

AN ABSTRACT OF THE THESIS OF

Karl J. Martin for the degree of Master of Science in Wildlife Science presented on October 31, 1994. Title: Movements and Habitat Associations of Northern Flying Squirrels in the Central Oregon Cascades.

Abstract approval: Robert Anthony

Robert G. Anthony, Ph.D.

We used radio-telemetry techniques to estimate home range size, movements, den sites, and habitat selection of 39 northern flying squirrels (Glaucomys sabrinus) in 2 old- and 2 second-growth stands in the central Oregon Cascades. Sampling periods were at night during summer and fall of 1991-92. Home ranges were smaller for female squirrels (3.9 ha, SE = 0.37) than male squirrels (5.9 ha, SE = 0.75); there was no detectable difference in home range size between stand types. Movements between successive, noncorrelated telemetry locations averaged 71 m (SE = 1.6 m;  $n = 1090$ ) with no detectable differences between stand types or sexes. Northern flying squirrels had similar home range sizes, and movements in old- and second-growth coniferous forests of the central Oregon Cascades.

Northern flying squirrel core-use areas (75% of the utilization area) were used to assess habitat selection in both old- and second-growth stands. Logistic regression procedures resulted in 1 significant microhabitat variable from the 22

variables measured in each stand type. In the old-growth stands, squirrels avoided areas with high proportions of large ( $\geq 50$  cm diameter) down wood ( $P = 0.0002$ ). In the second-growth stands squirrels avoided areas with high densities of small (10 - 49 cm dbh) snags ( $P = 0.003$ ).

In the summer of 1992 we used daytime telemetry techniques to locate 42 den sites in an old-growth stand and 64 den sites in a second-growth stand. Den trees were larger than the average available den tree in each stand type. Den trees averaged 36.0 cm dbh (SE = 1.6 cm) in the second-growth stand and 101.0 cm (SE = 6.1 cm) in the old-growth stand. Squirrels did not seem to select snags for den sites more frequently than expected in either stand type, as other studies have suggested.

**MOVEMENTS AND HABITAT ASSOCIATIONS OF NORTHERN FLYING  
SQUIRRELS IN THE CENTRAL OREGON CASCADES**

by

**Karl J. Martin**

**A THESIS**

submitted to

**Oregon State University**

**in partial fulfillment of  
the requirements for the  
degree of**

**Master of Science**

**Completed October 31, 1994**

**Commencement June, 1995**

**Master of Science thesis of Karl J. Martin presented on October 31, 1994**

**APPROVED:**

*Robert D. Anthony*

---

**Major Professor, representing Wildlife Science**

*Earl K. Fjell*

---

**Head of Department of Fisheries and Wildlife**

*John C. Ringle*

---

**Dean of Graduate School**

**I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.**

*Karl J. Martin*

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**Karl J. Martin, Author**

## ACKNOWLEDGEMENTS

After tracking squirrels for 13 months at all hours of the night, I'm thankful to have something to show for it. I would like to thank Bob Anthony for his continuous support and guidance throughout the project. I would especially like to thank Bob for allowing me the freedom to explore certain aspects of the project that I found particularly interesting.

I would like to acknowledge Keith Apfelbeck and Carmen Thomas for their patience and perseverance during all those long nights of radio-tracking squirrels. Without their assistance and willingness to work in all types of conditions none of this would have been possible. Not only did we develop close friendships; we had fun, which I feel is an important component of successful field research.

I would like to thank Dan Rosenberg, Keith Swindle and Steve Desimone for helping me set up my stands, and answering my questions. Dan was especially helpful in developing the project and how to approach the important questions of interest. Bruce Coblentz, Bill McComb and Chuck Meslow provided me with ideas, problems, criticisms, and solutions that I often overlooked myself. I would especially like to thank my sister Ruth Martin and my fiancée Karen Porter for their support, assistance, and ideas throughout the duration of this project.

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# MOVEMENTS AND HABITAT ASSOCIATIONS OF NORTHERN FLYING SQUIRRELS IN THE CENTRAL OREGON CASCADES

## Chapter I

### GENERAL INTRODUCTION

Forest practices in the Pacific Northwest have created a fragmented landscape with patches of old-growth forests interspersed among a matrix of second-growth forests (Harris 1984:27). Less than 14% of the temperate rainforests in Oregon and Washington remain in the old-growth seral stage (Booth 1991). The northern spotted owl (*Strix occidentalis caurina*) selects late-successional (> 100 yrs) forests for roosting, nesting, and foraging (Forsman et al. 1977, 1982, 1984; Thomas et al. 1990:7-20, Bart and Forsman 1992, Carey et al. 1992) throughout the Pacific Northwest, and the amount of spotted owl habitat has declined over the last half century. As a result, the northern spotted owl was listed as a threatened species under the Federal Endangered Species Act of 1972. The number of owls was thought to have declined to dangerously low levels with the continued cutting of the remaining old-growth forests in the Pacific Northwest. The reason for the owls' association with late-successional forests is unclear; however, 6 primary hypotheses have been proposed (Forsman et al. 1984, Carey 1985, Miller 1989, Carey et al. 1990, Ripple et al. 1991, Carey et al. 1992).

Two of these hypotheses relate to the diet of spotted owls, which is dominated by northern flying squirrels (*Glaucomys sabrinus*) and woodrats

(Neotoma spp.). The prey availability hypothesis suggests that northern spotted owls select old forests because prey is more abundant in old than young forests. Alternatively, the prey vulnerability hypothesis is based on the ability of owls to forage successfully in old stands. It suggests that the dense structure of the second-growth forests may limit the owls ability to forage successfully, although prey may be equally abundant in both forest types.

Rosenberg and Anthony (1992) conducted an extensive capture-recapture study on northern flying squirrels in old- and second-growth forests of the central Oregon Cascades, where flying squirrels are the primary prey of spotted owls (Forsman et al. 1984). They reported similar densities in old- and second-growth forests; thus providing evidence for rejecting the prey abundance hypothesis.

My goal was to more closely examine northern flying squirrel home ranges and movements using telemetry techniques in these 2 forest stand conditions. We hypothesized that if northern flying squirrels had equal densities, home ranges and movements in both forest types, we could provide strong evidence to reject the prey abundance hypothesis for the central Oregon Cascades. We chose 4 of the 10 stands used by Rosenberg and Anthony (1992) because of the existing database available for these stands, including the density estimates, capture rates, and vegetative characteristics.

Northern flying squirrels are strictly nocturnal and rather difficult to live-trap, which makes use of traditional small mammal research techniques impractical. With little information on movements and habitat associations of

northern flying squirrels, I wanted to estimate habitat selection, using home range data and the previously collected vegetation data. I also suspected that den site availability may be important to the use of second- and old-growth forests by squirrels; therefore, I used daytime telemetry tracking to locate den sites and evaluated den tree characteristics in 2 of our 4 stands in 1992.

## Chapter II

### MOVEMENTS OF NORTHERN FLYING SQUIRRELS IN DIFFERENT-AGED FOREST STANDS OF WESTERN OREGON

#### ABSTRACT

We radio-marked 39 northern flying squirrels (*Glaucomys sabrinus*) to estimate their home range sizes and describe movements in 2 old- and 2 second-growth conifer stands in the Cascade Mountains of Oregon. Sampling periods were at night during the summer and fall of 1991-92. Home ranges averaged 4.9 ha. Home range size did not differ ( $P = 0.30$ ) between the 2 stand types. However, male flying squirrels had larger ( $P < 0.05$ ) mean home ranges ( $\bar{x} = 5.9$  ha,  $SE = 0.75$ ,  $n = 20$ ) than females ( $\bar{x} = 3.9$  ha,  $SE = 0.37$ ,  $n = 19$ ). Squirrel movements between successive, noncorrelated telemetry locations averaged 71 m ( $n = 1090$ ). No association was found between distances moved and stand type or sex. Northern flying squirrels had similar home range sizes, movements, and densities in old- and second-growth coniferous forests of the Cascade Mountains of western Oregon. We suggest that the abundance and movements of northern flying squirrels are not influencing the selection of late-successional forests by northern spotted owls (*Strix occidentalis caurina*), their primary predator, in the western Oregon Cascades.

## INTRODUCTION

Forest practices in the Pacific Northwest have created a fragmented landscape with even-aged second-growth stands interspersed with patches of old-growth coniferous forests (Harris 1984:23-43). The northern spotted owl has demonstrated a preference for old-growth habitat throughout this region (Forsman et al. 1977, 1982, 1984; Thomas et al. 1990:7-20, Carey et al. 1992); however less than 14% of the land historically dominated by old-growth forests currently remains in old-growth (Booth 1991). Six hypotheses have been proposed to explain this selection (Forsman et al. 1984, Carey 1985, Miller 1989, Carey et al. 1990, Ripple et al. 1991, Carey et al. 1992), including 2 based on potential differences in prey abundance and prey vulnerability between second- and old-growth forests. The prey-abundance hypothesis suggests that spotted owls select habitat patches with the most abundant prey. The prey-vulnerability hypothesis is similar, but implies selection of habitat patches with the most vulnerable or available prey. Structural differences between second- and old-growth forest make both hypotheses plausible, but difficult to test.

Northern flying squirrels are also prey for other predators, such as martens (*Martes americana*; Murie 1961, Smith 1978, Zielinski et al. 1983), great horned owls (*Bubo virginianus*; Conor 1960, Jackson 1961), and weasels (*Mustela* spp.; reviewed in Wells-Gosling and Heany 1984). Northern flying squirrels comprise a relatively large proportion of the northern spotted owls' diet, ranging from 50% of the prey biomass in the central Oregon Cascades (Forsman et al. 1984) to > 60%

of the prey biomass in parts of the Olympic Peninsula (Forsman et al. 1991). Forsman (1980) estimated that 1 spotted owl consumes approximately 260 northern flying squirrels annually in the central Oregon Cascades.

Extensive research has been conducted to determine whether prey abundance is a factor in the selection of old-growth forests by northern spotted owls. Several investigators used capture-recapture methods to estimate densities and movements of flying squirrels in old- and managed second-growth stands of the Pacific Northwest (Witt 1991, Carey et al. 1992, Rosenberg and Anthony 1992). Results differed depending on the region, methods, and analysis used. In western Washington and the Oregon Coast Range, reported densities in old-growth stands ( $\bar{x} = 1.9$  squirrels/ha) were higher than in second-growth stands ( $\bar{x} = 0.9$  squirrels/ha) (Carey et al. 1992). Similarly, in the Oregon Coast Range, estimated densities were 0.85 and 0.12 squirrels/ha in old- and second-growth stands, respectively (Witt 1991). In contrast, Rosenberg and Anthony (1992) found similar densities in these 2 stand types in the Oregon Cascade Mountains, with estimates of 2.3 and 2.0 squirrels/ha in the old- and second-growth stands respectively. Additionally, capture rates and densities for northern flying squirrels were relatively low (Rosenberg 1991, Rosenberg and Anthony 1992) making estimates of density difficult, particularly with short trapping periods (White et al. 1982:164-165).

We studied home range size and movements of northern flying squirrels in second- and old-growth coniferous forests during 1991 and 1992. We

hypothesized that northern flying squirrels would have different home range sizes in the 2 forest types because of the substantial differences in structure, vegetation, and microclimate (Brown 1985, Ruggiero et al. 1991:71-142). We also predicted that male flying squirrels would have larger home ranges than female flying squirrels as observed with many other polygynous small mammals (Madison 1980, 1985; Wolff 1989).

We greatly appreciate the dedicated field work of K. B. Apfelbeck and C. M. Thomas. We also thank D. K. Rosenberg, K. A. Swindle and the H.J. Andrews Experimental Forest staff, Willamette National Forest, Blue River Oregon for their logistical support throughout this project. This project was funded through the U.S. Fish and Wildlife Service and the USDA Forest Service, Pacific Northwest Research Station, Olympia, Washington. We also thank A. B. Carey, B. E. Coblenz, S. DeStefano, W. C. McComb, and B. J. Verts for their input and critical evaluation of earlier drafts of this manuscript. This research was conducted through the Oregon Cooperative Wildlife Research Unit in cooperation with Oregon State University, Oregon Department of Fish and Wildlife, Wildlife Management Institute, and U.S. Fish and Wildlife Service.

## **STUDY AREA**

Study sites were located in the central Oregon Cascades in the Willamette National Forest near the towns of Blue River and McKenzie Bridge, OR (Fig. 2.1). Research was conducted out of the H.J. Andrews Experimental Forest,

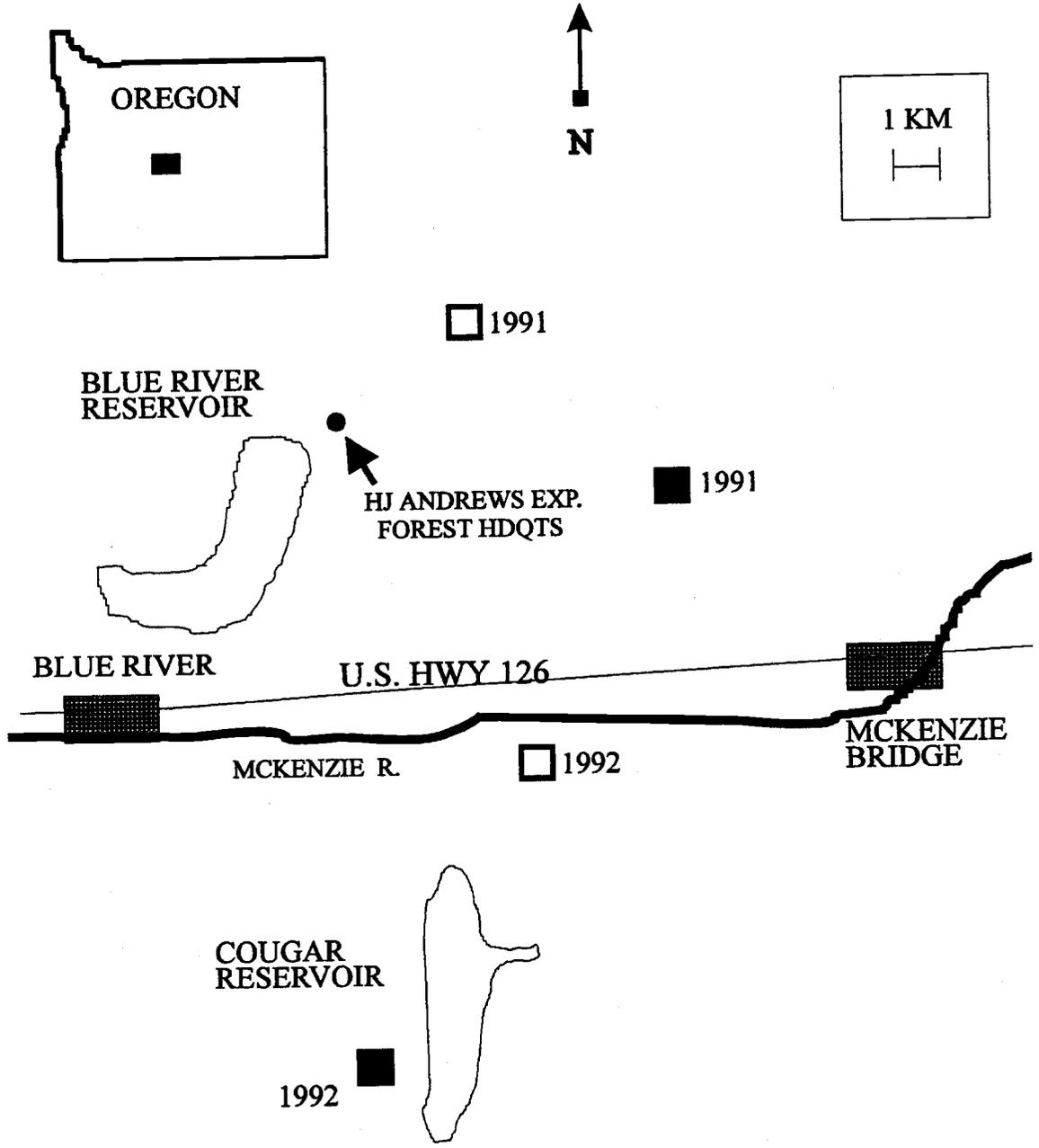


Fig. 2.1. Old-(□) and second-(■) growth study sites of northern flying squirrels in the Willamette National Forest, Oregon, 1991-92.

Blue River, Oregon. Climatic conditions in this region are characterized by warm, dry summers and mild, wet winters with mean annual precipitation of approximately 110 cm (Franklin and Dyrness 1973:38-42). Two old-growth and 2 second-growth stands were selected from the 10 stands used by Rosenberg and Anthony (1992).

The criteria used for selection included relatively level topographical features, low elevation, past history of management, and stand characteristics. The 2 second-growth stands had been clear-cut, burned, planted, and fertilized approximately 40 years previously. One old-growth stand had never been logged and both were > 400 years old. Light selection logging was done in the second old-growth stand in the early 1900's, with < 5% of the basal area removed. The 4 stands selected were relatively level (10-25% gradient) to reduce error and bounce in the telemetry bearings. The elevations of 1 old- and 1 second-growth stand were 800 and 600 m respectively, and the remaining 2 stands were < 500 m above sea level.

The 2 old-growth stands were dominated by a canopy of Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). The overstory of the 2 second-growth stands was dominated by Douglas-fir, with western hemlock and incense cedar (*Libocedrus decurrens*) also present. The upper understory (2-4 m tall) of all 4 stands was dominated by Pacific dogwood (*Cornus nuttallii*), vine maple (*Acer circinatum*), California hazel (*Corylus cornuta*), and western hemlock. Ground cover (< 2 m

tall) in all 4 stands was dominated by Oregon-grape (Berberis nervosa), salal (Gaultheria shallon), huckleberries (Vaccinium spp.), and swordfern (Polystichum munitum), with Pacific rhododendron (Rhododendron macrophyllum) exclusively in the 2 old-growth stands (see Rosenberg 1991; Rosenberg and Anthony 1992, 1993 for more detail).

## METHODS

Thirteen to 17 squirrels were live-trapped in each second- and old-growth stand in June of 1991 and 1992 (Table 2.1). Squirrels were anesthetized with metathane gas in a clear plastic cylinder to reduce stress before collaring and insure proper fitting of the radio-collar. The sex of each squirrel was determined and it was weighed, ear tagged, and fitted with a 2- to 3-g MD-2C Holohil radio-collar (Holohil Inst. Co., Ontario, Canada). Radio-telemetry techniques were used to reduce human-induced movements (e.g., attractions to trap bait) and temporal constraints associated with capture-recapture studies.

Nighttime radio-tracking began in July each year and continued through the beginning of December, at which time the batteries associated with the radiotransmitters began to fail. Simultaneous telemetry bearings were recorded by 2 observers from established grid points in each stand. Grids were approximately 13 ha with grid points located at 40-m intervals ( $\bar{n} = 100$  grid points/stand). To reduce autocorrelation in locations (Swihart and Slade 1985) and to eliminate observer-induced movements of animals,  $\leq 3$  locations ( $\bar{x} =$

Table 2.1. Number of northern flying squirrels radio-collared by stand type, sex, and year in the central Oregon Cascades, 1991-92.

Year	Old-growth		Second-growth		Total
	Male	Female	Male	Female	
1991	7	3	2	6	18
1992	6	2	5	8	21
Total	13	5	7	14	39

1.25) were obtained for each squirrel each night. Radio contact between 2 observers was used to coordinate simultaneous telemetry bearings, to assess the locations of squirrels, and to assure reasonable angles of intersection for the telemetry bearings. Three to 5 separate bearings were taken around each grid point to reduce error associated with signal bounce. The transmitters had signal distances of about 300 m; therefore, we used signal intensity to assess the approximate distance to each radio-collared squirrel and to eliminate unreasonable locations in the field. These locations occurred when there were large differences in distance estimates and squirrel locations using triangulation techniques. Radio locations  $> 300$  m from an observer or with angle intersections  $< 35$  degrees or  $> 145$  degrees were deleted to increase the precision of locations.

Animal locations were calculated and the adaptive kernel method (Whorton 1989) was used to estimate home range sizes. The CALHOME software package (J. Baldwin and J. Kie, U.S. Forest Service, Forestry Science Lab, Fresno, CA) was used to calculate and plot 95%, 90%, and 75% utilization distributions for squirrels for which  $> 40$  locations were obtained. The kernel method (Whorton 1989) was chosen to conform to the bimodal distributions of locations exhibited by several squirrels. Data for animals with  $< 40$  locations or with  $< 3$  months of telemetry data were not included in these analyses.

Eighteen animals from 1991 (7 M and 3 F in old-growth; 2 M and 6 F in second-growth) and 21 animals from 1992 (6 M and 2 F in old-growth; 5 M and 8

F in second-growth) met the criteria for analysis (Table 2.1). An effort was made to monitor equal numbers of males and females in each stand type, and year; however this was not always possible. An average of 66 locations were plotted per squirrel (range: 40-83) to determine home range and core-use areas.

### Statistical Analysis

Multiple linear regression techniques and correlation plots were used to eliminate time correlated movements. Multiple linear regression also was used to assess association of several factors to home range sizes and the distances moved between independent, successive locations. The 4 explanatory variables tested were stand age, sex, year, and the number of locations recorded for each animal. A forward stepwise variable-selection procedure was used to eliminate non-significant variables from the model. All interactions between the 4 primary covariates were explored for contributions ( $P < 0.10$ ) to the original model selected.

## RESULTS

### Daily Movements

Distances squirrels moved were not correlated with time intervals between locations when the interval between successive locations was  $> 24$  hrs ( $F = 1.13$ ; 1, 37 df;  $P = 0.30$ ), but were highly correlated with time when the interval

Table 2.2. Mean distances (meters) moved by northern flying squirrels between successive telemetry locations in old- and second-growth conifer stands of the central Oregon Cascades, 1991-92.

Sex	Old			Second		
	$\bar{x}$	(n)	SE	$\bar{x}$	(n)	SE
Males	70.6	(13)	4.3	79.3	(7)	8.7
Females	68.0	(5)	14.5	66.3	(14)	2.9

between successive locations was  $< 24$  hrs ( $P < 0.05$ ). Therefore, successive locations obtained within a 24-hr period were excluded from the analysis of squirrel movements. Squirrels moved an average of 71 m (SE = 1.6 m) between successive daily telemetry locations with a range of 0 to  $> 600$  m (Table 2.2). The longest movement was by a male that subsequently established a new home range. Distances moved over 24 hrs did not differ between stand types ( $F = 1.80$ ; 1, 2 df;  $P = 0.31$ ), or sexes ( $F = 0.47$ ; 1, 37 df;  $P = 0.50$ ); however there was a difference in distances moved between years ( $F = 14.7$ ; 1, 37 df;  $P = 0.001$ ). Movements averaged 63.5 m (SE = 2.2) in 1991 and 76.1 m (SE = 2.2) in 1992.

### Home Range Size

Home range size and number of locations ( $\bar{x} = 66$ , range: 40-83) used to calculate the areas were not related ( $F = 0.31$ ; 1, 37 df;  $P = 0.59$ ; slope  $< 0.01$ ). Home range sizes between the 2 stands of each forest type also did not differ significantly ( $F = 0.93$ ; 1, 2 df;  $P = 0.45$ ); thus the chance of individual stand or year effects were reduced.

Males had larger home ranges than females ( $F = 5.09$ ; 1, 37 df;  $P = 0.03$ ) at all utilization distributions (Tables 2.3, 2.4). Male flying squirrels had an average home range size of 5.9 ha (SE = 0.75, range 2.6-17.0), whereas female squirrels had a mean home range size of 3.9 ha (SE = 0.37, range 1.9-8.0) at the 95% utilization level.

Table 2.3. Mean home range sizes (SE) of northern flying squirrels by stand type, sex, and percent utilization distribution in the central Oregon Cascades, 1991-92.

	Mean utilization areas (ha)						Mean <sup>a</sup>
	Old			Second			
	75%	90%	95%	75%	90%	95%	
Males	2.09 (0.21)	4.53 (0.78)	6.26 (1.05)	2.21 (0.56)	3.87 (0.68)	5.14 (0.89)	5.9 (0.75)
Females	1.67 (0.50)	3.52 (0.90)	4.61 (1.16)	1.40 (0.14)	2.64 (0.23)	3.61 (0.30)	3.9 (0.37)
Mean	1.97 (0.85)	4.25 (0.61)	5.8 (0.83)	1.67 (0.22)	3.05 (0.30)	4.1 (0.38)	

<sup>a</sup> Mean 95% utilization level over both stand types.

Table 2.4. P-values from multiple linear regression models with stand age, sex, year, and number of locations used as explanatory variables. The response variables are northern flying squirrel utilization distributions at the 75, 90, and 95% levels and the distances moved between successive telemetry locations in the central Oregon Cascades, 1991-92.

Variables	Utilization levels			Distances moved
	75%	90%	95%	
Stand Age	0.99	0.34	0.30	0.84
Sex	0.02	0.03	0.02	0.17
Year	0.34	0.14	0.10	0.56
Number of locations	0.56	0.98	0.90	0.43

Northern flying squirrels had an average home range size of 5.8 ha (SE = 0.83, range 1.87-17.0) in the 2 old-growth stands and 4.1 ha (SE = 0.38, range 2.0-9.0) in the 2 second-growth stands (Table 2.3). Average home range sizes were slightly larger in old-growth stands for all utilization distributions, but these differences were not statistically significant ( $P > 0.05$ ; Power > 65%). The apparent difference in home range size between the 2 stand types was caused by the larger proportion of males in the old-growth and females in the second-growth stands (Fig. 2.2). There were 13 males and 5 females in the old-growth stands, and only 7 males and 14 females in the second-growth stands. Statistical analyses resulted in only 1 significant association between the various factors and estimated areas at the 3 utilization distribution levels. This factor was the difference associated with sex.

## DISCUSSION

Witt (1991) in the Oregon Coast Range and Weigl and Osgood (1974) in North Carolina reported home range areas for northern flying squirrels of 4.2 (range 3.4-4.9) and 4.9 ha (range 3.1-7.1), respectively. These home range areas are slightly smaller than we found; the relatively small differences could be a result of shorter sampling periods, smaller sample sizes, different analytical methods, or different habitat types used in their studies.

As with most polygynous mammals, male northern flying squirrels use larger home ranges than females. Because female northern flying squirrels are

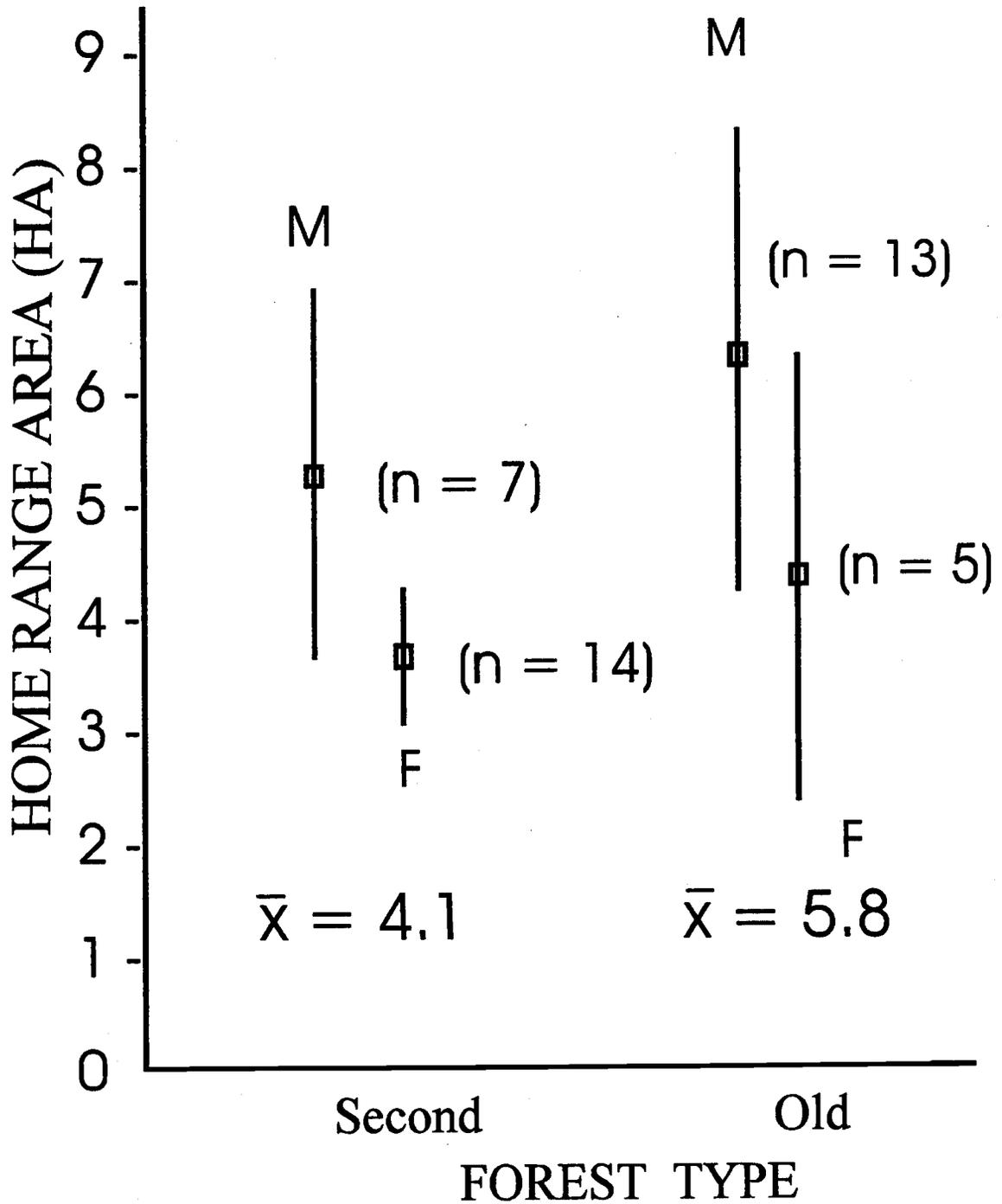


Fig. 2.2. Mean home ranges (95% utilization areas) of male and female northern flying squirrels in second- and old-growth coniferous forests of western Oregon, 1991-1992. Sample sizes ( $n$ ) represent combined data from two different stands of each forest type. The bars are  $\pm 2$  SE.

slightly larger than males (Davis 1963, Rosenberg and Anthony 1992) sexual dimorphism is not a likely explanation for this difference (Harestad and Bunnell 1979). Females probably use smaller home ranges because they have young to nurse and care for, whereas males may use larger areas to enhance their breeding potential and foraging opportunities. Similar determinants of sex-differential home range size have been observed in southern flying squirrels (Gilmore and Gates 1985, Bendel and Gates 1987, Fridell 1990) and are well documented for Microtus spp. (Madison 1980, 1985), and Peromyscus spp. (Wolff 1989).

There was no influence of stand type on home range size or squirrel movements between successive locations in this study. Rosenberg and Anthony (1992) also found no significant differences in density of flying squirrels in these 2 stand types in the Oregon Cascade Mountains. Therefore, the abundance, home range size and movements of northern flying squirrels seems not to be affected by inherent differences between second- and old-growth stands in the central Oregon Cascades. Our data indicates that some factor other than abundance or movements of flying squirrels is affecting differential use of old-growth or second-growth habitats by northern spotted owls in this area. A more plausible explanation may be the effect of vegetative structure on the selection of foraging habitat by spotted owls. We hypothesize that forest structure determines the owl's access to northern flying squirrels. The second-growth stands that we worked in were dense, and they may not provide sufficient open spaces below the canopy where spotted owls can fly to capture prey. The inferences from this study are

limited by the small number of stands sampled, the time of year sampling was done, and to the central Oregon Cascades.

## **RESEARCH AND MANAGEMENT IMPLICATIONS**

Habitat quality is difficult and probably inappropriate to judge for relatively abundant species based on density, movements, and home range data (Van Horne 1983). Other investigators (Carey et al. 1990, Witt 1991) inappropriately have used northern flying squirrel densities as an indicator of habitat quality in the Pacific Northwest. Although squirrel abundance is probably not a factor in the selection of old-growth versus second-growth habitat by spotted owls in the central Oregon Cascades, we did not assess the quality of these 2 habitat types for northern flying squirrels. Further research is needed to assess reproductive rates, and survival of northern flying squirrels in various habitat types, before we can address questions of habitat quality for this species.

Because prey vulnerability seems to influence stand selection by northern spotted owls in the central Oregon Cascades, research focused on the manipulation of stand structure in second-growth stands to assess impacts on flying squirrel populations and vulnerability to foraging by northern spotted owls is needed. Several researchers have predicted that creation of old-growth structure through thinning and selective cutting may provide habitat for northern spotted owls and their prey (U.S. Dep. of Inter. 1992:481-525). With northern spotted owl populations reduced to critically low levels it may be necessary to

supplement reserves of late-successional forests with areas managed to produce "old-growth" characteristics to enhance existing spotted owl populations. Whether these managed "old-growth" areas can provide habitat for all species associated with late-successional forests is uncertain (U.S. Dep. of Inter. 1992:336-337); therefore, they should not be used as a substitute for the conservation of late-successional forests.

### Chapter III

#### HABITAT SELECTION OF NORTHERN FLYING SQUIRRELS IN THE CENTRAL OREGON CASCADES

##### ABSTRACT

Thirty-nine northern flying squirrels (*Glaucomys sabrinus*) were radio-collared in June of 1991 and 1992 in 2 second- and 2 old-growth forest stands in the central Oregon Cascades. Squirrels were located using nighttime telemetry techniques from July through November each year. In 1992, 46 daytime den sites were located in the old-growth stand and 62 den sites were located in the second-growth stand. Home ranges and core-use areas (75% of the utilization distribution) were mapped and overlaid onto habitat sampling units distributed evenly throughout each stand. We used logistic regression procedures to estimate habitat selection by assigning numerical values to each habitat plot based on the number of squirrels which had core-use areas overlapping that particular plot. Squirrels avoided areas with large down wood ( $P = 0.0002$ ) in the old-growth stands and areas with high densities of small snags ( $P = 0.003$ ) in the second-growth stands. Trees used as daytime den sites were larger than the average tree available for nesting in both stand types ( $P < 0.0001$ ). Snags were not selected for den sites.

## INTRODUCTION

Northern flying squirrels are distributed in conifer, conifer-deciduous, and occasionally deciduous forests across North America (Wiegl 1978, Wells-Gosling and Heaney 1984). Estimated densities vary from 0.5 squirrels/ha to 2.0 squirrels/ha in various habitat types (Rosenberg and Anthony 1992). Although widely distributed and abundant, there have been few detailed studies on northern flying squirrels. Weigl and Osgood (1974) conducted the most extensive studies of habitat associations of northern flying squirrels using temperature-sensitive radio-telemetry techniques in North Carolina and Pennsylvania. In the Pacific Northwest, Rosenberg and Anthony (1992), Carey et al. (1992) and Witt (1991) used capture-recapture methods to estimate densities and movements. Witt (1991) also estimated squirrel home range sizes, but the sample size and period of radio-tracking were both too small to evaluate statistically. Davis (1963) used lethal methods in southeast Alaska to evaluate reproductive strategies and weight variations between males and females.

In the Pacific Northwest there has been a recent effort to learn as much as possible about northern flying squirrels, which are the primary prey of spotted owls in much of Oregon and Washington. One hypothesis for the spotted owls' selection of late-successional forests is the possible difference in prey abundance in old- and second-growth forests (the prey abundance hypothesis). Another possible explanation for the selection of older forests by spotted owls has to do with the differential vulnerability of squirrels to predation. Second-growth stands

are shorter in height and have higher stem densities than old-growth stands, which may inhibit the owl's flight and foraging ability (the prey vulnerability hypothesis).

We radio-collared northern flying squirrels in both old- and second-growth conifer stands in the central Oregon Cascades to learn more about their habitat relationships. Radio-tracking techniques were used to determine the home range, den sites, and core-use areas of northern flying squirrels. The primary objective of our research was to determine habitat characteristics associated with core-use areas and daytime den sites in both old- and second-growth forests.

## **STUDY AREA AND METHODS**

Study sites were located in the central Oregon Cascades in the Willamette National Forest near the towns of Blue River and McKenzie Bridge, OR. Research activities were conducted out of the H.J. Andrews Experimental Forest, Blue River, Oregon. Climatic conditions in this region are characterized by warm, dry summers and mild, wet winters, with mean annual precipitation of approx 110 cm (Franklin and Dyrness 1973:38-42). Two old-growth and 2 second-growth stands were selected from the 10 stands used by Rosenberg and Anthony (1992). The criteria used for selection included topographical features, elevation, past history, and stand characteristics.

The 2 second-growth stands had been clear-cut, burned, planted, and fertilized approximately 40 years previously. Both old-growth stands were > 400 years old, and 1 had never been logged. Light selection logging was done in the

second old-growth stand in the early 1950's, with < 5% of the basal area removed. The 4 stands selected were relatively level (10-25% gradient) to reduce bounce and error of telemetry bearings. The elevations of 1 old- and 1 second-growth stand were 800 and 600 m respectively, and the remaining 2 stands were < 500 m above sea level.

The 2 old-growth stands were dominated by a canopy of Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). The overstory of the 2 second-growth stands was dominated by Douglas-fir, with lesser amounts of western hemlock and incense cedar (*Libocedrus decurrens*). The upper understory (2-4 m tall) of all 4 stands was dominated by Pacific dogwood (*Cornus nuttallii*), vine maple (*Acer circinatum*), California hazel (*Corylus cornuta*), and western hemlock. Ground cover (< 2 m tall) was dominated by Oregon-grape (*Berberis nervosa*), salal (*Gaultheria shallon*), huckleberries (*Vaccinium* spp.), and swordfern (*Polystichum munitum*) in all 4 stands, with Pacific rhododendron (*Rhododendron macrophyllum*) exclusively in the 2 old-growth stands (see Rosenberg 1991; Rosenberg and Anthony 1992, 1993 for more detail).

Trapping grids (approximately 13 ha each) with 40-m grid intervals (approximately 100 stations) were trapped with 2 Tomahawk live-traps per station in an old- and second-growth stand in June of 1991 and 1992. Thirteen to 17 squirrels were live-trapped in each second- and old-growth stand in June of 1991 and 1992. Squirrels were anesthetized with metathane gas in a clear plastic

cylinder to reduce stress before radio-collaring and to insure proper fitting of the radio-collar. The sex of each squirrel was determined and it was weighed, ear tagged, and fitted with a 2- to 3-g MD-2C Holohil radio-collar (Holohil Inst. Co., Ontario, Canada).

### Core-use Areas

Nighttime radio-tracking began in July each year and continued through the beginning of December, at which time the batteries in the radio transmitters began to fail. Simultaneous telemetry bearings were recorded by 2 observers from established grid points in each stand. To reduce autocorrelation in locations (Swihart and Slade 1985) and to eliminate observer-induced movements of animals, no more than 3 locations ( $\bar{x} = 1.25$ ) were obtained for each squirrel per night. Radio contact between 2 observers was used to coordinate simultaneous telemetry bearings, to assess the locations of squirrels, and to assure reasonable angles of intersection for the telemetry bearings. Three to 5 separate bearings were taken from each grid point to reduce error associated with signal bounce. The transmitters had signal distances of about 300 m; therefore, we used signal intensity to assess the approximate distance to each radio-collared squirrel and to eliminate unreasonable locations in the field. These locations occurred when there were large differences in distance estimates and squirrel locations via triangulation techniques. Radio locations > 300 m from an observer or with

angle intersections  $< 35$  degrees or  $> 145$  degrees were deleted to increase the accuracy of locations.

Animal locations were calculated and the adaptive kernel method (Whorton 1989) was used to estimate home range sizes and core-use areas. The CALHOME software package (J. Baldwin and J. Kie, U.S. Forest Service, Forestry Science Lab, Fresno, CA) was used to calculate and plot 95%, 90%, and 75% utilization distribution areas for squirrels for which  $> 40$  locations were obtained. The kernel method (Whorton 1989) was chosen to conform to the bimodal distributions of locations exhibited by several squirrels. We used the 75% utilization distribution as the core-use areas since these were approximately half the size of the estimated home range areas (95% utilization distribution area; see Chapter 2). Data for animals with  $< 40$  locations or with  $< 3$  months of telemetry data were not included in these analyses. Five of the 39 collared squirrels established home ranges outside the grid areas. Home range data on these squirrels were not included in the habitat use analysis because there was no vegetative sampling done outside the established grids; therefore our core-use habitat analysis is based on a sample size of 34 squirrels.

Sixteen animals from 1991 (7 M and 3 F in old-growth; 2 M and 4 F in second-growth) and 18 animals from 1992 (6 M and 2 F in old-growth; 4 M and 6 F in second-growth) met the criteria for the core-use habitat analysis. An effort was made to monitor equal numbers of males and females in each stand type, and

year; unfortunately this was not always possible. An average of 67 locations were plotted per squirrel (range: 40-83) to determine home range and core-use areas.

Habitat variables were collected by Rosenberg and Anthony (1992, 1993) during the summer of 1988 in all 4 stands. Circular plots of 20-m-radius (0.12 ha) and 12.6-m-radius (0.05 ha) were used to measure 22 microhabitat variables (Table 3.1) at every third trapping station (approximately 33 habitat plots/stand). Squirrel core-use areas were overlaid onto each of these trapping grids in each stand to identify areas of high- and low-use. Each vegetative sampling station was given a rank of 0 to 4 depending on the number of core-use areas that overlapped the station. For example, a ranking of 4 was assigned to a station/plot when 4 squirrels had core-use areas overlapping that particular plot.

### Den Tree Characteristics

Radio-telemetry techniques were used to locate 108 daytime den sites (43 in old-growth and 65 in second-growth) for 39 squirrels (16 in old-growth, 23 in second-growth) between June and September of 1992. Potential den trees surrounding the actual den tree were eliminated using radio-signal intensity; this process usually required several hours before we were confident we had the correct tree. On 7 separate occasions it was impossible to determine which of 2 or 3 trees was the actual den tree. This occurred 6 times in the old-growth stand and once in the second-growth stand, when several large trees were located in close proximity to each other. The potential den trees were always the same

Table 3.1. Mean ( $\bar{x}$ ) and standard error (SE) values for habitat variables collected in 2 old- and 2 second-growth stands in the central Oregon Cascades during the summer of 1988 (Rosenberg and Anthony 1992, 1993).

Habitat Variables	Second-Growth				Old-Growth			
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Herb cover (%)	7.5	1.2	3.0	0.6	16.7	2.4	4.3	0.5
Woody debris cover (%)	8.4	0.9	7.4	0.8	11.5	1.0	10.9	1.1
Moss cover (%)	11.8	1.4	8.5	1.3	18.7	2.3	25.6	2.5
Salal cover (%)	3.5	0.6	2.0	0.6	0.5	0.2	6.6	1.2
Fern cover (%)	8.7	1.5	7.8	1.3	3.2	1.2	8.7	1.3
Deciduous cover (<5 cm DBH) (%)	16.2	2.1	1.0	0.4	6.6	1.4	9.5	1.9
Conifer cover (<5 cm DBH) (%)	1.1	0.3	2.5	0.5	6.8	1.1	6.3	1.3
Rhododendron cover (%)	0	0	0	0	3.8	1.6	1.8	0.5
Oregon grape cover (%)	7.1	1.1	3.6	0.5	3.1	0.7	7.6	1.1
Down-wood								
25-49 cm dia., m <sup>3</sup> /ha	13.2	1.7	22.5	2.3	27.0	2.4	17.6	2.6
≥50 cm dia., m <sup>3</sup> /ha	46.6	7.7	56.4	6.5	62.6	8.0	75.8	8.5
Snags								
10-49 cm DBH, #/ha	63.0	10.4	16.4	4.0	36.2	8.5	16.4	4.6
≥50 cm dia., m <sup>3</sup> /ha	4.1	0.9	0.7	0.4	16.7	2.0	10.1	1.9
Stumps (#/ha)	56.0	4.3	67.7	5.1	9.2	1.7	15.7	2.5
Conifer stems								
5-10 cm DBH, #/ha	69.6	10.2	311.4	34.1	113.6	14.1	128.4	15.2
>10-49 cm DBH, #/ha	446.1	29.7	777.6	35.6	228.6	25.7	210.2	21.7
≥50 cm DBH, #/ha	4.6	1.1	1.0	0.5	75.0	4.4	56.7	3.9
Deciduous stems								
5-10 cm DBH, #/ha	174.5	36.8	53.8	14.2	41.9	9.7	81.2	15.2
>10-49 cm DBH, #/ha	132.1	21.8	26.1	8.8	9.4	3.5	31.5	5.4
≥50 cm DBH, #/ha	1.0	0.5	0.7	0.5	0.2	0.2	1.0	0.6
Tree diameter CV (%)	25.1	1.4	26.5	0.9	36.7	1.4	40.1	1.0
Soil organic depth (cm) <sup>a</sup>	5.3		1.5		9.9		8.6	

<sup>a</sup>Values reported are the mean of the median for each plot

species and similar in diameter breast height (dbh), so habitat variables for the 2 or 3 potential den trees were averaged for this analysis. Dens were classified as dray (defined as visible nests made of sticks, moss, and grass) or unknown type, which may have been cavity nests or dray nests that were not visible from the ground. Den trees were classified as live or dead (snags), with species, dbh, and location recorded for each den tree. Average tree size and snag density were determined from habitat sampling plots (Rosenberg 1992, 1993) for each stand.

## **STATISTICAL ANALYSIS**

### **Core-use Areas**

Logistic regression procedures (Ramsey et al. 1994) were used to determine which microhabitat variables the squirrels were selecting or avoiding in their core-use areas compared to non-use or low-use areas. Old- and second-growth stands were evaluated separately and then combined to evaluate squirrel habitat relationships within each stand type and over all stand types regardless of age. The response variable for this analysis was the number of core-use areas that overlapped a particular habitat plot. The independent variables were the mean values for the microhabitat characteristics (Table 3.1) measured at each circular plot. A total of 90 second- and third-order interactions between related groups of habitat variables were explored for associations with the core-use areas.

The deviance statistic was computed for each variable in the model and evaluated for statistical significance with the chi-square distribution with 1 degree of freedom. The original 22 habitat variables and interaction terms with  $P \leq 0.02$  were included in the final models for evaluation. There were 3, 4, and 6 significant interactive terms in second-growth, old-growth, and combined stand ages respectively. For the final models we used an alpha-level of  $P \leq 0.03$  because of the large number of variables in the models ( $n \geq 25$ ).

### Den Tree Characteristics

We used a student's  $t$ -test to compare the dbh of den trees to the dbh of trees available for nesting in each stand. We also compared the use of live trees versus snags for den sites to what was available for nesting in the old- and second-growth stands.

## RESULTS

### Core-use Characteristics

Logistic regression procedures identified 1 main affect and 1 interactive term in our final model for the 2 second-growth stands. Squirrels tended to avoid areas with high numbers of small snags (10 - 49 cm dbh) in the second-growth stands ( $P = 0.003$ ) (Fig 3.1a). The interactive term of Oregon grape cover and salal cover was significant ( $P = 0.000001$ ) although neither Oregon grape nor salal

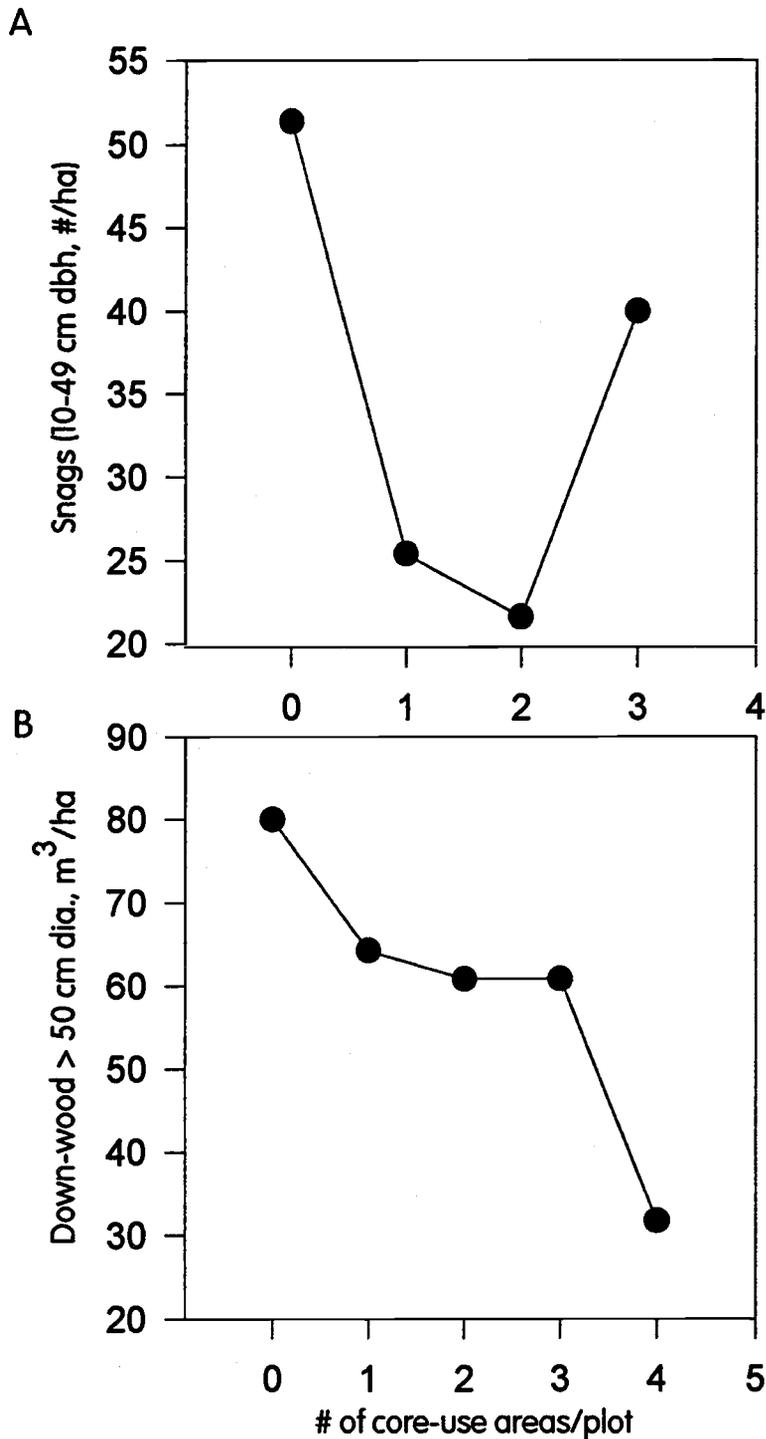


Fig. 3.1. Habitat characteristics vs. number of squirrel core-use areas overlapping vegetation sampling plots in the central Oregon Cascades. A) Small snags (10-49 cm dbh) vs. squirrel core-use areas in 2 second-growth stands. B) Abundance of large down-wood (> 50 cm dia.) vs. number of core-use areas in 2 old-growth stands.

were significant variables individually. Graphical representations (Fig. 3.2a) show that mean values of salal cover increase with squirrel use while mean values for Oregon grape cover show decreasing trends with squirrel use. Squirrels were selecting areas with increasing amounts of salal combined with decreasing amounts of Oregon grape in the 2 second-growth stands (Fig. 3.2b).

In the 2 old-growth stands, squirrels avoided areas with high amounts of large ( $\text{dbh} \geq 50 \text{ cm}$ ) down wood ( $P = 0.0002$ ) (Fig. 3.1b). The interactive term of deciduous cover ( $\text{dbh} < 5 \text{ cm}$ ) and salal cover ( $P = 0.0000001$ ) was significant (Fig. 3.3b); however neither of these terms were significant alone. It seems that squirrels are selecting areas with increasing amounts of deciduous cover combined with decreasing amounts of salal cover in the 2 old-growth stands (Fig. 3.3a).

When all 4 stands were combined, squirrels did not seem to be selecting for any of the main affects. The interactive term of salal and deciduous cover ( $P = 0.0043$ ) was significant; but this was probably a result of carry over effect from the old-growth stands where this term was highly associated ( $P = 0.0000001$ ) with core-use areas.

### Den Tree Characteristics

Den trees averaged 36.0 cm ( $\text{SE} = \pm 1.6$ ) and 101.0 cm ( $\text{SE} = \pm 6.1$ ) in the second- and old-growth stands, respectively. The average dbh of available den trees was 28.4 cm ( $\text{SE} = \pm 0.3$ ) and 59.0 cm ( $\text{SE} = \pm 1.8$ ) in the second- and old-growth stands respectively; therefore, squirrels selected trees for den sites that

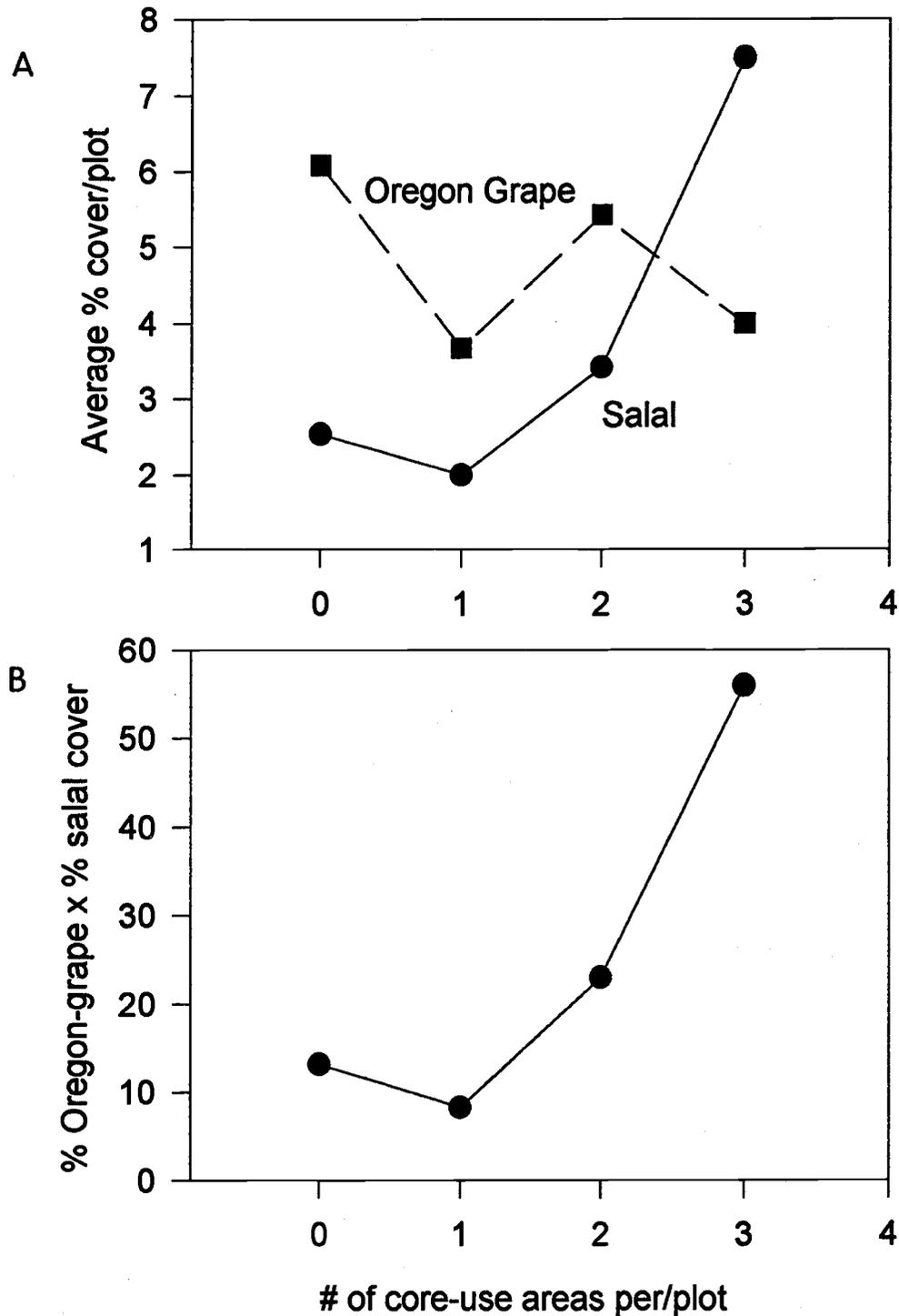


Fig. 3.2. Average % habitat cover vs. number of squirrel core-use areas overlapping vegetation sampling plots in 2 second-growth stands of the central Oregon Cascades. A) Percent Oregon grape and salal cover vs. core-use areas. B) The interaction term of % Oregon-grape cover and % salal cover vs. squirrel core-use areas.

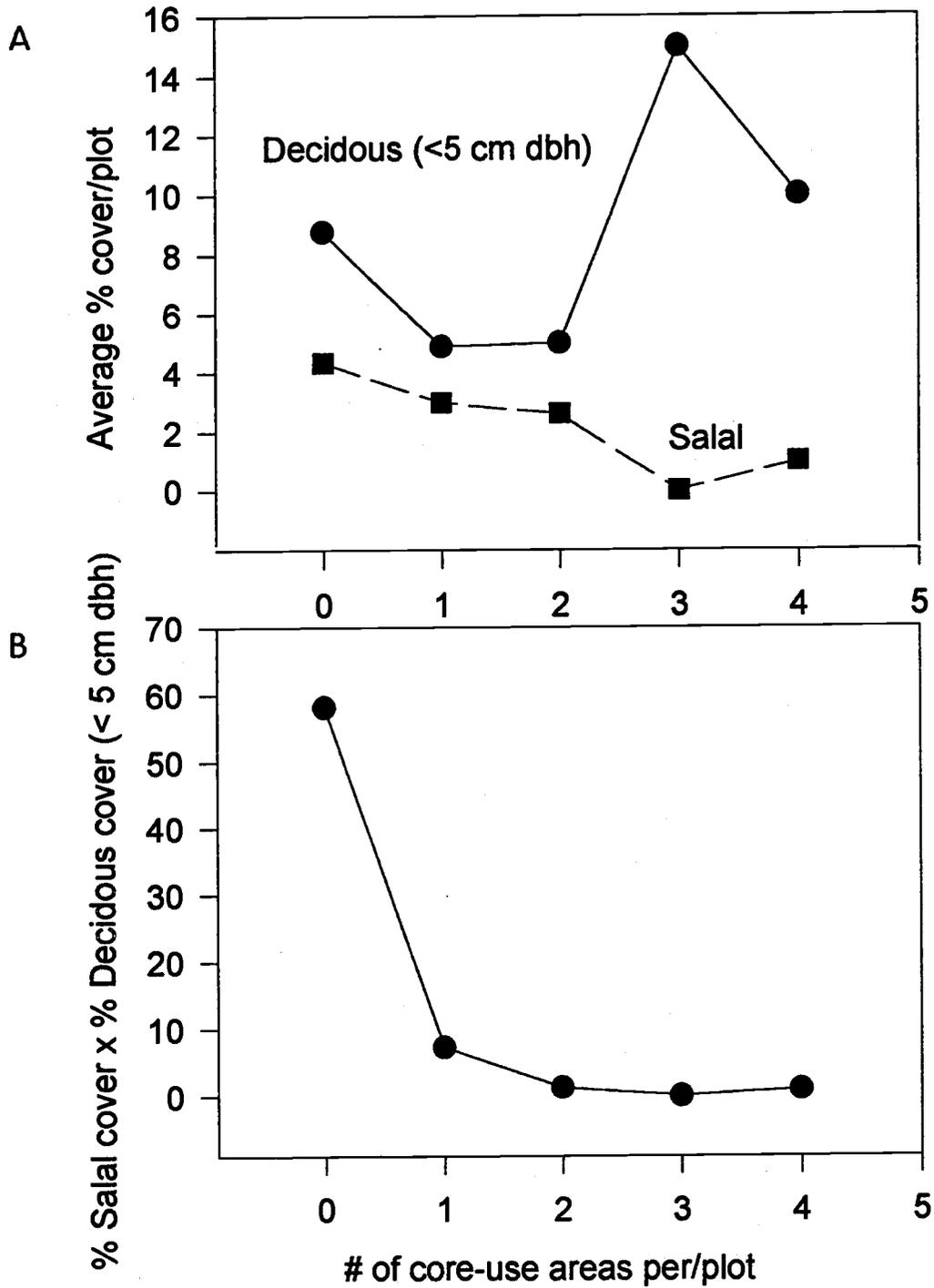


Fig. 3.3. Average % habitat cover vs. number of squirrel core-use areas overlapping vegetation sampling plots in 2 old-growth stands of the central Oregon Cascades. A) Percent deciduous (<5 cm dbh) and salal cover vs. core-use areas. B) The interaction term of % deciduous cover and % salal cover vs. squirrel core-use areas.

were significantly larger than average in both the second- ( $P < 0.001$ ) and old-growth ( $P < 0.001$ ) stands.

All 42 den sites located in the old-growth stand were in live trees. Of the 64 dens located in the second-growth stand, only 3 were in snags, with the remaining 61 in live trees. Therefore, squirrels did not select snags as den trees in either stand type.

## DISCUSSION

Northern flying squirrels avoided areas with high densities of small snags (10 - 49 cm dbh) in the second-growth stands of the central Oregon Cascades; these small snags usually result from suppression mortality in areas with extremely high tree densities in young stands. We hypothesize that squirrels may be avoiding areas with high densities of small snags because of the associated high tree densities. High tree densities might limit flying squirrels' ability to glide effectively.

In the 2 old-growth stands, squirrels avoided areas with large amounts of woody debris (dbh  $\geq$  50 cm). In old-growth forests of the Pacific Northwest, areas with high quantities of large woody debris may be associated with gaps in the forest canopy (Spies pers. comm.). We speculate that squirrels are avoiding these areas because: 1) they may be more vulnerable to avian and mammalian predation caused by a lack of ground cover, 2) there are few large trees to climb and glide from, and 3) squirrels are extremely uncoordinated on nonbark surfaces

(personal observation). These areas also may lack appropriate structure (large trees/snags) in which squirrels could construct nest sites.

The interaction terms of Oregon-grape cover and salal cover in second-growth and deciduous cover and salal cover in old-growth were highly significant, but the ecological interpretation of these interactions is difficult and highly speculative. In second-growth stands squirrels may be selecting areas with increasing amounts of salal cover and decreasing amounts of Oregon grape cover to provide protection from predators. Likewise, squirrels in old-growth stands may select areas with increasing amounts of deciduous cover and decreasing amounts of salal cover to avoid predation while still being somewhat mobile. Another possibility is that squirrels are not selecting for these habitat characteristics themselves, but for some other characteristic which is associated with these interactive terms. If so, the most likely association would be a food source, such as lichens or truffles, which comprise the majority of the squirrels' diet in the Pacific Northwest (Maser et al. 1985, Maser et al. 1986).

Squirrels do not seem to be old-growth obligates or to select old-growth as several investigators have suggested (Carey 1991a, Witt 1991, Carey et al. 1992), although they do seem to select trees > 25 cm in diameter for their den sites. There may be a minimal stand age or structure that squirrels require, but this is probably between 20 and 40 years in the Pacific Northwest since the 40- to 50-year-old stands we studied had similar squirrel densities (Rosenberg and Anthony 1992), movements and home ranges to our old-growth stands.

We also found no selection for snags as den sites, as several researchers have reported (Carey et al. 1991a). Den site data were collected from July through September, so squirrels in our stands may be using snags as den sites at higher rates during the winter months, although cavities in snags were rare in our second-growth stands.

Squirrels did not clearly select any habitat; they seemed to be habitat generalists within each stand type. However, we may not have sampled the particular habitat variable(s) that squirrels select in these stands. We did not look at food abundance relative to core-use areas, which may be a key factor in habitat selection by northern flying squirrels.

#### **ACKNOWLEDGEMENTS**

We greatly appreciate the dedicated field work of K. B. Apfelbeck, C. M. Thomas, and Spencer Smith. We also thank D. K. Rosenberg, K. A. Swindle and the H.J. Andrews Experimental Forest staff, Willamette National Forest, Blue River Oregon for their logistical support throughout this project. This project was funded through the U.S. Fish and Wildlife Service and the USDA Forest Service, Pacific Northwest Research Station, Olympia, Washington. We also thank B. E. Coblenz, W. C. McComb, and B. J. Verts for their input and critical evaluation of earlier drafts of this manuscript. This research was conducted through the Oregon Cooperative Wildlife Research Unit in cooperation with Oregon State

University, Oregon Department of Fish and Wildlife, Wildlife Management  
Institute, and U.S. Fish and Wildlife Service.

## Chapter IV

### SUMMARY AND CONCLUSIONS

Northern flying squirrels seem to be habitat generalists in old- and second-growth conifer forests of the central Oregon Cascades. The vegetative and microclimate conditions vary greatly between old- and second-growth forests; however, we did not detect differences in squirrel activity patterns (home range sizes and movements) or densities (Rosenberg 1991, Rosenberg and Anthony 1992) in these 2 stand types. Squirrels avoided habitat conditions with either an extremely dense cover or no cover at all, but did not seem to select areas according to variations in any of the 22 habitat variables measured.

The selection of old-growth forests over second-growth forests by northern spotted owls does not seem to be associated with differences in prey abundances in the central Oregon Cascades as several researchers have speculated. I hypothesize that the dense forest structure in the second-growth forests may be limiting the spotted owls' ability to forage successfully.

Future research objectives on northern flying squirrels in the Pacific Northwest should be focused on diets, food availability, reproduction, and dispersal of squirrels in a variety of forest types, structures, and ages. To get accurate measures of squirrel fitness it will be necessary to improve existing

techniques or develop new ones to monitor reproduction and survival of these arboreal rodents.

To further test hypotheses on prey relationships associated with the spotted owls' preference of old-growth forests, it may be necessary to manipulate second-growth forests within existing spotted owl home-ranges. Intense thinning of these second-growth forests may create an open forest structure that could be more conducive to flight and foraging by spotted owls. If spotted owls continue to avoid these artificially created second-growth areas within their home ranges, then we could reject the hypothesis that forest structure limits the spotted owls' ability to forage successfully (prey vulnerability hypothesis) in second-growth stands.

## BIBLIOGRAPHY

- Bart, J., and E. D. Forsman. 1992. Dependence of northern spotted owls Strix occidentalis caurina on old-growth forests in the western USA. *Biol. Cons.* 62:95-100.
- Bendel, P. R., and J. E. Gates. 1987. Home range and microhabitat partitioning of the southern flying squirrel (Glaucomys sabrinus). *J. Mammal.* 68:243-255.
- Booth, D. E. 1991. Estimating prelogging old-growth in the Pacific Northwest. *J. For.* 89:25-29.
- Brown, E. R. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. U.S. For. Serv. Publ. No. R6-F&WL-192-1985. 332pp.
- Carey, A. B. 1985. A summary of the scientific basis for spotted owl management. Pages 100-114 in R. J. Gutierrez and A. B. Carey, eds. Ecology and management of the spotted owl in the Pacific Northwest. U.S. For. Serv. Gen. Tech. Rep. PNW-185.
- \_\_\_\_\_, J. A. Reid, and S. P. Horton. 1990. Spotted owl home range and habitat use in southern Oregon Coast Ranges. *J. Wildl. Manage.* 54:11-17.
- \_\_\_\_\_, 1991a. The biology of arboreal rodents in Douglas-fir forests. U.S. For. Serv. Gen. Tech. Rep. PNW-276.
- \_\_\_\_\_, 1991b. Methods for measuring populations of arboreal rodents. U.S. For. Serv. Gen. Tech. Rep. PNW-GTR-273.
- \_\_\_\_\_, S. P. Horton, and B. L. Biswell. 1992. Northern spotted owls: influence of prey base and landscape character. *Ecol. Monogr.* 62:223-250.
- Conor, P. F. 1960. The small mammals of Otsego and Schoharie counties, New York. *New York State Mus. Sci. Serv. Bull.* 382:1-84.
- Davis, W. 1963. Reproductive ecology of the northern flying squirrel in Saskatchewan. M.A. Thesis, Univ. Saskatchewan, Saskatoon. 87pp.
- Forsman, E. D. 1980. Habitat utilization by spotted owls in the west-central Cascades of Oregon. Ph.D. Thesis, Oregon State Univ. Corvallis. 95pp.

- \_\_\_\_\_, K. M. Horn, and W. Neitro. 1982. Spotted owl research and management in the Pacific Northwest. *Trans. N. Amer. Wildl. and Nat. Resour. Conf.* 47:323-331.
- \_\_\_\_\_, E. C. Meslow, and M. J. Straub. 1977. Spotted owl abundance in young versus old-growth forests, Oregon. *Wildl. Soc. Bull.* 5:43-47.
- \_\_\_\_\_, \_\_\_\_\_, and H. M. Wight. 1984. Distribution and biology of the spotted owl in Oregon. *Wildl. Monogr.* 87. 64pp.
- \_\_\_\_\_, I. Otto, and A. B. Carey. 1991. Diets of spotted owls on the Olympic Peninsula, Washington and Roseburg District, Bureau of Land Management. Page 527 in L. R. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, tech. coordin. *Wildlife and vegetation of unmanaged Douglas-fir forests.* U.S. For. Serv. Gen. Tech. Rep. PNW-285.
- Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. U.S. For. Serv. Gen. Tech. Rep. PNW-8. 417pp.
- Fridell, R. A. 1990. The influence of vegetation composition on habitat use and home range size of southern flying squirrels. M.S. Thesis, Univ. New Hampshire, Durham. 49pp.
- Jackson, H. H. T. 1961. *Mammals of Wisconsin.* Univ. Wisconsin Press, Madison. 504pp.
- Gilmore R. M., and J. E. Gates. 1985. Habitat use by the southern flying squirrel at a hemlock-northern hardwood ecotone. *J. Wildl. Manage.* 49:703-710.
- Harris, L. D. 1984. *The fragmented forest: island biogeography theory and preservation of biotic diversity.* University of Chicago Press, Chicago, Ill. 211pp.
- Harestad, A. S., and F. L. Bunnell. 1979. Home range and body weight--a reevaluation. *Ecology* 60:389-402.
- Madison, D. M. 1980. An integrated view of the social biology of Microtus pennsylvanicus. *The Biologist.* 62:20-33.
- \_\_\_\_\_. 1985. Activity rhythms and spacing. Pages 373-419 in R. J. Tamarin, ed. *Biology of New World Microtus.* Spec. Publ. Am. Soc. Mammal. No. 8.

- Maser, C., Z. Maser, J. Witt, and G. Hunt. 1986. The northern flying squirrel: a mycophagist in southwestern Oregon. *Can. J. Zool.* 64:2086-2089.
- Maser, Z., C. Maser, and J. M. Trappe. 1985. Food habits of the northern flying squirrel (*Glaucomys sabrinus*) in Oregon. *Can. J. Zool.* 63:1084-1088.
- Miller, G. S. 1989. Dispersal of juvenile spotted owls in western Oregon. M.S. Thesis, Oregon State Univ., Corvallis.
- Murie, A. 1961. Some food habits of the marten. *J. Mammal.* 42:516-521.
- Ramsey, F. L., M. McCracken, J. A. Crawford, M. S. Drut, and W. J. Ripple. 1994. Habitat association studies of the northern spotted owl, sage grouse, and flammulated owl. Pages 189-209 (Chapter 10) in N. Lange, L. Ryan, L. Billard, D. Brillinger, L. Conquest, and J. Greenhouse Editors. Case studies in biometry. John Wiley and Sons, Inc.
- Ripple, W. J., D. H. Johnson, K. T. Hershey, and E. C. Meslow. 1991. Old-growth and mature forests near spotted owl nests in western Oregon. *J. Wildl. Manage.* 55:316-318.
- Rosenberg, D. K. 1991. Population characteristics of northern flying squirrels and Townsend's chipmunks in second- and old-growth forests. M.S. Thesis, Oregon State Univ., Corvallis. 62pp.
- \_\_\_\_\_, and R. G. Anthony. 1992. Characteristics of northern flying squirrel populations in second- and old-growth forests in western Oregon. *Can. J. Zool.* 70:161-166.
- \_\_\_\_\_, and \_\_\_\_\_. 1993. Differences in Townsend's chipmunk populations between second- and old-growth forests in western Oregon. *J. Wildl. Manage.* 57:365-372.
- Ruggiero, L. F., K. B. Aubry, A. B. Carey, and M. H. Huff. 1991. Wildlife and vegetation of unmanaged Douglas-fir forests. U.S. For. Serv. Gen. Tech. Rep. PNW-GTR-285. 533pp.
- Smith, C. C. 1978. Structure and function of the vocalizations of tree squirrels (*Tamiasciurus*). *J. Mammal.* 59:793-808.
- Swihart, R. K., and N. A. Slade. 1985. Testing for independence of observations in animal movements. *J. Wildl. Manage.* 66:1176-1184.

- Thomas, J. W., E. D. Forsman, J. B. Lint, E. C. Meslow, B. R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. U.S. Gov. Printing Off., Washington, D.C. 427pp.
- U.S. Department of Interior. 1992. Recovery plan for the northern spotted owl - draft. Washington, D.C. 662pp.
- Van Horne, B. 1983. Density as a misleading indicator of habitat quality. *J. Wildl. Manage.* 47:893-901.
- Weigl, P. D. 1978. Resource overlap, interspecific interactions, and the distribution of the flying squirrel, *Glaucomys volans* and *G. sabrinus*. *The Am. Midl. Nat.* 92:482-486.
- \_\_\_\_\_, and D. W. Osgood. 1974. Study of the northern flying squirrel, *Glaucomys sabrinus*, by temperature telemetry. *Am. Midl. Nat.* 92:482-486.
- Wells-Gosling, N., and L. R. Heaney. 1984. *Glaucomys sabrinus*. *Mammal. Species No.* 229. 8pp.
- White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos Natl. Lab. Publ. La-8787-NERP. 235pp.
- Whorton, B. J. 1989. Kernel methods for estimating the utilization distribution in home range studies. *Ecology* 70:164-168.
- Witt, J. W. 1991. Home range and density estimates for the northern flying squirrel, (*Glaucomys sabrinus*), in western Oregon. *J. Mammal.* 73:921-929.
- Wolff, J. O. 1989. Social behavior. Pages 271-291 in G. L. Kirkland, Jr., and J. N. Layne, eds. *Advances in the study of Peromyscus (Rodentia)*. Texas Tech. Univ. Press, Lubbock. 367pp.
- Zielinski, W. J., W. D. Spencer, and R. H. Barrett. 1983. Relationship between food habits and activity patterns of pine martens. *J. Mammal.* 64:387-396.