of each tree or snag also were recorded.

A GIS was used to identify a landscape polygon for each of the drainages in the study area. The Lookout Creek drainage was defined using the existing boundary for H.J. Andrews Experimental Forest with the addition of three stands on the northern boundary (Stands # 100532, 1000535, and 100540, as defined in Willamette N.F. GIS Vegetation layer 5A). The boundary for the H.J. Andrews Experimental Forest primarily follows prominent ridge lines. The Quentin Creek drainage was defined using prominent ridgelines, stand boundary lines, and portions of roads # 1513, 1509, and 1516. I drew the boundary to include all known day roosts and the stands they occurred in, the known night roost, and encompass the Quentin Creek drainage. The UTM coordinates for both of these boundaries are on file with the author

Statistical Methods

This was an observational study with a relatively small sample size, limiting the scope of statistical inference of the results to the populations being sampled in Lookout Creek and Quentin Creek. A portion of the analysis involves a retrospective matched case-control design, and for this part of the study the statistical results are reported as odds in a prospective manner.

Summary statistics were calculated using Paradox version 4.5 (Borland Int., Inc.), and JMP statistical software version 3.1 (SAS Institute Inc., Cary, N.C.). I used a GIS to determine averages for distances between day roost structures, distances from day roost structures to night roost structures, the area encompassing day roost sites (verified roosts and locations), and the area encompassing verified roosts only, for individual bats. Roosts selected the morning a radio-marked bat was released were excluded from these analyses.

Characteristics of Snags and Associated Micro-habitat Selected as Day Roosts

Since the majority of day roosts were snags (33 of 41 day roosts), I tested the hypothesis that the odds of a snag being selected for a roost was associated with characteristics of snags and the surrounding micro-habitat (within a 20-m radius) that differed from what was generally available. I contrasted characteristics of 33 snags used as day roosts and the surrounding micro-habitat with 66 randomly located snags. Randomly selected snags were matched to known snag roosts by stands where the known roosts occurred.

This was a retrospective, matched case-control study. This type of study design has it's historical roots in cancer research (Breslow and Day 1980) and it's application is relatively new to natural resource analysis. It is a statistically powerful design that can increase accuracy and lends itself well to comparative studies with a binary response (Ramsey et al. 1994). I matched known roost snags (case) with randomly selected snags (control) within the same stand, and based on the range of dbh measurements taken from known roost structures in 1994 (n=30). A binary response variable represented either known roost snags (y=0) or randomly selected snags (y=1). (Hosmer and Lemeshow 1989, Ramsey and Schafer 1994, Ramsey et al. 1994).

The average dbh for the known roost structures measured in 1994 was 92.5 cm (95% CI = 76.54 - 108.46 cm). I determined a sample size of 34 for this analysis (Appendix B) using a practically significant difference in dbh (30 cm) that I felt was measurable, and was more than the half-width of the 95% CI (15.96) for dbh taken from the 1994 sample of roost structures (Ramsey and Schafer 1994). Matched case-control studies will accept a smaller sample size than simple random sample studies (Ramsey et al. 1994) because they reduce the individual to individual variation through matching, so the sample size (n = 34) I estimated using this method is more than adequate for this type of retrospective analysis.

I used SAS/STAT® software (SAS Institute Inc., Cary N.C.) to analyze habitat variables associated with the micro-habitat within 10- and 20-meter radius nested circular plots around, and the physical characteristics of, all known roost snags and randomly selected snags by comparing conditional likelihood functions (Breslow and Day 1980). I developed continuous and categorical explanatory variables to reflect measurements, means, and classification of data using JMP software (SAS Institute Inc., Cary N.C.) for use in the matched case-control analysis (Appendix C). The null hypothesis I tested using these variables was Beta=0, or in other words, that I would find no difference between characteristics in the case and control samples based on a chi-square distribution.

I tested the explanatory variables for redundancy in explanatory power using correlation analysis (Hosmer and Lemeshow 1989) to identify variables with moderate correlation ($r => 0.4$). I combined correlated variables where the biological integrity was not compromised, so I could avoid having variables that were redundant in explaining patterns in the data. For instance, average canopy closure within 10 meters and average canopy closure between 10 and 20 meters were strongly correlated ($r=0.81$), so I averaged them to create one variable (average canopy closure within 20 meters).

I used a stepwise analysis to determine which variables to include in the initial model using a PHREG procedure (SAS Institute, Inc. 1992) (Appendix D). Once this process was complete, I added the variable DBH (dbh of the roost or random structure) despite it's high p-value (p-value = 0.769) to control for it in my study design. Although the parameter estimate and p-value for the variable DBH has no real interpretive value, it needs to be included in the model to account for the variability in the data attributed to DBH since it was pre-determined as a selection criterion in the study design. I included stratification in the model by using a dummy variable, STAND, to account for matching the known roost snags with randomly selected snags by stands where the known roost structures were located (Ramsey and Schafer 1994).

A deviance statistic is analogous to a residual mean square in ordinary least squares regression. The deviance is the difference between the likelihood function based on fitting each data point exactly and the likelihood function based on the model of interest. A drop in deviance test (likelihood ratio test) reflects the difference of deviance from two competing models to a chi-square distribution. This is done by subtracting the deviance in the full model (model including the given variable or variables) from the reduced model (model without the given variable or variables). A p-value for the discrepancy is retrieved from a chi-square distribution table based on the difference in degrees of freedom between the two nested models being tested. The drop in deviance test used in my analysis equates to an extra-sum-of-squares F-test used for normal linear regression analysis (Ramsey and Schafer 1994). I completed a drop in deviance test using the model selected through the stepwise process plus the variable DBH as the reduced model, and testing it against full models which additionally included variables I felt to be biologically significant and resulted in a p-value of less than 0.20 when added to the model. Once a model was selected using this process, I tested for interactions between the explanatory variables.

Roost Stand Selection

I tested the hypothesis that roost selection was influenced by late seral stand conditions, by comparing the frequency with which roosts occurred in early seral stand conditions and late seral stand conditions (Appendix E), to the frequency with which roosts would be expected to occur within these two categories as they were proportionately represented in each landscape polygon encompassing Quentin Creek, and Lookout Creek roost sites. A GIS vegetation layer was used to identify stand conditions within the two landscape polygons. I calculated the percentage of the landscape polygon that fell within 3 early seral stages combined, and separately calculated the percentage of the landscape polygon that fell within the late seral stands. I multiplied the proportion of these two stand conditions (early seral stands and late seral stands) within the landscape polygon by the total number of known day roosts within the landscape polygon to determine expected values. I used the number of known roosts that occurred within the early seral stands and the number of known roosts in the late seral stands as the observed values for a chi-square analysis. I analyzed the data separately for each landscape polygon and if results were consistent between landscapes, combined the data sets and analyzed them together.

A chi-square analysis also was used to compare expected and observed frequencies of roosts in stands with a harvest history (managed) and stands without a harvest history (unmanaged). Stand types were determined using a GIS, and were defined using aerial photographs and information from the Total Resource Inventory system (TRI). A stand was considered as having a harvest history if any harvest activities occurred after 1950. All other stands were designated as not having a harvest history. Older thinned and salvaged stands were difficult to identify, and it is assumed they were often included as stands without a harvest history (Adee 1991).

Landscape Level Analysis

I determined the average area encompassing multiple roost sites for bats that were found using 3 or more roost sites, and mapped these areas using a GIS. "Roost sites" which included both verified roosts, and unique compass locations where a specific roost structure was not verified, yet the location was clearly different from any other verified roost. These roost locations included situations (1) where a roost could not be assigned to a particular tree or snag, but none of the possible roost trees or snags had a previous record of roosting or (2) where three or more compass bearings were used to identify an area 0.5 km^2 or less that did not include known roost locations. Since I had no means of determining a margin of error for non-verified roost locations which were included in my definition of roost sites, I also determined an average area encompassing only verified roost structures.

I tested the hypothesis that bats selected roosts closer to class I (largest stream), II, III, and IV (smallest stream) streams (Appendix F) than would be expected by chance. I compared the distance from known roosts to the closest stream representing each stream class with distances between randomly selected points and the nearest stream. A GIS was used to overlay a grid on each landscape polygon with a cell size of 400 m^2 to reflect the average distance between multiple roosts of individual bats. The

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nodes on the grid were numbered, and this range of numbers was entered into a random numbers generator. Three random points were selected for every known day roost (excluding roosts selected the morning a bat was radio-marked and released), and the closest distance from each random point and known roost to class I-IV streams was calculated using GIS. A two-sample t-test was used to determine if the distances were different between random and known locations. I analyzed the data separately for each landscape polygon.

I completed a power analysis for all of the two-sample t-tests comparing the distance between randomly selected points and known roosts to different class streams for all situations where the difference in distance between roosts and random points was not significant (Appendix G).

Results

Radio Telemetry

Sixteen out of a total of 22 bats radio-marked were tracked to day roosts for an average of 8 days per bat (SE=1.3) and a range from 1-24 days. The other 6 bats left the study site, had radio failure, or their radio signal could not be located consistently within a single 0.5 km^2 area. Fifteen of the 22 total bats were tracked for 4 or more days and 13 bats were tracked to multiple day roosts. Forty-one day roost structures were located, of which 1 was a rock crevice, 4 were live trees, and 36 were snags.

General Day Roost Characteristics

The mean height of all roost structures was 40 m (SE=2.5). The mean dbh for all snags and trees used as day roosts was 100 cm (SE=6.1), whereas snags used as day roosts had a mean dbh of 97 cm (SE=6.6) and mean height of 38 m (SE=2.8). Nearly half (47%) of the snags used for roosts were decay class 1 and 2 Douglas-fir averaging 108 cm (SE=7.4) dbh and 46 m (SE=2.9) tall. Nine (25%) of the snags used as day roosts were decay class 3 and 4 Douglas-fir averaging 99 cm (SE=10.1) dbh and 33 m (SE=5.7) tall. The remaining snags were western hemlock snags (*Tsuga heterophylla*) (14%, n=5) mostly decay class 1 and 2 (n=4), and western redcedar snags (11%, n=4) decay class 0.5 (n=3) and 2 (n=1).

Characteristics of Snags and Associated Micro-habitat Selected as Day Roosts

The matched case-control study analysis of snags used for day roosts, reflected that the odds that a snag will be selected as a day roost increase as snag height increases (p-value=0.0002); and given snag height, the odds of selection decrease as the stand height adjacent to the snag increases (p-value = 0.0243)(Table 1). Additional variables that I felt were biologically significant, and when added to the above model, resulted in a p-value < 0.20., BARK (percent bark) and GAP (canopy open around roost or randomly selected snag), were analyzed using a drop in deviance test which resulted in BARK and GAP showing a p-value of 0.10 when a model with both variables included (full model) was tested against the above model (reduced model) without these variables. This p-value is low enough that I feel these habitat characteristics warrant discussion, yet the statistical evidence to include them in the final model was inconclusive (GAP p-value = 0.1485, BARK p-value = 0.1187).

Table 1: Parameter estimates (log scale) and associated values resulting from matched case-control analysis for study on selection of day roosts by female long-legged myotis in the central Oregon Cascades 1993-95.[1]

Variable	DF	Parameter Estimate	95% CI	P > Chi-sq	Odds Ratio
DBH	1	0.003524	-0.0202 to 0.0273	0.7690	0.996
HEIGHT	1	0.128426	0.0603 to 0.1965	0.0002	1.137
CANOPY	1	-0.063136	-0.1186 to -0.0076	0.0243	0.939

The exponentiated values of the parameter estimates, exclusive of DBH , are the odds ratios for habitat characteristics associated with day roost selection of snags. Standard errors for these values cannot be directly interpreted and then applied to individual values of the explanatory variables because of the asymmetrical range of the log scale used in the analysis. The standard errors can be used to report a confidence interval by taking the value of the standard error at the log scale, multiplying it by the t-value for the appropriate degrees of freedom (n-2 = 97 for this study), and subtracting it from the associated parameter value (at the log scale, as it appears above), prior to transforming it exponentially (Hosmer and Lemeshow 1989, Ramsey and Schafer 1994).

The odds a snag will be selected for a day roost increase 1.137 times (95% CI=1.062 - 1.217) for every meter increase in snag height, and having accounted for snag height, the odds of a snag being selected as a day roost decreases 0.9388 times

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[1] Where DBH=dbh of known roost snag, HEIGHT=height of known roost snag, and CANOPY=height of stand canopy within 20 m of roost snag

(95% CI=0.888 - 0.993) for every meter increase in the stand height within 20 m of a snag. For example, the odds of a snag 38 m tall (average height of known roost snags) being selected as a day roost are 19 (38-15=23 and $1.137^{23}=19$) times (95% CI= 17.91-20.53) that of a snag that is 15 m tall (average height of randomly selected snags); and given snag height, the odds of a snag being selected where the mean stand height within 20 m is 42 m (mean stand height within 20 m of known roost snags) are 0.69 (48-42=6 and $0.9391^{6}=0.69$) times (95% CI= 0.65-0.72) that of snags where the mean stand height within 20 m is 48 m (mean stand height within 20 m of randomly selected snags).

Frequency of Use of Day Roost Structures

Bats were located at 41 day roosts on 93 occasions (Appendix H). Twice, two bats that were radio-marked at the same night roost were found using the same day roost at the same time. There were no other instances where radio-marked bats were found to use the same day roosts. The low incidence of radio-marked bats day roosting together (2 instances), and that no two bats used the same day roost on separate occasions simply shows that the radio-marked bats did not share a single common day roost. Because too few bats were radio-marked at any one time, conclusions cannot be drawn about the social interactions at the day roosts among all bats radio-marked. An average of 2.2 days (SE=0.27) was spent at a day roost by bats that were tracked more than one day (n=15 bats, the number of days bats were tracked ranged from 4-24 days).

Roost Stand Selection

The number of roosts in late seral stands, compared to all early seral stands combined did not differ significantly from what would be expected (Table 2), although there was some indication (one-tailed p-value=0.08) that roosts occurred in late seral stands more often than would be expected in Quentin Creek. The number of roosts occurring in harvested and unharvested stands did not differ significantly from what would be expected (Table 3).

Table 2: Stand conditions associated with 41 day roosts used by long-legged myotis in central Oregon Cascades, 1993-1995

	Quentin Creek		**Lookout Creek**		**Combined**	
Stand History	Expected	Observed	Expected	Observed	Expected	Observed
Late seral	7	11	9	11	20.50	22
Early seral	19	15	6	4	20.50	19
χ^2	3.13		1.11		0.12	
1 tailed P-value >	0.08		0.26		0.76	

Table 3: Distribution of 41 day roosts used by long-legged myotis between managed and unmanaged stands in the central Oregon Cascades, 1993-95.

	Quentin Creek		**Lookout Creek**		**Combined**	
Stand History	Expected	Observed	Expected	Observed	Expected	Observed
Mng.	6.76	4	4.05	2	10.25	6
Unmng.	18.72	22	10.95	13	30.75	35
χ^2	1.702		1.422		2.35	
1 tailed P-value >	0.21		0.24		0.14	

Landscape Level Analysis

The average distance of day roosts (exclusive of day roosts selected the morning a bat was released) from the night roost where the bats were radio-marked was 2.5 km (SE=0.25 km) and ranged from 0.7 km to 6.5 km. An area encompassing all day roosts (n=26) and the night roost for Quentin Creek drainage covered 3,258 ha. An area encompassing all day roosts (n=15) and the night roost for Lookout Creek drainage covered 6,391 ha. The estimated area encompassing multiple (3 or more) day roost sites for 7 bats averaged 13 ha (SE=3.0 ha) and 175 ha for one bat (Figures 1 and 2). The estimated area encompassing multiple verified day roosts only was 7.5 ha (SE=3.2 ha). The average distance between day roosts (2 or more verified roosts) of individual bats was 398 m (SE=59) for 11 bats, and 3,693 m (SE=1409) for one bat.

The mean distances from random points and from known roosts to the nearest stream of a given class, became progressively smaller from class I (largest streams) to class IV (smallest streams) streams under all circumstances tested. Day roosts were located closer to streams than randomly selected locations in both Lookout and Quentin Creek drainages with 1 exception (Lookout class III). In 2 cases day roosts were significantly closer to streams than randomly selected locations; class I stream (two-tailed p-value=0.03), and class II stream for Lookout Creek (two-tailed p-value=0.003) (Table 4).

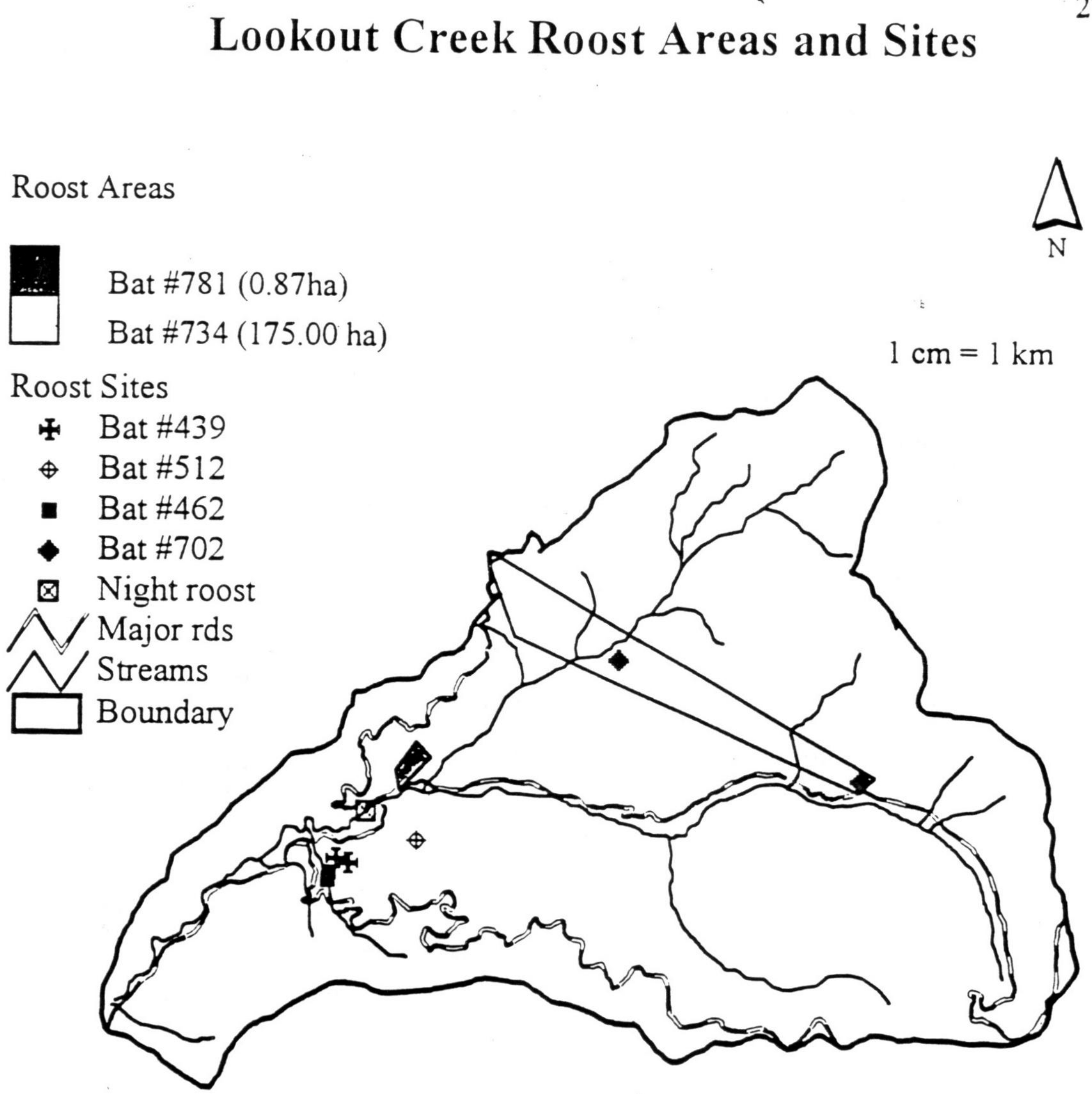

Figure 1: Lookout Creek (6,391 ha) roost areas for bats with 3 or more day roost sites and roost site locations for bats with 1-2 day roost sites, exclusive of first-day roost sites, from the study on selection of day roosts by female long-legged myotis in the central Oregon Cascades 1993-95

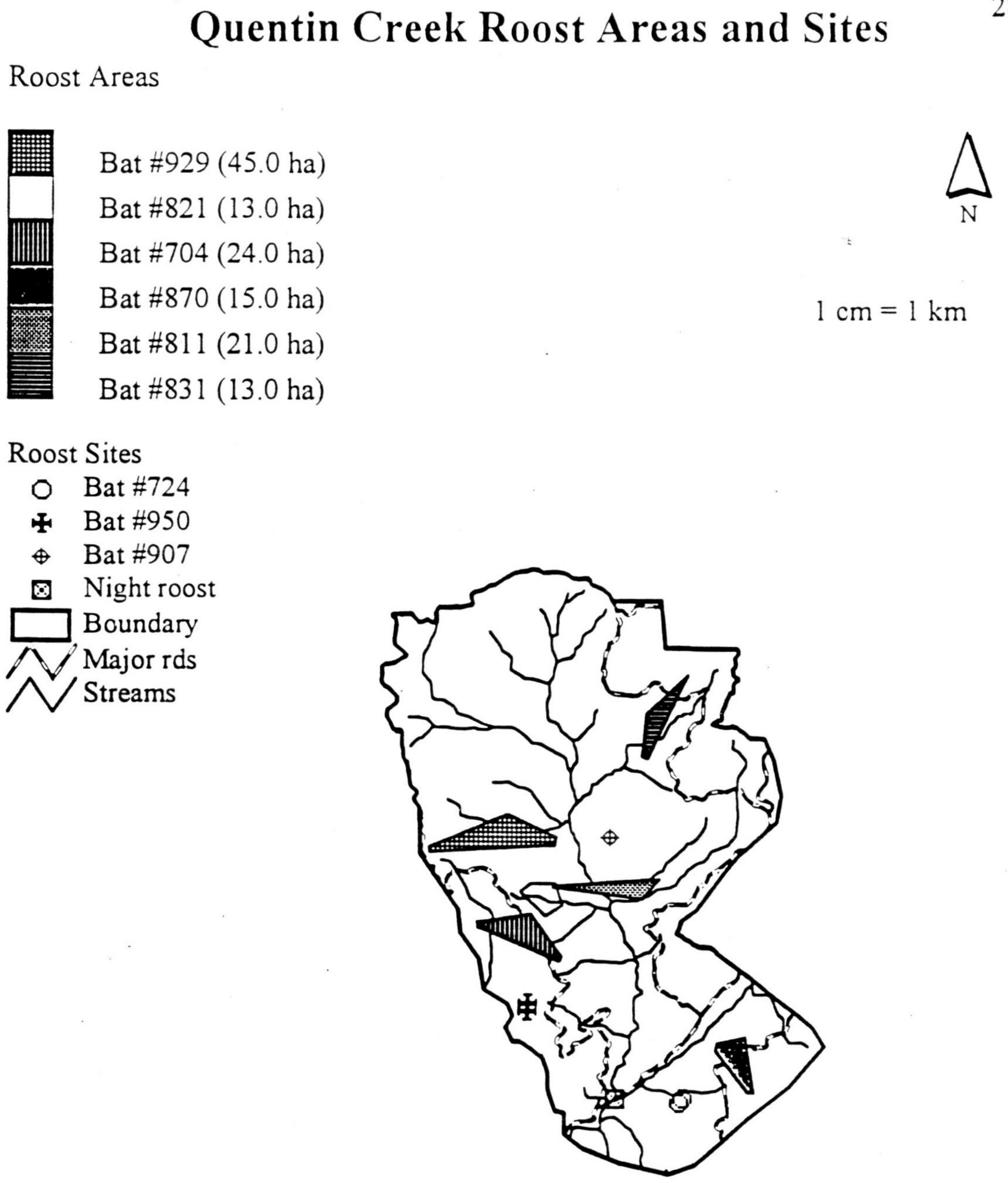

Figure 2: Quentin Creek (3,258 ha) roost areas for all bats with 3 or more day roost sites and roost site locations for all bats with 1-2 day roost sites, exclusive of first-day roost sites, from the study on selection of day roosts by female long-legged myotis in the central Oregon Cascades 1993-95

Table 4: Comparison of distances (m) between known day roosts used by long-legged myotis and random locations from stream classes I-IV in the central Oregon Cascades 1993-95

Stream Class	Roost $\bar{x}$	Roost SE	Random $\bar{x}$	Random SE	2-tail P
Quentin Class I	2152.00	365.01	2949.96	210.74	0.061
Lookout Class I	2371.81	383.27	3417.73	221.28	0.030
Quentin Class II	753.648	93.457	797.364	53.57	0.686
Lookout Class II	490.035	123.20	947.131	71.13	0.003
Quentin Class III	259.414	52.86	347.287	30.52	0.154
Lookout Class III	778.262	150.55	676.209	86.92	0.560
Quentin Class IV	229.819	37.16	246.129	21.45	0.705
Lookout Class IV	351.873	85.24	357.302	49.21	0.956

Ancillary Observations

The design of this study did not call for in depth observations of bat activity at the day roosts. However, on 6 occasions I returned to 4 different roosts at dusk to observe radio-marked bats exiting from their day roosts (emergence). Three of these roosts were Douglas-fir snags in decay class 1 and 2. The fourth roost was a 70 cm dbh hollow western redcedar (*Thuja plicata*) in decay class 0.5.

I witnessed 3 to 12 bats exit the Douglas-fir snags each time I observed emergence. Over 300 bats exited from the western redcedar roost on 2 separate occasions, and many of the bats were observed exiting and returning to the roost. behavior that is typical of neonatal bats testing their flight skills. Large accumulations of guano were present at the base of this and one other hollow tree in the same cedar grove. Three evenings later, not a single bat exited either of the western redcedar roosts. Guano catches placed at the base of both roosts indicated the bats did not return to either roost during the remainder of the summer.

On 4 of the 6 occasions where I witnessed emergence, radio-marked bats remained in the vicinity of the day roost and foraged with other bats, along roads, forest edges and above early seral stage 1 and 2 stands (Appendix E) for approximately 20-35 minutes. On 2 occasions the radio-marked bats headed directly down-slope towards class I or II streams.

Discussion

Characteristics of Snags and Associated Micro-habitat Selected as Day Roosts

Female long-legged myotis are more likely to select day roosts in tall snags surrounded by a shorter canopy than they are to select short snags surrounded by a taller canopy. I hypothesize that the snag height and surrounding canopy associated with roost selection may be related to detection and accessibility. Perhaps bats can differentiate the echo deflected off of snags from that of green trees. Snags that can be detected because they are tall enough to be part of the upper canopy would seem to be easier sound targets than snags much shorter than the surrounding forest canopy.

The roost snag height and adjacent stand height may be important in allowing the roost increased exposure to the sun and improved thermal conditions within the roost. This would increase the day time temperature of the roost over that of shaded conditions, and could also be important if heat is retained within the roost through some portion of the night, when altricial young that cannot thermoregulate are left alone at the roost for periods during the night. I found some indication that an open canopy surrounding a snag could increase the odds of selection, which would further enhance the solar exposure of a roost snag. While the evidence for selection of snags surrounded by an open canopy was weak and inconclusive in my study, other studies on bats have reported such exposure as significant. Campbell (1993) reported that all day roosts in her radio telemetry study of the silver-haired bat in Eastern Washington were in snags or partially dead trees that were significantly taller than other trees in the area, with sparser vegetation surrounding the roost trees than at comparable random sites. In northeastern Oregon, Betts (In press) found silver-haired and big brown bats day roosting in large snags that received solar radiation throughout the day. Vonhof (In press) found that silver-haired bats and big brown bats in the southern interior of British Columbia selected roosts in tall trees surrounded by a low percentage of canopy closure. Based on measurements of heat retention in the boles of live trees and the heat reflection ability of green foliage (Geiger 1957), a large snag, or a portion of a snag that has had exposure to the sun, will accumulate more heat than a snag that is shaded by forest canopy all day.

Testing the relationship between canopy characteristics and selection of snags as day roosts can be difficult in tall and densely forested stands when measurements are taken from the ground. Exploring canopy and tree or snag roost measurements from an aerial perspective could reveal more accurate and conclusive findings about these habitat characteristics and relationships. More accurate testing of these relationships may be possible using such tools as geographical positioning instruments, and low altitude aerial photos.

I found inconclusive evidence that the percentage of bark on a snag may be positively associated with the selection of snags for day roosts. Crevices formed behind loose bark are used by bats for roosting (Kunz 1982). Sasse and Pekins (In press) compared 49 snags used as day roosts by the northern long-eared bat *(Myotis* *septentrionalis)* in the White Mountains in New Hampshire to randomly selected snags. They found roost structures are taller, and have more bark than randomly selected snags. I limited measurements of bark to ocular estimates, taking more accurate and detailed measurements of bark characteristics such as thickness, aspect, and size of plates, could be helpful in analyzing the importance of bark to the selection of snags for day roosts.

Frequency of Use of Day Roost Structures

The bats I radio-tracked generally used more than one day roost. Roosting habits of bats can vary and be influenced by reproductive status, environmental conditions such as microclimate, parasite load, threat of predation, proximity to food sources, and social organization (Kunz 1982). Lewis (1995) reported that these factors also influence roost lability. The use of multiple roosts by female long-legged myotis could be a result of any one or combination of these influences.

While relatively large diameter, tall, newly dead, Douglas-fir snags dominated the roost structures selected by individual bats in my study, other types of day roosts may be of equal or more critical value to this species. For instance, only a few western redcedar snags in decay class 0.5 were selected, and thus could be viewed as minor contributors to the pool of day roosts. Fire-hollowed western redcedar are relatively rare (9% of snags selected for known roosts, and 0% of snags selected for random roosts in this study) compared to Douglas-fir snags, provide large chambers or cavities that can house large numbers of bats, and provide different microclimatic conditions compared to the cracks and crevices typical of Douglas-fir snags.

The difference in physical characteristics, and the discrepancy in the number of bats I witnessed during ancillary observations of emergence, indicate that different types of day roosts may serve different functions which may be influenced by different stages of offspring development. I hypothesize that reproductive females who are caring for altricial pups that are not able to thermoregulate, echolocate, or fly, increase the safety and energy conservation for themselves and their pups by roosting in one location as a large group. Once the pups are more independent of their mothers, learning a variety of roosts and foraging sites in smaller, less competitive groups, could increase a pups chance of survival.

My study was not designed at a scale to address questions related to the possibility of different roosts serving different functions within the reproductive time frame for this species. Based on my ancillary observations I believe further study to address and quantify these differences could be valuable in fully understanding the roosting behavior of this species. Further analysis of this type would require a larger sample size where the number of days each bat is tracked covers more than a few days to offset occasions when a bat spends several days at one roost. A more accurate measurement to determine the stage of pregnancy, or rearing young would help to identify associated roosting behavior.

Kunz (1982) suggested that roost fidelity is partially based on abundance and permanence of roosts. Lewis (1995) reviewed literature on roost fidelity and lability for 43 species of bats and found that fidelity is positively related to permanence of the roost and inversely related to roost availability. Because of the temporary nature of snags relative to a bat's life span, maintaining several roost snags in an area that provides desirable habitat conditions may be ecologically more efficient than being loyal to one snag that will almost inevitably become a log.

Use of several roosts has been attributed to predator avoidance for some species of bats in tropical zones. In temperate regions such as the Pacific Northwest, predation of bats by raptors and some mammals is probably opportunistic, and there is little evidence bats are a major food source for other species of wildlife (Fenton 1983). Results from pellet analysis of northern spotted owls *(Strix occidentalis)* within the Oregon Cascades for an area encompassing this study produced only occasional records of bat remains (Swindle, pers. comm).

Although collecting specific data on parasites was not a part of this study, ectoparasites were commonly noted on the long-legged myotis in this study. No information on endoparasites was collected. Many parasites that live in and on bats, are strictly associated with Chiroptera, and can be species-specific (Fenton 1983). The relationship between parasite load and bat selection of day roosts has not been well studied, yet ectoparasites associated with bats are known to spend their whole lives in bat roosts or on the host (Marshall 1982). The presence of ectoparasites in a maternity roost may present a threat to young bats before they are fully developed; that threat can be somewhat reduced by switching roost locations (Lewis 1995).

I radio-tracked too few bats at any one time to draw conclusions about the social interactions at the day roosts among all bats radio-marked. While there is evidence that these bats varied individuals with whom they day roosted, the extent of the variation is unknown. It may be that the community structure of bats in day roosts is determined through a system of social hierarchy or by compatibility of stages of reproduction.

Roost Stand Selection

My findings indicate a lack of association by reproductive female long-legged myotis with any particular stand condition. Thomas (1988) used ultrasonic detectors to assess bat activity in different ages of Douglas-fir forests in the Oregon Coast Range and Washington Cascades. Based on activity levels early in the evening, he inferred that myotis species and silver-haired bats may use old-growth stands more often than young and mature stands for day roosting because of the greater availability of large snags in old stands for day roosting. Crampton and Barclay (1995) used ultrasonic bat detectors and radio telemetry to determine if bats preferred certain ages of aspen (*Populus* sp.) mixedwood forests in Alberta for roosting and foraging. They found a significantly higher activity level in old rather than young or mature stands. All Alberta roost sites for little brown bats and silver-haired bats (n=27) were large snags, that apparently were only present in old stands.

The utility of ultrasonic detectors as a means of determining specific day roosting associations is limited (Thomas 1988), whereas the results of day roost use through radio telemetry is more reliable for collecting specific data on day roosts (Wilkinson and Bradbury 1988). Based on the results of my study, it is likely that female long-legged myotis select day roosts in a variety of seral stages of forested habitat, as long as adequate roost structures and micro-habitats are present.

Landscape Level Analysis

The distribution of multiple day roosts for individual bats within discrete roost areas is consistent with the work of Taylor and Savva (1988) who found several species of Tasmanian bats using multiple day roosts. They hypothesized that the bat's fidelity was to a roost area rather than to a specific roost. Kunz (1982) identified a growing recognition that most bats use one or more alternate day roosts, and found fidelity to a home area rather than a specific day roost common among foliage-roosting bats. Vonhof (in press) found female big brown bats and silver-haired bats using multiple day roosts within relatively small areas.

The proximity of roosts to class I streams may reflect an association between day roosts and the streams where night roosts were located. The Quentin Creek night roost was located on the same class I stream that was used to discern the distances between day roosts and random points to class I streams for both the Quentin Creek and Lookout Creek roosts. The Lookout Creek night roost was located in the class II drainage used to analyze the proximity of the Lookout Creek day roosts in comparison to random points. It is possible that the bats that used Lookout Creek also used the Quentin Creek night roost or that they foraged within the drainage where the night roost occurs. Bats banded and recaptured a second time (n=28) at Quentin Creek and Lookout Creek from 1992 - 1995 were primarily from the same night roost where they were originally banded (82.1%) (Perlmeter 1995). However, not all banded bats were recaptured, and there were occurrences of recaptured bats changing between night roosts in Quentin Creek and Lookout Creek; the degree to which this interchange occurs has not been documented. The contrast between fidelity to the night roost and lability with day roosts may be due in part to the consistently higher temperature at the night roost when compared to the ambient temperature (estimated difference=14.5° C, SE=0.2) (Perlmeter pers. comm), and permanence of the night roosts. While the difference in internal temperatures between snags used as day roosts and the night roosts has not been measured, the relatively massive concrete bridges used as night roosts are likely to be more effective at collecting and retaining heat than the relatively smaller snags. Further study of the relationship between day roosts and night roosts, and the differences in fidelity to both types of roosts would be valuable in assessing landscape level distributions and habitat use by this species.

Known roosts and random points were progressively closer to streams as the stream size decreased. Although this may be an artifact of the increase in density of streams as the class increases, it is important to note that day roosts are in upland habitat an average 270 m from class IV streams (95% CI=198 - 340 m) and 2222 meters from class I streams (95% CI=1821 - 2624). In general, this places roost sites outside of riparian reserves as are described in USDI (1994). and in locations that for much of public and private land involves commercial forest management. Therefore, consideration of day roost management in these areas is prudent.

The association of bats with streams may be more a function of night roost and foraging habitat selection than selection of day roosts. Collecting data on foraging habits is labor intensive and difficult, because it requires observations of bats when they are mobile and difficult to observe (at night). Brigham (1989) found big brown bats in British Columbia that he radio-marked to consistently forage along a 300-m stretch of the Okanogan River that was an average of 1.8 km from day roosts. Big brown bats in Ontario traveled less than 1 km from day roosts to forage in different locations each night. Clark et al. (1993) studied the foraging behavior of lactating Ozark big-eared bats (*Plecotus townsendii ingens*) in Oklahoma. They found 4 females using the same foraging site over multiple nights, and 6 using 2 or more sites. Overall, the bats showed foraging site specificity, while the distance they traveled from the maternity roost to the foraging site increased as lactation progressed. There is evident variation in foraging habits over time and for individual bats in both of these studies.

While long-legged myotis have shown some level of fidelity to night roosts at bridges (Perlmeter 1995) and there is an indication of reproductive females having an association with specific day roost areas, no study on foraging habits has been completed. How these three elements of habitat selection inter-relate, influence one another, or dictate a bats' association with a specific stream class, stand condition, or other habitat characteristics cannot be addressed from the results of this study.

Scale and Precision

McGarigal (1993) cautioned against inferring habitat relationships defined at one scale to another scale for birds he studied in the Oregon Coast Range. I advocate the same caution with the results of my study. For example, because there is no evidence of association between day roosts of female long-legged myotis and late seral stand conditions does not necessarily imply that an entire drainage in young seral stand conditions with suitable roost structures will provide adequate day roost habitat for this species. A snag in a young seral stand may meet day roost requirements for a given time or condition that shift so at a different time, or under different conditions day roost requirements are met by a snag within an old-growth stand.

Consideration of the precision of measurement also is important even at the same scale. Although there was no statistically significant variation in roost selection across relative proportions of stand conditions, there may be stand attributes not included in this analysis that are associated with day roost selection. For instance, if the data were available on the number of large snags present within each stand, this would allow analysis of this stand attribute by stand condition, increasing the precision of analysis.

Although my study was confined to correspond with the reproductive stage of females, the duration of this study is still a fairly broad time frame to identify specific biological, social, and environmental factors influencing habitat associations. There undoubtedly remains variability researchers have yet to identify or understand about this life stage for this species. I base this hypothesis in part on the use of multiple roosts, and the difference in numbers of individuals observed exiting the western redcedar roost compared to the Douglas-fir roosts. These events suggest that different roosts, with different characteristics, serve different functions within the relatively short time frame of reproduction. This implies that the social, biological, and environmental factors related to successful reproduction and the rearing of young can be scaled to yet a finer degree of precision. Because this hypothesis is partially based on ancillary observation, it would be valuable to formally test variation in the use of day roosts.

Management Recommendations and Research Needs

Ensuring adequate roost distribution and abundance for snag-dependent species such as long-legged myotis in forested habitats of the Pacific Northwest will require maintenance of adequate snag resources over time, especially on lands designated for commercial forestry where snags may be at risk due to safety considerations of logging operations.

Tall (>32 m), large diameter (>83 cm), decay class 1 and 2 Douglas-fir snags distributed across all seral stages in a watershed will provide one level of day roost habitat for female long-legged myotis. To provide for roost areas, I recommend managing for large Douglas-fir snags on a rotational basis, providing solitary snags, clumps of 3-5 snags, and snags within patches of residual forest or green tree retention zones. Given that roost snags will fall over, the objective is to provide snags as described above, distributed over both time and place within a watershed as opposed to attempting to preserve specific snags and their associated micro-habitat that are known to be used as roosts.

Managing for some number of snags for the benefit of numerous wildlife species on commercial forest lands is a common practice on most Federal, State, and some private lands. My recommendation to insure large, sound, snags and green trees in harvest units overtime is compatible with other recommendations for snag management that benefits wildlife (Neitro 1985, USDI 1993). The number of snags for a given area that is necessary to provide adequate roosting habitat for forest-dwelling bat species is not known, and is an area that could use study.

Roosts that are found in more uncommon structures such as hollow trees and rock outcrops may not be readily replaceable. Where such structures are being used by a significant number of bats (defining "significant" will depend in part on the locality), especially as maternity roosts or hibernacula, or where alternative day roost structures are not available, I recommend evaluating the value of, and need to protect the roost structure and surrounding habitat. It may be reasonable to monitor the structure and surrounding habitat conditions for shifts in micro-climate conditions such as temperature and air flow, as well as monitoring bat use which could provide information on which to base a decision to manage the site or not.

In cases where managing for roost sites is desired, considering topography, vegetation, and position of the roost structure could be helpful in determining an effective strategy. Maintaining day roost conditions may require no action at all, or entail vegetation protection or management out to 240 meters from the roost structure (Chen et al. 1992). In many cases, reserve buffers could be counter productive to maintaining the microclimate around day roosts. For instance, in the case of a maternity roost in a rock outcrop in a newly harvested sale unit that is on relatively flat ground, where monitoring of micro-climate conditions and use may show a decline in use as vegetation in the unit grows. The vegetation around the roost may need to be thinned or removed to re-establish micro-climate conditions suitable for a maternity roost. Equally, large hollow trees within a forested stand may require vegetation management that protects the current micro-habitat conditions around the roost, which may include vegetation removal. Monitoring temperature, air flow, solar exposure, and use at more permanent roosts, using techniques that limit disturbance to bats, would be important groundwork for developing appropriate management strategies for these sites. Experimenting with creating roost structures such as hollow trees, through fire prescriptions or mechanical means could be insightful for managing replacement structures.

Refining techniques for collecting data on roost characteristics, and stand and landscape attributes could increase the precision of analysis and provide a finer scale of understanding habitat associated with day roosts of long-legged myotis. For instance, developing techniques to evaluate roost snags and the surrounding canopy from an aerial perspective could improve the detail and precision of collecting data at a height that reflects more of a bats' perspective on habitat selection than collecting such data while standing on the ground.

Further study on the concept of day roost areas and day roost fidelity would be helpful in better understanding and managing for roost types and distribution. Research on the different types of day roosts and differences in population and survival between different day roosts would help us to better develop roost management strategies.

Day roosts are one component of the ecology of long-legged myotis. Other components such as foraging areas and hibernacula are not well studied or understood and undoubtedly play an equally important role influencing the distribution and

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APPENDICES

Appendix A

Decay Classes for snags (adapted from Neitro et al. 1985)

Snag Attributes	Decay Class 0.5	 1	 2	 3	 4
% Dead	± 50%	100%	100%	100%	100%
Branches	All or most present	All or most present	few - no branches	limb stubs to none	none
Bark	80 - 100%	80 - 100%	varies	varies	0 - 50%
Condition	hard	hard	hard/soft	soft	soft
Height	± full	full - broken top	broken top	upper bole gone	less than 50% full

Appendix B

Sample size estimate based on dbh measurements from 1994 roost structure data (n=30). Standard deviation was adjusted to account for estimated correlation between dbh, height, and decay class.

Average dbh = 92.5 95% CI = 76.54 - 108.46

standard deviation = 42.73 practical significant difference (psd) = 30 cm

estimated R^2 correlation with height = 30%, with decay class = 25%

adjusted standard deviation to account for estimated correlation:

$$[(42.73 \sqrt{1-0.30})\ \sqrt{1-0.25}] = 30.96$$

$$n = (\text{constant})\ \frac{[\,t_{df}\,(1-\alpha/2)]^2\ (\text{standard deviation})^2}{(\text{psd})^2}\ (C_1{}^2 + C_2{}^2 + C_3{}^2 + \ldots. C_k{}^2)$$

Where n = sample size to be estimated, constant = 4, $[\,t_{df}\,(1-\alpha/2)]^2$ = 4, standard deviation = 30.96, $(C_1{}^2 + C_2{}^2 + C_3{}^2 + \ldots. C_k{}^2)$ = coefficients for a linear combination, in this case, -1 and 1 are used for a contrast linear combination, and psd = 30

$$4 \times \frac{4\ (30.96)^2}{(30)^2}\ (-1)^2 + (1)^2 = \frac{30673}{900} = 34$$

Estimated sample size = 34

Appendix C

Mean ($\bar{x}$) and standard error (SE) values for the variables were collected at snags used by long-legged myotis for day roosting, and at randomly selected snags in the central Oregon Cascades 1993-95.

		Known Roosts (n=33)		Random Roosts (n=66)	
HABITAT VARIABLES	**Type**	**X**	**SE**	**X**	**SE**
Roost Structure					
Height (m)	Continuous	38	2.80	15	1.75
Dbh (cm)	Continuous	97	6.63	73	3.54
Decay class[1]	Categorical	---	---	---	---
branch cover %	Continuous	25	5.29	9	2.40
bark cover %	Continuous	67	6.23	60	5.03
20-meter Radius Plot					
Canopy height[2] (m)	Continuous	42	3.2	48	2.30
Canopy ht. - Roost ht. (m)	Continuous	3	3.8	33	2.64
Canopy closure %	Continuous	49	0.05	45	0.03
Avg. dbh trees (>= 25 cm)	Continuous	56	3.73	61	2.30
Snag density (> =15 cm)	Continuous	6	0.92	3	0.38
# trees < 100 cm	Continuous	24	2.35	21	1.58
# trees > 100 cm	Continuous	3	0.46	3	0.39
Canopy open around roost[3]	Categorical	---	---	---	---

---

[1] Decay classes were grouped into two categories: 1) decay class 0.5 - 2, and 2) decay class 3 and 4

[2] Dominant height of stand within 20 meters of roost structure

[3] Two categories were used: 1) roost structure exposed to sky, and 2) enclosed by forest canopy

Appendix D

SAS language for PHREG procedure used for match case-control study analysis of known roost snags and randomly selected snags

```
OPTIONS OBS=MAX PS=60 LS=75;
DATA A1; INFILE 'a:\bats2.txt';
  INPUT
   DUMMY RANDOM ROOST $ STAND DBH HEIGHT
   DIFF CC DOM_T GAPC BARK
   SNAGS DECAY
   DECAYC AVGDBH LIVE BRANCH
   DENS100 DENSV100 ASPECT
   SLOPE;
   RUN;


PROC PHREG DATA = A1;
    MODEL DUMMY*RANDOM(1) = DBH HEIGHT CC DOM_T GAPC BARK
    SNAGS DECAYC AVGDBH LIVE BRANCH DENS100 DENSV100 SLOPE
    / TIES=DISCRETE selection=stepwise;
    STRATA STAND;
    RUN;
```

Where RANDOM (censor identifier) =
    0 - known roost snag (case), 1 - randomly selected snag (control)
Where DUMMY = 1 - case, 2 - control
Where (1) = censored data (control) from RANDOM

PHREG procedure written with the assistance of Lisa Ganio, Bill McComb, Fred Ramsey, and SAS Institute, Inc. 1992.

Appendix E

Stand conditions used for analysis, derived from stand conditions and classes as defined in the GIS data dictionary for the Willamette National Forest. For purposes of this analysis, the first three stand conditions were considered early seral.

Seedling/sapling (early seral stage 1)

- nonforest and private lands

- seedlings less than (1.0"dbh, => 6" high)

- seedlings and saplings (1.0-4.9" dbh) mixed

Pole (early seral stage 2)

- saplings

- saplings and poles (5.0-8.9" dbh) mixed

- poles,

- poles and small trees (9.0-20.9" dbh) mixed

Small/medium trees (early seral stage 3)

- small trees

- small and medium trees (21.0-31.09" dbh) mixed

- medium trees

Large trees/old-growth (late seral stage)

- medium trees and large trees (32.0-47.9" dbh) mixed

- large trees

- large and giant trees (48.0" or greater dbh) mixed

- giant trees

Appendix F

Stream Classes (as described in Gregory and Ashkenas, 1990)

Class I: Perennial or intermittent streams with one or more of the following: 1) direct source of water for domestic use; 2) habitat for spawning, rearing or migration for large numbers of fish; or 3) sufficient discharge to have a major effect on water quality of another class I stream.

Class II: Perennial or intermittent streams with 1) habitat for spawning, rearing or migration of moderate through significant numbers of fish; and/or 2) sufficient discharge to have moderate influence on other class I or II streams. Game fish are present for at least part of the year or the stream has the potential for the establishment or re-establishment of a game fish population.

Class III: Any perennial streams not meeting the criteria for class I and II streams.

Class IV: Any intermittent or ephemeral streams not meeting the criteria for class I, II, or III streams.

In general, and for Lookout and Quentin Creeks, class I streams constitute the largest waterways, and stream size reduces in gradation from class I to IV. Waterways can also be categorized by stream order (1-10). While stream classes are responsive to management agendas (i.e. a class I stream may be small in size, but is used for domestic water, thus warranting class I status), stream orders are strictly associated with geomorphological criteria. Interchanging stream classes and stream orders is not always straight forward.

Appendix G

Power analysis was completed on the two-sample t-tests for distances from roosts to different stream classes compared to distances from random points to different stream classes in all situations where the difference in distance between roosts and random points was not significant (failed to reject the null hypothesis).

The method I used for power testing required a designation of a practical (biological) significant difference (psd). I tested if δ and it's 95% CI for distance of known roosts to streams and random locations to streams included three psds of 50, 75, or 100% of the mean distance of known roosts from the stream class being tested. Because bats are volant animals and are relatively mobile, I'd judge a 75-100% additional distance to be a more practical significant difference than 50%.

The values for the H_0 and psd are used to define a measuring stick for the likelihood of detecting the psd when δ and it's 95% CI is compared against it. The results of this comparison reflect the power of the analysis to detect the psd which equates to $1-\beta$.

Quentin Creek (Roosts n=23 (df=22) Random n=69 (df=68) Total df=90)

Quentin Class II

< 95% CI >
|-----------|-----------| $\bar{x}_1$ **distance for roosts (m)**
571 753 935
(-182) $\bar{x}_1$ (+182)

< 95% CI >
|-----------|-----------| **$\delta=(\bar{x}_2-\bar{x}_1)$ = avg. random dist. - roost dist (m)**
-173 42 257
(-215) (+215)

---------------|---------------|--------|------| **practical significant difference (m)**
0 377 564 753
H_0 50 75 100 % of distance from roosts

Appendix G (continued)

Since δ ($\bar{x}_2$-$\bar{x}_1$) including the 95% confidence interval (CI), encompasses the value used for the null hypothesis ($\bar{x}_2$-$\bar{x}_1$ = 0), than there is inconclusive evidence to reject the null hypothesis. Since δ and it's 95% CI falls below the p.s.d. for 50, 75, and 100 % additional distance from the roosts, I am confident that no practically significant difference would be mistaken as correct. These results reflect adequate power for the analysis.

Quentin Creek Class III

< 95% CI >
¦--¦--¦ $\bar{x}_1$ **distance for roosts (m)**
192 259 326
(-67) $\bar{x}_1$ (+67)

< 95% CI >
¦-----------¦------------¦ δ=($\bar{x}_2$-$\bar{x}_1$) = **avg. random dist. - roost dist (m)**
-33 88 209
(-121) (+121)

----------------¦------¦-----¦-------¦ **practical significant difference (m)**
0 130 194 259
H_0 50 75 100 % of distance from roosts

Since δ ($\bar{x}_2$-$\bar{x}_1$) including the 95% confidence interval (CI), encompasses the value used for the null hypothesis ($\bar{x}_2$-$\bar{x}_1$ = 0), than there is inconclusive evidence to reject the null hypothesis. Since δ and it's 95% CI include the p.s.d. values for 50 and 75% additional distance from the roosts, I cannot be confident these values would be detected, and the power of this analysis for detecting these psds is low. Since δ and it's 95% CI falls below the p.s.d. value for 100 % additional distance from the roosts, I am confident that no practically significant difference would be mistaken as correct for this value, and power for this analysis for this value is adequate.

Appendix G (continued)

Quentin Creek Class IV

```
        < 95% CI >
 |-----------|------------|          x̄1 distance for roosts (m)
158         229          300
(-71)        x̄1          (+71)
```

```
        < 95% CI >
 |----------|----------|       δ=(x̄2-x̄1) = avg. random dist. - roost dist (m)
-69         16         101
(-85)                  (+85)
```

```
-----------|------------------|---//----|---//----|  practical significant difference (m)
           0                 114       172       229
           H0                 50        75       100 % of distance from roosts
```

Since δ ($\bar{x}_2$-$\bar{x}_1$) including the 95% confidence interval (CI), encompasses the value used for the null hypothesis ($\bar{x}_2-\bar{x}_1 = 0$), than there is inconclusive evidence to reject the null hypothesis. Since δ and it's 95% CI falls below the p.s.d. for 50, 75, and 100 % additional distance from the roosts, I am confident that no practically significant difference would be mistaken as correct. These results reflect adequate power for the analysis.

Appendix G (continued)

Lookout Creek (Roosts n=11 (df=10) Random n=33 (df=32) Total df=42

Lookout Creek Class III

```
             < 95% CI >
|--------------------|------------------------|          $\bar{x}_1$ distance for roosts (m)

180                 351                     523
(-171)              $\bar{x}_1$                      (+171)


               < 95% CI >
        |-----------|------------|      $\delta=(\bar{x}_2-\bar{x}_1)$ = avg. random dist. - roost dist (m)
      -194          5           204
      (-199)                   (+199)


  ----------------|------------|-----|----|     practical significant difference (m)
                  0          176   263  351
                  $H_0$           50    75  100 % of distance from roosts
```

Since δ ($\bar{x}_2-\bar{x}_1$) including the 95% confidence interval (CI), encompasses the value used for the null hypothesis ($\bar{x}_2-\bar{x}_1 = 0$), than there is inconclusive evidence to reject the null hypothesis. Since δ and it's 95% CI include the p.s.d. values for 50% additional distance from the roosts, I cannot be confident that this value would be detected, and the power of this analysis for detecting this p.s.d. is low. Since δ and it's 95% CI falls below the p.s.d. values for 75 and 100 % additional distance from the roosts, I am confident that no practically significant difference would be mistaken as correct for these values, and power for this analysis for these values is adequate.

Appendix G (continued)

Lookout Creek Class IV

< 95% CI >
¦-----------¦-----------¦ $\bar{x}_1$ **distance for roosts (m)**
158 229 300
(-71) $\bar{x}_1$ (+71)

< 95% CI >
¦----------¦----------¦ $\delta=(\bar{x}_2-\bar{x}_1)$ **= avg. random dist. - roost dist (m)**
-69 16 101
(-85) (+85)

-----------¦-----------------¦----//----¦----//----¦ **practical significant difference (m)**
0 114 172 229
H_0 50 75 100 % of distance from roosts

Since δ $(\bar{x}_2-\bar{x}_1)$ including the 95% confidence interval (CI), encompasses the value used for the null hypothesis $(\bar{x}_2-\bar{x}_1 = 0)$, than there is inconclusive evidence to reject the null hypothesis. Since δ and it's 95% CI falls below the p.s.d. for 50, 75, and 100 % additional distance from the roosts, I am confident that no practically significant difference would be mistaken as correct. These results reflect adequate power for the analysis.

Appendix H

Summary of roost history by individual bat

Bat ID	Days tracked	Days located at roost sites	Verified roost ID	Dates at verified roost	Days found at verified roost	Largest number of consecutive days
439	8	7	L1	8/17-19/94	3	3
-	-	-	L4	8/20-23/94	4	4
462	4	3	L3	8/19-20/94	2	2
512	8	7	L2	8/17-23/94	7	7
704	8	7	Q7	8/5,6,9/94	3	3
-	-	-	Q11	8/7/94	1	1
-	-	-	Q13	8/10/94	1	1
724	7	6	Q14	8/11/94	1	1
-	-	-	Q17	8/12-16/94	5	5
811	8	8	Q2	8/3/94	1	1
-	-	-	Q4	8/4/94	1	1
-	-	-	Q5	8/5/94	1	1
-	-	-	Q9	8/6,10/94	2	1
-	-	-	Q10	8/8-9/94	2	2
-	-	-	Q19	8/25/94	1	1
821	24	18	Q1	8/2/94	1	1
-	-	-	Q3	8/4-8/94	5	5
-	-	-	Q16	8/13/94	1	1
-	-	-	Q19	8/14,23,25/94	4	3
-	-	-	Q20	8/16,18-22/94	6	5
831	8	8	Q6	8/5/94	1	1

Bat ID	Total days tracked	Days located at roost sites	Verified roost ID	Dates at verified roost	Days found at verified roost	Largest number of consecutive days
-	-	-	Q8	8/6-9/94	4	4
870	11	7	Q12	8/10/94	1	1
-	-	-	Q15	8/12-15/94	4	4
-	-	-	Q23	8/17/94	1	1
-	-	-	Q18	8/20/94	1	1
907	4	1	Q25	8/27/94	1	1
929	7	4	Q26	8/27/94	1	1
-	-	-	Q21	8/28,30/94	2	1
950	10	2	Q24	8/26/94	1	1
-	-	-	Q27	8/28/94	1	1
781	6	6	L931	8/14/93	1	1
-	-	-	L932	8/13/93	1	1
-	-	-	L933	8/15-16/93	2	2
-	-	-	L934	8/15/93	1	1
-	-	-	L935	8/18/93	1	1
734	14	13	L6	7/24/95	1	1
-	-	-	L8	7/26,27,29/95	3	2
-	-	-	L9	7/28,30/95	2	1
-	-	-	L10	7/31/95-8/6/95	7	7
702	4	3	L7	7/24/95	1	1
-	-	-	L8	7/26/95	1	1
714	1	1	L5	7/24/95	1	1