

AN ABSTRACT OF THE THESIS OF

Rebecca Goggans for the degree of Master of Science in
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Title: Habitat Use by Flammulated Owls in Northeastern Oregon.

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Abstract approved: _____
E. Charles Meslow

The reproductive ecology, diet and habitat used by flammulated owls (Otus flammeolus) during the breeding seasons of 1983 and 1984 were studied in northeastern Oregon. Remote photography was used at 5 nest cavities to record diet; radiotelemetry was used to determine habitat used for home ranges, nesting, roosting and foraging by 5 male owls; arthropod window traps were used to sample relative abundances of prey between 3 habitats.

Density of breeding pairs was estimated at 0.47/40 ha. Home range areas averaged 10.3 ha. The diet (N=352), monitored after hatching, spanned 8 orders of arthropods but 62% of the prey items and 85% of the biomass were order Orthoptera. Relative proportions of arthropods trapped were greatest in grassland habitat (70% of total) and least in mixed conifer habitat (8% of total). Of 5 owls monitored while foraging (N=352 locations), 4 used ponderosa pine (Pinus ponderosa)/Douglas-fir (Pseudotsuga

menziesii) forest type and 5 used the edge between forests and grasslands significantly more than these types occurred within their home ranges. Owls used roost stands (N=37) of mixed conifer forest type significantly more than it occurred on the combined home ranges, however, within roost stands, flammulated owls selected ponderosa pine trees for roosts over grand fir (Abies grandis), western larch (Larix occidentalis) or Douglas-fir. This may be related to predator avoidance since flammulated owls are better camouflaged in ponderosa pine than in the other tree species.

Nest sites were selected apparently for the surrounding forest stand and ground cover rather than for any variable measured at nest cavities or trees. Owls used forest stands characterized by ponderosa pine/Douglas-fir species composition, trees 30-50 cm dbh, canopies with less than 50% closure and slopes of 16 to 25 percent significantly more than these occurred on the study area. Characteristics of ground cover at nest sites included dominance by several species rather than by a single species, combination of types (grass, forb, shrub) and greater than 33% ground coverage. These forest stand and ground cover characteristics are interrelated and likely influence prey populations.

Timber production may affect habitat used by flammulated owls for breeding. With suitable management, however, timber

production and viable populations of flammulated owls may be compatible.

**Habitat Use by Flammulated Owls
in Northeastern Oregon**

by

Rebecca Goggans

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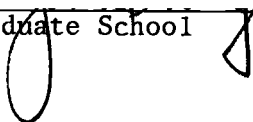
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HABITAT USE BY FLAMMULATED OWLS IN NORTHEASTERN OREGON

INTRODUCTION

Information on flammulated owls is meager. Their small size, nocturnal habits, and habitat effectively camouflage them. The species winters south of the United States (Winter 1974) and migrates north to nest in cavities in trees in montane forests of western North America. Timber management (e.g. reduction in snag density, stand diversity and stand complexity) is changing these forests. Investigating the dependence of the flammulated owl on particular forest components will help evaluate impacts of timber management on this species.

The literature reveals little about use of the forest by flammulated owls. Most records of flammulated owls are from calls of territorial males, rather than sightings or nest records. These reports associate the species with mature ponderosa or yellow pine (Pinus jeffreyi) in the Canadian and Transition zones (Jacot 1931, Miller 1936, Marshall 1939, Johnson and Russell 1962). Occasional nests have been found in forest stands of ponderosa pine and mixed conifer in Oregon (Bull and Anderson 1978), aspen (Populus tremuloides) in Colorado (Winn 1979, Richmond et al. 1980), and gambel (Quercus gambelii) and black oak (Quercus kelloggii) in California and Utah (Miller

1936, Hasenyager et al. 1979, Johnson and Russell 1962). Descriptions of the structure of breeding habitat of flammulated owls include open forests with multi-layered canopies, clumps of dense vegetation, and forest openings (Bull and Anderson 1978, Cannings et al. 1978, Marcot and Hill 1980). The role and importance of these characteristics in the reproductive biology of flammulated owls are poorly documented.

Selection for breeding habitat may be influenced by diet (Johnson 1980). Flammulated owls are insectivorous. Examinations of stomach contents of flammulated owls revealed crickets and grasshoppers (Orthoptera), moths (Lepidoptera), beetles (Coleoptera), spiders (Araneida) and centipedes (Chilopoda) (Marshall 1939, Kenyon 1947, Johnson and Russell 1962). Temporal and spatial dietary characteristics and the importance of other habitat requirements, such as foraging and roosting sites are unknown. Such information is required to understand breeding habitat selection.

The purpose of this study was to provide information to resource managers charged with maintaining viable populations of breeding flammulated owls. The objectives were to describe for flammulated owls within a limited geographical area:

- 1) reproductive ecology,
- 2) diet, and

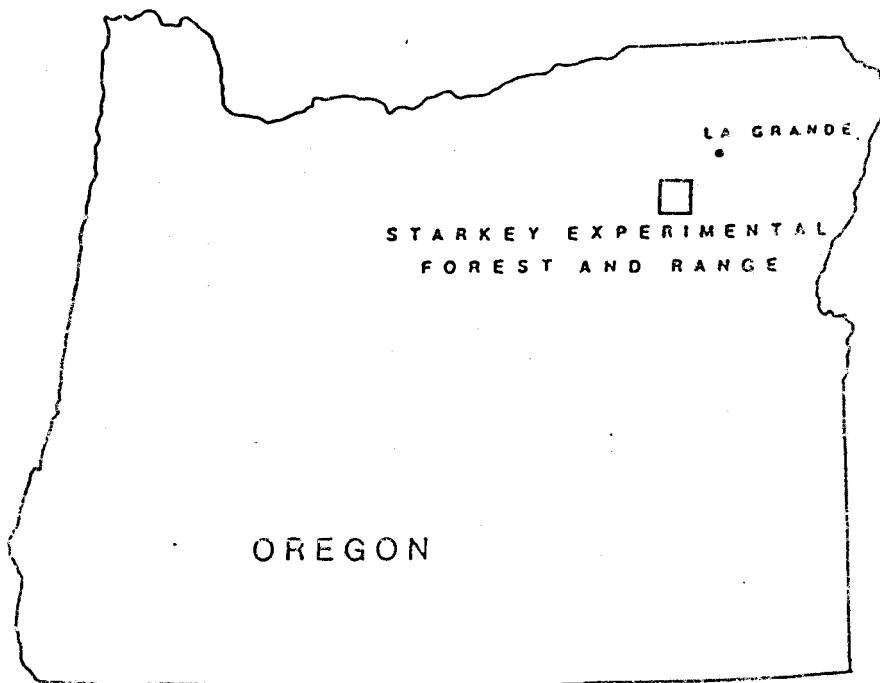
- 3) habitat selection for home ranges, nests, roosts and foraging sites.

STUDY AREA

The study area, selected because previous investigators had reported the presence of breeding flammulated owls (Bull and Anderson 1978), was in the Blue Mountains of northeastern Oregon on the U.S.D.A. Forest Service Starkey Experimental Forest and Range (Starkey) (Fig. 1). The study area comprised 1657 ha of rolling hills; elevations ranged from 1070 to 1525 m. During May through August when flammulated owls are resident, precipitation is minimal (monthly mean=1.2 cm) with most falling in May and June; temperatures are warm during the day (mean daily maximum=22.5 C), cool at night (mean daily minimum=8.7 C), and frost is possible during any month (U.S. Dept. Commerce 1970).

A mosaic of forests and grasslands covered the study area. The structural diversity created by this interspersion was great though species composition was limited. Grasslands and ponderosa pine forests occurred mostly on xeric, upland sites with shallow, stony soils. Ponderosa pine/Douglas-fir forests occurred on deeper soils and southerly aspects. Mixed conifer forests predominated on northerly aspects and in draws where soils are mesic and well developed. Surface water occurred in drainages and stockponds throughout the study season.

Figure 1. Location of the study area for
flammulated owls during 1983 and 1984 in
northeastern Oregon.



Methods

Classification of Forest Habitats. Classification of forests on the study area was based on Burr (1960). Certain structurally similar classes were combined so that 3 forest types were recognized: (1) ponderosa pine (Burr's 203 and 204 combined), (2) ponderosa pine/Douglas-fir (Burr's 215), and (3) mixed conifer (Burr's 305 and 315 combined), consisting of grand fir, western larch, Douglas-fir and occasional ponderosa pine trees.

Location of Owls and Nests. Searches for flammulated owls were conducted nightly from the time owls arrived on the study area in mid-May, until mid-June when vocal responsiveness declined. Searches were conducted on foot to survey all forested areas and thus locate all pairs and territorial males on the study area. Male owl territorial calls or female owl begging calls were imitated frequently as we systematically searched the study area to spot map all flammulated owls that responded. When a flammulated owl responded, we remained in the area of response, or returned on subsequent nights until we determined if a pair was present and the area a pair was using. Nests were located during the day using a heavy stick to pound live and dead trees with cavities to induce incubating or brooding females to look out of the cavity. If this method failed, all cavities were marked and observed at dusk to watch for activity by owls (Reynolds and Linkhart 1984).

Nest Habitat Evaluation. Forest, tree and cavity characteristics were measured at each nest site (Appendix 1). Selection by the owls for nests was tested by comparing a systematic sample of 60 other sites on the study area to nest sites. A 400 m grid was superimposed on the study area to select the systematic sample. Each grid intersection was a point of departure to locate a sample plot by walking increasing concentric circles until the nearest tree with a cavity opening at least 6 cm in diameter was located. This tree was used as the plot center, and a 12.6 m radius circular plot (0.05 ha) centered on this "nest tree" was used to measure forest stand characteristics (Appendix 1). The species, dbh (diameter at breast height) and condition (live or dead) of each tree within the 0.05 ha plot were recorded. Cavities were not verified for their suitability as nests because most snags were unsafe to climb. However, experience in distinguishing woodpecker feeding holes from nest cavities helped us select trees or snags that contained cavities suitable for nesting.

Radiotelemetry Data Collection. Breeding male owls were captured at nest cavities in 1984 and equipped with 164 mhz radio transmitters (Advanced Telemetry Systems, Inc.). Radios were attached to the owls using a backpack harness constructed of cotton ribbon. Radio packages weighed less than 3 gm (3-5% body weight), including harness and battery, and had an operational

life of about 30 days.

Tracking was done with an AVM Model LA 12 receiver and a hand-held 2-element Yagi antenna. Owls were usually monitored from the time they left their day roost, until they returned to a roost the following morning. Locations of owls were determined at intervals of not less than 15 minutes. Locations were based upon actual sightings of an owl, or on determination from signal strength and bearings that the bird was in a specific tree or clump of trees within 5 m of the observer. Most locations were of perched owls because it is difficult to "fix" (plot the exact location of) moving birds at night.

Locations of owls were field-marked by surveyor flagging recorded with the date, time, and activity of the bird. Six types of activity were recognized: (1) foraging, (2) calling, (3) resting (a bird remaining in one location for at least 30 minutes), (4) male-female interaction, (5) male-male interaction, and (6) roosting (daylight hours). Owls were assumed to be foraging at night when not involved in another activity. Locations were plotted on 1:24000 scale aerial photographs during September after all radio tracking had ceased.

Home Range Determinations. The computer program HOME RANGE (Samuel et al. 1983) was used to calculate 95% ellipses (Jennrich and Turner 1969), 90% harmonic mean contours of utilization distributions (Dixon and Chapman 1980, Samuel et al. 1983) and

minimum convex polygons (Mohr 1947). Statistical methods of calculating home range assume (1) successive locations are independent and (2) the probability of locating an animal in any part of its home range is proportional to the amount of time the animal spends there. Both assumptions were violated during this study, thus the nonstatistical method, minimum convex polygon, was used to estimate home range. Statistical estimates are provided for comparative purposes.

Foraging Habitat Evaluation. Habitats in the home range of each owl (minimum convex polygon) were mapped by field surveys. Species composition and average dbh class of the overstory and understory trees, as well as a relative, subjective index of stem density (0=occasional to 3=high) were recorded. These habitats were delineated on aerial photographs and measured using a polar planimeter. Habitat selection was determined by comparing the proportion of habitats used (telemetry locations) to the proportion of habitats available within the home ranges of owls.

Roost Habitat Evaluation. Day roost sites were located by homing in on radio-marked owls. Roost trees were identified by visually locating owls or by identifying the tree from which the owl departed at dusk. Roost habitat characteristics were measured using a 5 m radius (0.008 ha) circular plot centered on the roost tree. The variables measured included landform, aspect and gradient and tree species, dbh and height. Selection was

determined by comparing roost habitat used to habitat available within the home ranges of owls.

Diet Observation. Diet was determined by remote photography. An aluminum frame was mounted on the nest tree. Electric eyes were attached to the frame and positioned above and below the cavity. A 35 mm single lens reflex camera with a motor drive, flash unit, and 50 mm lens was mounted on the frame. As an owl approached the cavity, it broke the electric eye beam, triggering the connected camera. Insects, visible in the beak of owls, were identified to order and classified as adult or larvae. Prey photographed at nest cavities represented diet fed to owlets; concern for nest abandonment precluded photography prior to hatching.

Relative Abundance of Prey. Relative abundance of prey between cover types was determined using insect window traps (Southwood 1966). Two trap stations were randomly located in each of 3 major types of habitat: grassland, ponderosa pine/Douglas-fir forest, and mixed conifer forest. Window traps consisted of a wooden frame holding a 60 x 45 cm plexiglass plate. A 30 x 45 cm aluminum pan was placed at the base of the plexiglass and filled with a water-KAAD (Peterson 1962) mixture. When insects hit the plexiglass, they fell into the collecting pan and were preserved. The traps were set at 2 heights: (1) with the plexiglass set at ground level so that the collecting pan was sunk into the ground,

thereby acting as a pit trap for crawling insects, and (2) with the plexiglass set at 2.1 m and the collecting pan just below it. Traps were checked and all insects removed weekly. Trapped insects were stored in 95% ethanol until identified. Once identified, insects were oven dried to a steady weight (approximately 50° C for 60 hours), and weighed to the nearest 0.01 mg to determine biomass. Insect captures were converted to a trap day basis for calculations.

Statistical Analysis. Statistical tests were done using Chi square and Student's T-test statistics. Selection for nesting, roosting and foraging habitat was determined using the technique of Neu et al. (1974) for utilization-availability. All tests were conducted at a significance level of $p < 0.05$, unless indicated otherwise.

RESULTS AND DISCUSSION

Reproductive Ecology

Density. Previous estimates of density of flammulated owls were crude (number of males per unit area, including areas of suboptimal habitat), extremely variable (range = 0.03 - 5.3 males /40 ha) (Marcot and Hill 1980), and, based on numbers of territorial males, did not necessarily reflect density of breeding pairs. Breeding density on the study area during 1984 was estimated as 0.47 pairs/40 ha (N=19 pairs on 1657 ha). Density of territorial male owls was greater: 0.72 males/40 ha. Nonbreeding male owls are territorial and will respond by calling (Reynolds and Linkhart 1984, pers. obs.). Thus, surveys based on calling male flammulated owls may overestimate breeding density.

Chronology. Male flammulated owls were first heard calling on 27 May 1983 and 19 May 1984. Initial nest occupancy (defined as owl presence in a cavity during the day) was observed on 12 June in both years. Date of clutch initiation was not determined. The female flammulated owl, like screech (Otus asio), saw-whet (Aegolius acadicus) and elf (Micrathene whitneyi) owls, performs all incubating and brooding (Sherman 1911, Santee and Grenfield 1939, Ligon 1968). The incubation period was 23 ± 2 days (N=2). This is similar to elf owls, a slightly smaller, insectivorous species that incubates for 24 days (Ligon 1968) and screech owls, a related, but slightly larger species that incubates for 26 days

(Sherman 1911). The brooding period of flammulated owls was 22 ± 2 days ($N=3$). This is comparable to estimates of 21-27 days in Colorado (Richmond et al. 1980) and 23 days in British Columbia (Cannings and Cannings 1982). Mean fledging dates were 28 July 1983 (range=19 July-1 Aug, S.D.=4.6, $N=4$) and 26 July 1984* (range=19-31 July, S.D.=7.2, $N=5$). Similarly, Richmond et al. (1980) observed a mean fledging date of 28 July ($N=3$) in Colorado.

Fledging terminates the ties of flammulated owls to nests. Thus, the critical period during which proximal human activities might affect breeding success, is brief and probably restricted to June (incubation) and July (brooding), when the nest is occupied.

*Two juveniles at one nest in 1984 did not fledge until 15 and 19 August. This was much later than other fledgings and only 2 eggs were laid. Although renesting by flammulated owls has not been documented, I suspect this was a second nesting attempt thus it was excluded from the previous calculations.

Productivity. Clutch size on the study area averaged 2.7 (range=2-3, S.D.=0.76, N=7). At 3 additional nests clutch size was unknown, however, 3 young fledged at each. Productivity during the study was high: 2.7 young fledged per nest (range=2-3, S.D.=0.5, N =9). Productivity of a population in Colorado was similar: 2.6 young of banding age per nest (S.D.=0.6, N=13 nests) (Linkhart et al. in review). Other reports, however, averaged only 1.9 fledglings per nest (N = 10 nests) (Hasenyager et al. 1979, Richmond et al. 1980, Cannings and Cannings 1982, Bloom 1983).

Fidelity to Nest Sites. Fidelity to nest sites in successive years, but not to cavities, was evidenced by flammulated owls during this study. Of 10 nest cavities located in 1983, 0 were reused by flammulated owls in 1984. Nest site fidelity was documented in 1984 at 2 sites; at each, a banded male was found nesting within 300 m of its 1983 nest. Three other nesting attempts in 1984 were within 100 m of 1983 nests, but because the birds were not banded, site fidelity could not be assessed. Nest cavity reuse has been reported in other areas (Bloom 1983, Boula pers. comm.). Newton (1979) suggested that breeding site fidelity is advantageous for raptors. By exploiting familiar hunting areas, avian predators increase their efficiency and thereby increase breeding success. Occupying familiar areas for breeding may be particularly important to migratory predators

such as flammulated owls because energy reserves can be severely depleted during migration.

Diet

Composition. Arthropods in 5 classes (8 orders) were identified from photographs (N = 311 from 5 nests) (Table 1), suggesting that flammulated owls were opportunistic predators. All orders of arthropods identified in the diet were caught in insect traps. Proportions of prey items trapped did not differ significantly from their frequency of occurrence in the diet, indicating again that flammulated owls were opportunistic.

The diet of flammulated owls, although diverse, was dominated by a single prey (Table 1). Insects in the order Orthoptera comprised 62% of the prey items and 85% of the biomass. Insects in the order Lepidoptera comprised 13% of the prey items but only 2% of the biomass. Arachnids and Chilopods comprised an additional 6% and 5% of the prey items, respectively. Orthopteran insects were an efficient prey choice in 2 respects: (1) the biomass per individual was greater than other prey; thus, the energy gained per prey capture was maximized, and (2) orthopteran insects were the most abundant prey; thus, by concentrating predation on these insects, the time and energy spent in search of prey was likely minimized.

Breeding Period Variation. Diet early in the breeding season

Table 1. Percent frequency of occurrence and biomass¹ (mg) of prey (N=352) photographed at 5 flammulated owl nest cavities (1983, 1984) and trapped on the study area (1984) in northeastern Oregon.

Arthropods	Frequency		Biomass	
	Diet	Trap	Diet	Trap
Arachnida				
Araneida(spiders)	5.9	3.3	tr ²	13.3
Chilopoda (centipedes)	4.8	tr	2.0	tr
Diplopoda(millipedes)	tr	tr	1.0	tr
Insecta				
Orthoptera (grasshoppers)	61.9	60.5	85.0	74.4
Lepidoptera(moths)-adult	6.3	7.9	1.0	tr
-larvae	6.5	tr	1.0	tr
Ephemeroptera(mayflies)	tr	---	tr	---
Homoptera (cicadas)	tr	---	1.0	---
Coleoptera(beetles)	tr	14.6	tr	6.0
Unidentified ³ /Other	11.6	10.3	8.0	4.2

¹Biomass was calculated from average dry weight (mg) of Arthropods trapped on the study area.

²tr = <1.0%.

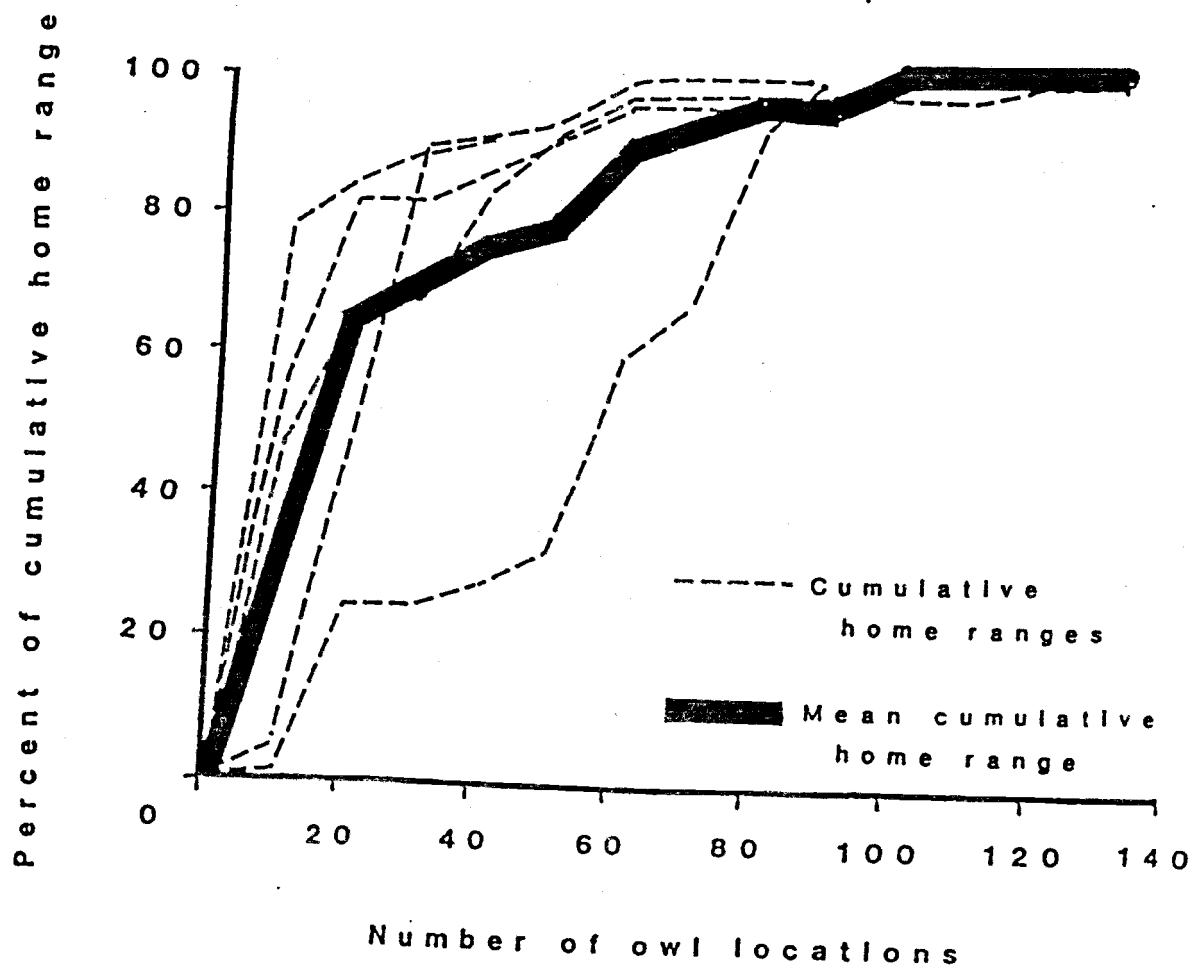
³Unidentified because of photographic difficulties (i.e. images out of focus, arthropods too small).

remains undocumented but may have differed from that recorded post hatching. Although owls arrived on the study area in May, photographs were not taken until 6-24 July 1983 and 9 July-14 August 1984. During the period that diet was observed (July/August), more orthopterans and lepidopterans were captured in insect window traps than were trapped prior to observation (May/June) (Fig. 2). In contrast, trap captures of beetles, spiders, millipedes, and centipedes were greater prior to observation of diet (May/June) than during observation (July/August). The latter items may have been more important in the diet early in the breeding season since flammulated owls appear to be opportunistic predators.

Home Ranges

Determination of Home Range. Information on home range size and composition is requisite to planning for habitat to support a viable population. Estimates of home range vary with intensity of observation (Samuel et al. 1983). Observations of 5 male flammulated owls indicated that the first 60 telemetry locations delineated 90% of the eventual average home ranges (minimum convex polygon), including pre- and post-fledging data (Fig. 3). The minimum number of locations recorded per owl was 72 (maximum=142) and the minimum number of monitoring nights per owl was 5 (maximum=9), over a minimum of 1 month. Centers of activity for all owls were at or near the nest tree. Apparent

Figure 3. Size of home range as a function of the number of owl locations (data averaged for 5 owls) during 1984 in northeastern Oregon.



"outlier" radio locations, present on 4 of 5 home ranges, were probably a result of data collection limitations; it was difficult to track foraging owls to distant locations because such forays were rapid. Such distant areas may have been used more often than the data indicate. Thus, apparent outlier locations were not excluded from the home range analyses.

Cumulative Home Range Size. Home ranges (minimum convex polygon) of male flammulated owls breeding in 1984 averaged 10.3 ha (range=5.5-19.3, S.D.=6.3, N=5) (Table 2). Flammulated owls in Colorado had mean home ranges (minimum convex polygon) of 14.1 ha (range=8.5-24.0, S.D.=5.0, N=7) (Linkhart et al. in review). The difference between these estimates is statistically significant ($p < .01$) and may be related to food availability (Schoener 1968). Prey densities may differ between the Colorado and Oregon breeding areas as a result of differences in overstory continuity. Higher densities and biomass of prey were trapped in grasslands than in forests (Table 3), suggesting that in Oregon, areas with broken overstories may have higher densities of prey. Seven of 9 home ranges in Colorado were in forests with a continuous overstory. If broken canopies are indicative of higher prey densities, then flammulated owls in Oregon may meet their energy demands within a smaller area than owls in Colorado.

Breeding Period Differences in Home Range Size. Changes in home range size between breeding periods (incubation, nestling,

Table 2. Radiotelemetry tracking periods and home range sizes calculated by the minimum convex polygon (MCP), Jennrich-Turner ellipse (J-T) and utilization-distribution (U-D) methods for 5 male flammulated owls during 1984 in northeastern Oregon.

Owl	Tracking dates	Number of tracking nights	Number of tracking locations	Home range area (ha)		
				MCP	J-T	U-D
1	26 Jun-01 Aug	9	142	19.3	28.6	24.2
2	30 Jun-30 Jul	7	133	14.5	18.3	18.0
3	12 Jul-10 Aug	5	72	6.3	6.6	8.4
4	13 Jul-14 Aug	5	94	6.0	6.1	6.5
5	1 Aug-28 Aug	8	86	5.5	8.0	7.4
Total		34.0	527.0			
Mean		6.8	105.4	10.3	13.5	12.9
S.D.		1.8	30.5	6.3	9.8	7.8

Table 3. Mean number, percent frequency and dry weight (mg) of arthropods captured per trap day at window traps during 1984 in northeastern Oregon.

Habitat	Number	Frequency	Dry weight
Grassland	9.6	70	82
Ponderosa pine/Douglas-fir	3.0	22	15
Mixed conifer	1.1	8	3

fledgling) may reflect frequency of nest visits by male flammulated owls. Mean home range size decreased substantially from the incubation to the nestling periods (Table 4). Flammulated owls are "single-prey loaders" (Orians and Pearson 1979), thus the rate of visits to the nests by male owls varies with demands for food by female owls and nestlings. During incubation, food demands were low: male owls visited nests infrequently, and foraged far from nests ($\bar{X}=194$ m, S.D.=7.1, N=2). After hatching, food demands increased and male owls foraged closer to nests ($\bar{X}=81$ m, S.D.=28.1, N=5), maximizing efficiency (Orians and Pearson 1979). Availability of appropriate foraging sites and adequate prey densities near nests may influence nest site selection.

Mean home range size decreased further after owlets fledged (Table 4). Changes in foraging locations and brood division may have caused this reduction. After owlets fledged, male owls were free to exploit new foraging areas because ties to nests were defunct. By foraging in tracts with high prey densities, male owls may reduce the total area required to meet energy demands. Brood division, which occurred at fledging, reduced the number of young fed by male owls, concomitantly reducing the total area required to meet their foraging demands.

Influence of Topography on Home Range Sizes. The location of home ranges of flammulated owls seemed to be influenced by

Table 4. Minimum convex polygon home range size (ha) by breeding period of 5 male flammulated owls during 1984 in northeastern Oregon.

Owl	Breeding periods		
	Incubation	Nestling	Fledgling
1	19.3 (43) ¹	12.5 (53)	7.2 (46)
2	12.5 (38)	10.5 (95)	
3		2.2 (63)	3.3 (31)
4		4.8 (55)	3.6 (31)
5		9.7 (54)	0.4 (18)
Mean	15.9 (81)	7.9 (320)	3.6 (126)

¹() = number of telemetry locations

topography and habitat. Home ranges of owls were on upper slopes and plateaus, with no home range overlap between adjacent pairs. This topographical segregation of owl pairs was probably associated with avoidance of the dense mixed conifer forest type located in draws. Consequently, draws often provided well defined boundaries between territories. Xeric sites, located on upper slopes and ridgetops also support grasslands and the ponderosa pine/Douglas-fir forest type preferred by flammulated owls. Home range shapes of spotted owls (Strix occidentalis) were also influenced by avoidance of certain habitats (Forsman et al. 1984). The causes of habitat avoidance by avian species are unclear, but may relate to food and other resource use.

Relative Abundance of Prey

Prey density may influence the characteristics (i.e. shape, size) of home ranges. Arthropod and orthopteran abundances differed substantially between habitats (Table 3). Seventy percent of the total number and 82% of the total biomass of arthropods trapped were in grassland. Twenty-two percent of the total number were in ponderosa pine/Douglas-fir. Mixed conifer was a relatively unimportant source of arthropods. Orthopterans comprised 76% of the arthropods trapped in grassland and only 40% of the arthropods trapped in either forest type. For flammulated owls, other environmental constraints excluded, more encounters with prey were likely in grasslands, followed by ponderosa

pine/Douglas-fir forest stands. Furthermore, each prey capture in grassland, was likely to involve more biomass than a prey capture in forest, since orthopterans have the greatest biomass per individual. If prey densities (and biomass) influenced foraging locations, flammulated owls should be expected to take prey primarily from grassland and should select home ranges according to the spatial distribution and relative proportions of grassland.

Habitat Selection for Foraging

Differential use of habitats by 5 male flammulated owls was related to vegetation structure. Vertical and horizontal vegetative diversity influenced prey densities and potential hiding cover. Owls foraged in forest stands with "low" and "medium" stem density more than expected from availability on home ranges and avoided stands with "high" stem density (Table 5). Trees in highly stocked stands compete intensely for light, creating abundant dead limbs on the trunks beneath dense crowns. The effects of this on flammulated owls were dual: (1) density and diversity of ground dwelling arthropods were limited probably by lack of ground vegetation, and (2) maneuverability of foraging owls was impeded by limbs and stems. Owls also selected other structural characteristics for foraging sites, including edge between forest and grassland (Fig. 4, 5) and ponderosa

Table 5. Occurrence and use of levels of understory stem density¹ for foraging in the home ranges of 5 male flammulated owls during 1984 in northeastern Oregon.²

Understory stem density	Number of owls using habitat	
	Significantly more than expected	Significantly less than expected
Occasional	0	0
Low	2	0
Medium	3	1
High	0	4

¹Subjective measure indicating relative differences.

²Utilization-availability test, $p < .05$ (Neu et al. 1974).

Figure 4. Foraging locations of 1 flammulated owl during 1984 in northeastern Oregon.

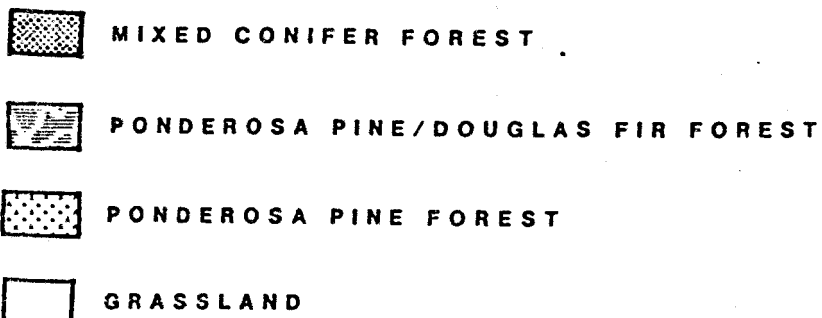
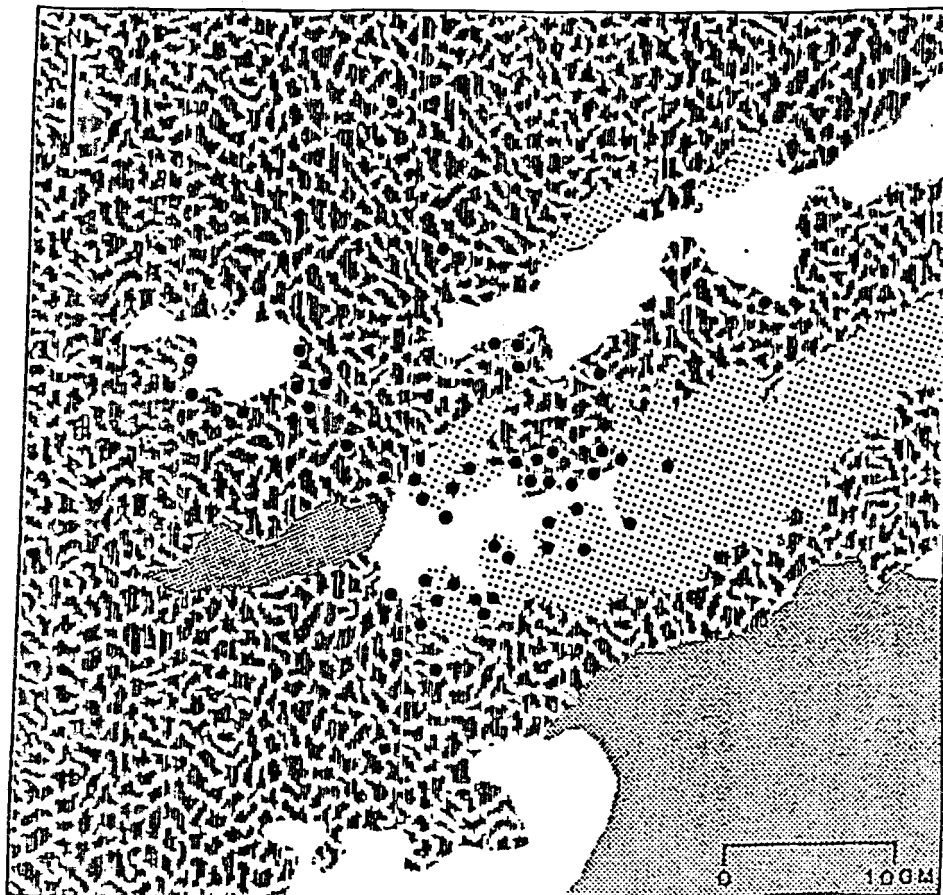
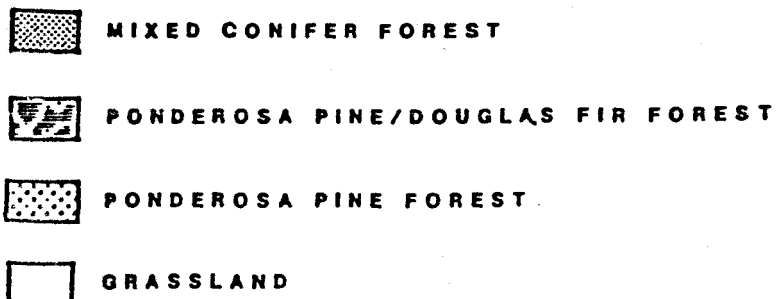
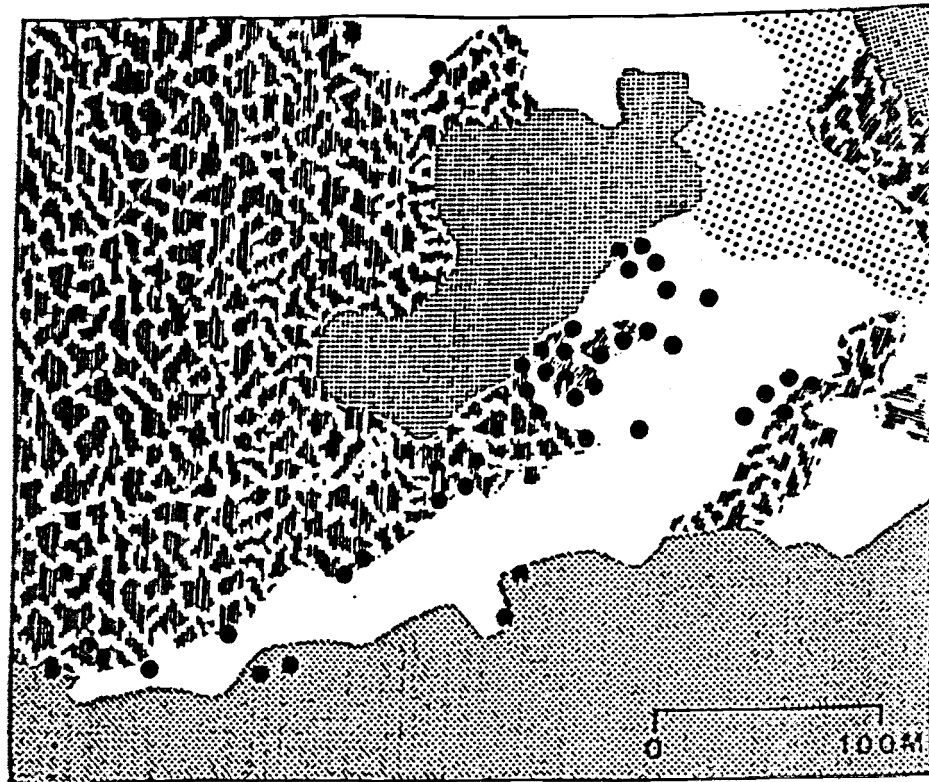


Figure 5. Foraging locations of 1 flammulated owls during 1984 in northeastern Oregon.



pine/Douglas-fir forest type (Tables 6 and 7). Use of these habitat components may represent a balance between highest prey densities and hiding cover. Flammulated owls are "sit and wait" predators. Grassland, where prey densities were highest, lacked cover for perched flammulated owls. The forest edge provided perch sites protected from predators, yet juxtaposed with grasslands. Grasslands may be used more often than the data indicated. "Fixing" moving owls was difficult because sorties for prey were brief. Thus, forays into grassland for prey may have occurred more often than recorded. Use of ponderosa pine/Douglas-fir may also be a compromise between foraging efficiency and cover. Although prey densities were not as high as in grassland, densities in ponderosa pine/Douglas-fir were higher than in mixed conifer and cover was abundant. By foraging in forests with low stocking, ponderosa pine/Douglas-fir and grassland edge, flammulated owls may exploit relatively high prey densities while remaining close to suitable hiding cover.

Habitat Selection for Roosting

Availability of suitable roosting habitat may influence selection of breeding habitat. Roosts averaged only 53 m from nests during the nestling period (Table 8). In Colorado, flammulated owls roosted less than 20 m from nests for 3-4 days prior to fledging of juveniles (Linkhart et al. in review). If requirements for roosts are specific, the "search image" of

Table 6. Percent occurrence and use of cover types for foraging in the home ranges of 5 male flammulated owls during 1984 in northeastern Oregon.¹

Habitat	Occurrence on home ranges	Locations ² in habitat	Number of owls using habitat	
			Significantly more than expected	Significantly less than expected
Edge ³	29-61	42-80	5	0
Grassland	7-52	1-16	0	4
Forest	17-63	9-36	0	2

¹Utilization-availability test, $p < 0.05$ (Neu et al. 1974).

²Locations determined by radiotelemetry.

³Edge=10 m strip extending from grassland border into forest.

Table 7. Percent occurrence and use of cover types for foraging in the home ranges of 5 male flammulated owls during 1984 in northeastern Oregon.¹

Cover type	Occurrence on home ranges	Locations ² in habitat	Number of owls using habitat	
			Significantly more than expected	Significantly less than expected
Ponderosa pine	1-11	9-51	4	0
Ponderosa pine/ Douglas-fir	23-41	46-65	4	0
Mixed conifer	8-55	2-26	0	4
Grassland	0-24	1-16	0	4

¹Utilization-availability test, $p < 0.05$ (Neu et al. 1974).

²Locations determined by radiotelemetry.

Table 8. Mean distances (m) of roosts from nests by breeding period for 5 male flammulated owls during 1984 in northeastern Oregon.

Owl	Breeding periods		
	Incubation	Nestling	Fledgling
1	153.5	76.7	84.4
2		36.1	160.7
3	247.0	33.3	159.0
4		74.5	74.5
5		39.9	170.6
Mean	200.2	53.3	128.6
S.D.	129.4	24.9	76.7

flammulated owls for nest sites may include roosting habitat.

Vegetative density may be the structural key in day roost selection by flammulated owls. During 1984 we located 37 day roosts of 5 male radio-marked flammulated owls. Owls roosted in the mixed conifer forest type significantly more than expected from availability within the combined home ranges and avoided roosting in the ponderosa pine forest type (Table 9). The primary structural difference between these forest types is the degree of openness: mixed conifer stands are denser than ponderosa pine stands. High foliage density is a key structural component of day roost selection. Eighty-nine percent of the roosts were in stands with multilayered canopies, and 74% had canopy closure greater than 50%. Mean stem density of roost sites (in the 0.008 ha plot centered on the roost tree) was 2016 trees/ha (range=509-5346, S.D.=1378, N=31); mean basal area was 129 m²/ha (range=21-239, S.D.=48.5, N=31). Availability of these components was not measured.

Use of dense clumps of vegetation in territories of flammulated owls during the breeding season were noted previously (Bull and Anderson 1978, Marcot and Hill 1980), but the significance of these clumps was unknown. Roosts in mixed conifer stands with dense, multilayered canopies may aid in thermoregulation during the hot daytime temperatures of summer. Cool microclimates in dense, multilayered canopies have been

Table 9. Percent occurrence and use of habitat for roosting (n=35) in the home ranges of 5 flammulated owls during 1984 in northeastern Oregon.¹

Habitat characteristics	Occurrence on home ranges	Location of roosts
Forest type		
Ponderosa pine	18	0*
Ponderosa pine/Douglas-fir	50	46
Mixed conifer	32	54*
Forest canopy layers		
Multiple	69	89*
Single	31	11*

¹Utilization-availability test, $p < 0.05$ (Neu et al. 1974).

*Indicates statistically significant use or avoidance.

documented for spotted owl roosts (Forsman et al. 1984, Barrows and Barrows 1978). Ligon (1969) examined tolerance in small owls to elevated temperatures and concluded they may be less able to survive temperature increases than other avian species of similar size. Dense vegetative cover probably provides a high degree of protection from predators. High foliage density at sharp-shinned (Accipiter striatus) and Cooper's (Accipiter cooperii) hawks nests may have reduced predation (Reynolds et al. 1982). Defense by concealment as a factor in roost selection by flammulated owls is supported by other data. Within the mixed conifer stands, flammulated owls selected for ponderosa pine as a roost tree rather than Douglas-fir or grand fir (Table 10). Because of their coloration, flammulated owls are relatively more difficult to observe in ponderosa pine. Predator avoidance while roosting is further evidenced behaviorally. Owls were never observed spontaneously leaving a roost prior to sunset or remaining active past sunrise, and were reluctant to leave day roosts even when prodded with sticks. As in selection for foraging sites, suitable cover seems to influence the selection of roosts by flammulated owls. Availability of suitable roosting and foraging sites may, as indicated by proximity to nests, influence nest location.

Habitat Selection for Nesting

Nests. Nest cavities were located in live trees (N=1), dead

Table 10. Percent occurrence and use of tree species for roosting (N=33) by 5 flammulated owls during 1984 in northeastern Oregon.¹

Tree species	Occurrence in roost stands	Location of roosts
Ponderosa pine	17	67*
Douglas-fir	39	15*
Grand fir	37	9*
Western larch	6	9

¹Utilization-availability test (Neu et al. 1974).

*Indicates statistically significant use or avoidance.

portions of live trees (N=3) and snags (N=16). Seventeen cavities were in ponderosa pine, 2 in western larch and 1 in Douglas-fir. Ten of the nest cavities were assumed (from size and shape) to be excavated by common flickers (Colaptes auratus), 8 by pileated woodpeckers (Dryocopus pileatus), and 2 were natural cavities that formed where limbs broke out of tree trunks. Selection for these and other variables measured at nest cavities and trees was not statistically significant. The range in acceptable cavity and tree sites suggest that other factors determine nest site selection (Table 11).

Nest Sites. Selection by flammulated owls for a number of forest and ground cover characteristics at nest sites was statistically significant and may be related to diversity and density of prey. Forest stands used by owls were characterized by ponderosa pine/Douglas fir species composition, mature trees (30-50 cm dbh), canopies with less than 50% closure, and slopes of 16 to 25 percent (Table 12). Mean stem density of nest sites was 589 stems/ha (range 60-809, S.D.=450.9, N=19); mean basal area was 23.7 m²/ha (range 2.5-66.5, S.D.=19.4, N=19). Eighty percent (N=20) of the nest sites were within 30 m of a clearing, and all were in stands with multilayered canopies. Characteristics of ground cover at nest sites included species, diversity and percent ground cover (Table 12). These forest stand and ground cover characteristics are interrelated and likely influence prey

Table 11. Characteristics of 20 flammulated owl nest trees and cavities located during 1983 and 1984 in northeastern Oregon.

Measurement	N ¹	Mean	S.D.	Range
Tree height (m)	20	26.6	12.0	7-40
Tree dbh (cm)	20	56.3	11.9	22-80
Nest height (m)	20	10.0	5.9	5-35
Tree diameter at nest (cm)	9	44.2	10.9	20-78
Cavity opening length (cm)	9	8.6	1.7	7-12
Cavity opening width (cm)	9	7.2	1.4	6-10
Cavity depth (cm)	9	20.4	15.9	10-55
Cavity diameter (cm)	9	16.5	1.5	9-22

¹ Cavity characteristics were not measured at all nests.

Table 12. Percent occurrence and use of habitat for nesting by 20 pairs of flammulated owls during 1983, 1984 in northeastern Oregon.¹

Habitat Characteristics	Occurrence on study area	Nests in habitat
Slope gradient		
0-15%	65	45
16-25%	15	45*
26+%	20	10
Cover type		
Ponderosa pine/Douglas-fir	50	75*
Other combined (mixed conifer, ponderosa pine, and grassland)	50	25*
Percent forest canopy closure		
Less than 50%	42	68*
Greater than 50%	58	32*
Ground cover composition		
Multi-species	42	84*
Single species	58	16*
Ground cover type		
Forb or shrub with grass	53	89*
Grass	47	11*
Percent ground cover		
Greater than 33%	47	79*
Less than 33%	53	21*

¹Utilization-availability test, $p < 0.05$ (Neu et al. 1974).

*Indicates statistically significant use or avoidance.

populations. The open canopy and widely spaced trees of the forest stands used for nesting allowed ample light penetration to the understory, stimulating growth of ground cover. Ground cover at nest sites was abundant and diverse relative to sample plots; nest sites may have a concomitant increase in diversity and density of prey for flammulated owls. Vegetative diversity typically indicates high arthropod diversity because food habits of arthropod species are widely divergent (Borror and White 1970). Diversity of prey is important because the composition of an invertebrate community can vary greatly within a season. A wide array of prey species at a nest site may insure a constant food supply for breeding flammulated owls. Vegetative diversity (Pimentel 1961), as well as biomass may positively influence arthropod densities. Sites high in vegetative biomass should support more herbivores than sites low in biomass. This may be important for flammulated owls on the study area. Diets were dominated by orthopterans, most of which are herbivorous ground or understory dwellers (Borror and White 1978). It follows that orthopteran densities may be directly affected by ground level biomass. Flammulated owls, by nesting in open forests with broken canopies, use habitat with a well-developed ground cover that can support a diversity of prey species, as well as high densities of orthopteran species.

CONCLUSIONS

Flammulated owls were common summer residents in certain areas of northeastern Oregon. Breeding home ranges averaged 10.3 ha. Breeding habitat appeared to be a mosaic of structurally and functionally distinct components, including grassland, snags, open ponderosa pine/Douglas-fir and dense mixed conifer forest types. Access to each of these within the home ranges of flammulated owls requires a high degree of habitat interspersion. The level of habitat interspersion present in northeastern Oregon could decrease as intensive forestry increases. Additionally, the numbers and characteristics of habitats used by flammulated owls may be affected by timber production. With appropriate planning, however, intensive timber management and viable populations of flammulated owls may be compatible.

Management Implications

Grassland. Grassland may be the primary source of prey for flammulated owls breeding in northeastern Oregon. Care should be taken to maintain grasslands in as undisturbed condition as possible, thereby ensuring a prey substrate for flammulated owls.

Snags. Flammulated owls rely upon snags for nest cavities. Timber management reduces snag densities, limiting cavities. Breeding density of cavity nesting birds decreases with decreasing snag (and cavity) density. Flammulated owls may be particularly sensitive to reductions in cavity density. They are

the last of the cavity-nesting birds to arrive in northeastern Oregon. If cavities are limited, all may be occupied by other species prior to arrival of flammulated owls (breeding by flammulated owls is thereby limited).

Other practices, particularly fuelwood collection, reduce densities of snags. In Oregon, demands for fuelwood are increasing. During 1984, 151.6 million board feet of timber were cut for fuelwood on National Forests in Oregon (U.S.D.A. Forest Service Office, Region 6, pers. comm.). Much of this wood is cut as snags. Passive protection of snags may be ineffective against woodcutters. In Colorado during 1977, 110 snags were tagged with "wildlife tree" signs. By 1979, 107 had been cut by woodcutters (Scott et al. 1980). Snags occurring in nesting habitat of flammulated owls in northeastern Oregon are particularly vulnerable to woodcutters. The open forests broken by grassland that were used by flammulated owls allow potential fuelwood to be easily seen and accessed.

Although current forest planning includes snags, retention is usually based on size and decay classes. This may be ineffective for flammulated owls. Flammulated owls, like some other cavity nesting species, appear to select nests for the habitat surrounding nest trees rather than for characteristics of the cavity or tree (Bull 1983, Hay and Guntert 1983).

Use of nest boxes has been proposed to mitigate the effects

of snag reductions on secondary cavity nesters. Nest boxes may, however, have limited management potential for flammulated owls. They were used by flammulated owls in California (Bloom 1983), Utah (Hasenyager et al. 1979) and British Columbia (Cannings and Cannings 1982), but were not used by flammulated owls during 3 years of monitoring 813 nest boxes in areas inhabited by flammulated owls in the Wallowa Mountains, Oregon (R. Anderson pers. comm.). Suitable placement of nest boxes, with respect to roosting, foraging and nesting microhabitat, may promote use. Artificial nest substrate provision is, however, a short term solution to a long term management problem.

Ponderosa pine/Douglas-fir forest type. Ponderosa pine/Douglas fir forest stands with open, multilayered canopies and diverse, well-developed ground vegetation were selected by flammulated owls for nesting and foraging sites. These traits are characteristic of mature (30-50 cm dbh), uneven-aged forest stands. Timber management for even-aged, pure ponderosa pine stands on short rotations eliminates the structural coherence of habitat used by flammulated owls for nesting and foraging.

Mixed conifer forest type. Flammulated owls selected densely stocked, multilayered mixed conifer forest stands for roosting. Development of these structural features is precluded by silvicultural prescriptions for even-aged stands with optimal stocking.

Management Guidelines

The integrity of the existing landscape of the Blue Mountains can be retained through forest management that includes maintaining juxtaposition and interspersions of various habitat components. Timber management, based on the following suggestions, can provide suitable breeding habitat for flammulated owls.

- (1) maintain condition and distribution of grasslands,
- (2) provide forest buffer zones around montane openings,
- (3) retain snags during logging and silvicultural treatments and offset losses of snags to fuelwood through planning,
- (4) maintain some silvicultural units in open, uneven-aged ponderosa pine/Douglas fir,
- (5) maintain portions of some stands of mixed conifer at high stocking levels, and
- (6) retain a mosaic of habitat types and structure.

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APPENDICES

Appendix 1. List of characteristics measured at 20 flammulated owl nest sites and 60 sample sites.

CAVITY

Type

Pileated woodpecker

Flicker woodpecker

Natural

Shape

Oval

Round

Amorphous

Height

0-5

6-10

11-15

16-20

21-25

26-35

36-45

>45

Aspect

0-45

46-90

91-135

136-180

181-225

226-270

271-315

316-359

Diameter of tree

<2

2-10

11-30

31-50

51-70

>70

Nearest Perch to Cavity

<1

1-3

3-10

>10

Nearest Hiding Cover

<1

1-3

3-10

>10

Location in Tree

Live Wood

Dead Wood

Partial

Cavity Surrounded by Bark

Yes

No

Partial

TREE

Species

Ponderosa Pine

Douglas Fir

Grand Fir

Western Larch

Condition

Live

Dead

Partial

Height

0-5

6-10

11-15

16-20

21-25

26-35

36-45

>45

DBH (Succession)

<2 (Regeneration)

2-10 (Subclimax)

11-30 (Subclimax)

31-50 (Mature)

51-70 (Old Growth)

>70 (Remnant)

Percent Bark

100

>50

<50

0

Lean Direction

0-45

46-90

91-135

136-180

181-225

226-270

271-315

316-359

Distance to Clearing (0.5 acre minimum)

- <5
- 5-10
- 10-30
- 30-65
- >65

GROUND COVER

- Percent
 - <33
 - 33-66
 - >66
- Type
 - Grass
 - Forb
 - Shrub
 - Grass-Forb
 - Grass-Shrub
 - Forb-Shrub
 - Grass-Forb-Shrub
- Species
 - Feid-Agsp
 - Posa-Agsp
 - Posa-Feid
 - Ag spp
 - Caru
 - Po spp
 - Po spp-Feid

FOREST

- Height
- Cover Type
 - Grassland
 - Ponderosa Pine
 - Ponderosa Pine/Douglas Fir
 - Mixed Conifer
- Layers
 - 1
 - 2
 - 3
- Canopy Closure
 - <25
 - 26-50
 - 51-75
 - >75
- Bole Height (each layer)
- Stringer
 - Yes
 - No

LANDFORM

- Bottom
- Lower midslope

Upper midslope
 Slope Aspect
 00-45
 46-90
 91-135
 136-180
 181-225
 226-270
 271-315
 316-359
 Slope Gradient
 0-5
 6-10
 11-15
 16-20
 21-25
 26-30
 CLEARING Distance from nest/sample tree
 <5
 5-10
 10-30
 30-65
 >65
 Species Composition
 Feid-Agsp
 Posa-Agsp
 Posa-Feid
 Ag spp
 Po spp
 Caru
 Po spp-Feid
 Axis length
 Axis width
 WATER Distance
 Source
 Creek
 Stockpond
 Other

Appendix 2. Some records (1983-1985) indicating distribution of flammulated owls in Oregon.

County	Location	Date	Type
Deschutes	T22S, R10E Rosland Campground Deschutes National Forest	06/14/84	Call
Douglas	T32S, R6W Grants Pass RA Bureau of Land Management		Sight
	T26S, R3E, Sec 9 Diamond Lake Ranger District Umpqua National Forest	07/02/85	Nest
Harney	T20S, R26E, Sec 25 Snow Mountain Ranger District Ochoco National Forest	08/06/83	Sight
Hood River	T5S, R11E, Sec 33, 34 Bear Springs Ranger District Mt. Hood National Forest	07/11/84	Sight
Josephine	T41S, R8W, Sec 7, 8 T41S, R7W, Sec 12 Illinois Valley Forest	05/23/84 06/13/84	Call
Klamath	T27S, R7E, Sec 23, 24, 26 Chemult Ranger District Winema National Forest	05/26/85	Call
Lake	T39S, R16E, Sec 1 T40S, R14E, Sec 34, 35 T40S, R14E, Sec 3, 4 Lakeview Ranger District Fremont National Forest	07/ /84 06/ /85 06/ /85	Sight
	T29S, R14E, Sec 21, 22 Silver Lake Ranger District Fremont National Forest	06/10-27/84	Nest
Umatilla	T4S, R33E, Sec 28 Ukiah Ranger District Umatilla National Forest	07/ /83	Nest

Wallowa	T2N, R4SE, Sec 20	07/12/84	Nest
	Wallowa Valley Ranger District		
	Wallowa Whitman National Forest		