INTEGRATED MANAGEMENT OF FLAMMULATED OWL BREEDING HABITAT AND TIMBER HARVEST IN BRITISH COLUMBIA

By

ASTRID MICHELE VAN WOUDENBERG

B.Sc., The University of British Columbia, 1987

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES

(Department of Forestry)

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

April 1992

Department of Forest Sciences

The University of British Columbia
Vancouver, Canada

Date September 15, 1992

ABSTRACT

The Flammulated owl (Otus flammeolus) is an insectivorous, secondary cavity-nester which breeds in old-growth, montane forests of western North America. It is migratory and has been listed as vulnerable by the Committee on the Status of Endangered Wildlife in Canada. The Flammulated owl inhabits mixed pine and Douglas-fir (Psuedotsuga menziesii) stands at elevations upwards of 850 meters. The study site was Wheeler Mountain, a 1,600 ha area 10 km north of Kamloops, British Columbia, near the species' northern limit. The area has the largest known population of Flammulated owls in Canada and potential impacts of forest harvesting on its breeding habitat were unknown. A logging moratorium was therefore initiated by the Ministry of Environment after Wheeler Mountain was scheduled for timber harvest by the B.C. Ministry of Forests. This study documented foraging and nesting habitat to develop forest management recommendations that would maintain a Flammulated owl breeding population.

Conservative estimates from census work suggest there may up to 24 birds on the study site during migration. Nesting density was recorded at 0.1 pairs per 40 ha. Twelve nest sites were found in both Ponderosa pine (Pinus ponderosa) and Douglas-fir snags and trees (mean DBH 61 cm, range = 33 - 82, SD = 15.8). Data suggest that Ponderosa pine may be preferred for nesting. Radio-telemetry indicated that thickets of dense, regenerating Douglas-fir adjacent to open spaces were critical for foraging habitat

and were a smaller component of nesting habitat. Stand structure of foraging habitat was characterized by a range of 22 - 559 stems per 500 m^2 and canopy cover less than 15% for the same area. A broad inverse relation between stem density and canopy cover resulted from high stem density and defoliation by Western Spruce Budworm (Choristoneura occidentalis) in lower canopy layers. Windfall and previous selective timber harvests had created openings in foraging areas. The results suggest that stand structure is critical for foraging habitat and that once foraging areas are located by the Flammulated owl, a suitable nesting cavity is sought nearby.

The northern aspect of Wheeler Mtn. was used more frequently for nesting. Denser thickets of Douglas-fir on the northern aspect apparently provided greater foraging opportunities because of the higher abundance of Western Spruce Budworm. The denser stand structure also provided security cover for the Flammulated owl from the Barred owl (Strix varia), which was more common on the north aspect. Open stands with no budworm defoliation were not used by Flammulated owls.

Uneven-aged management is recommended to maintain the existing stand structure. A selective harvest of Douglas-fir only, scheduled both temporally and spatially, will sustain the heterogeneous stand structure. Small openings that allow regeneration of Douglas-fir thickets (up to 1 ha) and Ponderosa pine trees (2 ha) also will enhance both foraging and nesting habitats. Nesting and foraging habitats should be contiguous and include security cover. Any snags or mature trees of Douglas-fir and

Ponderosa pine with existing cavities must be retained. Patches of mature and mid-seral trees should be retained where they occur in densities of 5 or more stems per 500 m^2 for future suitable nest-cavities. Habitat for primary cavity-excavators must also be maintained. Suitable nest sites may be limiting the breeding population of the Flammulated owl on Wheeler Mountain.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

The successful completion of this project was made possible by the assistance and advice from several people. I thank Les Lavkulich for his professional guidance and advice in the initiation of this master's program. I especially thank Fred Bunnell, my advisor, and Dave Low, Ministry of Environment wildlife biologist, who were both instrumental throughout this project in helping me meet the objectives. Fred Bunnell provided professional, academic guidance throughout each stage of this study. I am very grateful for his discussion, advice, and humour. Dave Low offered both theoretical and practical field advice and I greatly appreciate his countless laughs and thought-provoking conversations.

I thank John MacLean, Val Lemay, and Tom Sullivan for their academic advice and cheerful encouragement provided freely throughout this study. I am very grateful to Richard Reynolds, Brian Linkhart, and Dick Cannings for their advice regarding methodology. I appreciate the technical support from Fraser Russell and Lorraine MacLaughlin. I also thank Chris Harris for the use of his leg bands.

For their financial contributions to make this project possible I thank World Wildlife Fund, Science Council of B.C., Habitat Conservation Fund (B.C. Ministry of Environment), Weyerhaeuser Ltd., Tolko Inc., and B.C. Ministry of Forests. I also thank B.C. Conservation Foundation and Bob Moody for their administrative contribution.

I am grateful to Pat and Leo Strausser at the Pass Lake Agriculture Canada Research Station for endless favours and practical advice. I also appreciate the many favours and administrative details Jackie Johnson always took care of cheerfully.

Over three years of study many people assisted in the field and I am grateful to them all. In particular, I thank Peter Bodley, Michael Burwash, and Charles Lawson for their field assistance during long nights of radio-telemetry and their hard work and ever-cheerful dispositions.

I especially thank David Christie for his assistance in the field, particularly with capturing owls, and for producing maps of the study site on a GIS. I am very grateful for his constant support, encouragement, and enthusiasm which he gave generously.

Finally, I am extremely grateful my parents, Gus and Yvonne van Woudenberg, for the encouragement, love, and support they have always provided and which made this project and master's program possible.

DEDICATION

I dedicate this thesis to my parents. To my father, Gus van Woudenberg, whom I lost during this project, for his wisdom, advice, and enduring support. And to my mother, Yvonne van Woudenberg, for the same reasons but also for her patience and understanding, and her persistent, steadfast encouragement.

I am especially grateful to my advisor, Fred Bunnell, for his support and understanding following the sudden, tragic circumstances during my master's program.

You can do as much as you think you can
But you will never accomplish more.
And if you are afraid of yourself, young man,
There is little for you in store.
For failure comes from the inside first
It's there if we only knew it.
And you can win though you face the worst,
If you know that you are going to do it.

Edgar A. Guest

INTRODUCTION

The Flammulated owl (Otus flammeolus) is a small (55-68 grams), insectivorous, secondary cavity-nester which breeds in old-growth montane forests in the mountains of western North America (Reynolds and Linkhart 1987). It winters as far south as Mexico and Guatemala (Cannings et al. 1978, Cannings 1982). The species has been designated vulnerable by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Nesting has been reported in California (Winter 1974; Marcot and Hill 1980), Utah (Hasenyager et al. 1979), Colorado (Richmond et al. 1980; Linkhart and Reynolds in press), Oregon (Bull and Anderson 1978; Goggans 1986) and British Columbia (Cannings et al. 1978; Cannings 1982; this study). The interior of British Columbia is the known northern limit of the species and the only area in Canada it is known to inhabit. Its elevational range is reported to vary from 370 meters in northern areas of the United States to over 2,700 meters in more southerly regions (Winter 1974).

Flammulated owl sightings have been reported in mature and old-growth, mixed-conifer forests with varying pine components and canopy closures less than 50% (Goggans 1986). Other than studies by Reynolds and Linkhart (1987) in Colorado and Goggans in Oregon (1986), current literature provides little further documentation of nesting and foraging requirements of the species. Little is stated about potential forest management impacts on the owl. Although management guidelines have been proposed for populations in Colorado and Oregon, an understanding of specific habitat requirements at the northern range of the species could reveal differences in management needs. This study examined habitat use by Flammulated owls in the Kamloops area, near the northern limits of its range.

A population of Flammulated owls inhabits Wheeler Mountain, approximately 10 km north of the City of Kamloops, near Lac du Bois. The area has been observed to have the largest numbers of Flammulated owls known in B.C. (Howie and Ritcey 1987). Wheeler Mountain had been proposed for timber harvest within the B.C. Forest Service Small Business Program. The Ministry of Environment, Wildlife Branch, placed a logging moratorium on the area (1989) to allow study of potential timber harvest impacts on the Flammulated owl. The objective of this study was to determine whether a timber harvest prescription could be developed that was compatible with maintaining the Flammulated owl nesting population. The project included examining basic life requisites of the species, including nesting, foraging, and security, and documenting critical habitat components to be preserved during timber harvest.

DESCRIPTION OF STUDY SITE

The study site (Wheeler Mountain, Figure 1), is a 1,600 ha area approximately 10 km north of Kamloops, located on the west side of Lac du Bois (50°46' north and 120°28' west). The elevation ranges 850 to 1,200 meters with slopes up to 75%. It is in the interior Douglas-fir biogeoclimatic zone, subzone IDFxh2, also known as the Thompson very dry hot interior Douglas-fir variant (Lloyd et al. 1990).

The stands on the north and south aspects of the mountain are mature to old-growth (80 - 200+ years). Douglas-fir is the climax species which dominates the study site with Ponderosa pine occurring as a subdominant on the southern aspect of the mountain. Fire suppression - due in part to decreased understory fuel loading caused by cattle grazing - and previous selective timber harvests, 25 to 35 years before this study, reduced the Ponderosa pine component, particularly on the northern aspect (D. Low pers. comm.). Fire suppression had also encouraged Douglas-fir regeneration in the form of dense thickets. The stem density of these thickets has led to stagnant stands with recurring outbreaks of Western Spruce Budworm (Choristoneura occidentalis). Budworm damage is extensive on the northern aspect of the mountain; damage on the southern side is limited to wetter areas where thickets of Douglas-fir regeneration occurred.

The predominant understory species includes saskatoon (Amelanchier alnifolia), birch-leaved spirea (Spirea betulifolia), soopolallie (Shepherdia canadensis), kinnickinnick

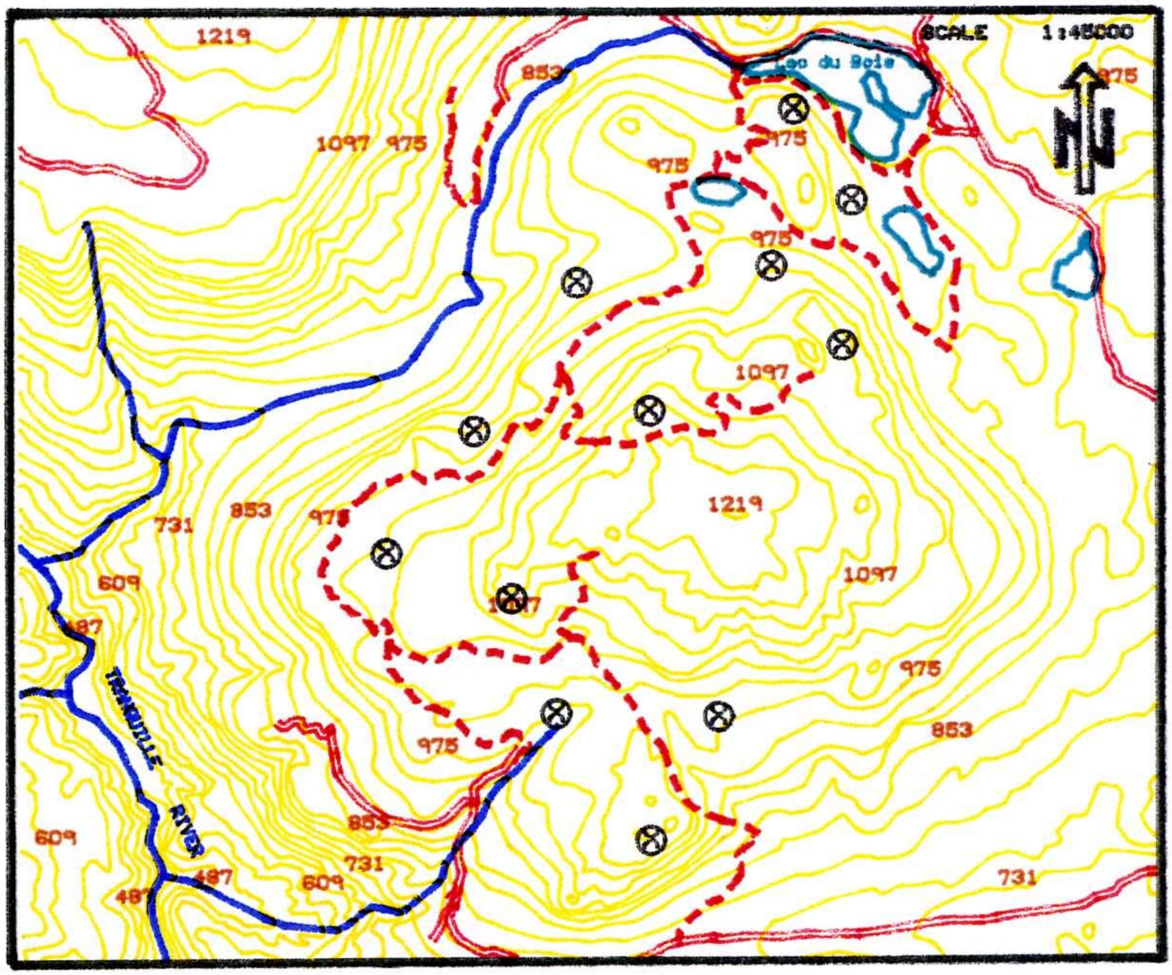


Fig. 1 Study site at Wheeler Mountain with Flammulated owl locations.

(Arctostaphylos uva-ursi), pinegrass (Calamagrostis rubescens), bluebunch wheatgrass (Agropyron spicatum), and rough fescue (Festuca scabrella). On drier sites, particularly the southern aspect of the study site, the understory is dominated by bluebunch wheatgrass with small amounts of saskatoon and birch-leaved spirea, and common juniper (Juniperus communis) at lower elevations. The bryophyte layer is sparse on both wet and dry sites.

Both Douglas-fir and Ponderosa pine snags and mature trees containing Pileated woodpecker (Dryocopus pileatus) and flicker (Colaptes auratus) holes are common on the study site. Dead and down woody material occurs throughout the area and most of the stands contain decadent trees. Open spaces are frequent and range in size from a few square meters to, occasionally, 2 ha. Most of these large openings are old skid trails, created by past selective timber harvests; smaller openings are due to windfall of mature, decaying trees. The mean annual precipitation for the area is 37.5 cm with maximum precipitation in spring (May and June) and winter (December and January) (Mitchell and Green 1981). Mean annual temperature is -5°C with a mean July temperature of 16°C and a frost free period of 90 days.

An area under 2 ha on the north side of the mountain, directly west of Lac du Bois, had been thinned with 4000+ stems removed per ha. Three sample plots in the area showed the original stocking level was 413, 270, and 525 stems per 500 m^2; thinning had reduced the stand to 163, 72, and 138 stems per 500 m^2, respectively (respective densities are: pre-thinned stocking levels at 8,260, 5,400, and 10,500 stems per ha and post-thinned stocking levels at 3,260, 1,440, and 2,760 stems per ha). The area remained well stocked with an even-age stand 15-20 m in height.

METHODS

Field Work

The study was conducted over three field seasons, from May until August, 1989 and 1990, and June until September 1991. In the first field season surveys documented locations of Flammulated owls, nest sites were located, and various capture techniques were evaluated. In the second and third field seasons nest sites also were located and foraging habitat was identified using radio-telemetry. Characteristics of nesting and foraging habitats were documented. During the last field season small mammal and Barred owl surveys were conducted.

During the months of May and June of 1989 both the north and south aspects of the study site where censused at fixed locations 500 m apart along secondary roads (Figure 1). Ten minutes was spent at each census stop, first listening for birds and then calling for them. Locations were later referenced on aerial photographs (1:15,840) and triangulation revealed where the same bird may have been heard more than once. In some areas two or three birds could be heard at a time and occasionally one would fly across the road. These areas were marked and searched for nest sites during the latter half of June in each field season.

Both north and south aspects of the study site had one area of unused habitat. Three or four nights spent calling and listening for birds in these areas revealed no Flammulated owls were present.

Nest sites were found by checking cavities during the day. By the middle of June females had begun incubating their clutch and would often reveal themselves at the cavity entrance upon disturbance. Nest sites were found by knocking on the bole of trees and snags containing cavities and watching for the female owl to emerge. In April of 1990, 50 nest boxes were erected and were checked for occupation in May and June of that year. Due to the work schedule in the following season (from May until June, 1991), only the 16 nest boxes located at previous nest sites were checked periodically.

Adult birds were captured outside their nest cavities using a mist-net fixed at the end of a telescoping pole. Male birds were equipped with 3-gram, radio-transmitter back-packs; the transmitters each had a posture switch to indicate when the bird was flying or stationary. Both males and females were also fitted with leg bands.

For approximately three weeks during 1990 and 1991 male birds were radio-tracked at night to locate foraging habitat. The batteries of the transmitters usually expired near the time of fledging (last week of July).

Foraging, nesting, and unused habitats were sampled within 12.6 m radius plots

(500 m^2) around nest trees and telemetry point locations; random locations were used to place plots in unused habitats. The understory was classified according to Lloyd et al. (1990). Overstory was divided into four canopy layers for documenting stem density and percent canopy cover: A1 (trees taller than about 25 m), A2 (trees 20 - 25 m tall), A3 (trees 10 - 20 m tall), and B1 (trees less than 10 m tall). The forest stand at each site was quantified according to four distinct canopy layers which approximated these height boundaries. Veteran trees were measured in the A1 canopy layer, mature trees in the A2 layer, dense Douglas-fir in the A3 layer, and seedlings to juveniles less than 10 m in height were in the B1 canopy layer.

For ease of measurement the plots were divided into quadrats (125 m^2). Numbers of trees per quadrat were counted for each canopy layer and the typical or median tree size for each canopy layer in each quadrat was measured for diameter (cm) at breast height (DBH). Ponderosa pine and Douglas-fir were sampled independently. These data were used to generate DBH-frequency indices for the two lower canopy layers (comprising thickets of Douglas-fir regeneration) for foraging and unused habitats. The indices were used to compare stand densities between habitats and variability of stand structure within habitats. The number of trees counted for the A3 and B1 layers was multiplied by the typical DBH for that quadrat to generate the DBH-frequency index.

In foraging and unused habitats the number of stumps per quadrat were counted and identified as either a previous selective cut, natural windfall, or thinned stand (smaller diameter trees removed). In nesting habitat, nest tree status (alive or dead), species, and DBH (cm) were recorded. Cavity height and slope of nest sites also were measured.

During the 1991 field season, surveys for Barred owls (Strix varia), a Flammulated owl predator, were completed to identify potential differences between the southern and northern habitats of the study site. The presence of Barred owls was evaluated at the same census locations used for the Flammulated owl surveys. A recorded audio tape of the Barred owl call was played at each census stop. Small mammal surveys also were made on the southern and northern aspects of the study site to estimate the potential prey base for Barred owls. Trap lines of 28 Longworth traps, 15 m apart, were placed in one Flammulated owl foraging area on the northern side and in the single foraging area used on the southern side. Two other similar trap lines were placed randomly, one on each aspect of the study site.

Statistical Analysis

The Smirnov non-parametric test (Conover 1971) was used to distinguish the northern and southern aspects of the study site as distinct foraging habitat types and to identify differences among nest sites and individual foraging areas on both aspects. The Smirnov test also was used to compare foraging habitats with unused habitats. The level of statistical significance was set at $p=0.05$; only significant tests are reported.

A test of proportions (Hicks 1982) was used to compare the abundance of small mammals on the northern and southern sides of the study site.

RESULTS

Census

At least 8 Flammulated owls were heard on the north aspect and 4 along both forks of the road on the south aspect of the study site (Fig. 1). In total, a conservative estimate of 12 birds were located on Wheeler Mountain (0.3 birds per 40 ha). The earliest birds were heard calling was May 3.

Nesting Habitat

Nesting habitat was characterized for 12 Flammulated owl nest sites on Wheeler Mountain (Figure 2). During three field seasons of this project 7 nest sites were found on the northern side and 4 on the southern side. A nest site on the northern side used in previous years (R. Howie pers. comm.) was also documented. None of the nest boxes were utilized by Flammulated owls for nesting during the 1990 field season; however, a northern flying squirrel (Glaucomys sabrinus) was found occupying one. During the 1991 field season nest boxes close to past natural nest sites were observed to be unoccupied.

Four of the northern nest trees were Douglas-fir and four were Ponderosa pine; on the southern aspect one nest tree was a Douglas-fir and three were Ponderosa pine. Only

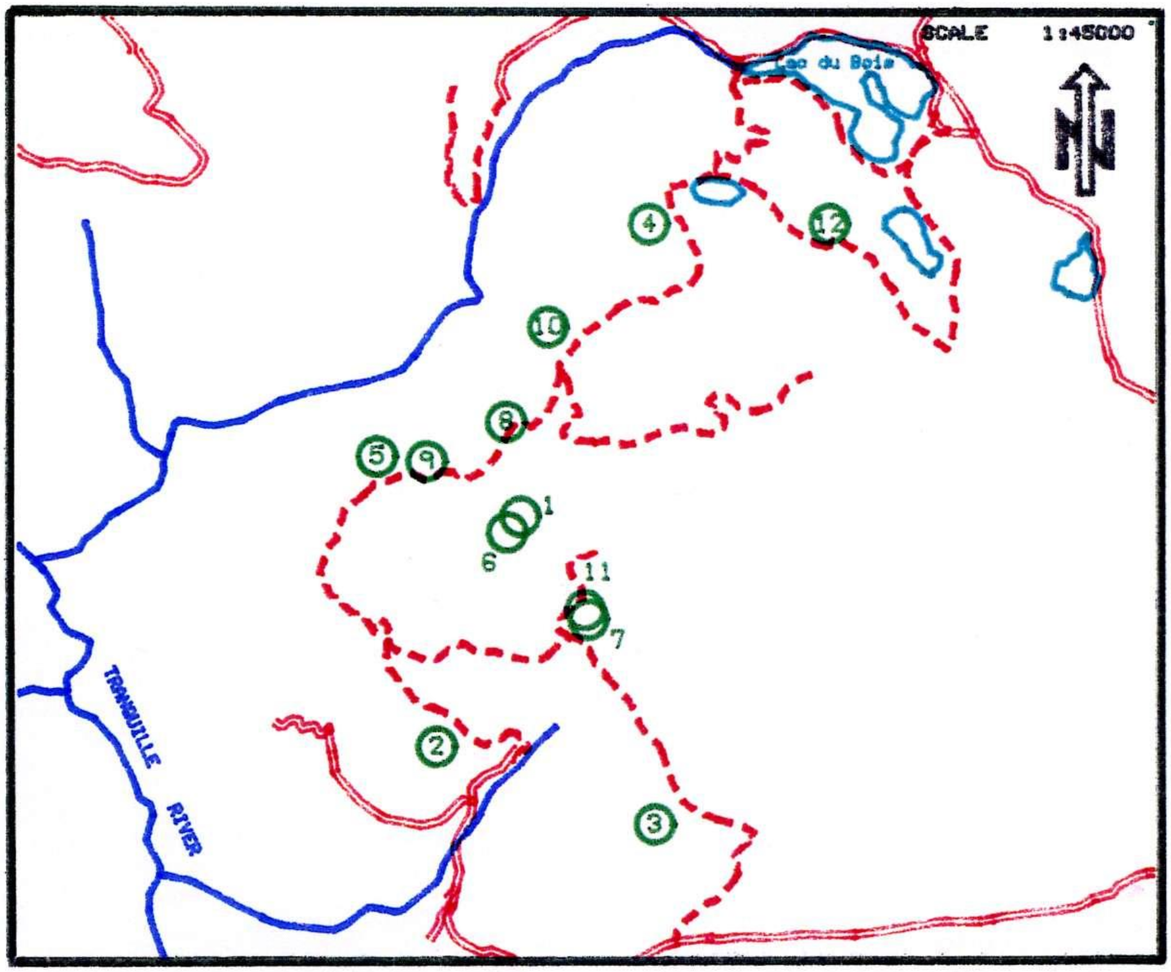
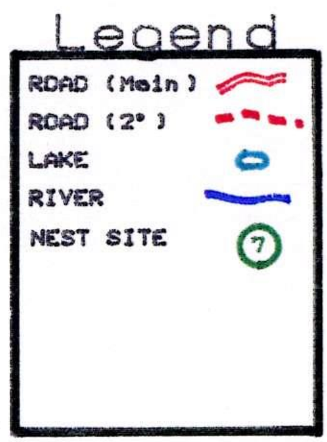


Fig. 2 Total nest sites found on Wheeler Mountain.



three nest trees were live with dead tops, the others were snags. Table 1 summarizes nest tree characteristics. Mean nest tree diameter overall was 61.3 cm (range = 33 - 82, SD = 15.8). Northern nest sites had larger mean diameters than southern nest sites for both Douglas-fir and Ponderosa pine nest trees. On both northern and southern aspects of the study site, Douglas-fir snags used as nests were covered with bark, while Ponderosa pine snags were not.

Overall mean nest cavity height was 8.4 m (range = 3.6 to 18, SD = 4.1). Aspects of cavities ranged widely from 29° to 339° (mean = 174.3, SD = 118.1); none faced directly north. Mean slope of nest sites was 28.8° (range = 8 to 54, SD = 14.7). Cavity height and slope precluded accurate measurement of cavity diameter. Visual estimates of cavity diameters were between 10 and 15 cm.

Tables 2 and 3 show stand characteristics of nesting habitat. Table 2 shows mean numbers of stems per quadrat for each canopy layer separately for southern and northern nest sites. Results of Smirnov statistical comparisons of stem density among nest sites showed few trends in nesting habitat stand structure. When total numbers of stems (Douglas-fir and Ponderosa pine) per quadrat for each canopy layer were compared among all nest sites, the results showed stem density differed significantly only in the lower canopy layers (A3 and B1). Similar comparisons of total numbers of stems at northern nest sites showed differences in all canopy layers except A1 ($p < 0.05$). When only Douglas-fir stems were compared, significant differences in all canopy layers

Table 1. Characteristics of Flammulated owl nest trees.

	Northern nest sites		Southern nest sites	
	Douglas-fir Nest trees (n=4)	Ponderosa pine Nest trees (n=4)	Douglas-fir Nest trees (n=1)	Ponderosa pine Nest trees (n=3)
DBH (cm)				
Mean	60.6	71.7	33.0	57.7
Range	49 - 82	51 - 81.2	-	46.2 - 66.8
SD	14.6	14.1	-	10.5
Cavity height (m)				
Mean	7.4	7.4	3.6	12.6
Range	5 - 10.4	6.3 - 10	-	8.6 - 18
SD	2.3	1.7	-	4.8
Cavity aspect (°)				
Mean	130*	161.7*	332	178.7
Range	29 - 300	86 - 239	-	92 - 339
SD	148.1	76.5	-	139.0
Slope (%)				
Mean	34.3	23.8	37.0	25.3
Range	8 - 54	22 - 25	-	16 - 43
SD	23.0	1.3	-	15.3

*(n=3)

Table 2. Mean number of stems per quadrat (125 m^2) at Flammulated owl nest sites. (4 Quadrats/Nest Site)

		North aspect (8 sites)	South aspect (4 sites)
A1 Canopy layer			
Douglas-fir	Mean	1.4	1
	Range	1 - 3	1 - 1
	SD	0.7	0
Ponderosa pine	Mean	1	1
	Range	1 - 1	1 - 1
	SD	0	0
A2 Canopy layer			
Douglas-fir	Mean	7	3.4
	Range	1 - 44	1 - 10
	SD	10.5	2.5
Ponderosa pine	Mean	0	1
	Range	0	1 - 1
	SD	0	0
A3 Canopy layer			
Douglas-fir	Mean	11	4.2
	Range	1 - 35	1 - 12
	SD	9.4	3.6
Ponderosa pine	Mean	0	1.8
	Range	0	1 - 3
	SD	0	1.0
B1 Canopy layer			
Douglas-fir	Mean	22	5
	Range	1 - 109	1 - 19
	SD	25.2	5.3
Ponderosa pine	Mean	0	2
	Range	0	1 - 3
	SD	0	1.4

Table 3. Percent canopy cover per plot (500 m^2) at Flammulated owl nest sites.
(1 Plot = 1 Nest site)

		North aspect (8 sites)	South aspect (4 sites)
A1 Canopy layer			
Douglas-fir	Mean	6	5
	Range	2 - 15	5 - 5
	SD	5.1	0
Ponderosa pine	Mean	0	3
	Range	0	3 - 3
	SD	0	0
A2 Canopy layer			
Douglas-fir	Mean	13.6	15.5
	Range	4 - 33	4 - 31
	SD	10.1	13.2
Ponderosa pine	Mean	0	4.5
	Range	0	1 - 8
	SD	0	5
A3 Canopy layer			
Douglas-fir	Mean	11.6	6.7
	Range	5 - 18	2 - 11
	SD	4.8	4.5
Ponderosa pine	Mean	0	6
	Range	0	6 - 6
	SD	0	0
B1 Canopy layer			
Douglas-fir	Mean	4.3	3.3
	Range	1 - 12	1 - 8
	SD	3.9	3.3
Ponderosa pine	Mean	0	1
	Range	0	1 - 1
	SD	0	0

showed that this species accounted for the variability in stem density among northern nest sites ($p < 0.05$); the A3 layer showed the least differences among nest sites (3 out of 8 nest sites differed at $p < 0.05$). Ponderosa pine was rare in nesting habitat on the north aspect (Table 2). Southern nest sites were the least variable with no significant differences among total numbers of stems in the upper two canopy layers and only two nest sites differing in the A3 layer according to the Smirnov test ($p < 0.05$). Douglas-fir stems varied among southern nest sites in all layers except the A3 canopy layer. Ponderosa pine stems differed between only two nest sites in each canopy except the A2 layer.

Table 3 illustrates percent canopy cover per plot for both northern and southern nest sites (one nest site = one plot). When compared among nest sites, canopy cover showed similarities in stand structure. Two southern nest sites differed in the three lower canopy layers and no difference was found among northern nest sites.

Within the IDFxh2 biogeoclimatic variant most nest sites fell between vegetation site units 4 and 5 of Lloyd et al. (1990). These sites had poorly developed shrub layers usually with less than 10% ground cover of birch-leaved spirea and saskatoon. The herb layer was dominated by bluebunch wheatgrass and/or pinegrass; some rough fescue occurred and kinnickinnick was present. The moss layer usually was poorly developed consisting of less than 20% ground cover of lichen (Peltigera species) and red-stemmed feathermoss (Pleurozium schreberi).

Figure 2 illustrates the locations of all known nest sites on Wheeler Mountain. More nest sites were located on the northern side. Figures 3 and 4 show locations of nest sites and associated foraging areas found in 1990 and 1991, respectively (not all male owls of nest sites found were radio-equipped). Nest sites found in consecutive years were sometimes near each other. Table 4 summarizes distances between nest sites. On the southern aspect two nest sites found in consecutive years were 20 m or less apart (nest sites 7 and 11). New nest sites were not found in areas of other southern nest sites used in previous years. On the north aspect, three nest sites were found in areas near the previous year's nests. The mean distance between northern nest sites used in successive years was 380 m (SD = 242.84) and the closest any nest site was to a previous year's site was approximately 150 m (nest sites 1 and 6, used in 1989 and 1990, respectively; maximum = 630 m for nest sites 4 and 10, used in 1990 and 1991, respectively, shown in Figure 3). No banded birds were identified in consecutive years anywhere on the study site.

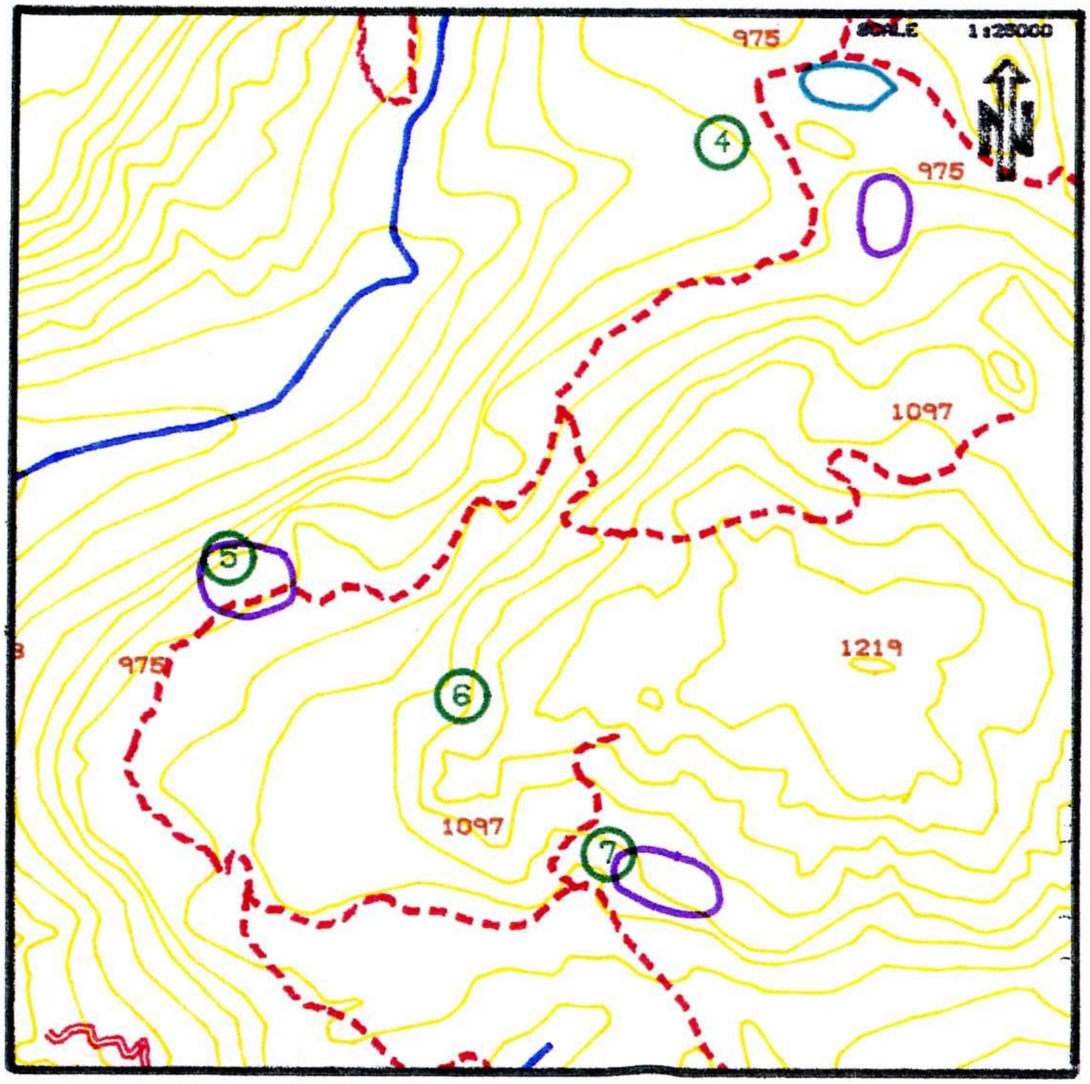
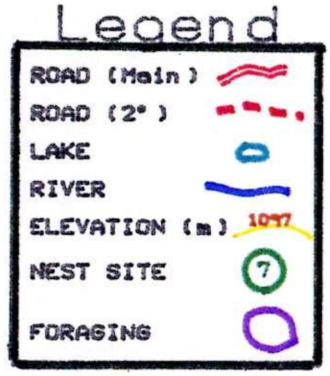


Fig. 3 Nest sites and foraging areas in 1990.



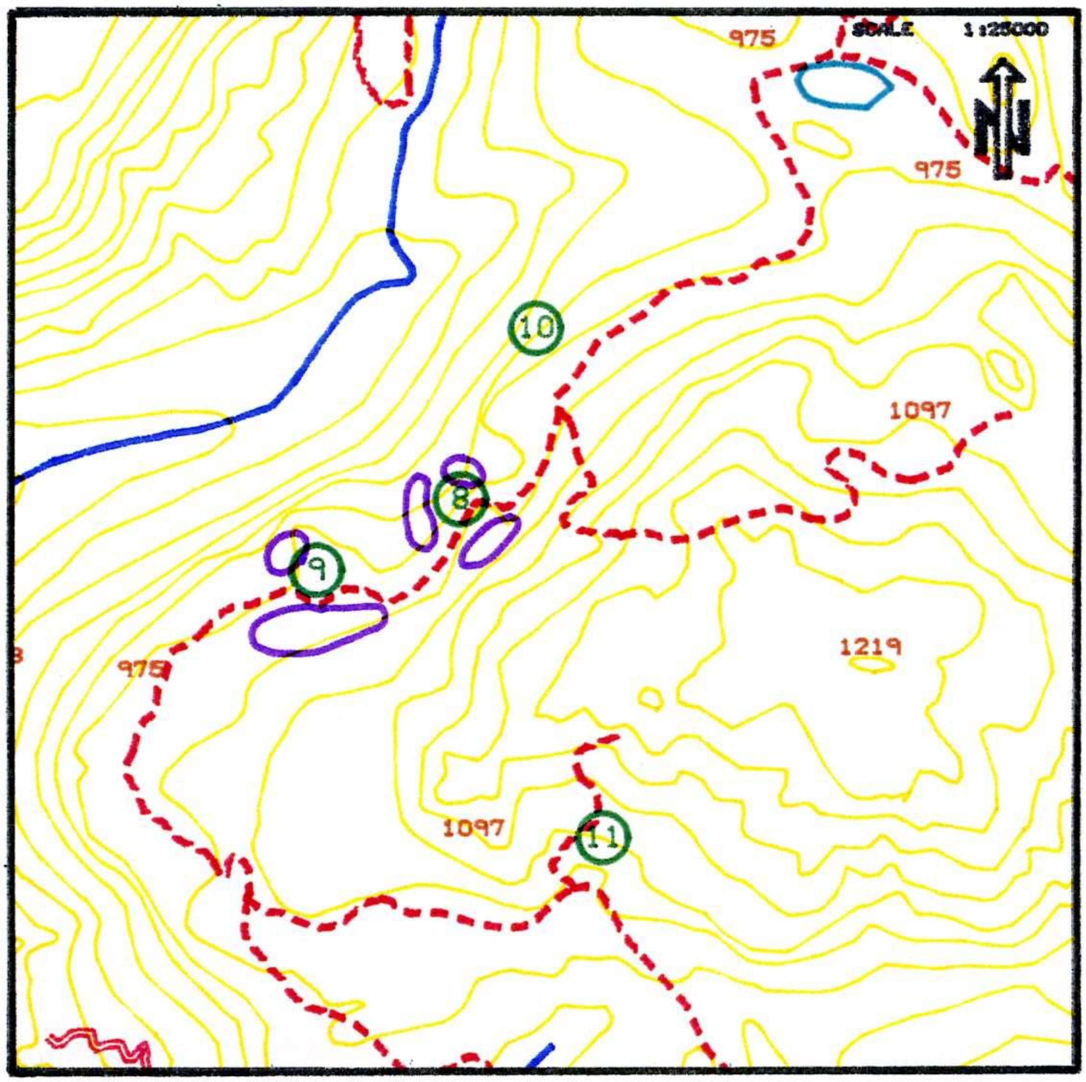


Fig. 4 Nest sites and foraging areas in 1991.

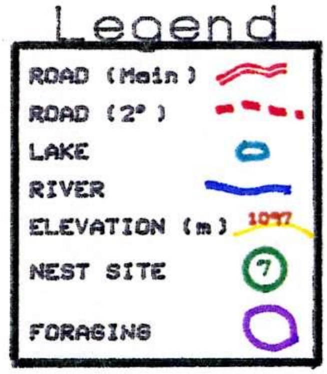


Table 4. Distances (m) between nest sites and from the road.

Nest Site	1	2	3	4	5	6	7	8	9	10	11	12	From road
1	-												348
2	1290	-											158
3	2040	1180	-										238
4	2300	3430	3560	-									79
5	660	1740	2630	2340	-								143
6	160	1150	1900	2500	700	-							554
7	900	950	1200	2500	1500	780	-						48
8	1320	2470	2820	970	1400	380	1670	-					48
9	470	1740	2500	2090	300	600	1340	1140	-				16
10	1700	2800	3000	630	1750	1780	1990	400	1440	-			95
11	880	960	1220	3480	1480	770	16	1660	1330	1990	-		63
12	2680	3550	3690	860	2700	2740	2770	1550	2690	1260	2750	-	48

Foraging and Unused Habitats

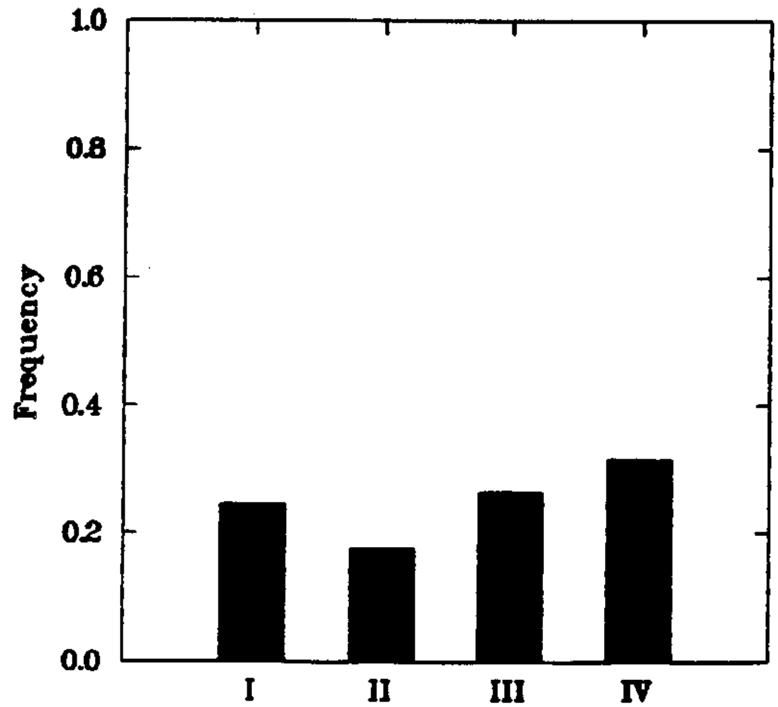
Foraging habitat was documented for both northern and southern aspects of the study site. Five male Flammulated owls were radio-tracked during two field seasons. Each season two birds were tracked on the northern aspect and during the first season one bird was tracked on the southern aspect. Figures 3 and 4 indicate the corresponding nest sites and foraging habitats these birds used in each of the two years, respectively. Table 5 presents the mean distance each bird foraged from its nest site; overall mean distance was 145 meters (range = 7 - 586; SD = 191.2). Figure 5 illustrates typical foraging distance more clearly by summarized frequency distribution over distance categories. Areas 26 - 50 m from the nest tree were used least often for foraging. Rough home range areas were estimated at 2.2 and 3.7 ha for nest sites 8 (17 telemetry locations) and 9 (15 telemetry locations), respectively, which had the most foraging observations (Figures 2 and 4).

Figure 6 summarizes stand structure for the north and south aspects of the study site and illustrates differences between foraging and unused habitats. The southern aspect is a much more open forest with far fewer stems in the lower canopy layers and somewhat more canopy cover. The overstory (A1 and A2 layers) is more dominant on the southern aspect while the northern aspect has a high component of dense Douglas-fir regeneration. Douglas-fir regeneration is found in southern foraging habitat, but at a lower stem density.

Table 5. Mean distances (m) birds foraged from nest sites.

Nest site	Mean distance foraged	Range	Standard Deviation
4 (n=9)	566	554 - 586	13.30
5 (n=11)	27	11 - 95	28.5
7 (n=6)	123	55 - 210	62.3
8 (n=17)	67	8 - 190	50.1
9 (n=15)	79	7 - 300	81.5

Frequency distribution of foraging distances.



Distance Category

FIGURE 5. Frequency distribution of distances birds foraged from nest sites. Distance category I = 1 - 25 m, II = 26 - 50 m, III = 51 - 100 m, and IV = >100 m.

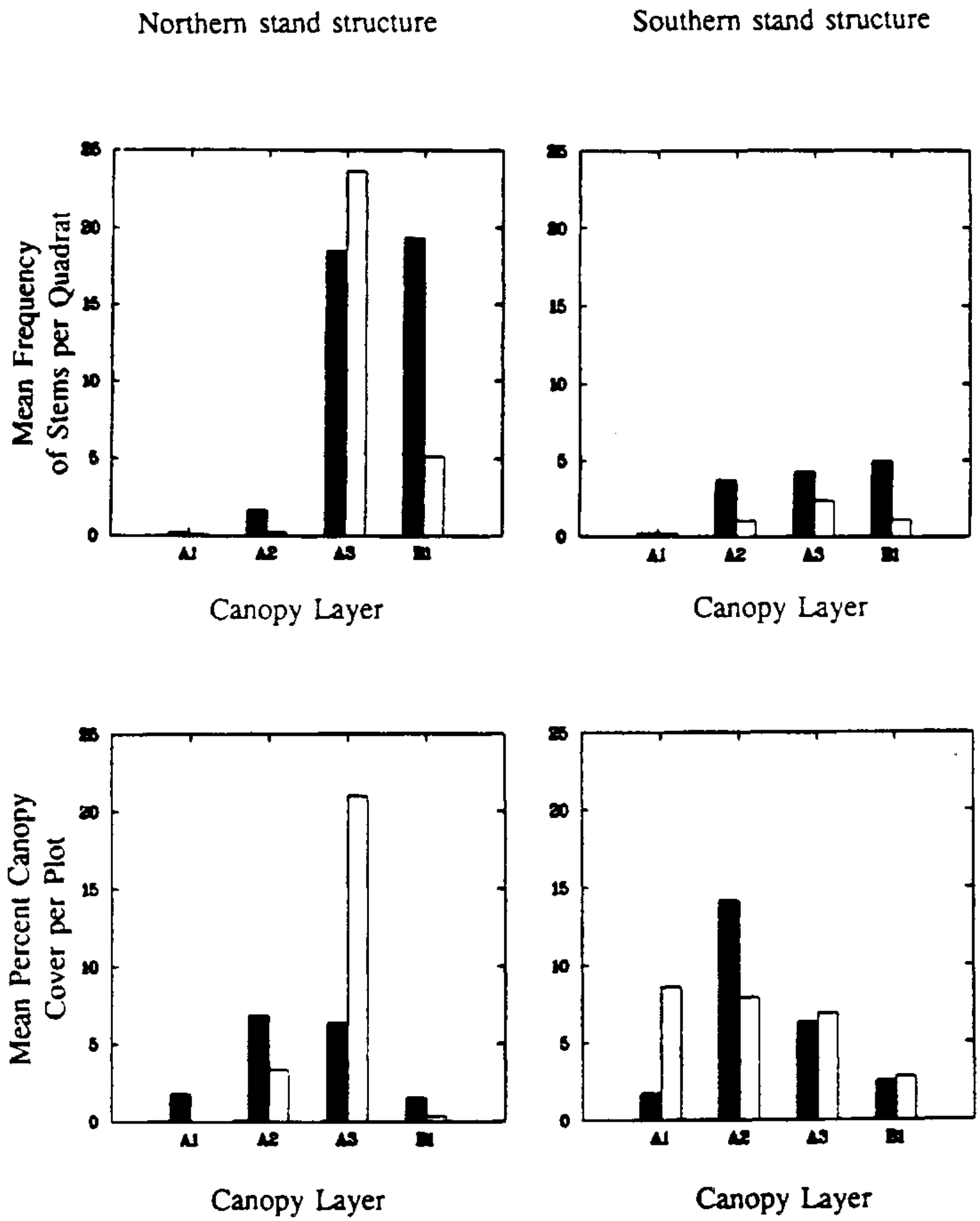


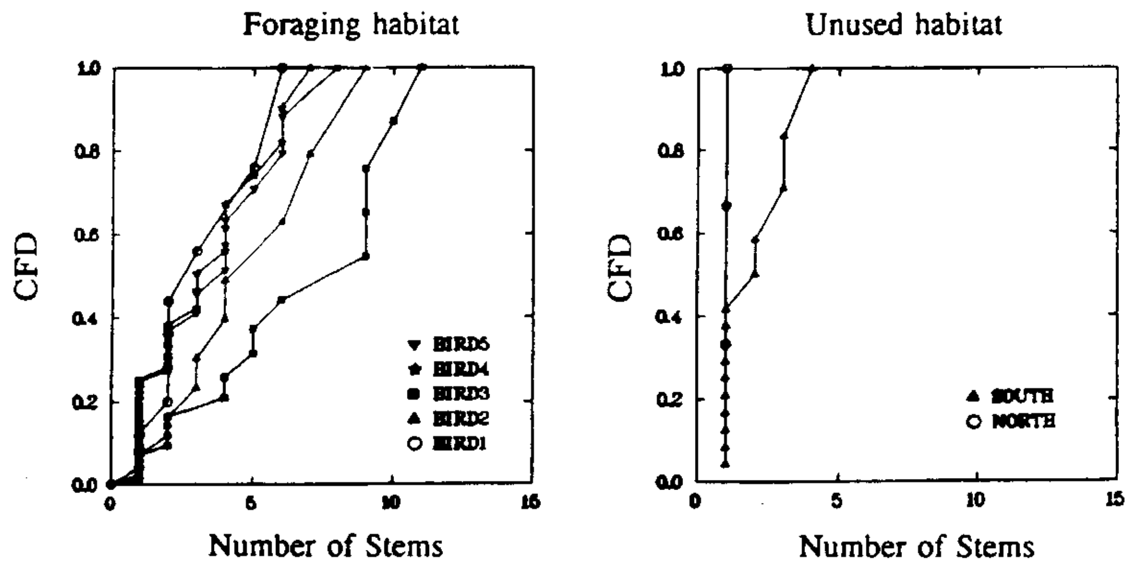
FIGURE 6. Mean stems per quadrat (125 m^2) and percent cover per plot (500 m^2) for forests at foraging ▮ and unused ▯ sites on northern and southern aspects of Wheeler Mtn.

Both foraging and unused habitats have a higher component of Ponderosa pine on the southern aspect than on the northern aspect. Southern foraging habitat had an overall mean (including all canopy layers) of 2.4 pine stems per plot (range = 0 - 6, S.D. = 2.3) compared to 5.0 (range = 0 - 12, S.D. = 4.4) in unused habitat. On the northern aspect, overall mean Ponderosa pine stems were 0.3 stems per plot for both habitats (range = 0 - 3, S.D. = 0.7; range = 0 - 1, S.D. = 0.6; respectively).

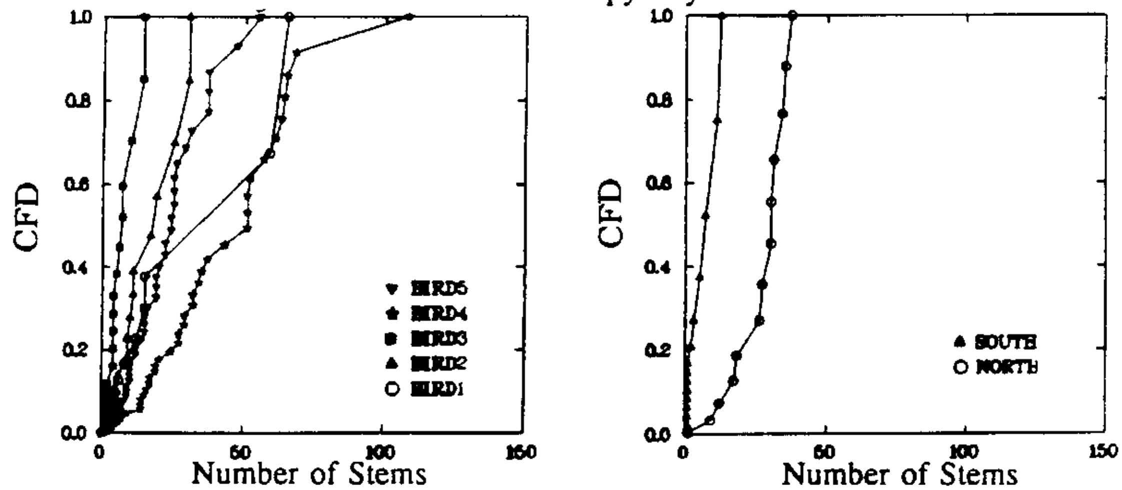
Smirnov test results comparing number of stems per quadrat indicated that southern and northern foraging habitats differed most in canopy layers A1, A3, and B1 ($p < 0.05$) and least in the A2 layer ($p = 0.05$). Figures 7 and 8 illustrate this in the cumulative frequency distributions of stem density and DBH-frequency indices.

These figures show that the stand structure of foraging habitat is more variable than the structure in unused areas. Distribution of stems and their diameters in the foraging areas indicate a heterogeneous stand of thickets of Douglas-fir regeneration adjacent to open spaces. The Smirnov test indicated a significant difference in the number of stems per quadrat between southern foraging and unused habitats only for the two lower canopy layers (A3: $p = 0.03$; B1: $p = 0.02$); no difference was found in canopy cover. Despite a larger number of stems, less canopy cover is present in the lower canopy layers of southern foraging habitat than in unused habitat. The northern foraging and unused habitats differed in numbers of stems per quadrat for all canopy layers except the A3 layer ($p < 0.001$ for A1, A2, and B1 layers). Contrary results

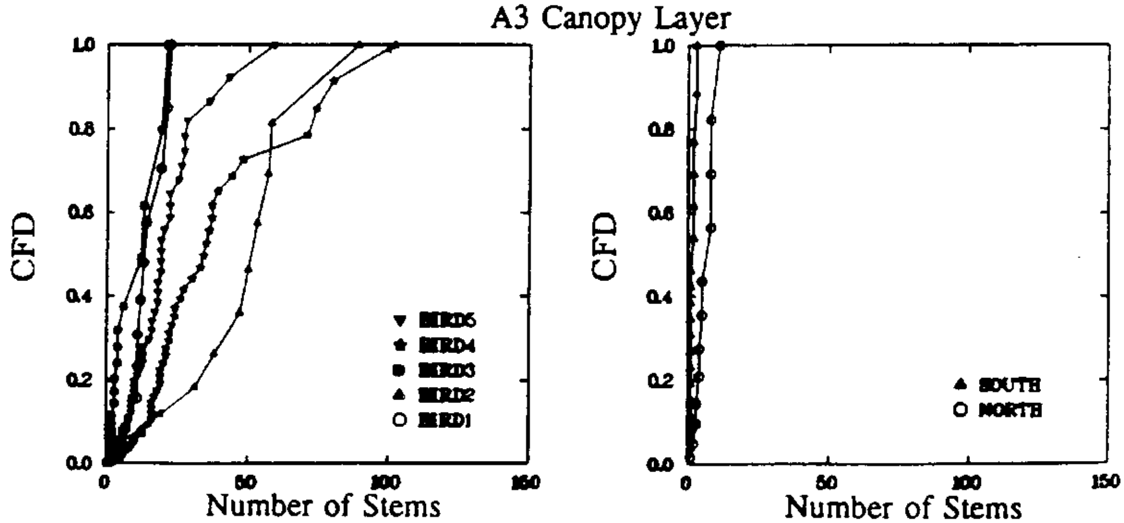
FIGURE 7. Cumulative frequency distribution (CFD) of number of stems per quadrat (125 m^2) for foraging and unused habitats on the northern and southern aspects of Wheeler Mtn. Birds 1, 2, 4, and 5 represent north foraging habitats; bird 3 represents south foraging habitat.



A2 Canopy Layer



A3 Canopy Layer



B1 Canopy Layer

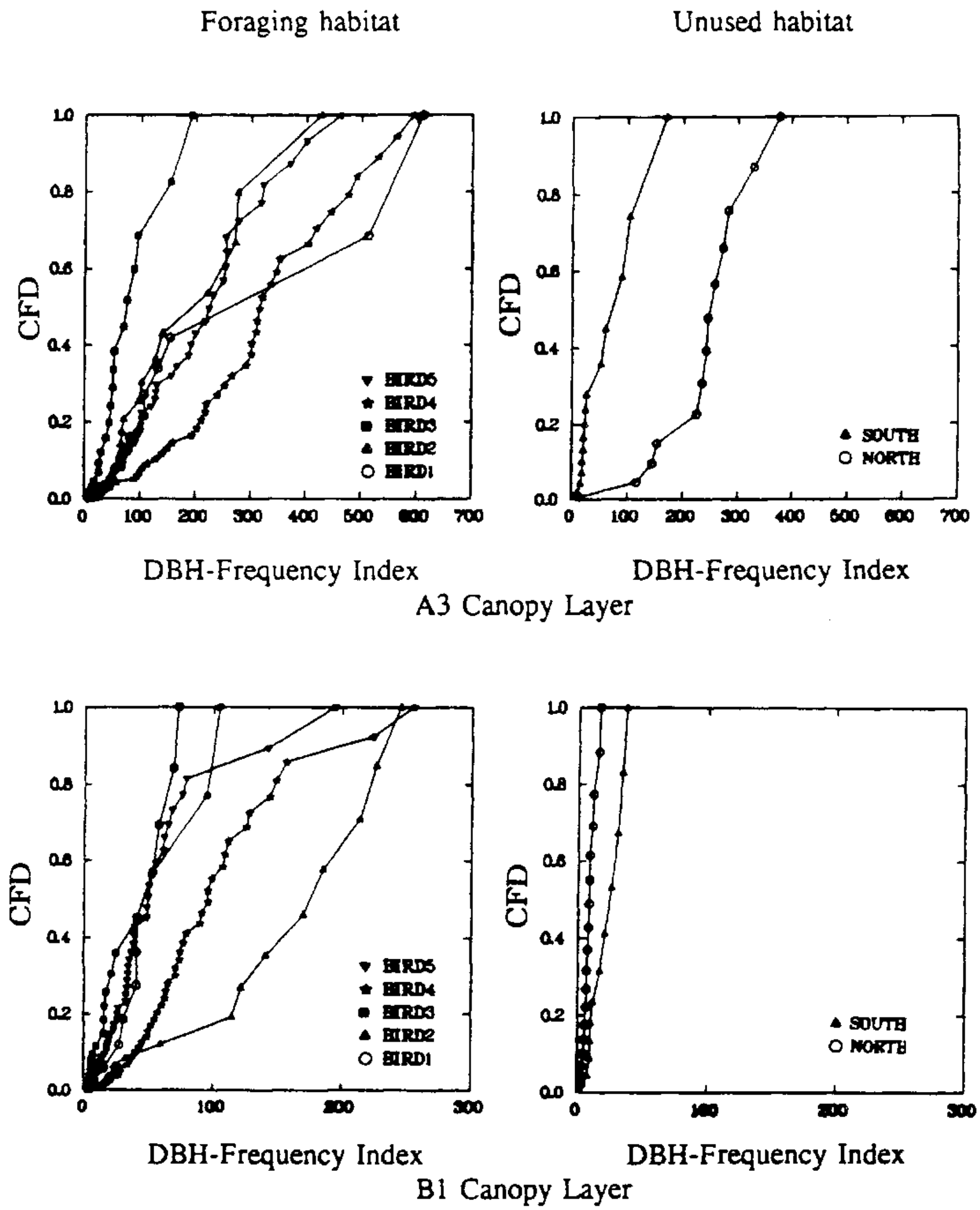


FIGURE 8. Cumulative frequency distribution (CFD) of DBH-frequency index for foraging and unused habitats on the northern and southern aspects of Wheeler Mtn. Birds 1, 2, 4, and 5 represent north foraging habitats; bird 3 represents south foraging habitat. Mean diameter at breast height (cm) for each quadrat was multiplied by the number of stems for that quadrat to generate the index.

were found for canopy cover per plot, with a significant difference found only in the A3 layer ($p = 0.04$). The northern unused habitat had been thinned and is a monoculture of evenly spaced Douglas-fir trees comprising a homogeneous A3 canopy layer.

The coefficient of variation (CV) values (Table 6) also indicate the variability of number of stems per quadrat in foraging habitat (Sokal and Rohlf 1981). CV equals 0.39 for the A3 canopy layer in the homogeneous, northern unused habitat plots and 0.88 for that of foraging habitat. Similarly, for the homogeneous stand structure the magnitude of change in CV from quadrat to plot data is less than that for the heterogeneous foraging stand (CV = 0.47 and 1.12, respectively, for the A3 canopy layer).

The cumulative frequency distributions also show differences among the foraging areas used by individual birds on northern aspects. Table 7 summarizes results of the Smirnov test comparing overall numbers of stems per quadrat for each northern foraging area; significant differences were found between these areas in each canopy layer except A2. Table 8 indicates there was a birch component in only one of these foraging areas. That area and one other had a small amount of aspen and Ponderosa pine. When numbers of Douglas-fir stems alone were compared among the four north foraging areas the results were similar to those for the overall stem comparison - the A2 canopy layer was the only layer that did not differ among northern foraging areas. The predominant species by far is Douglas-fir. When the same test compared the overall canopy cover per plot, no differences were found among these foraging areas (except between foraging

Table 6. Coefficient of variation ($s/\bar{x}$) of stem density in foraging habitat.

Frequency of stems plot data (500 m^2)	Canopy layers A1	A2	A3	B1
Foraging habitat				
Overall	1.303	1.135	0.996	0.973
North	1.354	0.993	0.882	0.891
South*	0.935	1.147	0.874	1.002
Unused habitat				
North	1.732	1.000	0.392	0.475
South	1.491	0.974	2.096	0.923
Individual foraging birds				
Bird 1	0.866	0.616	1.024	0.312
Bird 2	0.667	0.947	0.486	0.939
Bird 4	1.629	0.780	0.869	0.750
Bird 5	1.432	1.142	0.646	0.691

Frequency of stems quadrat data (125 m^2)	A1	A2	A3	B1
Foraging habitat				
Overall	2.420	1.228	1.117	1.034
North	2.495	1.208	1.030	0.954
South*	2.052	0.958	0.953	1.221
Unused habitat				
North	3.464	1.809	0.474	0.577
South	2.442	1.061	1.496	0.769
Individual foraging birds				
Bird 1	2.335	0.879	1.309	0.522
Bird 2	2.150	1.014	0.739	0.890
Bird 4	2.825	1.208	0.956	0.859
Bird 5	2.417	1.360	0.882	0.840

*Area represented by Bird 3, south foraging habitat.
Birds 1,2,4, and 5 represent north foraging areas and together are referred to as north foraging habitat.

Table 7. Smirnov test results from comparison of number of stems per quadrat (125 m^2) for northern foraging areas.

A1 Canopy layer				
	Birds 1&4 p=0.001	Birds 1&5 p=0.001	Birds 2&4 p=0.001	Birds 2&5 p=0.001
A2 Canopy layer				
	No difference			
A3 Canopy layer				
	Birds 4&5 p=0.023			
B1 Canopy layer				
	Birds 1&4 p=0.039	Birds 2&5 p=0.010	Birds 4&5 p=0.025	

Table 8. Mean stems per plot (500 m²) for northern and southern foraging habitats.

	Overall	Douglas-fir	Ponderosa pine	Aspen	Birch
Bird 1					
(n=3)					
Mean	124	124			
Range	61 - 224	61 - 224			
SD	87.6	87.6			
Bird 2					
(n=4)					
Mean	181	181			
Range	56 - 336	56 - 336			
SD	124.3	124.3			
Bird 3					
(n=5)					
Mean	57.6	55.2	2.4		
Range	22 - 91	21 - 91	0 - 6		
SD	25.0	25.2	2.3		
Bird 4					
(n=12)					
Mean	211.9	211.3	0.5	0.1	
Range	80 - 559	80 - 559	0 - 3	0 - 1	
SD	138.3	138.6	0.9	0.3	
Bird 5					
(n=12)					
Mean	134.8	127.1	0.3	0.3	7.083
Range	63 - 252	61 - 251	0 - 2	0 - 3	0 - 53
SD	48.1	50.0	0.7	0.9	17.1

(Overall = All species of stems included per plot)
Birds 1,2,4, and 5 represent north foraging habitat;
Bird 3 represents south foraging habitat.

areas for birds 1 and 4 in the A1 layer; $p = 0.012$).

Figure 9 illustrates the stand structure of foraging habitat on the northern aspect. The scatterplots reveal broad inverse relationships between canopy cover and stem density and stem diameter and density in the lower canopy layers. This relation is also present on the southern aspect.

Stumps due to selective cutting or windfall were frequently found in the open spaces adjacent to thickets of Douglas-fir regeneration. Northern foraging habitats overall had a mean of 5.2 stumps per plot (range = 0 - 21, SD = 4.96). Only 1.7 (range = 0 - 10, SD = 2.17) of those stumps were from windfall; the remaining were the result of a previous cut. On the southern side, 2.4 stumps per foraging plot were found (range = 1 - 4, SD = 1.14), and 1.6 (range = 0 - 4, SD = 1.67) were from windfall.

Understory in foraging habitat was documented similarly to that of nesting habitat. Most foraging plots, including both northern and southern aspects, were characterized by vegetation site unit 5 of the IDFxh2 biogeoclimatic variant. Some foraging areas had a higher moisture regime and were characterized by site units 6 and 7 and one by site unit 8. These plots had a moderately developed shrub layer with common snowberry (Symphoricarpos albus), Douglas maple (Acer glabrum) and red-osier dogwood (Cornus sericea). The herb and moss layers were less developed and variable; site units 7 and 8 lacked a bryophyte component.

Stand structure of north foraging habitat.

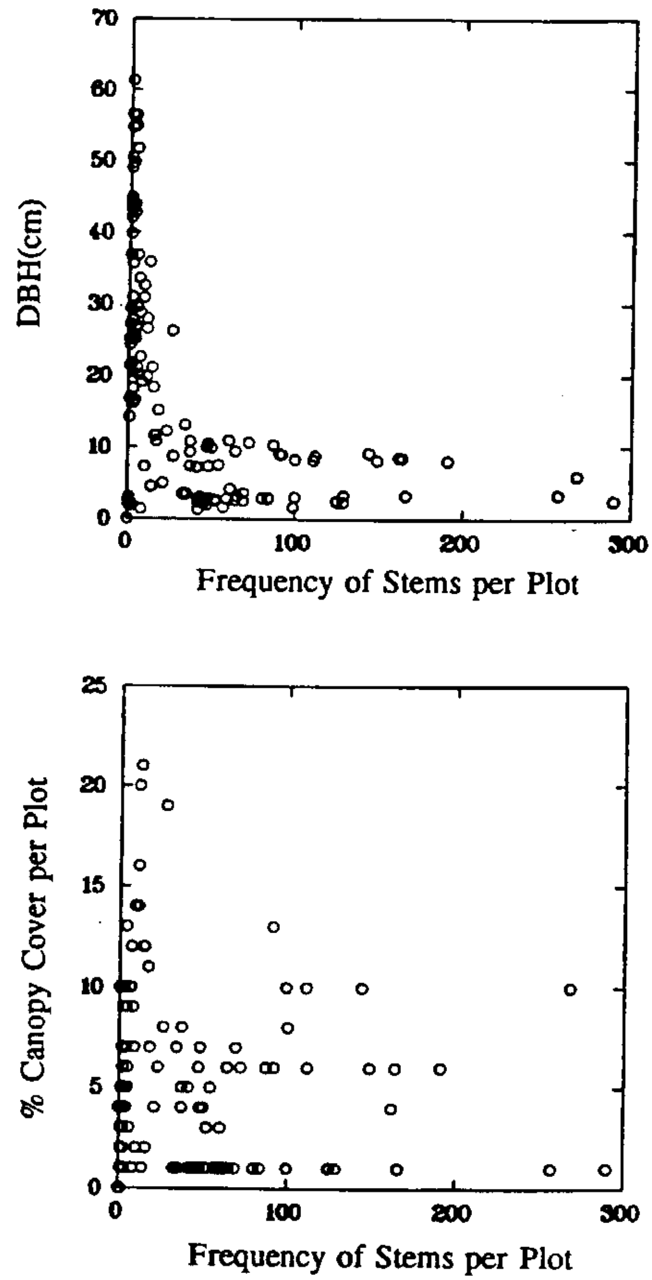


FIGURE 9. DBH (cm) and percent canopy cover as a function of number of stems in northern foraging habitats.

Barred owl and Small Mammal Surveys

Surveys conducted on the northern and southern aspects of Wheeler Mountain revealed that the Barred owl and Great Grey owl (Strix nebulosa) were present on the northern aspect only. At least two Barred owls were resident on the northern aspect during the 1991 field season and three during the 1990 field season. One Great Grey owl was present during the 1991 field season; its presence in other field seasons was unknown. Barred owls have been sighted on the northern side frequently throughout the three year study; only once was one sighted on the southern side.

Small mammal surveys comparing the northern and southern aspects of the study site showed a greater abundance of small mammals on the north aspect. The overall mean number of animals caught per trap-night was 10 on the northern aspect (range = 6 - 13, S.D. = 2.04) and 3 on the southern aspect (range = 0 - 4, S.D. = 1.16). Northern foraging habitat showed a significantly higher number of small mammals compared with southern foraging habitat ($p < 0.05$); southern and northern areas randomly compared also revealed more small mammals on the northern aspect ($p < 0.05$). Deer mice (Peromyscus maniculatus) and red-backed voles (Clethrionomys gapperi) comprised most of the small mammals caught.

DISCUSSION

Census

More Flammulated owls were located on the northern side (8 birds) than on the southern side (4 birds). This observation suggests habitat may be more favourable on the northern aspect. Access on the north aspect, however, permitted transects of approximately 7 km while on the south aspect only about 4 km of road were surveyed, leaving a southeast area of the study site uncensused (Fig. 1).

According to R. Reynolds and B. Linkhart (pers. comm.) vocal birds are males either calling from their territories or from along their migration routes. If there are equal numbers of non-vocal females, the census observations made on Wheeler Mountain suggest there could be as many as 24 birds on the study site during May and early June.

This estimate likely includes individuals along a migration route onto more northerly nesting habitats, including Opax Mountain, McQueen Lake, and Pass Lake (birds were heard calling in these areas). During the nesting period (from mid-June until the end of July or early August) only unmated male Flammulated owls will call spontaneously (R. Reynolds and B. Linkhart pers. comm.) Nesting birds are usually non-vocal, particularly during foraging times, when they will not or are slow to respond to a tape-recorded or human-vocalized call (R. Reynolds and B. Linkhart pers. comm., personal observation). These observations suggest that an estimate of population size for an area should be made based on numbers of nest sites found by early July and numbers of birds calling spontaneously at that time. Uncertainty in the estimate will persist without knowing the number of unmated females, although R. Reynolds and B. Linkhart speculate all females are mated if there are unmated males. The maximum number of 4 nest sites found on Wheeler Mountain in one nesting period suggests a minimum nesting population of 8 birds within the 1,600 ha area, or 0.1 paired birds per 40 ha, somewhat lower than the density based solely on calling male birds. Flammulated owls calling spontaneously during the nesting period were not recorded.

Nesting Habitat

Of the 12 Flammulated owl nests documented in this study 7 were in Ponderosa pine trees (6 snags and 1 live tree with a dead top); the remaining 5 were in Douglas-fir trees (3 snags and 2 live trees with dead tops). Although availability of suitable nest cavities in each tree species was not quantified during nest site searches, the data suggest that Ponderosa pine was used disproportionately (mean number of Douglas-fir stems/plot in A1 layer = 1.4, range = 0 - 3, SD = 0.8; mean number of Ponderosa pine stems/plot in A1 layer = 0.6, range = 0 - 1, SD = 0.5). Douglas-fir was the dominant species for both north and south aspects of Wheeler Mountain; Ponderosa pine was more common on the south aspect than on the north aspect, where it was rare (Tables 2,3, and 8). Of the 4 nest sites documented on the southern aspect, 3 were pine, and on the northern aspect 4 of the 8 nest sites were pine (Table 1). In Oregon Goggans found 85% of nests in Ponderosa pine (1986). Similarly, Horton and Mannan (1988) found most cavity nesting birds used Ponderosa pine.

Nest boxes were probably not weathered sufficiently for Flammulated owls to use them for nesting (D. Low pers. comm., personal observation). It remains possible that they will be utilized in years to come. However, they may preclude successful recruitment if they increase predation risks by flying squirrels or other rodents.

Douglas-fir nest trees found in this study had smaller diameters than Ponderosa pine nests and had retained bark. Other work has shown that snags without bark decay at a slower rate and those of larger diameters are more stable and have a greater longevity (Lyon 1977; Cline et al. 1980). Raphael and White (1986) suggest that a limiting factor in the density of cavity-nesting birds is the availability of large diameter snags. Together these observations suggest why Flammulated owls used Ponderosa pine disproportionately, since the results show the species is more likely than Douglas-fir to have the suitable nesting characteristics (Table 1 and 2).

The combination of steepness of slope and height of cavities tended to be greater on Wheeler Mountain compared to nest sites in Colorado (personal observation). This situation inhibited efficient capture and banding of owls. Stand structure was variable among nest sites. Canopy cover was the only consistent characteristic indicating that those nesting areas with more stems had some defoliation (Tables 2 and 3). Some nest trees were within a thicket of dense Douglas-fir while others were in an open space with a thicket nearby. Most nest sites (10 out of 12) had a thicket of dense Douglas-fir regeneration and an adjacent open space within 30 m of the nest tree. Goggans found similar results (1986). Adult Flammulated owls were incidentally observed flying between these thickets and the nest cavity, returning to the cavity often with moths in their beaks. Table 6 shows how close some birds foraged to their nest sites. Occasionally male Flammulated owls were observed roosting in these thickets. Often during failed capture attempts the male bird would fly into these thickets and call from them. The two nest sites which did not have the Douglas-fir regeneration component in their proximity were both on the more open, southern side of the study site. They were in open areas of healthy, uneven-aged stands which had little or no defoliation within 25 m of the nest tree. Although the males of the these two nest sites were not radio-tracked, observations of foraging activity suggested adult birds were not foraging near their nest sites (within 25 m of nest tree).

Results of analysis of nesting habitat support the suggestion made by Linkhart et al. (manuscript) that characteristics of the stands surrounding nest sites "...may not always indicate the habitat preference of this owl." Those authors suggest nesting habitat may better reflect the requirements of the primary cavity excavator. Flammulated owls respond to specific habitat components associated with prey abundance and opportunistically seek a suitable cavity nearby. The characteristics of the nest tree itself may be more important than its surrounding habitat (see Fig. 5). Those nest sites situated within a thicket of dense Douglas-fir provided close foraging opportunities during budworm outbreaks.

Foraging Habitat

Northern and southern foraging habitats had similar stand structures, although the northern side had a higher stem density in the lower canopy layers (Figures 6 and 7). Foraging areas on the northern side had dense thickets of Douglas-fir regeneration adjacent to open spaces. The thickets of Douglas-fir regeneration in the southern foraging area had fewer stems spaced further apart, also adjacent to openings. Unused habitats on both aspects lacked these thickets and overall had very open stands. The predominant species in all habitats was Douglas-fir. These observations suggest Flammulated owls are responding to stand structure rather than tree species for foraging.

Although structure and composition of foraging and unused habitats differed with aspect, Western Spruce Budworm defoliation was common to foraging habitats and absent from unused habitats on both aspects. Budworm damage reduced canopy covers in the A3 and B1 layers (Figures 6 and 9). The southern unused habitat lacked the thickets of Douglas-fir in the canopy layers that would sustain budworm outbreaks (L. McLauchlin pers. comm.). Because the northern unused habitat had been thinned, the stems were far enough apart to allow a healthy canopy to fill in; the absence of a developed overstory in the even-aged stand precluded budworm from raining down onto this younger canopy.

The stand structure of their foraging habitat offers Flammulated owls two habitat requirements - security cover and prey. The high stem density of the stand sustains budworm for prey and offers security cover from larger predators, such as the Barred owl. Incidental observations of adult Flammulated owls delivering prey items to nest sites and gleaning from budworm infested trees suggest they are using budworm for prey. The stages of the Western Spruce Budworm life cycle yielding the greatest biomass (late larval instars, pupa, adult) correspond with Flammulated owl nesting chronology - clutch initiation in the first half of June to fledging at the end of July (Furniss and Carolin 1980; J. MacLean pers. comm.).

Furthermore, there are other Lepidopterans associated with the Western Spruce Budworm that are often found in the deciduous understory and could be potential prey for Flammulated owls (L. MacLauchlin pers. comm., Stevens et al. 1984). Some of these include various loopers and shoot moths. Interestingly, the Flammulated owl and Western Spruce budworm share a similar elevational range, upwards of 850 m.

The study took place during the middle to late stages of the most recent Western Spruce Budworm outbreak (L. MacLauchlin pers. comm., Koot and Hodge 1990). Years of budworm damage had created an increase in the dead and down woody material which, together with the high stem density, created more cover for small mammals. The northern aspect, with greater defoliation and higher stem density, offered small mammals much more cover compared with the southern aspect. The northern aspect had the highest small mammal abundance which in turn may have attracted the Barred owl. There were at least two resident Barred owls on the northern side of the study site during the 1991 field season. During the 1990 field season three Barred owls were observed around nest site 4, shown in Figure 3, at the time of fledging.

The mechanical density of stands in the northern foraging habitat precluded Barred owls from entering thickets of Douglas-fir regeneration. Flammulated owls could not be lured into the thinned stand in the northern unused habitat by the usual method of calling. The stems in this stand were well spaced and Barred owls had been sighted nearby. Flammulated owls responded to calls, but remained in thickets of surrounding, dense Douglas-fir.

The thickets in northern foraging areas provide security for Flammulated owls which allows them to make quick forays into adjacent open spaces and use the edge thus optimizing their prey opportunities; edge was also found to be important for foraging in Oregon (Goggans 1986). The openness of the stand structure and possibility of fewer predators on the southern aspect suggest that Flammulated owls foraging in this area may not require the security component they do on the northern side. Thickets of dense Douglas-fir in southern foraging habitat may be required more as a source of prey only.

These results contradict Goggans (1986) findings that Flammulated owls used higher stem density areas less than lower stem density stands for foraging (Goggans used a subjective rather than quantitative measure of stem density indicating relative differences as 'high', 'medium', and 'low'; she describes 'high' stem density as crowded thickets).

Goggans, however, does not report Western Spruce Budworm as a prey source and concludes the importance of grasslands and open forest for the availability of ground insects for foraging (Orthopterans comprised 62% of prey items while Lepidopterans comprised only 13%). A more developed understory may be responsible for the diet difference observed in the Oregon study and may partly account for the difference in foraging habitat structure.

The presence of Barred owls on Wheeler Mountain may have determined where Flammulated owls foraged on the north aspect. Table 4 indicates that the male bird from nest site 4, which had been harrassed by Barred owls, was the only bird out of the 4 tracked on the north aspect during radio-telemetry that was never observed foraging near its nest site (within 25 meters). This bird foraged the furthest, a mean distance of approximately 566 m. The other birds foraged near their nest sites as well as at distances between 51 and 100 m (Figure 5). Only one of these three birds (nest sites 5, 8, and 9) was observed to forage as far as 300 m in one observation; out of 43 foraging observations of these nest sites, only 6 were recorded at distances greater than 100 m from the nest tree. Therefore, Figure 5 showing most frequent foraging distances to be greater than 100 m from the nest tree is somewhat skewed due to the results of nest site 4.

The mean distances the three birds at northern nest sites 5, 8, and 9 foraged from their nest sites (Table 5) were lower than foraging distances observed by Reynolds and

Linkhart (1987) for birds in Colorado. These authors documented intensive foraging areas (IFA's) within the home ranges of foraging males. They found IFA's to have a mean distance of 125 m (range = 10 - 410) from nest sites. It is possible that the denser stands on the north aspect of Wheeler Mountain (Reynolds and Linkhart 1987; personal observation) and presence of Western Spruce budworm - which was absent from the Colorado study site (B. Linkhart pers. comm.) - provided a greater abundance of prey within a smaller area for foraging owls. The data suggest that the risk of predation (observed at nest site 4) may increase the foraging distance from the nest tree. The bimodal trend shown in Figure 5 may be driven by opportunitic feeding on budworm in thickets immediately surrounding the nest tree (1 - 25 m) and foraging at distances to avoid increasing the risk of attracting predators to the nest site (foraging at distances > 51 m).

Since the risk of predation was reported less on the southern aspect, foraging distances there may be influenced more by feeding opportunity. The greater mean foraging distance recorded at the southern nest site (nest site 7, Table 5) and the fewer southern nest sites found suggest foraging opportunities may not be as abundant as they are on the northern aspect. In fact, the mean foraging distance for the southern nest (123 m) was similar to the Colorado mean foraging distance (125 m). Foraging habitat on the south aspect may be less suitable in comparison to the north aspect due to the lower stem density in Douglas-fir thickets and consequently fewer budworm and associated Lepidopteran prey.

Home range areas of 2.2 amd 3.7 ha calculated for the two nest sites with the most foraging observations - nests sites 8 and 9, respectively - likely represents only part of the full home ranges the birds used. In Colorado home range size averaged 14 ha (Reynolds and Linkhart 1987) and in Oregon Goggans (1986) recorded mean home range at 10 ha. Nesting birds on Wheeler Mountain probably use areas similar to home range sizes in Oregon. On the northern aspect of the study site home range size may be less than that found in Oregon. There may be a northward trend in the species range where denser foraging habitats provide closer prey opportunities and therefore shorter foraging distances are necessary. The southern aspect of Wheeler Mountain may be more characteristic of more southerly habitats within the Flammulated owl breeding range.

It remains possible that the southern nesting density is lower because some southern nest sites were not detected. Table 2 indicates that cavities documented never faced directly north. According to R. Reynolds (pers. comm.) female Flammulated owls will often roost in a tree adjacent to the nest tree when the temperature within the cavity rises during the day. If females roosted outside their nest cavities more frequently on the warmer south aspect than on the north aspect, southern nest sites may have been missed during searches for nest sites where detection was based on the presence of the female in the cavity. Finally, differences between the north and south aspects of Wheeler Mtn. in snag decay rates and habitat preference of primary cavity excavators may account for fewer suitable nesting cavities on the southern aspect of the study site.

CONCLUSIONS

Flammulated owls require a heterogeneous stand structure characteristic of an uneven-aged forest. Snags and mature to decadent Douglas-fir and Ponderosa pine are required for nest trees, although Ponderosa pine seems to be preferred. Dense thickets of regenerating Douglas-fir is a critical component of Flammulated owl foraging habitat.

The structural heterogeneity created by these thickets adjacent to open spaces provides both security and diversity in prey opportunities for the owl. Results suggest that this stand structure is associated with nesting habitat, although to a lesser extent. Flammulated owls are 'sit and wait' predators and dense Douglas-fir provides security for those foraging on northern aspects. More open stands are tolerated on the southern aspect possibly because there were fewer predators. Dense Douglas-fir thickets offer security cover for adult Flammulated owls returning to the nest from foraging. Thickets close to the nest tree or within the surrounding area (>25 m) allow adult Flammulated owls to remain hidden until it is safe for them to fly directly into the cavity.

It appears the Flammulated owl searches for stand characteristics suitable for foraging first and then seeks a nest cavity. Because the species is a single-prey loader, it is advantageous to find a cavity within reasonable proximity to its foraging habitat. Understory structure in both nesting and foraging habitats is probably important for increasing abundance of insects. Denser stands, typical of the north aspect, offer a greater abundance of prey during budworm outbreaks and may be selected for foraging habitat over more open, southern stands. In fact, more birds were found on the northern side of Wheeler Mountain both nesting and spontaneously calling during census work.

Nesting density (0.1 pairs per 40 ha) was considerably lower than 0.36 pairs per 40 ha found in Colorado (Reynolds and Linkhart 1987) and 0.47 pairs per 40 ha found in Oregon (Goggans 1986). The availability of suitable nest sites on Wheeler Mountain may be limiting the breeding population of Flammulated owls there. The documented use of available foraging habitat suggest it is not inhibiting nesting density.

MANAGEMENT RECOMMENDATIONS

Flammulated owls require dense thickets of regenerating Douglas-fir adjacent to openings (<1 ha) for foraging and security cover and large snags or live trees (33 - 82 cm DBH) with cavities for nesting. Current forest management in mature and old-growth interior Douglas-fir stands within very hot and dry climates (IDFxh) includes partial or diameter cuts (A. Vyse pers. comm.; D. Lloyd pers. comm.). This type of silviculture practice may enhance regeneration of shade-tolerant Douglas-fir in small openings (<1 ha) for foraging habitat and recruitment of shade-intolerant Ponderosa pine in large openings (2 ha or more) for future nest sites (Watts 1983). However, diameter cuts and most partial cuts include harvest of both large Ponderosa pine and Douglas-fir trees (>30 cm DBH) and preclude snag recruitment for future nesting habitat. Also, large openings (>2 ha) will reduce security cover for the Flammulated owl.

A timber harvest compatible with Flammulated owl breeding habitat should include uneven-aged management where patches (1 - 2 ha) of various age classes (0 to >250 years) and stand structures create a mosaic of structural diversity. Small openings (up to 1 ha) will provide foraging and security habitat over time, and eventually become nesting habitat with trees greater than 33 cm DBH containing cavities. Larger openings (up to 2 ha) will allow Ponderosa pine to regenerate and, eventually, Douglas-fir in its shade. All existing snags and mature trees with cavities should be retained for immediate nesting habitat. The surrounding stand should remain intact (1 ha or more) for windfirmness and thermal cover. This habitat will also provide roost sites for nesting parent birds (Goggans 1986; R. Reynolds and B. Linkhart, pers. comm.; personal observation). Some single-tree selective cutting is acceptable within this patch if these components can be maintained. Retention of patches of the original forest where stocking of mid- and later seral Douglas-fir trees (20 - 25 m tall; 28 cm mean DBH, range = 17 - 52 cm DBH) is 5 or more per 500 m^2 (100 trees/ha) will ensure the availability of future nest sites. Ponderosa pine should not be cut on the northern aspect where it is rare and apparently used disproportionately for nesting. Nest boxes should not be relied upon for nesting cavities because they may enhance predation from flying squirrels (personal observation).

Foraging and security habitat should be contiguous with nesting habitat within 3.7 ha areas. Within a 10 ha stand (Goggans 1986), thinned or open patches up to 1 ha can separate these 3.7 ha habitat patches. Ideally, removal of small groups of trees in 500 m^2 areas or less would provide the best sustainable foraging and security habitat; the frequency of these openings should mimic the existing patchiness of the forest. Outside 10 ha stands thinned or open patches can be up to 2 ha. Large openings (2 ha) should be infrequent and also mimic the existing structure of the forest; one 2 ha opening that separates two 10 ha stands is likely acceptable. Habitat for primary cavity excavators should be preserved to ensure an availability of suitable cavities, which may be limiting Flammulated owl nesting density.

The Flammulated owl is on the Provincial Blue List of species at risk in British

Columbia (D. Low pers. comm.). The southern interior of B.C. is the only part of Canada it is known to inhabit and is likely close to the northern limits of the species. If an area is scheduled for timber harvest in higher elevation (850+ m), montane old-growth forest, it should be censused for Flammulated owl breeding habitat. A census taken between mid-May and mid-June, when the bird is most vocal, will confirm if an area is used for nesting. Harvest schedules for areas of Flammulated owl breeding habitat should not be planned during the breeding season from late April until the end of August to avoid nesting disturbance.

LITERATURE CITED

Bull, E.L. and R.G. Anderson. 1978. Notes on Flammulated owls in Northeastern Oregon. The Murrelet 59(1):26-27.

Cannings, R.J. 1982. A Flammulated owl nests in a nest box. The Murrelet 63(2):66-68.

Cannings, R.J., S.R. Cannings and J.M. Cannings. 1978. Successful breeding of the Flammulated owl in British Columbia. The Murrelet 59(2):74-75.

Cline, S.P., A.B. Berg and H.M. Wight. 1980. Snag characteristics and dynamics in Douglas-fir forests, Western Oregon. J. Wildlife Management 44:773-786.

Conover, W.J. 1971. Practical non-parametric statistics. John Wiley & Sons, Inc. New York. 493 pp.

Furniss and Carolin. 1980. Western forest insects. Miscellaneous Publication No. 273. USDA Forest Service. 654 pp.

Goggans, R. 1986. Habitat use by Flammulated owls in Northeastern Oregon. M.Sc. Thesis, Oregon State University. 54 pp.

Hasenyager, R.N., J.C. Pederson and A.W. Heggen. 1979. Flamulated owl nesting in a squirrel box. Western Birds 10:224.

Hicks, C.R. 1982. Fundamental concepts in the design of experiments. Third ed. CBS College Publishing, New York. 425 pp.

Horton, S.P. and R.W. Mannan. 1988. Effects of prescribed fire on snags and cavity-nesting birds in southeastern Arizona pine forests. Wildlife Society Bulletin 16:37-44.

Howie, R.R., and R. Ritcey. 1987. Distribution, habitat selection, and densities of Flammulated owls in British Columbia. Pp. 249-254 in R.W. Nero, R.J. Clark, R.J. Knapton, and R.H. Hamre (eds.). Biology and conservation of northern forest owls: symposium proceedings. 1987 Feb. 3-7; Winnipeg, Manitoba. USDA Forest Service Gen. Tech. Rept. RM-142, Fort Collins, Colorado.

Koot, H.P. and J. Hodge. 1990. Forest insect and disease conditions: Kamloops Forest Region 1990. FIDS report 91-2. Forestry Canada.

Linkhart, B.D. and R.T. Reynolds. Brood division and postnesting behavior of Flammulated owls. In press. Wilson Bull.

-----, R.T. Reynolds and R.A. Ryder. Nesting home ranges and habitat use by Flammulated owls in Colorado. Manuscript. 24 pp.

Lloyd, D., K. Angove, G. Hope and C. Thompson. 1990. A guide to site identification and interpretation for the Kamloops Forest Region. Land Management Handbook No. 23. British Columbia Ministry of Forests, Victoria, B.C.

Lyon, J. 1977. Attrition of lodgepole pine snags on the Sleeping Child Burn, Montana. USDA Forest Service Research Note INTRN-219-FR12. 4 pp.

Marcot, B.G. and R. Hill. 1980. Flammulated owls in northwestern California. Western Birds 11:141-149.

Mitchell, W.R. and R.E. Green. 1981. Identification and interpretation of ecosystems of the western Kamloops Forest Region. Land Management Handbook No. 2, Vol. 1: Very dry climatic region. B.C. Ministry of Forests, Victoria, B.C.

Raphael, M.G. and M. White. 1986. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildlife Monographs 86:1-66.

Reynolds, R.T. and B.D. Linkhart. 1987. The nesting biology of Flammulated owls in Colorado. Pp. 234 - 238 in R.W. Nero, R.J. Clark, R.J. Knapton, and R.H. Hamre (eds.). Biology and conservation of northern forest owls: symposium proceedings. 1987 Feb. 3-7; Winnipeg Manitoba. USDA Forest Service Gen. Tech. Rept. RM-142, Fort Collins, Colorado.

Richmond, M.L., L.R. DeWeese and R.E. Pillmore. 1980. Brief observations on the breeding biology of the Flammulated owl in Colorado. Western Birds 11:35-46.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. 2nd ed. W.H. Freeman and Co. New York. 859 pp.

Stevens, R.E., V.M. Carolin and G.P. Markin. 1984. Spruce Budworms Handbook: Lepidoptera associated with Western Spruce Budworm. USDA Forest Service Agriculture Handbook No. 622.

Watts, S. (ed.). 1983. Forestry handbook for British Columbia. Forest Undergraduate Society, Faculty of Forestry, University of B.C., Vancouver, B.C.

Winter, J. 1974. The distribution of the Flamulated owl in California. Western Birds 5:25-44.