AN ABSTRACT OF THE THESIS OF

Kit Hershey for the degree of Master of Science in Wildlife Science presented on November 7,1995. Title: Characteristics of Forests at Spotted Owl Nest Sites in the Pacific Northwest

Abstract approval: Redacted for Privacy

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This study describes the composition and structure of forests within the immediate vicinity of Northern spotted owl (*Strix occidentalis caurina*) nest sites in the Klamath, Coast, and Cascade provinces of western Oregon and the Olympic province, Washington. I compared forest stand data collected at 105 nest sites with data from 105 random sites located in older forests within the owl's home range using paired t-tests and multiple logistic regression.

Most nests in Oregon were in Douglas-fir (*Pseudotsuga menziesii*) trees (88%) whereas in the Olympics, they were equally divided among Douglas-fir, western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuga plicata*). Mean dbh of all nest trees (n = 105) was 139.4 cm (SE = 5.2 cm). Most nests were in cavities (83%), and of the 17% that were on platforms, most were in the Klamath province.

The majority of nest sites were found from the middle to the bottom of slopes. Mean aspects at nest sites were southerly in Oregon and northeasterly in the Olympics. Elevations at nest sites were lower than their paired random sites and evidence of fire was present at 86% of nest sites.

Logistic regression and univariate analyses indicted that spotted owl nest-sites were associated with structurally diverse, decadent older forests. Nest sites had more densely multilayered canopies than random sites as evident from the greater density of trees, especially trees <53 cm dbh and <38 m in height. Basal area of broken-top trees

and volume of decay class 5 logs were also greater at nest sites than at random sites in all physiographic provinces, ($P < 0.0001$ and $P < 0.0293$ respectively), and were indications of the greater decadence found at nest sites.

Silvicultural prescriptions designed to produce the stand structure of nesting habitat must consider both the role fire and other disturbances have played to create the diverse species composition and stand structure found at nest sites and the importance of stand decadence in nest-site selection by spotted owls.

Characteristics of Forests at Spotted Owl Nest Sites
in the Pacific Northwest

by

Kit Hershey

A Thesis

submitted to

Oregon State University

in partial fulfillment of
the requirement for the
degree of

Master of Science

Completed November 7, 1995
Commencement June 1996

Master of Science thesis of Kit Hershey presented on November 7, 1995

APPROVED:

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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.

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Kit Hershey, Author

ACKNOWLEDGEMENTS

This study was funded by the U. S. Fish and Wildlife Service and was conducted through the auspices of the Oregon Cooperative Wildlife Research Unit. Cooperators on the project included the U. S. Forest Service (USFS), Bureau of Land Management (BLM), Oregon Department of Fish and Wildlife (ODF&W), and Washington Department of Fish and Wildlife (WDF&W). I thank my major professor, Dr. E. Charles Meslow, for his advice during all phases of this project. I also thank the members of my graduate committee, Dr. John Tappeiner and Dr. Daniel Edge for their guidance and useful suggestions on my thesis draft.

This study would not have been completed but for the expert advice of Dr. Fred Ramsey who selflessly spent hours upon hours helping me with statistical analyses and drafting several figures. I also owe a very special thanks to Dr. Bob Steidl for invaluable suggestions on several drafts of this thesis, statistical advice, drafting figures, and for all his kind words of encouragement.

The field portion and logistics of this study were accomplished through the efforts of an incredible number of people. A sincere thanks to Charlie Bruce from ODF&W, Kathy O'Halloran and Hugh Black from the USFS, and Bill Neitro from the BLM for helping me get this project started. I would also like to acknowledge Ann Potter of WDF&W and Greg Sieglitz of ODF&W for providing spotted owl master site list numbers.

I am particularly grateful to all the people at the USFS and BLM that helped with locating nest trees, providing aerial photographs and maps, providing housing or finding us places to park our trailers. At the Forest Service these people included: Karen Holtrop, Pat Van Eimeran, Elizabeth Milliman, Fred Craig, Vanessa Cataldo, Mary Lou Schnoes, Linda Burkhardt, Carl Frounfelker, Barry Shriver, Steve Symeonides, Ken Byford, Clyde Romero, Virgil Morris, Cheryl Friesen, Barbara Fountain, Cindy Barkhurst, Keith Graves, Fred Wahl, Mike Bauer, Mario Mamone, Rob Huff, Sherrie Julian, Rick Newton, Sarah Hall, Dan Taylor, Dede Steele, Nancy Wells, Ken Kestner, Suzanne Rock, and Rachael Barton and at the BLM: Larry Mangan, Charlie Thomas, Scott Hopkins, Wayne Logan, Jim Harper, Dick Bonn, and Ray Bosch (thanks Ray for a great barbeque). I am particularly grateful to the biologists at Roseburg BLM, Joe Lint, Robin Bown, Frank Oliver and Jerry Mires for their hospitality and logistical support. Also a very special thanks to Eric Forsman and his PNW crews: Ivy Otto, Rich Lowell, Pete Loschl, Janice Reid, and Rob Horn and to OSU owl project personnel: Jim Thrailkill, Gary Miller, Frank Wagner, Keith Swindle, and Mark Brown for taking time out of their busy schedules to show me locations of nest trees. Last, but not least, I want to acknowledge the tireless efforts my field crew: Carlo Abruzzese, Jim Marquardt, Bridget Canty, Lance Brown, Steve Small, Greg Orlowsky, Carl Sanders, Abby Kirkaldie, Tanya Silver, and Darryl York.

A very heartfelt thanks to my family for their encouragement and understanding throughout this lengthy process and to my friend, Sue Brooks, for lending me her home and computer. Most especially, I thank my daughter, Emma, for enduring my many absences.

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INTRODUCTION

The northern spotted owl (*Strix occidentalis caurina*) was listed as a threatened species in July 1990 under the Endangered Species Act of 1973. Loss of spotted owl habitat to timber harvest and natural disturbances was determined to be one of the most critical threats facing the owl. To provide for the persistence and recovery of this species, forest managers require accurate information on the characteristics of spotted owl habitat.

Comprehensive studies have previously been conducted on nest sites in northern California (LaHaye 1988) and on the east side of the Washington Cascade Range (Buchanan 1991). Those studies compared spotted owl nest sites with available habitat and concluded that, in general, owls were nesting in older forests with greater complexity and structure than forests available to them (USDI 1992:20). Little is known, however, of nest site characteristics in the Olympic Peninsula, and information on nest sites in Oregon is limited to details on nests, nest trees, and qualitative descriptions of the habitat surrrounding nests (Forsman et al. 1984:30).

Because forests in the various physiographic provinces used by spotted owls for nesting differ in composition, structure, management history, and disturbance history, information is needed on nesting habitat in all provinces within the range of the spotted owl. This study was designed to provide quantitative information on the nesting habitat of spotted owls in the western Oregon Cascades, the Oregon Coast Range, the Oregon Klamath Mountains, and the Olympic Peninsula in Washington.

My objectives were to: (1) quantify the habitat characteristics of a random sample of spotted owl nest sites in western Oregon and the Olympic Peninsula, and (2) test the null hypothesis that there was no difference between habitat characteristics at owl nest sites and randomly selected locations in forests with a similar range of overstory diamater sizes within the owls' home ranges.

STUDY AREA

I measured forest characteristics within 100 m of spotted owl (*Strix occidentalis caurina*) nest trees (n=105) in 4 physiographic provinces: The Southern Oregon Klamath Mountains, the Oregon Coast Range, Western Oregon Cascade Mountains, and the Olympic Mountains of the Washington Olympic Peninsula (USDI 1992) (Fig. 1). The Klamath Mountains sites (n = 30) were located on 6 resource areas of the Medford and Roseburg Bureau of Land Management (BLM) Districts, and on 5 ranger districts of the Siskiyou, Rogue River, and Umpqua National Forests. The Coast Range sites (n = 30) were located on 2 ranger districts of the Siuslaw National Forest and 7 resource areas of the Coos Bay, Roseburg, Eugene, and Salem BLM Districts. The Cascade Range sites (n = 30) were located on 11 ranger districts of the Mt. Hood, Willamette, and Umpqua National Forests and 1 resource area of the Roseburg BLM District. The Olympic sites (n = 15) were located on 4 ranger districts of the Olympic National Forest. A list of nest sites by site name, master site list number, and ownership is found in Appendix 1.

The majority of nest sites in the Cascade, Coast, and Olympic Mountains were located in the lower to middle elevations in the *Tsuga heterophylla* vegetation zone whereas a few sites in the Cascades and Olympics were located at higher elevations in the *Abies amabilis* Zone (Franklin and Dyrness 1973).

In the *T. heterophylla* Zone of the Cascade and Coast Ranges, Douglas-fir (*Pseudotsuga menziesii*) is the dominant overstory tree. In the Olympics, Douglas-fir and/or western hemlock (*Tsuga heterophylla*) constitute the dominant overstory trees. Western hemlock and western redcedar (*Thuga plicata*) comprise the majority of the

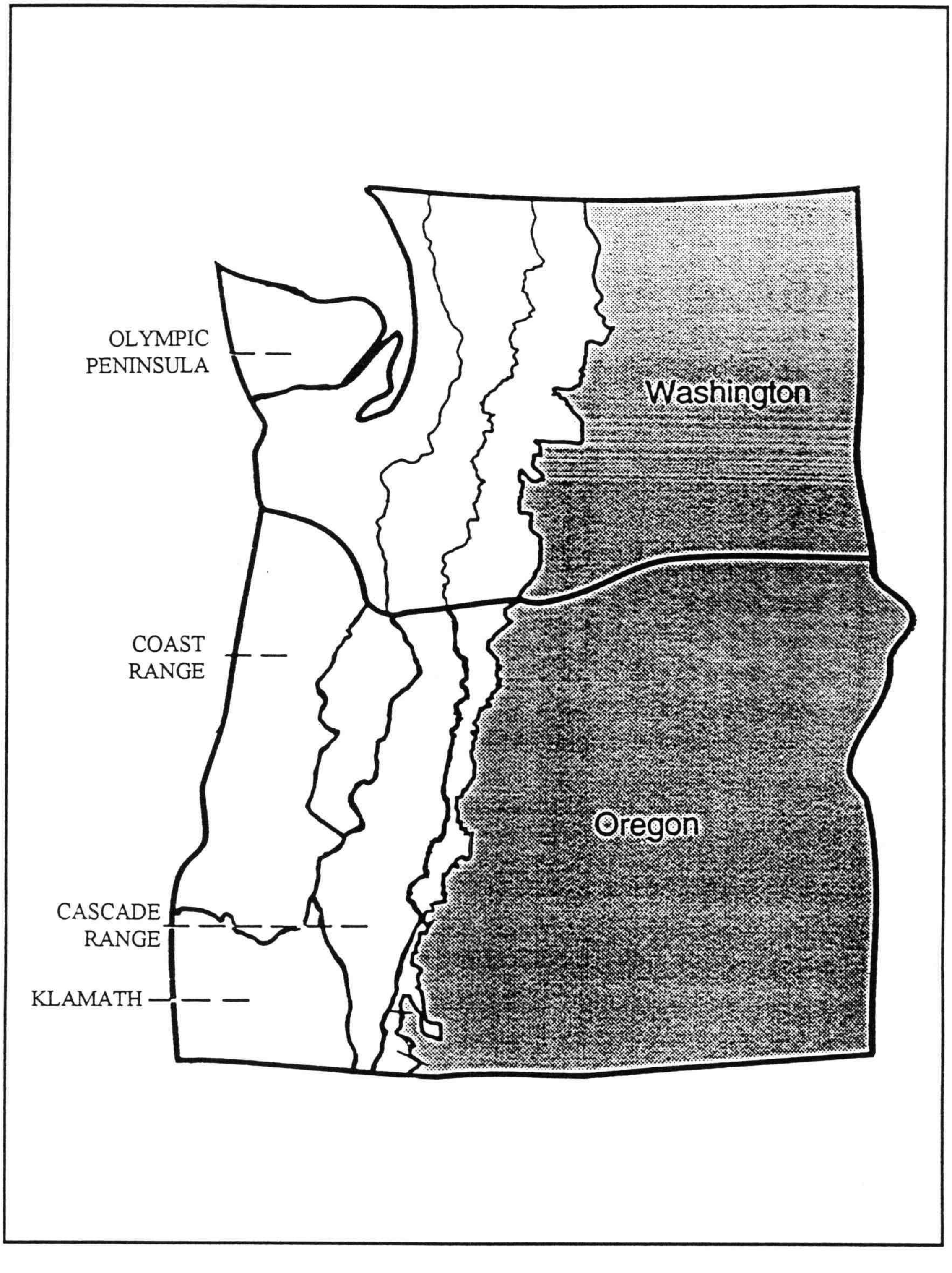

Figure 1. Study area map of the 4 physiographic provinces within the range of the spotted owl from which nest site samples were drawn.

softwood understory in association with a variety of other softwoods, hardwoods, shrubs, and forbs. At sites in the *A. amabilis* Zone, Douglas-fir and western hemlock dominate the overstory and Pacific silver fir (*Abies amabilis*) dominates the understory.

The majority of nest sites in the Klamath Mountains were in the Mixed Evergreen Zone or the Mixed-Conifer Zone (Franklin and Dyrness 1973). In the Mixed Evergreen Zone, Douglas-fir and low densities of sugar pine (*Pinus lambertiana*) and ponderosa pine (*Pinus ponderosa*) constitute the major overstory layer. The hardwood understory is dominated by tanoak (Lithocarpus densiflorus) in association with white oak (*Quercus chrysolepis*), madrone (*Arbutus menziesii*), and golden chinkapin (*Castanopsis chrysophylla*). Douglas-fir and incense-cedar (*Calocedrus densiflorus)* constitute the majority of the conifer trees in the understory. In the Mixed-Conifer Zone, white fir (*Abies concolor*) and Douglas-fir with low densities of sugar pine, ponderosa pine and incense-cedar comprise the overstory. The understory typically consists of white fir, Douglas-fir, incense-cedar, and madrone.

Plant associations at nest sites in each of the physiographic provinces vary along moisture gradients resulting from differences in soil type, aspect, slope, elevation, longitude, and latitude. Major disturbances such as logging and wildfire have also influenced plant associations found in each area.

A list of tree species found at spotted owl nests in each of the 4 provinces is found in Appendix 2.

METHODS

Nest Site Selection

I randomly selected a sample of spotted owl nest sites from nests previously located by Oregon State University or federal employees on U. S. Forest Service (USFS) and BLM lands. Techniques used to locate spotted owl nests are described by Forsman (1983). I selected 30 sites in each of the western Oregon provinces (Klamath, Cascades, and Coast Range) and 15 sites in the Olympic province. Young successfully fledged from all nests included in the study in at least 1 of the years between 1988-90. To insure a broad geographic representation, I chose no more than 1 nest site in any given township. I defined a nest site as the vegetative, structural, and physiographic characteristics included within a circle of a 100-m radius (3.14 ha) centered on a spotted owl nest tree.

General Site Characteristics

The physiographic information recorded at nest sites included elevation, aspect, slope, position on slope, and evidence of logging or fire. Elevation and position on the slope were obtained from topographic maps. I measured aspect with a compass and percent slope with a clinometer. Fire scars on trees, snags, and logs were considered evidence of fire disturbance. Logging was recorded if cut stumps were present in any of the sampling plots.

Nest-trees and Nests

I recorded the species, condition (i.e., live, dead, broken top, intact top), diameter at breast height (dbh), height, height of crown base, number of secondary crowns on broken-top trees, and evidence of fire for all nest trees. I did not age nest trees. I categorized nests into 1 of 3 types: top cavity (chimney), side cavity, or platform. Top cavity nests were those located at or near the top of the bole of a broken-top tree. Side cavity nests were located within the bole of the tree with entrances on the side. Platform nests were located outside of the bole and were generally in abandoned or usurped raptor or mammal nests, in mistletoe clumps, or accumulations of debris on branches.

I measured the aspect of platform and side-cavity nests with a compass and nest height with a clinometer. I visually assessed nest position in the nest-tree canopy (upper 1/3, mid 1/3, bottom 1/3).

Site Vegetative and Structural Characteristics

I sampled vegetative and structural information using 5 circular plots per nest site. Each plot consisted of a nested set of circular plots of 3 sizes: 0.001 ha, 0.1 ha, and 0.2 ha. The first plot was centered on the nest tree and the 4 others were centered 75 meters from the nest tree with the first of the 4 plots oriented in a random compass direction and the other 3 placed consecutively at 90 ° angles from one another (Figure 2).

At each 0.1 ha plot we recorded information on all trees, saplings, down logs, canopy closure, and tall shrub cover. Trees (woody stems >10 cm dbh) were measured

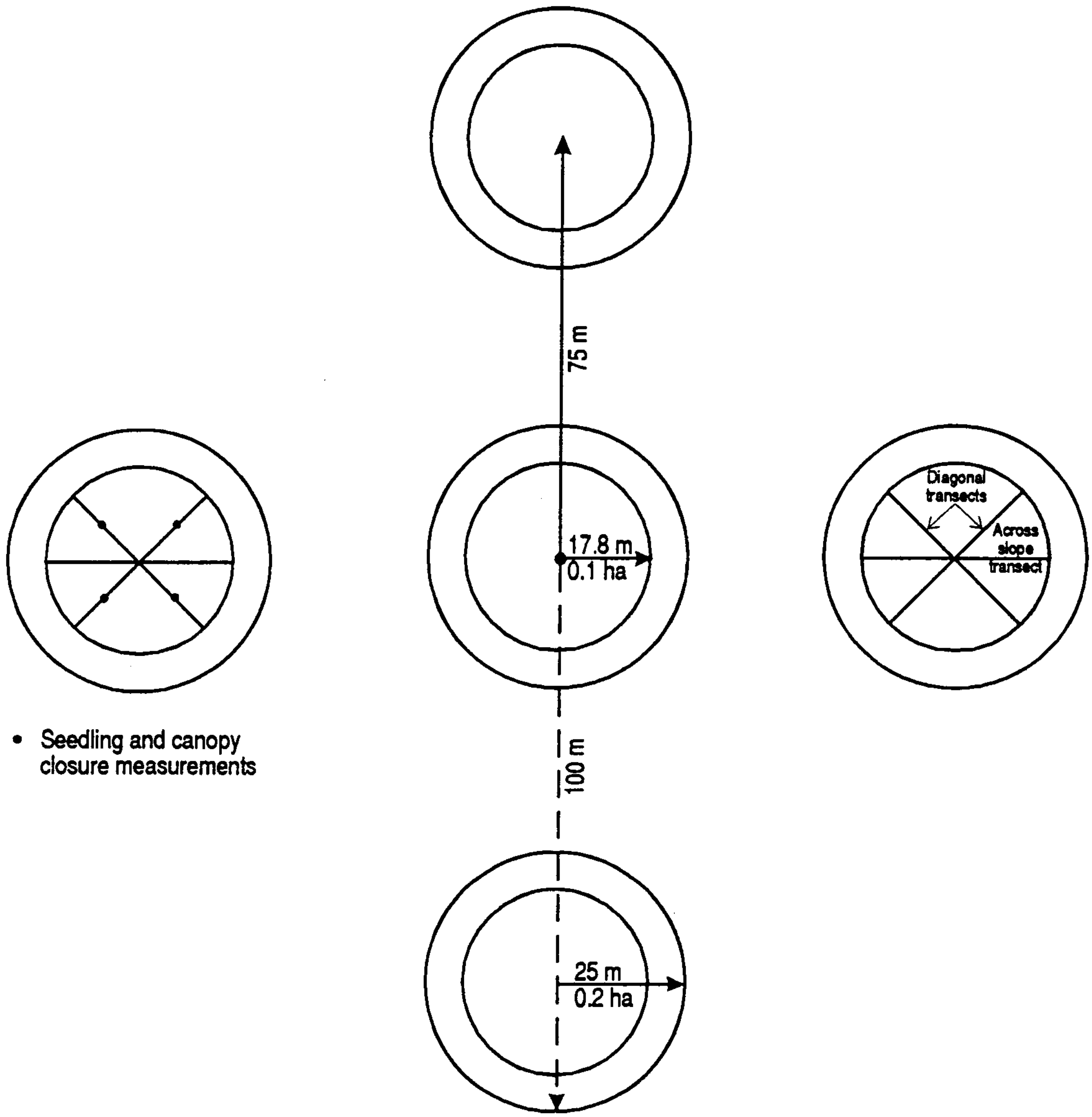

Figure 2. Sampling scheme at spotted owl nest and random sites in the Pacific Northwest, 1990-91.

(not to scale)

and information was recorded by species, dbh, and height class. I did not age trees. Each tree was classified into 1 of 8 height classes: Class 1 - 7.6-15.2 m, Class 2 - 15.3-22.9 m, Class 3 - 23.0-30.6 m, Class 4 - 30.7-38.3 m, Class 5 - 38.4-46.0 m, Class 6 - 46.1-53.7 m, Class 7 - 53.8-61.4 m, and Class 8 - >61.4 m. I measured tree diameters with a diameter tape and determined tree heights by measuring the heights of several representative trees in each plot and estimating the remainder. In addition, I recorded the top condition of each tree, number of secondary crowns (for broken-top trees), and evidence of fire. The number of saplings (woody stems > 5 cm but < 10 cm dbh) was recorded by species.

I measured tall shrub cover (deciduous vegetation > 3 m tall and < 10 cm dbh) along two 35.6-m transects (35.6 m = diameter of 0.1-ha-circular plot) using a line intercept method (Mueller-Dombois and Ellenberg 1974:90-92). I placed each line diagonally to the slope of the plot, perpendicular to each other, with the nest tree in the center. I recorded shrub species and the number of meters of each shrub species covering each transect.

I measured down logs (> 10 cm dbh) also using a line intercept method (Van Wagner 1968). I recorded the species, diameter, and decay class (Maser and Trappe 1984) for each log intercepting three 35.6 m transects. In addition to the 2 diagonal transects mentioned above, I used a third line placed across the slope of the plot.

I measured canopy closure with a spherical densiometer (Lemmon 1958) as the average of 16 readings in each plot (4 readings taken in each cardinal direction at 4 points). Each point was located 9 m from the nest tree along the diagonal transects.

Nested within each 0.1-ha plot, the number of tree seedlings by species (stems < 5 cm dbh) was recorded within four 2-m-radius-circular plots (0.001 ha). Each of these plots was centered on the points at which canopy closure was measured.

In each 0.2-ha plot, I recorded snags by species, dbh, height, and decay class. Decay class categories were the same 3 class system used by Nelson (1988) which corresponds to the 1, 2 + 3, and 4 + 5 classes of Cline's classification system (Cline et al. 1980). I measured snag dbh with a diameter tape and estimated heights.

Random Site Selection

I selected an equal number of random sites to nest sites in each of the 4 physiographic provinces. Each of the 105 random sites was located between 1,000 m and 2,400 m from a sampled nest tree. This distance requirement insured that the random point fell outside of the sampled nesting area but within the theoretical home range of an owl. Orientation and distance of the random site from the nest were chosen randomly. Additionally, we restricted random sites to forested areas in which the dominant overstory trees were a minimum of 53.3 cm (21 inches) dbh to exclude habitat in which spotted owls do not typically nest (Forsman et al. 1984). We sampled random sites using the same sampling scheme employed at nest sites except for the nest-tree-specific variables.

Univariate Analyses

Before analysis, I divided several variables into classes. Trees and snags were divided into 4 dbh classes: Class 1 - 10.0-27.9 cm (4-11 in), Class 2 - 28.0-53.3 cm (11-21 in), Class 3 - 53.4-78.7 cm (21-31 in), and Class 4 - > 78.7 cm (> 31 in). The first 3 classes correspond with the forest land classes of pole timber, small sawtimber, and large sawtimber (Bell and Dilworth 1989).

I analyzed density and basal area of trees and density of snags by dbh class. Basal area of snags was analyzed by decay class regardless of dbh. I analyzed tree heights by density of trees in each height class and Classes 6-8 were collapsed into a single Class 6 (> 46 m). Density of individual tree species was analyzed by dbh class and the basal area of tree species was analyzed by total basal area. I analyzed log volumes by decay class.

I compared continuous habitat variables among physiographic provinces using paired t-tests after using Levene's test of homogeneity of variance to determine if variances were constant between samples (Sabin and Stafford 1990:11). I assessed the normality of each variable by examining stem-and-leaf diagrams and normal-probability plots of the residuals from an analysis of variance of each variable. I transformed variables that did not meet assumptions of equal variances or normality using log, square root, or inverse transformations prior to conducting parametric tests and also analyzed each variable using a signed rank test. Because there was no difference in results between transformed and untransformed data, all results presented are from untransformed data. I used an alpha level of < 0.1 to denote statistical significance.

Categorical variables were compared using chi-square tests. Circular data (i.e., aspect) were analyzed using the Rayleigh test (Batschelet 1981) which tests for nonrandomness or directedness. The mean angle, angle deviation [S], and length of the mean vector [r] were calculated. All univariate analyses were performed with SAS (SAS Institute Inc. 1988)

Multivariate Analyses

I used conditional logistic regression for 1-1 matched data to model habitat variables that best distinguished nest from random sites. With this analysis, each sampling unit is a paired nest and random site, and the response variables are the arithmetic differences between variables measured at the paired sites (Breslow and Day 1980:253).

Logistic regression was used rather than discriminate analyses for several reasons: it does not require the assumption of multivariate normality (Press and Wilson 1978, Ramsey and Schafer 1995), it allowed me to maintain the paired structure of the data, and to analyze first-order interactions between significant main-effect variables and first-order interactions between the main-effects and physiographic provinces to account for geographic differences in the main effect variables.

To reduce the number of variables for multivariate analyses, I ran paired t-tests on measured variables from all physiographic provinces combined and chose only those variables with P-values < 0.25. I used the significance level of 0.25 because more restrictive levels may fail to identify important variables (Hosmer and Lemeshow 1989:86). Further, where variables were highly correlated ($r > \pm 0.70$), I retained for analysis only the variable that was most biologically interpretable or most easily measured in the field. I then used a stepwise procedure on the 12 remaining variables. The *P*-value for a variable to both enter and stay in the model was set at 0.1.

I expanded the model to include all first-order interactions between the significant main-effect variables and the main-effects by physiographic province indicator variables. The drop-in-deviance test (Ramsey and Schafer 1996) was used to determine if any interactions or group of interactions explained a significant amount of model deviance. Deviance measures lack-of-fit of a proposed model to the observed data. The drop-in-deviance for entering a set of variables into the logistic model has an approximate chi-square distribution with the degrees of freedom equalling the number of variables in the set. I used this approach to determine if a variable or set of variables should be included in the model (Ramsey et al. 1994:5). Only those interactions that significantly reduced model deviance ($P < 0.1$) were retained in the model.

I calculated odds ratios for each main-effect variable by physiographic province. In this instance, odds ratios are simply the odds that a site is a nest site rather than a random site given that the value of the main-effect variable is the mean value found at nest sites rather than the mean value found at random sites. I calculated the odds ratios using the following formula: exp [β_1 (mean of X_1 at nest sites – mean of X_1 at random sites)].

RESULTS

General Site Characteristics

Mean elevation at nest sites was significantly lower than at random sites in all physiographic provinces except the Olympic. Percent slope was not significantly different between nest and random sites in any province (Table 1). Aspects at nest sites showed no tendency toward a nonrandom distribution in any physiographic province. Mean angles and angular deviations were southwesterly in the Klamath, Coast, and Cascade provinces and northwesterly in the Olympic (Table 2). Aspects at random sites also tended to be random except for the Olympics where the measure of concentration (r) was 0.50 ($P < 0.02$) (Table 2).

Except for the Klamath, position on the slope varied little between nest and random sites with the majority of sites occurring on the middle 1/3 of slopes (Fig. 3). In the Klamath, the distribution of slope positions was significantly different between nest and random sites ($\chi^2 = 7.412$, df = 2, $P < 0.025$) with the greatest proportion of nest sites on the lower 1/3 of slopes and random sites in the middle 1/3 of slopes.

The majority of both nest and random sites showed some evidence of wildfire. However, only in the Klamath was there a significantly greater number of nest than random sites that showed evidence of wildfire (Table 3).

Seventy-two of the 210 nest and random sites (34%) showed some evidence of past logging entry. However, logging evidence was not different between nest and

Table 1. Comparison of elevation (meters) and percent slope (%) between spotted owl nest sites and random sites by physiographic province. P-values are from paired t-tests.

	Nest Sites				Random Sites				
	Mean	Min	Max	S.E.	Mean	Min	Max	S.E.	*P*
Klamath (n = 30)									
Elevation	836	439	1585	51	918	561	1756	51	0.0178
Slope	42	1	80	4	46	5	95	4	0.4274
Coast (n = 30)									
Elevation	315	122	707	27	389	171	762	29	0.0006
Slope	54	7	90	4	55	10	120	5	0.9171
Cascade (n = 30)									
Elevation	884	293	1372	48	968	320	1671	56	0.0265
Slope	45	5	166	6	42	3	150	6	0.6732
Olympic (n = 15)									
Elevation	464	220	671	38	507	244	744	39	0.3122
Slope	54	3	94	8	53	2	80	6	0.9278

Table 2. Mean aspect angle, angular deviation [s], *r*, and *P*-value for test of random distribution by physiographic province.

NEST SITES

	Mean Angle	Angular Deviation [S]	*r*	*P*
Klamath (n = 30)	190°	71°	0.24	0.23
Coast (n = 30)	205°	71°	0.24	0.20
Cascade (n = 30)	229°	74°	0.17	0.40
Olympic (n = 15)	330°	71°	0.23	0.40

RANDOM SITES

	Mean Angle	Angular Deviation [S]	*r*	*P*
Klamath (n = 30)	9°	74°	0.16	0.46
Coast (n = 30)	324°	71°	0.23	0.21
Cascade (n = 30)	113°	74°	0.17	0.42
Olympic (n = 15)	44°	57°	0.50	0.02

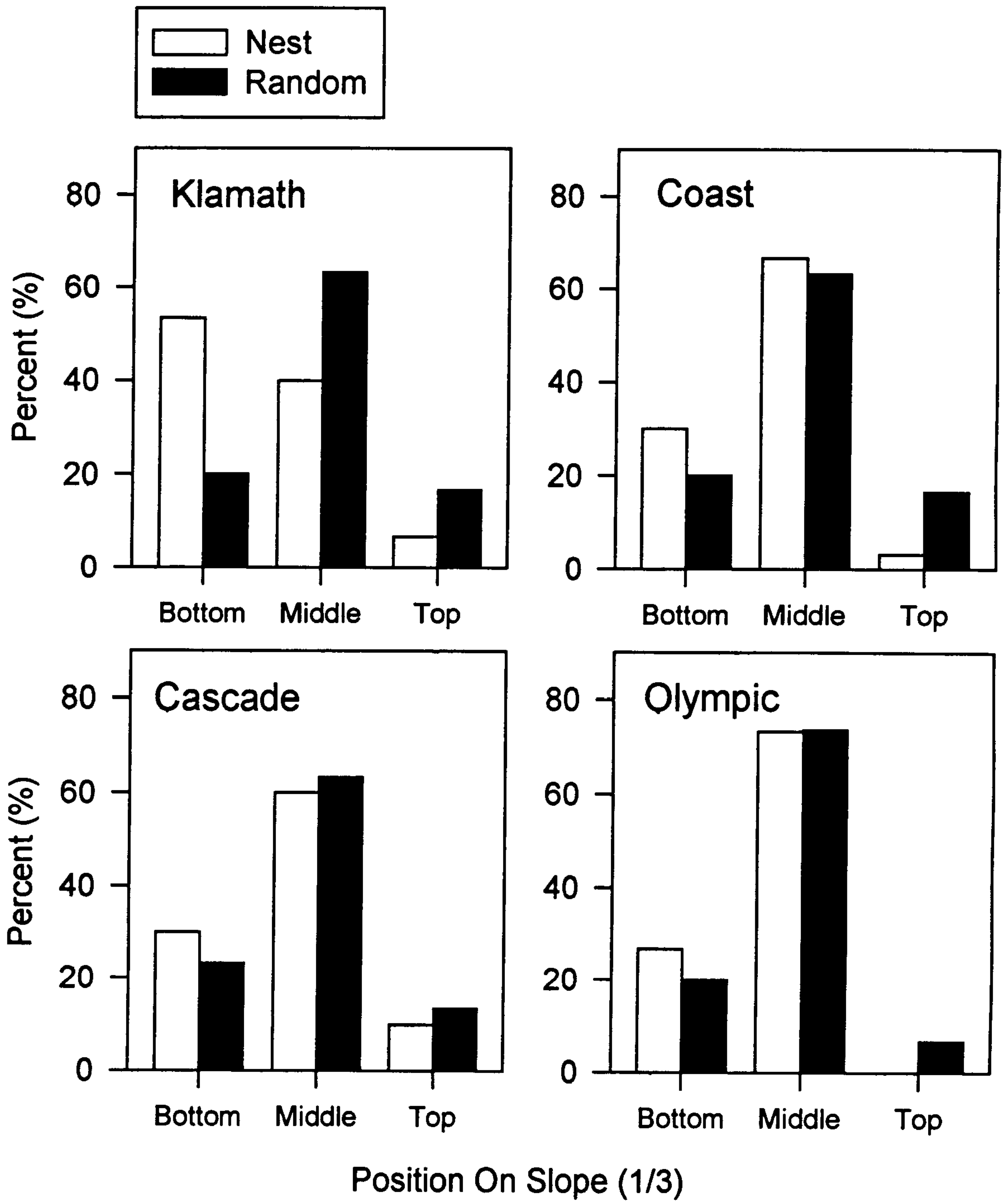

Figure 3. Position on slope (1/3) of spotted owl nest and random sites by physiographic province in the Pacific Northwest, 1990-91.

Table 3. Comparisons of spotted owl nest sites and random sites showing evidence of fire and logging by physiographic province.

Province	Evidence of fire: Number of nest sites	Evidence of fire: Number of random sites	χ^2 (1 df)	P
Klamath (n = 30)	27	20	4.812	0.028
Coast (n = 30)	23	26	1.002	0.317
Cascade (n = 30)	28	25	1.456	0.228
Olympic (n = 15)	12	9	0.659	0.417

Province	Evidence of logging: Number of nest sites	Evidence of logging: Number of random sites	χ^2 (1 df)	P
Klamath (n = 30)	12	9	0.659	0.417
Coast (n = 30)	9	11	0.300	0.584
Cascade (n = 30)	10	15	1.714	0.190
Olympic (n = 15)	2	4	0.833	0.361

random sites in any physiographic province (Table 3). Fifty-eight of 72 logged sites (81%) had fewer than 11 cut stumps within sample plots. The majority of logged sites contained decay classes 2 and/or 3 stumps indicating that logging took place ≥ 30 years before sampling. Twenty-eight of the 72 logged sites (39%) showed evidence of >1 entry based on the presence of stumps in different decay classes. Thirteen of 14 sites (93%) that contained >10 cut stumps showed evidence of >1 entry. At all logged sites, harvested trees were >50 cm dbh.

Nest-trees and Nests

Spotted owls nested most often in Douglas-fir trees in the Klamath, Coast, and Cascade provinces. In the Olympics, where Douglas-fir is often absent, western hemlock, western redcedar, and Douglas-fir were used equally for nesting (Table 4). In all 4 provinces, nests were most often located in live trees (73-97%) with broken tops (60-93%), most of which showed evidence of fires of varying intensities and frequencies (77-83%) (Table 5). For all 4 provinces combined, mean dbh of nest-trees was 139.4 ± 5.2 cm, height of live trees was 44.4 ± 1.2 m, and height of the crown base of live trees was 20.6 ± 3.1 m; mean height of snags was 19.8 ± 0.8 m. (Table 6).

Most nests in the Klamath, Coast, and Cascades were top-cavity (55-87%); in the Olympics, most nests were side-cavity (67%). Platform nests were used infrequently in the Coast, Cascades, and Olympics (7%) but were used more often (40%) in the Klamath (Table 7). All top-cavity nests in live trees were covered by 1 to 8 secondary crowns; all

Table 4. Tree species used as nest trees by spotted owls in the Pacific Northwest by physiographic province.

Species	Province: Klamath n = 30	Coast n = 30	Cascade n = 30	Olympic n = 15
Douglas-fir	25	28	26	5
Western redcedar		1	2	5
Western hemlock			1	5
White fir	3			
Incense cedar	1		1	
Port-Orford cedar *(Chamaecyparis lawsoniana)*	1			
Bigleaf maple *(Acer macrophyllum)*		1		

Table 5. Condition of spotted owl nest trees (%) by physiographic province.

Condition	Province: Klamath n = 30	Coast n = 30	Cascade n = 30	Olympic n = 15
Live	90	83	97	73
Snag	10	17	3	27
Broken-top	63	93	83	60
Intact top	37	7	17	40
Fire scar	83	80	77	80

Table 6. DBH, height, and crown base height of spotted owl nest trees by physiographic province.

	Province															
	Klamath				Coast				Cascade				Olympic			
Variable	N	Mean	SE	Range	N	Mean	SE	Range	N	Mean	SE	Range	N	Mean	SE	Range
DBH (cm)	30	122.2	7.6	22-209	30	154.3	7.9	78-266	30	138.1	7.6	84-257	15	147.0	24.5	60-447
Height (m) (live tree)	27	41	2	15-62	23[a]	48	2	22-78	29	45	2	25-68	11	45	3	30-58
Height (m) (snag)	3	31	8	19-47	5	17	5	7-36	1	20			4	17	3	10-23
Crown base ht (m)	27	19	1	10-37	23[a]	21	1	11-34	26[b]	22	2	9-48	11	15	2	3-24

[a] 2 missing observations
[b] 3 missing observations

Table 7. Nest types used by spotted owls by tree condition and physiographic province.

Nest type	Tree condition	Province Klamath n = 29[a]	Coast n = 30	Cascade n = 27[a]	Olympic n = 15
Top cavity	Live	15	22	20	1
	Snag	1	4	1	3
Side cavity	Live	0	1	4	9
	Snag	1	1	0	1
Platform	Live	12	2	2	1
	Snag	0	0	0	0

[a] 29 nests in the Klamath and 27 nests in the Cascades were identified in the 30 nest trees in each province.

top-cavity nests in snags were sheltered by branches from neighboring trees or by vegetation growing out of the top of the snag. Height of nests from the ground varied by nest type and nest-tree condition (Table 8). Platform and side-cavity nests tended to be in the bottom third of the nest-tree canopy (60-75%), and top-cavity nests were most frequently in the bottom to mid third (68-100%) (Table 9). Mean aspects of side-cavity and platform nests were southwesterly in the Klamath and Cascades and southeasterly in the Coast and Olympics. With the exception of nests in the Coast, aspects of nests were randomly distributed (Table 10).

Stand Structure of Nest and Random Sites

I performed 236 (59 each in 4 physiographic provinces) individual paired tests of structural variables, 64 (27%) of which were significant (Table 11), suggesting that forest structure differed considerably between nest and random sites. However, these results should be interpreted cautiously because 10% (24) of those tests at $P < 0.1$ could be expected to be significant by chance alone. Summary statistics for all 236 variables and associated P-values are found in appendices 3-15.

Density of live trees was significantly greater at nest sites than at random sites in each of the 4 provinces because of the greater densities of smaller Class 1 and 2 trees (Table 11); densities of Class 3 and Class 4 trees were generally similar at nest and random sites within each province (Appendix 3). Among the 4 diameter classes analyzed, density of Class 1 trees varied most among provinces and ranged from the lowest in the Coast (132 trees/ha) to highest in the Klamath (370 trees/ha) (Appendix 3).

Table 8. Height (m) of spotted owl nests above ground by nest type, tree condition, and physiographic province (n = 29[a] in Klamath, n = 30 in Coast, n = 27[a] in Cascades, and n = 15 Olympics).

		Province															
		Klamath				Coast				Cascade				Olympic			
Nest type	Condition	N	Mean	SE	Range	N	Mean	SE	Range	N	Mean	SE	Range	N	Mean	SE	Range
Top cavity																	
	Live	15	28	2	14-44	22	32	2	15-52	20	31	3	13-50	1	24		
	Snag	1	19			4	10	1	7-14	1	19						
													25-68	3	14	2	10-17
Side cavity																	
	Live					1	29			4	19	5	10-34	9	20	2	11-27
	Snag	1	21			1	28							1	20		
Platform																	
	Live	12	18	2	10-28	2	45	16	29-60	2	28	11	17-38	1	14		

[a] 29 nests in the Klamath and 27 nests in the Cascades were identified in the 30 nest trees in each province.

Table 9. Position of spotted owl nests in the canopy of live nest trees by nest type and physiographic province.

		Province			
Nest type	Canopy position	Klamath n = 27	Coast n = 25	Cascade n = 29	Olympic n = 11
Top cavity	Top 1/3	1	4	6	
	Mid 1/3	10	13	5	
	Bottom 1/3	4	5	8	1
Side cavity	Top 1/3				1
	Mid 1/3			2	3
	Bottom 1/3		1	2	5
Platform	Top 1/3				
	Mid 1/3	3	1	1	
	Bottom 1/3	9	1	1	1

Table 10. Mean aspect angle, angular deviation [s], *r*, and *P*-value for test of random distribution of spotted owl nests (side-cavity and platform) by physiographic province.

Province	Mean Angle	Angular Deviation [S]	*r*	*P*
Klamath (n = 12)	244°	67°	0.31	0.32
Coast (n = 3)	146°	32°	0.85	0.04
Cascade (n = 6)	235°	73°	0.17	0.85
Olympic (n = 10)	174°	71°	0.24	0.54

Table 11. P-values of 64 variables by physiographic province based on paired t-tests between spotted nest sites and random sites. Bolded and italicized *P*-values indicate those variables that differed significantly[a] ($P < 0.1$).

	Physiographic Province			
Variable	Klamath	Coast	Cascade	Olympic
Tree density (by dbh class)				
Class 1 (10.0-27.9 cm dbh)	***0.0243***	***0.0058***	***0.0024***	0.3590
Class 2 (28.0-54.3 cm dbh)	0.1899	***0.0148***	***0.0581***	***0.0467***
Total tree density	***0.0188***	***0.0046***	***0.0039***	***0.0547***
Softwood density (by dbh class)				
Class 1 (10.0-27.9 cm dbh)	0.6140	***0.0521***	***0.0030***	0.3339
Class 2 (28.0-54.3 cm dbh)	0.1136	***0.0846***	***0.0530***	***0.0526***
Total softwood density	0.4107	***0.0926***	***0.0046***	***0.0448***
Hardwood density (by dbh class)				
Class 1 (10.0-27.9 cm dbh)	***0.0094***	0.1004	***0.0955***	0.3510
Class 3 (53.4-78.7 cm dbh)	0.7590	***0.0657***	0.3746	-
Total hardwood density	***0.0182***	***0.0335***	0.1525	0.8130
Tree basal area (by dbh class)				
Class 1 (10.0-27.9 cm dbh)	***0.0175***	***0.0106***	***0.0012***	0.1642
Class 2 (28.0-53.3 cm dbh)	0.2350	***0.0101***	0.1101	***0.0831***
Total tree basal area	0.6344	0.2149	0.5867	***0.0776***
Softwood basal area (by dbh class)				
Class 1 (10.0-27.9 cm dbh)	0.4530	***0.0688***	***0.0020***	0.1545
Class 2 (28.0-53.3 cm dbh)	0.1806	***0.0717***	0.1085	***0.0924***
Total softwood basal area	0.9185	0.5170	0.6141	***0.0807***
Hardwood basal area (by dbh class)				
Class 1 (10.0-27.9 cm dbh)	***0.0128***	0.1412	0.1128	0.7611
Class 3 (53.4-78.7 cm dbh)	***0.0058***	0.4809	0.1421	-
Total hardwood basal area	0.1096	***0.0122***	0.5941	0.6100
Tree density by height class				
Class 1 (7.6-15.2 m)	***0.0325***	***0.0061***	***0.0060***	0.3326
Class 2 (15.3-22.9 m)	0.3252	***0.0019***	***0.0012***	0.6575
Class 3 (23.0-30.6 m)	***0.0680***	0.8261	***0.0101***	0.7768
Class 4 (30.7-38.3 m)	0.5545	***0.0338***	0.7768	***0.0226***
Broken-top trees[b]				
Density	0.1129	***0.0054***	***0.0001***	0.2787
Basal area	***0.0090***	***0.0150***	***0.0006***	0.3353
Sapling density				
Hardwood saplings	0.1309	***0.0194***	0.4612	0.5836
Softwood saplings	0.1923	0.2758	***0.0152***	0.7022

Table 11. continued.

	Klamath	Coast	Cascade	Olympic
Snag density (by dbh class)				
Class 1 (10.0-27.9 cm dbh)	***0.0713***	***0.0396***	0.1254	***0.0402***
Total snag density	***0.0668***	0.2203	0.2822	***0.0641***
Snag basal area (by decay class)				
Class 1	0.9650	0.1741	0.6392	***0.0451***
Class 2	0.3333	***0.0542***	0.9992	0.1415
Log volume (by decay class)				
Class 4	0.1480	***0.0145***	***0.0071***	0.6890
Canopy Closure (%)	0.6797	0.3820	***0.0040***	***0.0033***

[a] All significant differences were greater at nest than at random sites with the exception of the basal area of decay Class 2 snags in the Coast and the basal area of decay Class 1 snags in the Olympics which were greater at random sites than at nest sites.

[b] Trees > 53.3 cm dbh with 1 or more secondary crowns.

Tree density also differed among provinces when diameter classes were separated into their softwood and hardwood components (Appendices 4 and 5). The most notable differences were in the hardwood component which was well developed in the Klamath and Coast but not in the Cascades and Olympics (Appendix 5). As noted above, the density of smaller trees was greater at nest than at random sites (Table 11); this difference in density was generally expressed in the density of softwoods except in the Klamath province, where density of the smaller hardwoods outnumbered the smaller softwoods (Appendices 4 and 5).

Basal area of live trees was significantly greater at nest sites than at random sites in the Olympic province (Table 11) because of the higher basal area of Classes 1, 2, and 4 at nest sites (Appendix 6). In the other 3 provinces, the smaller diameter classes (Classes 1 and 2) often had higher basal area values at nest sites than at random sites (Table 11). As expected, the basal area of softwoods and hardwoods in all 4 provinces followed the same trends as softwood and hardwood densities (Appendix 7 and 8).

Nest sites tended to have a more densely, multilayered canopy than random sites based on tree density by height class. Tree density in height Classes 1 through 4 was generally greater at nest sites than at random sites in all provinces (Appendix 9); these differences were significant in several height classes and provinces (Table 11).

Large, broken-top trees, an indication of stand decadence, were more conspicuous at nest sites than at random sites in all physiographic provinces. The Cascades had the greatest density and basal area of large, broken-top trees whereas the Klamath had the lowest. Both basal area and density of broken-top trees were greater at nest than at random sites in all provinces (with the exception of Olympic densities) (Appendix 10) and these differences were highly significant in many cases (Table 11).

The volume of down logs varied between provinces and was lowest in the Klamath province for all volume classes (Appendix 14). The volume of down logs in decay Class 5 was greater at nest sites than at random sites in all physiographic provinces, although the difference was not statistically significant ($P > 0.1$). The volume of logs in decay Class 4 was significantly greater at nest than at random sites in the Coast and Cascade provinces (Table 11).

Snag density varied considerably among provinces (Appendix 12). Density of Class 1 snags was significantly greater at nest than at random sites in the Klamath, Coast, and Olympic provinces (Table 11). Total basal area of snags and basal area of snags within each of 3 decay classes was largely similar between nest and random sites in all provinces (Appendix 13), except for basal area of decay Class 2 snags in the Coast and the basal area of decay Class 1 snags in the Olympics which were both significantly greater at random sites than at nest sites (Table 11).

Percent canopy closure varied little among the physiographic provinces (Appendix 15), but was significantly greater at nest sites than at random sites in the Cascades and Olympics (Table 11). There was no significant difference in percent cover of tall shrubs between nest and random sites in any province (Appendix 15).

Tree Species Composition at Nest and Random Sites

Because of differing climates and latitudinal ranges, tree species composition at nest and random sites varied among provinces. However, with the exception of 6 nest and random sites in the wetter, western Olympic mountains, Douglas-fir was present at all sites. Western hemlock and western redcedar occurred at most sites in the Coast, Cascades, and Olympic provinces; in the Klamath province, white fir, incense-cedar and numerous hardwood species were found at most sites. Tree species at nest and random sites and the number of sites at which each species was found is in Appendix 2.

The mean number of tree species at nest and random sites ranged from 4 to 8 (Table 12) and most sites (88%) contained at least 3 softwood species. The Olympic province had the lowest number of species because of its poorly developed hardwood component, whereas the Klamath consistently had the greatest number because of its rich hardwood component. Except in the Klamath where bigleaf maple, Oregon white oak, and red alder (*Alnus rubra*) occurred more often at nest than at random sites ($P < 0.010$, $P < 0.035$, and $P < 0.035$ respectively) (Appendix 2), species richness was similar at nest and random sites.

In all provinces, total density and basal area of several species differed significantly between nest and random sites (Table 13). In most cases, these differences occurred in the smaller tree classes 1 and 2 and were comprised of hardwoods in the Klamath and Coast and softwoods in the Cascades and Olympics. The only exceptions were Class 3 bigleaf maple in the Coast, Class 4 incense-cedar in the Klamath, and Class 3 Pacific silver

Table 12. Mean number and standard error of tree species at spotted owl nest sites and random sites by physiographic province.

	Number of tree species			
	Nest		Random	
Province	Mean	SE	Mean	SE
Klamath	8.1	0.4	6.8	0.4
Coast	6.7	0.4	5.9	0.4
Cascade	6.3	0.3	6.3	0.4
Olympic	4.1	0.4	4.2	0.3

Table 13. P-values from paired t-tests of tree species variables that differed significantly[a] ($P < 0.1$) between nest and random sites by physiographic province.

Variable	Physiographic Province			
	Klamath	Coast	Cascade	Olympic
Bigleaf maple				
Class 1 (10.0-27.9 cm dbh)	0.0032			
Class 3 (53.4-78.7 cm dbh)		0.0456		
Total density	0.0097			
Total basal area	0.0602	0.0487		
Canyon live oak				
Class 1 (10.0-27.9 cm dbh)	0.0367			
Total density	0.0429			
Total basal area	0.0386			
Douglas-fir				
Class 1 (10.0-27.9 cm dbh)			0.0247	0.0781
Class 2 (28.0-53.3 cm dbh)				0.0352
Total density				0.0488
Incense-cedar				
Class 1 (10.0-27.9 cm dbh)	0.0704			
Class 4 (>78.7 cm dbh)	0.0785			
Total density	0.0682			
Total basal area	0.0667			
Madrone				
Class 1 (10.0-27.9 cm dbh)	0.0099			
Total density	0.0237			
Other Hardwoods[b]				
Class 1 (10.0-27.9 cm dbh)	0.0506			
Pacific silver fir				
Class 2 (28.0-53.3 cm dbh)				0.0820
Class 3 (53.4-78.7 cm dbh)				0.0859
Total density				0.0150
Red alder				
Class 1 (10.0-27.9 cm dbh)	0.0324			
Total density	0.0642			
Total basal area	0.0618			
Western hemlock				
Class 1 (10.0-27.9 cm dbh)			0.0378	
Total density			0.0993	

Table 13. continued.

	Klamath	Coast	Cascade	Olympic
Western redcedar				
Class 1 (10.0-27.9 cm dbh)			0.0272	0.0835
Class 2 (28.0-53.3 cm dbh)			0.0511	
Total density			0.0285	0.0422
Total basal area			0.0618	0.0719

[a] All differences were significantly greater at nest than at random sites with the exception of the Pacific silver fir variables in the Olympics which were significantly greater at random sites than at nest sites.

[b] Combined group of less common hardwoods: vine maple, Oregon white oak, and red alder.

fir in the Olympics. All were greater at nest than at random sites except for Pacific silver fir (Table 13).

Logistic Regression Model

Thirty-four variables were significant ($P < 0.25$) from the paired t-tests conducted on measured variables from all physiographic provinces combined (Table 14). After dropping correlated variables ($r > \pm 0.70$), I retained 12 variables for inclusion in the stepwise procedure. Four variables best explained habitat characteristics that differed between nest and random sites: basal area of Class 1 trees, basal area of broken-top trees, elevation, and volume of down logs in decay class 5 (Table 15). These habitat characteristics individually and collectively were responsible for a significant drop in model deviance. Mean values for the basal area of Class 1 trees, for the basal area of broken-top trees, and for the volume of decay class 5 logs were greater at nest sites, whereas mean elevations were greater at random sites (Appendices 6, 10, and 14 and Table 1).

The odds ratios in Table 16 represent how much more likely it is for a site to be a nest site when the corresponding variable changes from its mean value at random sites to its mean value at nest sites. For example, the mean basal area of broken-top trees at Cascade nest sites is 9.4 m^2/ha and for Cascade random sites the mean is 3.7 m^2/ha (Appendix 10); therefore, sites with a basal area of broken-top trees of 9.4 m^2/ha are 6.1 times more likely to be nest sites than are sites whose basal area of broken-top trees is 3.7 m^2/ha (Table 16).

Table 14. P-values from paired t-tests of 34 variables that differed significantly[a] ($P < 0.25$) between nest and random sites in all physiographic provinces combined. An asterix indicates variables retained after removal of correlated variables.

Variable	*P*-values
Tree density (by dbh class)	
Class 1 (10.0-27.9 cm dbh)	0.0001
Class 2 (28.0-54.3 cm dbh)	0.0001
Total tree density	0.0001
Softwood density (by dbh class)	
Class 1 (10.0-27.9 cm dbh)	0.0015
Class 2 (28.0-54.3 cm dbh)	0.0003
Class 4 (>78.7 cm dbh)	0.2349
Total softwood density	0.0002
Hardwood density (by dbh class)	
Class 1 (10.0-27.9 cm dbh)	0.0013
Total hardwood density	0.0016
Tree basal area (by dbh class)	
Class 1 (10.0-27.9 cm dbh) *	0.0001
Class 2 (28.0-53.3 cm dbh) *	0.0005
Total tree basal area	0.0377
Softwood basal area (by dbh class)	
Class 1 (10.0-27.9 cm dbh)	0.0003
Class 2 (28.0-53.3 cm dbh)	0.0011
Total softwood basal area	0.1527
Hardwood basal area (by dbh class)	
Class 1 (10.0-27.9 cm dbh)	0.0020
Total hardwood basal area	0.0035
Tree density by height class	
Class 1 (7.6-15.2 m)	0.0001
Class 2 (15.3-22.9 m)	0.0006
Class 3 (23.0-30.6 m)	0.0001
Class 4 (30.7-38.3 m)	0.0635
Broken-top trees[b]	
Density	0.0002
Basal area *	0.0001
Sapling density	
Hardwood saplings *	0.0404

Table 14. continued.

Variable	P-values
Snag density (by dbh class)	
Class 1 (10.0-27.9 cm dbh) *	0.0007
Class 2 (28.0-53.3 cm dbh) *	0.2028
Total snag density	0.0043
Snag basal area (by decay class)	
Class 2 *	0.1240
Log volume (by decay class)	
Class 4 *	0.0006
Class 5 *	0.0293
Total log volume	0.1674
Shrub cover (%) *	0.1016
Elevation (m) *	0.0001
Canopy Closure (%) *	0.0974

[a] All differences were significantly greater ($P < 0.25$) at nest than at random sites with the exception of basal area of decay Class 2 snags, shrub cover, and elevation which were significantly greater at random sites than at nest sites.

[b] Broken-top trees > 53.3 cm dbh with 1 or more secondary crowns.

Table 15. Four variable logistic regression model that best discriminates between spotted owl nest sites and random sites.

Variable	Parameter Estimate[a]	SE[a]	χ^{2b}	p-value[b]
Class 1 trees	0.3733	0.1053	12.56	0.0004
Decay class 5 logs	0.0022	0.0012	3.63	0.0567
Elevation	-0.0068	0.0022	9.64	0.0019
Basal area of broken-top trees	0.3172	0.0804	15.57	0.0001

[a] Parameter estimates and standard errors based on the model with all 4 variables included.
[b] χ^2 and p-values based on Wald test.

Table 16. Odds ratios by physiographic province for the 4-variable logistic regression model.

	Odds Ratios			
	Klamath	Coast	Cascade	Olympic
Basal area of Class 1 trees	2.2	1.7	2.2	1.9
Decay class 5 logs	1.2	1.2	1.0	1.2
Elevation	1.8	1.7	1.8	1.3
Basal area of broken-top trees	2.0	4.8	6.1	2.0

After expanding the model to include all 18 possible first-order interactions, there was a significant drop in deviance ($\chi^2 = 34.6$, $P < 0.011$). After dropping all interactions that contributed little to the model, three interactions were significant ($\chi^2 = 13.1$, $P < 0.005$) and suggestive of an effect: basal area of Class 1 trees x volume of decay Class 5 logs, elevation x the Klamath indicator variable, and basal area of Class 1 trees x the Klamath indicator variable. The first interaction indicates that the association between nest sites and higher basal area of Class 1 trees increases with increasing volumes of decay Class 5 down logs (Fig. 4). The second and third interactions indicate that the association between nest sites and lower elevations and higher basal areas of Class 1 trees is more pronounced in the Klamath province (Figs. 5 and 6).

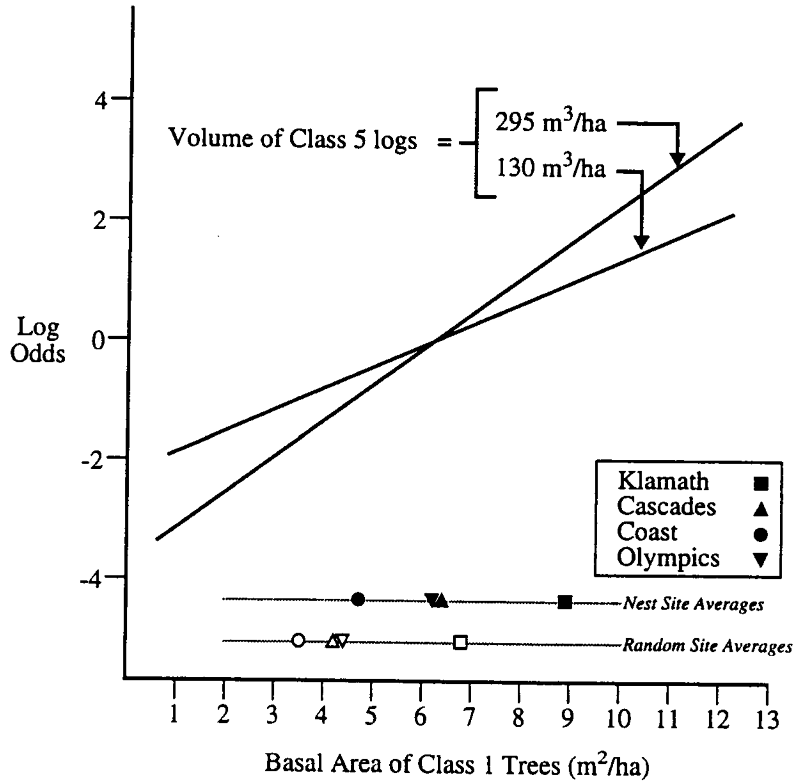

Figure 4. Interaction of volume of decay class 5 logs and basal area of class 1 trees. The association between nest sites and higher basal area of class 1 trees increases with higher volumes of decay class 5 logs.

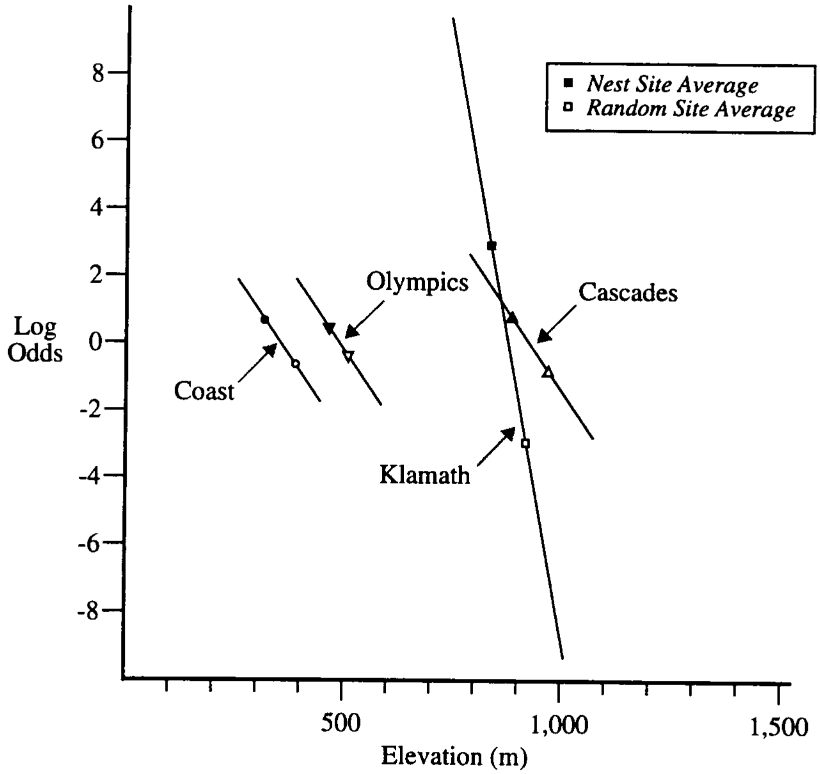

Figure 5. Interaction of elevation and the physiographic province indicator variable for the Klamath. Nest sites are associated with lower elevations and this association is more pronounced in the Klamath province.

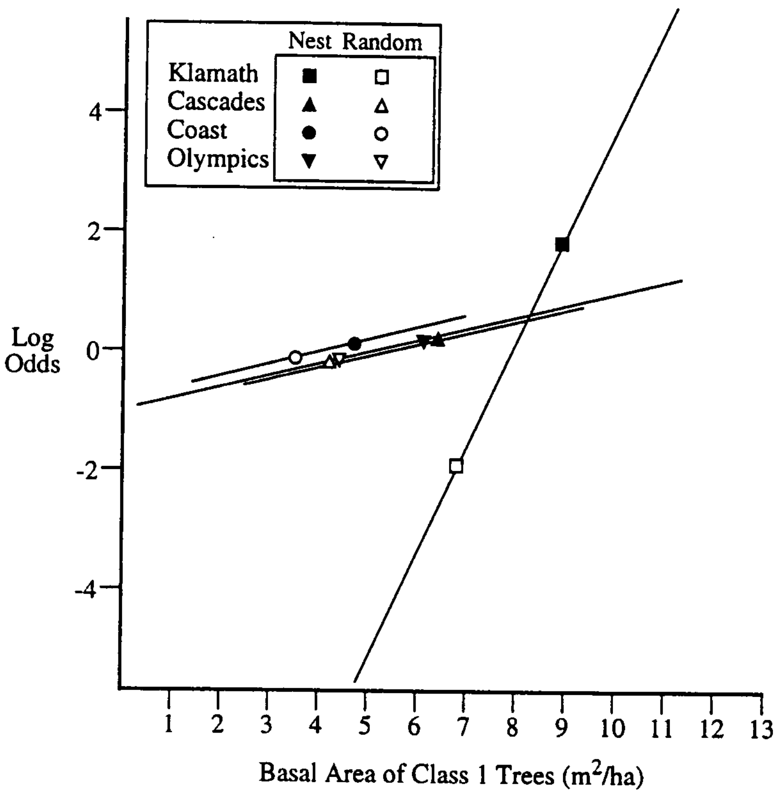

Figure 6. Interaction of basal area of Class 1 trees and the physiographic province indicator variable for the Klamath. Nest sites are associated with greater basal area of Class 1 trees and this association is more pronounced in the Klamath province.

DISCUSSION

This study focused on the structural characteristics of forests within 100 m of spotted owl nest sites in 4 of 11 physiographic provinces within the range of the northern spotted owl. All nest sites were located in older forests with dominant overstory trees that were >53.3 cm dbh (21 inches); random sites were selected from forest stands with the same minimum overstory diameter size. Most nest and random sites, however, had overstory trees that were >78.7 cm dbh. In addition, forest stands at both nest and random sites were comprised of mixed species of trees of various size classes, high densities and volumes of dead and down woody debris, and the multiple-layered structure typical of older forests in which there are many trees in the smaller diameter classes and progressively fewer in the larger diameters (Fig. 7).

It is difficult to categorize the forest stands at nest and random sites as either mature or old-growth (especially in the Klamath) as they had such diverse disturbance histories. At many sites, old-growth trees constituted the overstory canopy whereas at others the overstory consisted of mature trees with a supercanopy of scattered old-growth trees. The majority of sites, however, met most, if not all, of the minimum requirements of old-growth forests as defined in the interim definition of old-growth (Franklin et al. 1986) and as revised in Franklin and Spies (1991a) (Table 17). However, although density of trees >100 cm dbh was the same at nest and random sites, the mean diameter of these large trees was greater at nest than random sites (Table 18) and suggests that trees may be older at nest sites or that nest sites may be more productive.

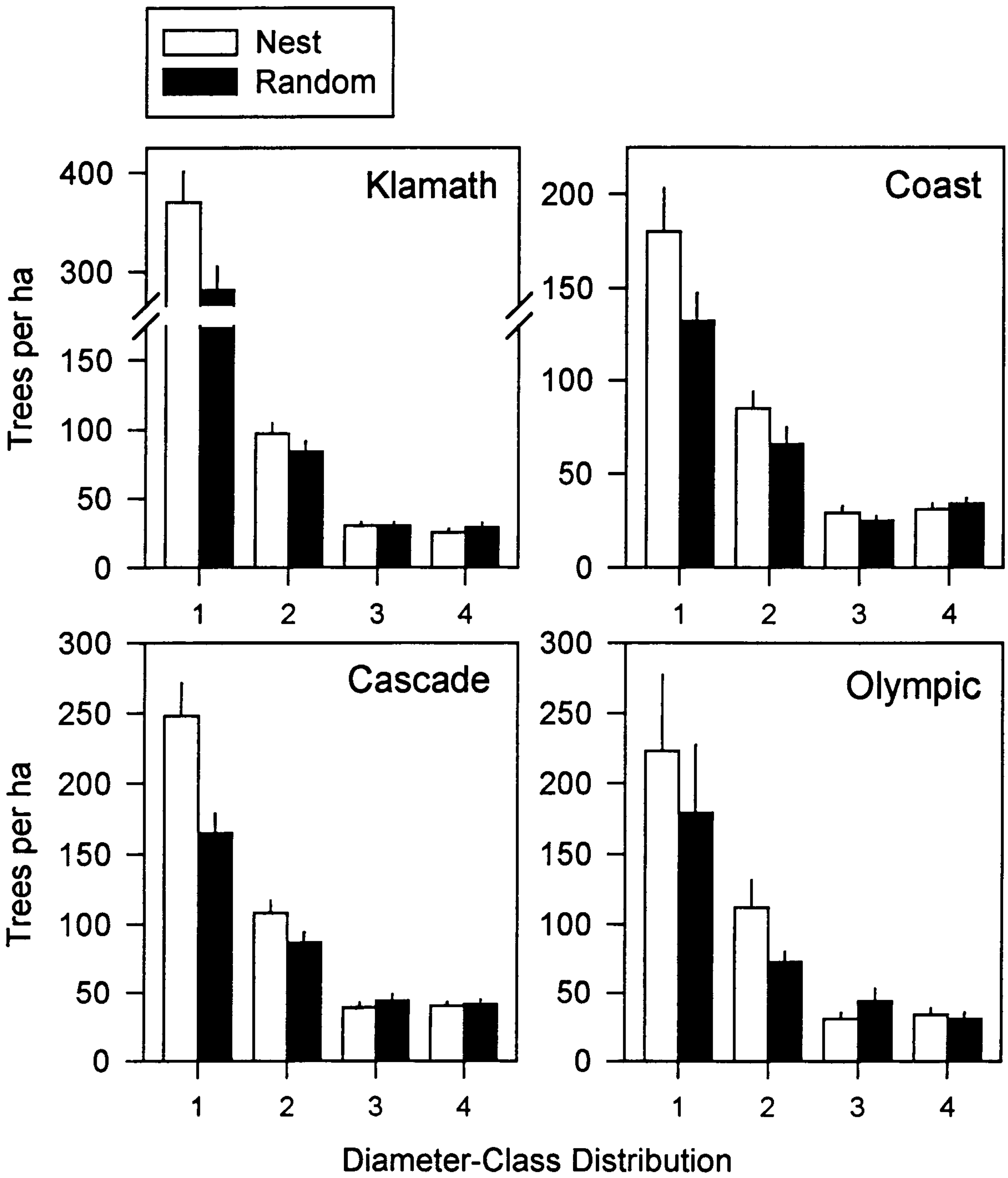

Figure 7. Diameter distributions by dbh class and physiographic province at spotted owl nest and random sites in the Pacific Northwest. Class 1 - 10.0-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - > 78.7 cm dbh. Whiskers on bars represent standard errors.

Table 17. Comparisons of mean densities/ha of 3 parameters[a] from the revised old-growth definition (Franklin and Spies 1991) by physiographic province.

Parameter and minimum standard	Physiographic Province: Klamath		Coast		Cascade		Olympic	
	Nest	Random	Nest	Random	Nest	Random	Nest	Random
All tree species >100 cm dbh[b] (≥ 10 per ha)	13.1	13.5	18.9	19.5	23.4	25.2	15.6	14.0
Shade associates[c] > 40 cm dbh (≥ 10 per ha)	-	-	37.4	33.0	46.5	46.8	-	-
Snags > 50 cm dbh > 5 m height (≥ 4 per ha)	4.7	4.8	6.0	7.7	8.3	8.8	11.4	12.8

[a] Downed log values not reported as they are not comparable between the studies.
[b] The minimum standards are for the Western Hemlock Series of the Oregon Cascade and Coast provinces. Values in the Klamath and Olympics are reported for comparative purposes.
[c] Minimum standards under the revised definition are not yet developed for the Klamath and Olympic provinces.

Table 18. Mean dbh of trees >100 cm dbh at spotted owl nest sites and random sites by physiographic province.

Mean dbh of trees >100 cm dbh							
	Nest Sites			Random Sites			
Province	N	Mean	SE	N	Mean	SE	*P*
Klamath	28	118.1	1.7	28	112.7	2.0	0.0881
Coast	30	138.5	3.3	30	127.2	2.6	0.0094
Cascade	29	130.1	3.1	28	123.5	2.5	0.1024
Olympic	15	130.7	6.2	14	123.6	4.6	0.3673
Total	102	130.6	1.8	100	123.1	1.3	0.0009

Based on the univariate results and the 4-variable logistic regression model (Table 15), spotted owl nest sites were associated with lower elevations and with older forests that are more decadent and structurally diverse than other older forest that was available within 1,000-2,400 m of a nest tree.

Nest sites were at lower elevations than random sites in all physiographic provinces; this association was particularly pronounced in the Klamath. This is probably because there is less older forest remaining at the more productive lower elevations due to agriculture and timber harvest. Nest sites also had greater horizontal and vertical diversity in stand structure than random sites in all physiographic provinces. Greater horizontal structural diversity at nest sites was evident by the higher density and basal area of understory trees (trees < 53.3 cm dbh) and was especially prominent in the Klamath hardwood understory. The interaction of the basal area of Class 1 trees and the volumes of decay Class 5 logs shows that the association of nest sites with Class 1 trees increases with the increase of decay Class 5 logs. This result is most likely because decay Class 5 logs are often used as "nurse logs" for seedlings, and therefore, the greater the volume of decay Class 5 logs, the greater the availability of rich seedbeds for tree regeneration. Greater vertical structural diversity at nest sites was evident in the higher density of trees in height classes 1 through 4 and indicated that nest sites had more densely, multilayered canopies than random sites.

The high level of understory structural diversity found at nest sites created a cooler and more humid microclimate during the hot, dry season because the deep, multiple canopy layers protects it from radiation and drying winds (Spies and Franklin 1991).

Because there is a suggestion that spotted owls are intolerant of high temperatures (Barrows and Barrows 1978, Barrows 1981), this moderated microclimate may explain their selection for such characteristics.

Basal area of broken-top trees and volume of decay Class 5 logs were greater at nest sites than at random sites in all physiographic provinces and were important discriminators between nest and random sites. These features add to the structural complexity at nest sites and indicate greater decadence at nest sites than at random sites. Large decaying logs are also a reservoir of moisture (Franklin et al. 1981:33) and may contribute to the cooler, more mesic microclimates at nest sites. In addition, large, broken-top trees were used most often for nest trees in all physiographic provinces (Table 5). As spotted owls do not build their own nests, but instead, use most often large, natural cavities in large broken-top trees, it may explain why the basal area of broken-top trees was the most significant variable distinguishing nest from random sites (Table 15).

Comparison to Other Research

In this section I compare my research with other studies of spotted owl nest sites, especially those of LaHaye (1988) and Buchanan (1991) who did extensive nest-site research in northern California and in the eastern Cascades in Washington, respectively, and Forsman et al. (1984) who measured characteristics of nests and nest trees in western Oregon and in the Oregon Klamath mountains. Methods used to sample nest sites were different in all of these projects. Buchanan (1991) sampled the habitat around nest trees and random locations using fixed-radius plots, and random sites were located in the nest stand within 400 m of the nest tree. LaHaye (1988) used variable-radius plots to sample around nest sites and random locations, and random sites were located between 200 and 1,500 m of the nest tree. Forsman et al. (1984) provided qualitative descriptions of nest stands in addition to the quantitative information on nests and nest trees.

General Site Characteristics

Nests sites in this study ranged in elevation from 122 m (400 ft) in the Coast Range to 1,585 m (5,200 ft) in the Klamath mountains. In LaHaye's (1988:13) study area, nest site elevations ranged from 36 m (118 ft) to 1,507 m (4,943 ft) and in Buchanan's (1991:24), elevations ranged from 381 m (1,250 ft) to 1,463 m (4,800 ft.) These elevations correspond to the elevational ranges of forest types with which spotted owl nest sites are associated.

Mean aspects at nest sites in this study were southwesterly in the Klamath, Coast and Cascades and northwesterly in Olympics. There was, however, no tendency toward a non-randon distribution of site aspects in any of the 4 provinces. Forsman et al. (1984:31), LaHaye (1988:18), and Buchanan (1991:79) also found that aspects at nest sites appeared randomly distributed.

Mean slopes at nest sites were similar in all provinces. I found that mean slopes ranged from 42% in the Klamath to 54% in the Cascades and Olympics. LaHaye (1988:18) reported mean slopes of 49% and Buchanan (1991:24) found mean slopes to be 41%. None of these slopes was statistically different from slopes at random sites.

Forsman et al. (1984:30) found that 57% of nest sites were located on the bottom 1/2 of slopes and LaHaye (1988:13) reported 68% on the bottom 1/2. Buchanan (1991:24-25) divided slopes into thirds and found the majority of nest sites (71%) in the bottom and middle thirds. I also found that majority of nest sites (80%) were located in the bottom and middle thirds of slopes. Only in the Klamath was the distribution of slope positions significantly different from random sites with a greater number of nest sites found in the bottom third of slopes.

Nest Trees and Nests

Douglas-fir was the most common species of nest tree in all studies (except the Olympic Peninsula). Previous studies have found that 83-92% of nests were located in Douglas-fir (Forsman et al. 1984:31, LaHaye 1988:18, Buchanan 1991:30). I found that 83-87% of nest trees were Douglas-fir in the Oregon provinces. In the Olympics, only 33% of nests were in Douglas-fir. This is because at many of the sites in the Olympics, Douglas-fir is absent or is replaced by western hemlock as the dominant overstory tree.

There are regional differences in the types of nests used by spotted owls. LaHaye (1988:27) reported that in northern California 80% of nests were in top or side cavities and that 20% were on platforms. Forsman et al. (1984:32) found that 81% of nests in western Oregon were in cavities, but that in the Klamath mountains and east slopes of the Cascades, 50% of nests were in cavities and 50% were on platforms. I found 93-94% cavity nests in the Cascade, Olympic and Coast provinces, and 58% in the Klamath province. In contrast, Buchanan (1991:85) reported that in the eastern Washington

Cacades, only 16% of nests were in cavities and that 80% were in “abandoned hawk nests” or mistletoe brooms. In many instances “hawk nests” were located on mistletoe brooms (74%) resulting in 66% of all nests in Buchanan's study on or within mistletoe clumps (Buchanan 1991:39). These differences likely depend on the availabilty of the different nest types. Forsman et al. (1984:32) reported that mistletoe infestations in Douglas-fir at his sites in the Klamath and east side of the Cascades were common, but that little mistletoe was associated with nest sites in western Oregon. I also found mistletoe infestations at many of the Klamath sites.

Mean nest aspect angles were either southeasterly or southwesterly in all studies and provinces. Buchanan (1991:41) reported 132° for the mean angle of nest exposures and LaHaye (1988:27) reported a mean aspect angle of 201°. In my study, Klamath and Cascade nests showed southwesterly mean aspect angles of 244° and 235° respectively, and Coast and Olympic nests showed southeasterly mean aspect angles of 146° and 174° respectively. In my study, the distribution of nest aspects was random; Buchanan (1991:41) found aspects of nests had a nonrandom distribution.

Stand Structure

Mean basal area of live trees varied considerably among the physiographic provinces, but was greater at nest sites than at random sites in all studies. The lowest basal area was found on the east side of the Washington Cascades where mean basal area was 38 m^2/ha (163 ft^2/ac) (Buchanan's 1991:88) and the greatest was found in the mixed conifer and Douglas-fir/tanoak forests of northern California with mean basal area of 77

m^2/ha (337 ft^2/ac) and 76 m^2/ha (330 ft^2/ac) respectively (LaHaye's 1988:93-94). In my study, mean basal area of live trees ranged from 53 m^2/ha in the Klamath to 73 m^2/ha in the Cascades.

Buchanan (1991:88) surmised that regional differences in live tree basal area most likely reflected differences in climate, tree growth rates, and fire histories. He also attributed the much larger basal area found in LaHaye's study to the greater abundance of hardwoods and large conifers (> 91 cm dbh). In addition, forest type and moisture regimes (Spies 1991) likely influence basal area. In my study, the high mean basal area of live trees found in the Coast, Cascade, and Olympic provinces is probably attributable to the density of large conifers which contrasts with the Klamath province, where the drier, hotter climate causes trees to grow more slowly and not reach the diameters and heights of the other regions.

In all provinces of my study the basal area of broken-top trees was greater at nest sites than random sites. LaHaye (1988:99-100) noted similar results, and found basal area of broken-top Douglas-firs was an important discriminator between nest and random sites. LaHaye (1988:67-68) surmised that spotted owls were nesting in these more decadent portions of forest because of the availability of broken-top nesting structures. I concur, but would add that it seems spotted owls are nesting in the more decadent old forest, as indicated by the presence of large, broken-top trees, regardless of the type of nesting structure they are using.

In my study there was little difference between density and basal area of snags at nest and random sites. Buchanan (1991:69) found that the basal area of his decay classes I and II snags and the density of his dbh class I snags were important discriminators between nest and random sites. In his study area, basal area of decay classes I and II snags were lower at nest sites and density of dbh class I snags was higher at nest sites than at random sites. Buchanan (1991:46) also found that basal area of decay class IV snags was significantly greater at nest sites. Because our snag dbh and decay classes were different, there were few comparisons that could be made between this study and Buchanan's. I found, however, that density of dbh Class 1 snags (10 - 27.9 cm dbh, Buchanan's class I was 10-33.0 cm dbh) were greater at nest sites than at random sites in the Coast and Olympic provinces.

In my study the volume of down logs in decay Classes 4 and 5 was greater at nest sites than random sites in all provinces combined (Table 14). Further, the volume of decay Class 5 logs was an important discriminator between nest and random sites in the final logistic regression model (Table 15). Buchanan (1991:137) did not find any difference between the volume of down woody debris at nest and random sites, although his analysis did not include decay Class 5 logs.

Mean canopy closure at nest sites was high and generally similar among studies. Forsman et al (1984:30) reported mean canopy closure at 26 nests at 69%. LaHaye (1988:93-94) found canopy closure to be 81-83% in northern California. Buchanan (1991:54) reported canopy closure to be 75% in his eastern Washington Cascade sites. In my study, canopy closure varied between 74% and 79% among physiographic provinces and was significantly greater at nest than at random sites in the Cascades and Olympics.

CONCLUSIONS

Forest managers need to know the range of habitat structures required for successful spotted owl nesting so that they can properly inventory their forests and set aside or produce sufficient nesting habitat to support nesting owls and their young. A forest landscape analysis of spotted owl nesting habitat (Ripple et al. 1991) indicates that nest sites are associated with greater amounts of older forest than at random sites in the general forest landscape. My study suggests that the older forests associated with spotted owl nest sites possess particular structures such multilayered canopies and high basal area of large broken-top trees that may not be present in all patches of older forest. It is, therefore, important that land managers set aside or produce sufficient amounts of older forests posessing these features.

Hall et al. (1985:299), USDI (1992:481-525), and Thomas et al. (1990:365-372), suggest ways that spotted owl habitat can be produced more rapidly by silvicultural means such as a series of thinnings, killing of some larger trees to produce large snags, and treatment of dense shrub layers to allow for regeneration of shade-tolerant conifers and hardwoods. These authors all recognize the need to create mixed species, multilayered stands, with trees, snags, and down woody debris of various ages and sizes and that tree diameter distributions should follow the reverse-J shaped curve found in old forest habitat where there are many small trees and a progressively fewer number of larger diameter trees.

In a natural setting it generally takes 175 to 225 years to begin to achieve the composition, structure, and function of older forests (Franklin et al. 1981, Franklin and Spies 1991b:77). In pursuing silvicultural prescriptions designed to mimic the stand structure of nesting habitat, it may be important to create forest stands that not only look structurally like nesting habitat but also function as nesting habitat. It is unclear whether the decadence that has been associated with the structural features at spotted owl nest sites such as large broken-top trees and decay class 5 logs can be reproduced silviculturally, and we have yet to document the function that decadence has in the selection of nest sites by spotted owls. Also fire, wind, pathogens, and other disturbances have acted jointly and sequentially at irregular intervals to produce the diverse species composition and stand structure found at nest sites (Agee 1991, USDI 1992), and we may not as yet have the understanding of these processes to reproduce them silviculturally.

There was evidence that some selective timber harvesting had occurred at a small percentage of nest sites. Buchanan (1991:81) reported that some selective or single-tree harvesting had occurred at 13 of 62 paired nest sites. He noted that these entries occurred at least 40 years prior to occupancy by owls and that structurally these stands were no different from unmanaged stands. Others have reported the presence of owls in managed forests in the California Klamath and Coast provinces (Diller 1989, Irwin et al. 1989a, 1989b, Kerns 1989, and Pious 1989), but researchers have pointed out that most of these stands exhibit high structural diversity, high canopy closure, large diameter trees or residual old trees, and that they are structurally similar to unmanaged stands (USDI 1992:21). In my study, the majority of nest sites in which some timber harvest had occurred had only a few trees removed and they also did not resemble what are usually thought of as "managed stands". Before any management plan included selective harvesting at nest sites or in potential nesting habitat, it would be important to document the survival, recruitment, dispersal, and reproductive success of spotted owls over time at sites where there has been selective harvesting (USDI 1992:21).

Also of critical importance at this time is the controversial issue of salvage logging. There is currently no general agreement in the scientific community as to how salvage logging would effect stand development in the long term. High volumes of dead trees and logs in all decay classes are integral components of habitat associated with spotted owl nest sites. Until we know more about the importance of snags and down logs in the stand structure of nest sites and potential nesting habitat, it seems wise to exclude salvage logging from such areas.

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APPENDICES

Appendix 1. List of northern spotted owl nest sites by site name, master site list number[a], and landownership in each physiographic province.

Site Name	Master Site Number	Ranger District (RD) or Resource Area (RA)	National Forest (NF) or BLM District
Klamath Province -			
Sykes Creek	964	Butte Falls RA	Medford BLM
Bowen Creek	2005	Butte Falls RA	Medford BLM
Shell Rock	884	Butte Falls RA	Medford BLM
Blue Goose	1831	Butte Falls RA	Medford BLM
Ragsdale	1825	Butte Falls RA	Medford BLM
Fredenburg	60	Butte Falls RA	Medford BLM
Deer Mobile	902	Ashland RA	Medford BLM
Rush Creek	97	Ashland RA	Medford BLM
Keeler Creek	2021	Ashland RA	Medford BLM
Honeysuckle Creek	1946	Grants Pass RA	Medford BLM
Board Tree East	877	Glendale RA	Medford BLM
Silver Fork	170	Applegate RD	Rogue River NF
Yale Creek	2713	Applegate RD	Rogue River NF
W. Branch Elk Creek	2002	Prospect RD	Rogue River NF
West Stouts	1935	South Umpqua RA	Roseburg BLM
Corn Creek North	1995	South Umpqua RA	Roseburg BLM
Turkey Creek	366	South Umpqua RA	Roseburg BLM
Catching Creek	2000	South Umpqua RA	Roseburg BLM
Peavine	2096	Dillard	Roseburg BLM
Dad's Creek	895	Dillard	Roseburg BLM
Yeager Creek	3228	Illinois Valley RD	Siskiyou NF
Elk Creek	470	Illinois Valley RD	Siskiyou NF
Miner's Shack	3186	Illinois Valley RD	Siskiyou NF
Lone Tree	420	Galice RD	Siskiyou NF
Secret Creek	472	Galice RD	Siskiyou NF
Devil's Canyon	403	Galice RD	Siskiyou NF
Silver Falls	471	Galice RD	Siskiyou NF
Meridian	1581	Tiller RD	Umpqua NF
Pickett Butte	2606	Tiller RD	Umpqua NF
Lucas Ranch	3808	Tiller RD	Umpqua NF
Coast Province -			
Upper Yellow Creek	1924	Drain RA	Roseburg BLM
Alder Creek	2038	Drain RA	Roseburg BLM
Eagle's View	1802	Drain RA	Roseburg BLM
Squaw Creek	514	Drain RA	Roseburg BLM
Riverview	281	Drain RA	Roseburg BLM
Cole Creek	1986	Drain RA	Roseburg BLM
Basin Creek	277	Drain RA	Roseburg BLM
Halfway Creek	264	Drain RA	Roseburg BLM

Appendix 1. continued.

Site Name	Master Site Number	Ranger District (RD) or Resource Area (RA)	National Forest (NF) or BLM District
Coast Province -			
Weaver Ridge	2190	Myrtlewood RA	Coos Bay BLM
Upper E.Fk. Brummet	537	Tioga RA	Coos Bay BLM
Bateman	2332	Tioga RA	Coos Bay BLM
Old Blue	541	Umpqua RA	Coos Bay BLM
Buck Creek	553	Umpqua RA	Coos Bay BLM
Little Paradise	2174	Umpqua RA	Coos Bay BLM
Wells Creek	2177	Umpqua RA	Coos Bay BLM
Bill Lewis	2139	Coast Range RA	Eugene BLM
Congdon Creek	520	Coast Range RA	Eugene BLM
Haight Creek Rec Site	129	Coast Range RA	Eugene BLM
Saleratus Creek	134	Coast Range RA	Eugene BLM
Walker Creek	159	Coast Range RA	Eugene BLM
Chinquapin	1850	Alsea RD	Siuslaw NF
Franklin Ridge	2638	Alsea RD	Siuslaw NF
Peach Branch	789	Mapleton RD	Siuslaw NF
Maria Creek	3124	Mapleton RD	Siuslaw NF
Morris Creek	769	Mapleton RD	Siuslaw NF
Deer Creek	770	Mapleton RD	Siuslaw NF
Wapiti	2737	Waldport RD	Siuslaw NF
Prairie Peak	188	Alsea RA	Salem BLM
Skunk Creek	187	Alsea RA	Salem BLM
West Dorn	189	Yamhill RA	Salem BLM
Cascade Province -			
Stoney Creek	354	North Umpqua RA	Roseburg BLM
Honey Creek	510	North Umpqua RA	Roseburg BLM
Wapiti Creek	350	North Umpqua RA	Roseburg BLM
Tumblebug	1072	Rigdon RD	Willamette NF
Will Bull	1083	Rigdon RD	Willamette NF
Leap Frog South	1113	Oakridge RD	Willamette NF
Lower Mckinley	2783	Oakridge RD	Willamette NF
Lower Goodman	2876	Lowell RD	Willamette NF
Boundary	2892	Lowell RD	Willamette NF
Florence Creek	2034	McKenzie Br RD	Willamette NF
Middle McRae	33	Blue River RD	Willamette NF
Lowder Mountain	857	Blue River RD	Willamette NF
Upper Gate Creek	672	Sweet Home RD	Willamette NF
Sheep Creek	14	Sweet Home RD	Willamette NF
Mansfield Creek	3317	Detroit RD	Willamette NF
Misery	3314	Detroit RD	Willamette NF

Appendix 1. continued.

Site Name	Master Site Number	Ranger District (RD) or Resource Area (RA)	National Forest (NF) or BLM District
Cascade Province -			
Lake Creek	1463	Tiller RD	Umpqua NF
Skookum Chuck	3773	Tiller RD	Umpqua NF
Withrow	1516	North Umpqua RD	Umpqua NF
Winslow	2594	North Umpqua RD	Umpqua NF
Grandad	3675	North Umpqua RD	Umpqua NF
Junction Creek	3691	North Umpqua RD	Umpqua NF
Bridal Veil	1714	Columbia Gorge RD	Mt. Hood NF
Reservoir	1724	Columbia Gorge RD	Mt. Hood NF
Bear Creek	3517	Hood River RD	Mt. Hood NF
Lost Lake North	1624	Hood River RD	Mt. Hood NF
Joy	3583	Clackamas RD	Mt. Hood NF
Rebuck	1410	Clackamas RD	Mt. Hood NF
Pyramid	3541	Clackamas RD	Mt. Hood NF
Bump Lake	3459	Clackamas RD	Mt. Hood NF
Olympic Province -			
Brandeberry Creek	7	Soleduck RD	Olympic NF
Cold Creek	152	Soleduck RD	Olympic NF
Reade Hill	400	Soleduck RD	Olympic NF
West Twin	255	Soleduck RD	Olympic NF
Big Canyon	411	Quilcene RD	Olympic NF
Mount Walker	171	Quilcene RD	Olympic NF
Skookum Creek	258	Quilcene RD	Olympic NF
Jimmiecomelately	768	Quilcene RD	Olympic NF
Stovepipe	86	Quinault RD	Olympic NF
Humptulip	80	Quinault RD	Olympic NF
East Methery	44	Quinault RD	Olympic NF
Sam's Ridge	449	Quinault RD	Olympic NF
Washington Creek	98	Hood Canal RD	Olympic NF
Rule Creek	17	Hood Canal RD	Olympic NF
Le Bar	709	Hood Canal RD	Olympic NF

[a] Master site list numbers from the Oregon Dept. of Fish and Wildlife and Washington Dept. of Fish and Wildlife spotted owl databases.

Appendix 2. List of tree species found at spotted owl nest and random sites. Numbers listed under NUMBER OF SITES indicate the number of sites at which each species can be found by physiographic province. (n=30 for Klamath, Coast, and Cascade sites and n=15 for Olympic sites).

Species name	Common name	Number of sites							
		Klamath		Coast		Cascade		Olympic	
		Nest	Random	Nest	Random	Nest	Random	Nest	Random
Abies amabilis	Pacific silver fir	0	0	0	1	8	12	9	12
Abies concolor	white fir	18	19	0	0	9	10	0	0
Abies grandis	grand fir	3	2	8	8	4	8	0	0
Abies magnifica	California red fir	1	2	0	0	0	0	0	0
Abies procera	noble fir	1	1	0	0	3	6	1	0
Acer circinatum	vine maple	2	2	11	14	4	7	6	2
Acer globular douglasii	Douglas maple	0	2	1	0	0	0	0	0
Acer macrophyllum	bigleaf maple	19	9	26	21	14	8	1	2
Alnus rubra	red alder	6	1	18	16	5	4	0	2
Arbutus menziesii	madrone	27	27	8	1	5	7	0	0
Castanopsis chrysophylla	golden chinkapin	18	14	12	9	9	7	0	0
Calocedrus decurrens	incense-cedar	25	19	3	3	11	10	0	0
Chamaecyparis lawsoniana	Port-Orford-cedar	2	1	1	0	1	0	0	0
Cornus nuttallis	Pacific dogwood	13	11	13	12	8	5	1	0
Lithocarpus densiflorus	tanoak	10	9	0	0	0	0	0	0
Picea sitchensis	Sitka spruce	0	0	1	1	0	1	2	5
Pinus attenuata	knobcone pine	2	1	0	0	0	0	0	0
Pinus lambertiana	sugar pine	10	11	0	0	7	6	0	0
Pinus monticola	western white pine	3	4	0	0	2	3	0	0
Pinus ponderosa	ponderosa pine	5	9	0	0	0	0	0	0
Pseudotsuga menziesii	Douglas-fir	30	29	30	30	30	30	9	9

Appendix 2. continued.

Species name	Common name	Number of sites							
		Klamath		Coast		Cascade		Olympic	
		Nest	Random	Nest	Random	Nest	Random	Nest	Random
Quercus chrysolepis	canyon live oak	16	11	0	1	0	0	0	0
Quercus garryana	Oregon white oak	6	1	0	0	0	0	0	0
Quercus kelloggii	California black oak	10	6	1	0	0	0	0	0
Taxus brevifolia	Pacific yew	11	7	9	9	17	12	4	5
Thuga plicata	western redcedar	0	0	21	20	21	15	12	11
Tsuga heterophylla	western hemlock	3	6	29	25	29	30	15	15
Tsuga mertiana	mountain hemlock	0	1	0	0	0	5	0	0
Umbellularia californica	California laurel	0	0	4	0	0	0	0	0

Appendix 3. Paired comparisons of tree density (trees/ha) by dbh class and physiographic province. P-values are from paired t-tests.

Tree density by dbh class[a]	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30									
Class 1	370	140	814	31	281	70	580	24	0.0243
Class 2	97	44	210	8	84	26	174	7	0.1899
Class 3	30	14	68	3	30	10	84	3	0.9245
Class 4	25	0	54	2	29	2	58	3	0.2519
Total	520	284	982	33	424	182	688	26	0.0188
Coast n = 30									
Class 1	180	10	362	20	132	22	310	15	0.0058
Class 2	85	30	202	8	66	16	288	9	0.0148
Class 3	29	6	92	4	25	2	54	2	0.2673
Class 4	31	4	70	3	34	10	62	3	0.3526
Total	325	126	498	21	258	112	514	19	0.0046
Cascade n = 30									
Class 1	248	46	490	23	165	20	336	14	0.0024
Class 2	108	46	278	9	87	4	170	7	0.0581
Class 3	39	8	94	4	44	8	100	5	0.2237
Class 4	40	6	70	3	41	12	80	4	0.6397
Total	435	190	704	26	338	140	498	17	0.0039
Olympic n = 15									
Class 1	223	30	736	54	179	70	812	48	0.3590
Class 2	112	48	278	20	73	36	118	7	0.0467
Class 3	41	12	78	4	44	12	142	9	0.7469
Class 4	34	4	58	4	31	4	60	4	0.5483
Total	410	180	946	63	327	188	910	48	0.0547

[a] Class 1 - 10-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - >78.7 cm dbh.

Appendix 12. Paired comparisons of snag density (snags/ha) by dbh class and physiographic province. P-values are from paired t-tests.

Snag density by dbh class[a]	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30									
Class 1	35	1	237	9	18	0	74	3	0.0713
Class 2	6	1	29	1	5	0	26	1	0.5363
Class 3	3	1	14	1	2	0	9	0	0.5931
Class 4	3	0	7	0	3	0	8	0	0.8790
Total	47	5	246	9	28	5	116	4	0.0668
Coast n = 30									
Class 1	19	1	54	3	12	1	97	3	0.0396
Class 2	5	1	18	1	6	1	24	1	0.4451
Class 3	3	0	6	0	2	0	7	0	0.5174
Class 4	6	0	31	1	7	0	24	1	0.2892
Total	32	4	85	4	27	5	104	3	0.2203
Cascade n = 30									
Class 1	25	1	152	5	16	1	82	3	0.1254
Class 2	7	0	21	1	10	0	45	2	0.1476
Class 3	5	0	15	1	6	0	18	1	0.2817
Class 4	7	2	25	1	6	0	15	1	0.2371
Total	44	17	170	6	38	7	105	4	0.2822
Olympic n = 15									
Class 1	33	5	110	9	17	0	76	5	0.0402
Class 2	10	2	21	2	11	3	29	2	0.4128
Class 3	9	2	21	1	8	4	14	1	0.7152
Class 4	8	0	24	2	10	0	27	2	0.2314
Total	60	28	135	8	47	22	96	5	0.0641

[a] Class 1 - 10-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - >78.7 cm dbh.

Appendix 5. Paired comparisons of hardwood density (trees/ha) by dbh class and physiographic province. P-values are from paired t-tests.

Hardwood density by dbh class[a]	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30[b]									
Class 1	190	2	710	31	113	0	486	20	0.0094
Class 2	25	0	46	2	26	0	88	5	0.8168
Class 3	2	0	12	1	2	0	10	1	0.7590
Class 4	0.06	0	2	1	0	0	0	0	0.3256
Total	216	2	756	33	140	0	576	24	0.0182
Coast n = 30[c]									
Class 1	49	0	294	12	31	0	122	5	0.1004
Class 2	18	0	54	3	13	0	56	2	0.1381
Class 3	4	0	36	2	2	0	14	1	0.0657
Class 4	0.4	0	4	0	0.1	0	2	0	0.1608
Total	72	0	346	13	47	0	152	7	0.0335
Cascade n = 30[d]									
Class 1	33	0	162	7	21	0	96	5	0.0955
Class 2	5	0	30	2	6	0	42	2	0.5876
Class 3	0.1	0	2	0	0.3	0	4	0	0.3746
Class 4	0	0	0	0	0	0	0	0	-
Total	38	0	168	8	28	0	102	6	0.1525
Olympic n = 15									
Class 1	3	0	20	1	4	0	20	2	0.3510
Class 2	1	0	18	1	0.4	0	4	0	0.4721
Class 3	0	0	0	0	0	0	0	0	-
Class 4	0	0	0	0	0	0	0	0	-
Total	4	0	38	3	5	0	24	2	0.8130

[a] Class 1 - 10-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - >78.7 cm dbh.
[b] Klamath- Class 3 based on 14 paired sites; Class 4 based on 1 site only.
[c] Coast- Class 3 based on 14 paired sites; Class 4 based on 5 paired sites.
[d] Cascades- Class 3 based on 3 paired sites.

Appendix 6. Paired comparisons of tree basal area (m^2/ha) by dbh class and physiographic province. P-values are from paired t-tests.

Tree basal area by dbh class[a]	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30									
Class 1	8.9	3.5	20.4	0.7	6. 8	1.8	14.1	0.6	0.0175
Class 2	11.1	4.8	24.4	0.9	9.7	3.3	22.0	0.9	0.2350
Class 3	10.0	4.1	22.2	0.9	10.1	3.6	28.2	0.9	0.8989
Class 4	23.2	0	63.8	2.8	25.2	1.1	56.4	2.9	0.5066
Total	53.2	29.6	85.2	2.6	51.8	35.8	81.6	2.3	0.6344
Coast n = 30									
Class 1	4.7	0.4	9.7	0.5	3.5	0.4	7.9	0.4	0.0106
Class 2	10.2	3.4	25.2	0.9	7.8	2.5	32.0	1.0	0.0101
Class 3	9.4	1.7	30.0	1.1	8.5	0.5	18.2	0.8	0.4415
Class 4	36.0	4.6	63.8	2. 6	35.6	6.9	80.4	3.4	0.8991
Total	60.4	28.2	98.4	3.1	55.4	21.8	95.6	3.4	0.2149
Cascade n = 30									
Class 1	6.4	1.4	12.4	0.5	4.2	0.5	7.4	0.3	0.0012
Class 2	12.7	6.1	31.0	1.0	10.6	0.6	21.6	0.9	0.1101
Class 3	13.0	2.3	32.8	13.0	15.0	3.5	35.4	1.6	0.2275
Class 4	41.4	3.5	85.2	3.5	41.6	9.5	86.8	4.4	0.9919
Total	73.4	51.8	106.6	2.7	71.4	38.8	104.2	3.1	0.5867
Olympic n = 15									
Class 1	6.1	1.1	18.1	1.4	4.4	1.9	18.4	1.1	0.1642
Class 2	13.4	5.7	34.2	2.3	9.1	4.9	17.5	1.1	0.0831
Class 3	13.5	3.7	24.6	1.3	15.0	4.4	49.2	3.0	0.6377
Class 4	37.2	3.9	110.0	7.3	29.0	2.1	73.2	4.9	0.2160
Total	70.0	45.6	136.0	6.1	57.6	35.8	95.6	4.4	0.0776

[a] Class 1 - 10-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - >78.7 cm dbh.

Appendix 7. Paired comparisons of softwood basal area (m^2/ha) by dbh class and physiographic province. P-values are from paired t-tests.

Softwood basal area by dbh class[a]	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30									
Class 1	4.3	1.1	11.1	0.4	3.9	0.9	11.3	0.5	0.4530
Class 2	8.6	2.6	20.0	0.9	7.2	2.5	21.8	0.8	0.1806
Class 3	9.4	3.4	22.2	0.9	9.5	3.1	28.2	0.9	0.9599
Class 4	23.2	0	63.8	2.8	25.2	1.1	56.4	2.9	0.4960
Total	45.4	19.0	75.8	2.6	45.8	14.3	75.0	2.6	0.9185
Coast n = 30									
Class 1	3.4	0	94.2	0.4	2.7	0.1	7.7	0.4	0.0688
Class 2	8.1	0.7	23.2	1.1	6.3	1.2	30.6	1.0	0.0717
Class 3	8.0	1.2	26.6	1.1	7.9	0.5	18.2	0.8	0.9546
Class 4	35.8	3.2	60.2	2.6	35.6	6.9	80.4	3.4	0.9564
Total	55.2	20.4	94.2	3.4	52.6	16.7	95.0	3.5	0.5170
Cascade n = 30									
Class 1	5.6	1.4	11.6	0.5	3.7	0.4	6.5	0.3	0.0020
Class 2	11.6	6.1	28.4	1.0	10.1	0.6	21.6	0.9	0.1085
Class 3	12.9	2.3	32.8	1.3	14.9	3.5	35.4	1.6	0.2441
Class 4	41.4	3.5	85.2	3.5	41.6	9.5	86.8	4.4	0.9919
Total	72.2	50.2	106.6	2.8	70.2	36.8	104.0	3.2	0.6141
Olympic n = 15									
Class 1	6.0	1.1	17.5	1.4	4.3	1.8	18.4	1.1	0.1545
Class 2	13.2	5.7	34.2	2.3	9.1	4.9	17.5	1.1	0.0924
Class 3	13.5	3.7	24.6	1.3	15.0	4.4	49.2	3.0	0.6377
Class 4	37.2	3.9	110.0	7.3	29.0	2.1	73.2	4.9	0.2160
Total	69.8	45.6	136.0	6.1	57.4	35.6	95.6	4.4	0.0807

[a] Class 1 - 10-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - >78.7 cm dbh.

Appendix 8. Paired comparisons of hardwood basal area (m^2/ha) by dbh class and physiographic province. P-values are from paired t-tests.

Hardwood basal area by dbh class[a]	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30[b]									
Class 1	4.6	0.0	17.6	0.7	2.8	0	13.1	0.5	0.0128
Class 2	2.4	0	5.7	0.3	2.5	0	8.4	0.4	0.8406
Class 3	0.5	0	3.4	1.7	0.6	0	3.0	1.7	0.0058
Class 4	0.0	0	1.3	0.0	0	0	0	0	0.3256
Total	7.6	0.0	21.0	0.9	6.0	0	22.0	1.0	0.1096
Coast n = 30[c]									
Class 1	1.2	0	7.5	0.3	0.8	0	3.7	0.1	0.1412
Class 2	2.1	0	8.2	0.4	1.5	0	6.9	0.3	0.1711
Class 3	1.4	0	11.4	0.5	0.5	0	4.5	0.2	0.4809
Class 4	0.3	0	3.3	0.1	0.1	0	1.4	0.1	0.1331
Total	5.1	0	19.5	0.9	2.9	0	12.4	0.5	0.0122
Cascade n = 30[d]									
Class 1	0.7	0	3.4	0.2	0.5	0	1. 8	0.1	0.1128
Class 2	0.5	0	2.7	0.2	0.6	0	4.3	0.2	0.7503
Class 3	0.0	0	0.5	0.0	0.1	0	1.4	0.1	0.1421
Class 4	0	0	0	0	0	0	0	0	-
Total	1.3	0	4.7	0.3	1.2	0	6.3	0.3	0.5941
Olympic n = 15									
Class 1	0.1	0	0.6	0.0	0.1	0	0.4	0.0	0.7611
Class 2	0.1	0	1.6	0.1	0.0	0	0.3	0.0	0.4356
Class 3	0	0	0	0	0	0	0	0	-
Class 4	0	0	0	0	0	0	0	0	-
Total	0.2	0	2.3	0.2	0.1	0	0.7	0.0	0.6100

[a] Class 1 - 10-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - >78.7 cm dbh.
[b] Klamath - Class 3 based on 14 paired sites; Class 4 based on 1 site only.
[c] Coast - Class 3 based on 14 paired sites; Class 4 based on 5 paired sites.
[d] Cascades - Class 3 based on 3 paired sites.

Appendix 9. Density of trees (trees/ha) by height class and physiographic province. P-values are from paired t-tests.

Tree density by height class[a]	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30									
Class 1	249	88	576	23	188	30	350	15	0.0325
Class 2	99	24	226	10	87	14	244	11	0.3252
Class 3	54	6	146	6	42	12	128	5	0.0680
Class 4	36	6	90	4	33	10	92	4	0.5545
Class 5	26	2	44	2	23	2	40	2	0.2489
Class 6	15	0	54	3	18	0	46	3	0.4143
Coast n = 30									
Class 1	102	4	280	13	71	6	184	9	0.0061
Class 2	62	8	170	6	40	6	96	5	0.0019
Class 3	52	12	180	6	36	2	104	4	0.8261
Class 4	36	2	152	5	28	8	202	6	0.0338
Class 5	28	0	124	4	25	4	172	6	0.4522
Class 6	31	2	90	4	40	6	94	4	0.1039
Cascade n = 30									
Class 1	134	38	284	13	92	16	170	7	0.0060
Class 2	86	22	188	8	54	0	49	5	0.0012
Class 3	68	22	240	8	45	8	90	4	0.0101
Class 4	49	14	152	6	51	8	132	6	0.7768
Class 5	31	8	72	3	32	2	90	4	0.9390
Class 6	29	0	70	4	33	0	92	5	0.5368
Olympic n = 15									
Class 1	98	18	272	21	82	30	334	20	0.3326
Class 2	85	24	298	11	74	20	388	24	0.6475
Class 3	75	18	208	18	41	12	108	7	0.7768
Class 4	63	20	194	13	35.2	4	98	7	0.0226
Class 5	41	2	108	6	35	4	98	7	0.5404
Class 6	26	0	56	5	26	8	62	4	0.9854

[a] Class 1 - 7.6-15.2 m; Class 2 - 15.3-22.9 m; Class 3 - 23.0-30.6 m; Class 4 - 30.7-38.3 m; Class 5 - 38.4-46.0m; Class 6 - >46.0 m.

Appendix 10. Paired comparisons of the basal area (m^2/ha) and density (trees/ha) of broken-top trees by physiographic province. P-values are from paired t-tests.

Broken-top trees[a]	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30									
Basal area	3.8	0	17.9	0.8	1.6	0	9.7	0.5	0.0090
Density	3	0	14	1	2	0	10	0.5	0.1129
Coast n = 30									
Basal area	7.1	0.5	42.8	1.6	2.2	0	5.4	0.5	0.0054
Density	5	2	14	1	3	0	14	1	0.0150
Cascade n = 30									
Basal area	9.4	1.2	35.6	1.4	3.7	0	19.1	0.9	0.0001
Density	9	2	30	1	5	0	18	1	0.0006
Olympic n = 15									
Basal area	7.7	0	31.4	2.1	5.6	0.5	14.7	0.9	0.3353
Density	7	0	18	1	9	2	22	1	0.2787

[a] Broken-top trees >53.3 cm dbh with 1 or more secondary crowns

Appendix 11. Paired comparisons of sapling and seedling densities (trees/ha) by physiographic province. P-values are from paired t-tests.

	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30									
Softwood sapling	93	18	194	9	127	6	664	25	0.1923
Hardwood sapling	32	0	256	12	10	0	142	5	0.1309
Sapling total	124	18	286	13	137	6	734	27	0.4466
Seedling total	1105	12	3320	148	945	0	3120	136	0.4685
Coast n = 30									
Softwood sapling	45	0	278	10	53	0	294	11	0.2758
Hardwood sapling	8	0	114	4	2	0	18	1	0.0194
Sapling total	52	0	278	10	54	0	312	11	0.8150
Seedling total	395	0	1560	79	555	0	2200	114	0.2706
Cascade n = 30									
Softwood sapling	122	28	456	18	90	12	508	18	0.0152
Hardwood sapling	12	0	104	4	9	0	70	3	0.4612
Sapling total	134	34	474	18	99	12	508	18	0.1223
Seedling total	911	0	2920	137	993	40	4240	187	0.6795
Olympic n = 15									
Softwood sapling	123	10	366	27	116	28	262	19	0.7022
Hardwood sapling	4	0	24	2	3	0	14	1	0.5836
Sapling total	127	12	366	28	119	28	262	19	0.6743
Seedling total	1589	120	3600	295	1517	40	3200	283	0.8657

Appendix 12. Paired comparisons of snag density (snags/ha) by dbh class and physiographic province. P-values are from paired t-tests.

Snag density by dbh class[a]	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30									
Class 1	35	1	237	9	18	0	74	3	0.0713
Class 2	6	1	29	1	5	0	26	1	0.5363
Class 3	3	1	14	1	2	0	9	0	0.5931
Class 4	3	0	7	0	3	0	8	0	0.8790
Total	47	5	246	9	28	5	116	4	0.0668
Coast n = 30									
Class 1	19	1	54	3	12	1	97	3	0.0396
Class 2	5	1	18	1	6	1	24	1	0.4451
Class 3	3	0	6	0	2	0	7	0	0.5174
Class 4	6	0	31	1	7	0	24	1	0.2892
Total	32	4	85	4	27	5	104	3	0.2203
Cascade n = 30									
Class 1	25	1	152	5	16	1	82	3	0.1254
Class 2	7	0	21	1	10	0	45	2	0.1476
Class 3	5	0	15	1	6	0	18	1	0.2817
Class 4	7	2	25	1	6	0	15	1	0.2371
Total	44	17	170	6	38	7	105	4	0.2822
Olympic n = 15									
Class 1	33	5	110	9	17	0	76	5	0.0402
Class 2	10	2	21	2	11	3	29	2	0.4128
Class 3	9	2	21	1	8	4	14	1	0.7152
Class 4	8	0	24	2	10	0	27	2	0.2314
Total	60	28	135	8	47	22	96	5	0.0641

[a] Class 1 - 10-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - >78.7 cm dbh.

Appendix 13. Paired comparisons of snag basal area (m^2/ha) by decay class and physiographic province. P-values are from paired t-tests.

Snag Basal Area by decay class[a]	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30									
Class 1	1.1	0.0	6.2	0.3	1.1	0	5.3	0.3	0.9650
Class 2	2.3	0.0	7.2	0.3	1.9	0.1	6.9	0.3	0.3333
Class 3	1.6	0	6.0	0.3	1.3	0	6.5	0.3	0.4466
Total	5.0	0.2	13.5	0.6	4.2	0.4	13.3	0.6	0.2449
Coast n = 30									
Class 1	0.3	0	1.7	0.1	0.6	0	6.2	0.2	0.1741
Class 2	2.7	0	9.2	0.4	4.3	0	15.7	0.8	0.0582
Class 3	5.7	0.1	41.6	1.5	5.7	0.1	20.4	1.0	0.9936
Total	8.6	0.7	43.4	1.5	10.5	1.1	32.0	1.4	0.2557
Cascade n = 30									
Class 1	2.3	0.0	9.2	0.4	2.0	0	10.0	0.4	0.6392
Class 2	2.8	0.1	10.1	0.5	2.8	0.1	9.8	0.5	0.9992
Class 3	5.3	0.7	11.1	0.5	4.2	0.1	13.7	0.7	0.2219
Total	10.4	4.0	29.5	1.0	9.0	0.9	2.2	0.9	0.3546
Olympic n = 15									
Class 1	1.1	0	4.9	0.3	2.6	0	7.8	0.5	0.0451
Class 2	2.8	1.5	6.7	0.4	4.2	0.9	10.8	0.8	0.1415
Class 3	9.2	1.9	26.0	2.2	8.2	1.3	22.8	1.7	0.6744
Total	13.1	4.1	32.7	2.3	14.9	4.1	33.5	2.1	0.4385

[a] Nelson (1988) modified from Cline (1980).

Appendix 14. Volume of down logs (m^3/ha) by decay class and physiographic province. P-values are from paired t-tests.

Log volume by decay class[a]	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30									
Class 1	54	0	487	20	77	0	433	22	0.4932
Class 2	226	0	944	51	235	0	714	41	0.8937
Class 3	583	51	1937	84	713	0	1932	84	0.2307
Class 4	492	1510	1201	64	369	0	1039	52	0.1480
Class 5	220	0	1510	57	130	0	816	34	0.1414
Total	1575	354	3744	174	1524	137	3339	143	0.8136
Coast n = 30									
Class 1	100	0	726	27	200	0	2659	91	0.3237
Class 2	659	12	2793	118	600	3	3144	119	0.7512
Class 3	1315	2	5988	222	1331	63	3531	162	0.8261
Class 4	1004	55	2008	107	674	8	2680	100	0.0145
Class 5	238	0	703	33	167	0	875	37	0.1346
Total	3375	362	11283	391	2981	266	7627	262	0.2372
Cascade n = 30									
Class 1	147	0	969	46	121	0	897	37	0.6604
Class 2	376	0	1626	61	474	29	1463	72	0.2917
Class 3	1276	222	3405	140	1198	42	4904	200	0.7252
Class 4	1079	109	2597	124	643	68	1635	83	0.0071
Class 5	295	15	697	36	276	0	1223	46	0.7293
Total	3173	426	5451	249	2714	237	7496	311	0.2269
Olympic n = 15									
Class 1	32	0	140	11	44	0	247	17	0.5572
Class 2	392	0	1267	98	702	69	229	160	0.1312
Class 3	2257	169	5417	418	2092	632	4328	291	0.6724
Class 4	1242	57	2683	190	1323	197	3620	223	0.6890
Class 5	221	0	624	45	150	3	742	48	0.3341
Total	4146	588	7961	569	4312	926	10500	568	0.7440

[a] Maser et al. (1979).

Appendix 15. Paired comparisons of canopy closure (%) and tall shrub cover (%) by physiographic province. P-values are from paired t-tests.

	Nest Sites				Random Sites				
	Mean	Min	Max	SE	Mean	Min	Max	SE	*P*
Klamath n = 30									
Canopy Closure	74	54	84	1	73	66	81	1	0.6797
Tall shrub cover	9.6	0	48.3	0.0	14.8	0	50.4	0.0	0.1230
Coast n = 30									
Canopy Closure	75	62	85	1	77	55	90	2	0.3820
Tall shrub cover	16.4	0	43.8	0.0	19.4	0	55.5	0.0	0.3411
Cascade n = 30									
Canopy Closure	79	70	90	1	76	69	92	1	0.0040
Tall shrub cover	7.0	0	46.0	0.0	8.6	0	60.5	0.0	0.5564
Olympic n = 15									
Canopy Closure	79	68	87	1	75	65	84	1	0.0033
Tall shrub cover	4.8	0	20.4	0.0	2.7	0	14.6	0.0	0.2212

Appendix 16. Mean density (trees/ha) by dbh class[a] and total basal area (m^2/ha) of major tree species in the Klamath province.

Tree species	Nest site N	Nest site Mean	Nest site SE	Random site N	Random site Mean	Random site SE
Bigleaf maple						
Class 1	19	17	4	8	15	5
Class 2	11	5	2	6	5	1
Class 3	1	6		1	2	
Class 4	0	0		0	0	
Total density	19	20	4	9	17	5
Total basal area	19	0.8	0.3	9	0.7	0.2
Black oak						
Class 1	9	22	9	5	24	12
Class 2	5	10	6	3	5	1
Class 3	1	10		1	2	
Class 4	0	0		0	0	
Total density	10	26	11	6	23	11
Total basal area	10	1.1	0.7	6	0.7	0.3
California live oak						
Class 1	16	44	18	11	22	8
Class 2	6	4	2	3	8	4
Class 3	2	2		0	0	
Class 4	0	0		0	0	
Total density	16	46	18	11	24	10
Total basal area	16	1.0	0.4	11	0.7	0.3
Dogwood						
Class 1	14	7	2	10	10	5
Class 2	1	2		0	0	
Class 3	0	0		0	0	
Class 4	0	0		0	0	
Total density	14	7	2	10	10	5
Total basal area	14	0.1	0.0	10	0.1	0.1
Douglas-fir						
Class 1	30	101	11	29	107	19
Class 2	30	49	6	28	43	5
Class 3	30	19	2	28	22	3
Class 4	29	18	2	27	24	3
Total density	30	187	16	29	198	20
Total basal area	30	31.6	2.4	29	35.6	2.9

Appendix 16. continued.

Tree species	Nest site N	Nest site Mean	Nest site SE	Random site N	Random site Mean	Random site SE
Golden chinkapin						
Class 1	17	30	10	14	42	18
Class 2	9	7	3	5	23	13
Class 3	0	0		0	0	
Class 4	0	0		0	0	
Total density	18	31	11	14	50	23
Total basal area	18	1.1	0.4	14	1.9	1.0
Incense-cedar						
Class 1	24	28	10	16	18	5
Class 2	14	5	3	11	5	1
Class 3	10	4	1	8	4	1
Class 4	14	6	1	8	5	1
Total density	25	37	12	19	22	6
Total basal area	25	4.8	1.0	19	3.0	1.0
Madrone						
Class 1	26	97	18	27	40	7
Class 2	27	18	21	22	20	3
Class 3	6	3	1	13	4	1
Class 4	1	2		0	0	
Total density	27	112	19	27	58	10
Total basal area	27	4.7	0.7	27	3.5	0.6
Pacific yew						
Class 1	11	10	3	6	27	12
Class 2	3	2		2	19	15
Class 3	0	0		0	0	
Class 4	0	0		0	0	
Total density	11	11	3	6	34	17
Total basal area	11	0.3	0.1	6	1.2	0.8
Tanoak						
Class 1	10	112	45	9	106	43
Class 2	6	6	2	4	22	10
Class 3	2	6	4	1	2	
Class 4	0	0		0	0	
Total density	10	117	46	9	116	49
Total basal area	10	2.9	1.2	9	3.2	1.6

Appendix 16. continued.

Tree species	Nest site			Random site		
	N	Mean	SE	N	Mean	SE
White fir						
Class 1	18	69	13	19	72	20
Class 2	15	28	8	11	30	7
Class 3	11	13	4	10	9	2
Class 4	6	13	5	7	8	4
Total density	18	104	23	19	97	26
Total basal area	18	10.3	3.2	19	7.4	2.3
Other hardwoods[b]						
Class 1	11	10	3	6	5	2
Class 2	2	4	2	2	4	2
Class 3	1	4		0	0	
Class 4	0	0		0	0	
Total density	11	12	4	6	7	2
Total basal area	11	0.4	0.2	6	0.2	0.1
Other softwoods[c]						
Class 1	12	22	13	18	10	3
Class 2	15	8	2	14	5	2
Class 3	12	7	1	15	6	1
Class 4	10	5	1	11	9	3
Total density	21	25	10	24	20	5
Total basal area	21	5.0	1.2	24	5.5	1.7

[a] Class 1 - 10-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - >78.7 cm dbh.

[b] Vine maple, red alder, Douglas maple, Oregon white oak.

[c] Sugar pine, Noble fir, ponderosa pine, Port-Orford cedar, western white pine, black cottonwood, knobcone pine, grand fir, Shasta red fir, and mountain hemlock.

Appendix 17. Mean density (trees/ha) by dbh class[a] and total basal area (m^2/ha) of major tree species in the Coast province.

Tree species	Nest site			Random site		
	N	Mean	SE	N	Mean	SE
Bigleaf maple						
Class 1	22	20	6	18	23	5
Class 2	20	13	2	17	12	3
Class 3	12	7	2	6	3	1
Class 4	4	2		2	2	
Total density	26	30	7	21	31	6
Total basal area	26	3.0	0.8	21	2.1	0.4
Douglas-fir						
Class 1	23	56	11	24	33	9
Class 2	27	35	7	24	27	11
Class 3	27	16	3	25	16	2
Class 4	30	24	3	30	29	3
Total density	30	113	16	30	90	16
Total basal area	30	40.0	3.0	30	38.4	3.0
Red alder						
Class 1	16	41	20	11	6	2
Class 2	14	14	4	12	12	2
Class 3	5	10	4	5	6	2
Class 4	2	2		0	0	
Total density	19	46	19	15	16	4
Total basal area	19	3.1	1.1	15	20	0.6
Western hemlock						
Class 1	27	55	12	24	69	12
Class 2	23	28	5	23	31	5
Class 3	19	9	2	20	11	2
Class 4	10	5	1	13	5	1
Total density	28	84	16	25	106	17
Total basal area	28	7.6	1.5	25	10.0	1.6
Western red cedar						
Class 1	18	32	6	16	19	6
Class 2	19	16	5	15	10	2
Class 3	12	7	2	15	5	1
Class 4	14	7	1	13	7	1
Total density	21	51	11	20	32	8
Total basal area	21	8.2	1.6	20	7.3	1.4

Appendix 17. continued.

Tree species	Nest site N	Nest site Mean	Nest site SE	Random site N	Random site Mean	Random site SE
Other hardwoods[b]						
Class 1	25	20	4	24	21	4
Class 2	15	5	1	7	5	2
Class 3	1	2		2	2	
Class 4	0	0		0	0	
Total density	25	23	5	24	23	4
Total basal area	25	0.7	0.2	24	0.6	0.2
Other softwoods[c]						
Class 1	10	45	27	7	29	11
Class 2	9	10	3	6	13	8
Class 3	4	10	3	4	5	3
Class 4	3	11	4	1	2	
Total density	12	51	28	9	35	15
Total basal area	12	5.4	2.4	9	2.6	1.4

[a] Class 1 - 10-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - >78.7 cm dbh.

[b] Vine maple, madrone, Douglas maple, canyon live oak, black oak, California laurel, Pacific dogwood, Pacific yew, and golden chinkapin.

[c] Pacific silver fir, Port-Orford cedar, Sitka spruce, and incense-cedar.

Appendix 18. Mean density (trees/ha) by dbh class[a] and total basal area (m^2/ha) of major tree species in the Cascade province.

Tree species	Nest site			Random site		
	N	Mean	SE	N	Mean	SE
Douglas-fir						
Class 1	27	52	14	24	27	8
Class 2	27	36	6	28	25	5
Class 3	26	21	4	28	26	4
Class 4	28	32	3	30	34	4
Total density	30	127	18	30	103	11
Total basal area	30	45.2	3.2	30	47.1	3.6
Western hemlock						
Class 1	29	103	16	30	64	8
Class 2	28	46	7	28	40	5
Class 3	22	14	2	24	16	3
Class 4	13	6	1	12	9	1
Total density	29	161	23	30	117	13
Total basal area	29	13.2	2.0	30	13.1	2.0
Western redcedar						
Class 1	19	43	9	15	22	8
Class 2	18	21	4	13	12	3
Class 3	14	7	2	9	11	3
Class 4	11	7	2	7	7	3
Total density	21	66	13	15	42	13
Total basal area	21	8.4	1.9	15	6.6	2.1
Other hardwoods[b]						
Class 1	13	13	3	12	10	2
Class 2	2	18	12	3	14	13
Class 3	0	0		1	2	
Class 4	0	0		0	0	
Total density	13	16	5	13	13	5
Total basal area	13	0.5	0.3	13	0.6	0.4
Other softwoods[c]						
Class 1	21	60	17	20	72	12
Class 2	20	23	8	20	22	4
Class 3	20	9	2	16	7	1
Class 4	15	8	2	15	5	1
Total density	23	88	22	24	85	15
Total basal area	23	10.6	2.2	24	8.2	1.3

[a] Class 1 - 10-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - >78.7 cm dbh.

[b] Vine maple, red alder, bigleaf maple, madrone, Pacific yew, dogwood, and golden chinkapin.

[c] Sugar pine, Noble fir, Port-Orford cedar, western white pine, grand fir, Pacific silver fir, mountain hemlock, white fir, incense-cedar, and Sitka spruce.

Appendix 19. Mean density (trees/ha) by dbh class[a] and total basal area (m^2/ha) of major tree species in the Olympic province.

Tree species	Nest site			Random site		
	N	Mean	SE	N	Mean	SE
Douglas-fir						
Class 1	8	88	33	6	33	25
Class 2	9	58	24	6	27	5
Class 3	8	30	8	6	38	14
Class 4	9	20	6	9	21	7
Total density	9	184	49	9	87	25
Total basal area	9	35.6	5.8	9	33.5	7.6
Pacific silver fir						
Class 1	5	30	11	12	20	3
Class 2	9	7	2	10	12	3
Class 3	5	5	2	9	7	2
Class 4	5	4	1	7	7	2
Total density	9	28	10	12	39	7
Total basal area	9	3.7	1.2	12	6.2	1.8
Western hemlock						
Class 1	14	122	14	15	130	36
Class 2	15	65	14	15	42	5
Class 3	13	24	5	14	22	4
Class 4	10	18	4	13	14	3
Total density	15	211	22	15	206	34
Total basal area	15	27.1	2.5	15	26.6	3.2
Western redcedar						
Class 1	11	68	26	10	23	10
Class 2	9	10	3	6	25	8
Class 3	9	4	1	6	8	4
Class 4	8	13	4	5	4	1
Total density	12	81	25	11	41	14
Total basal area	12	22.2	7.5	11	6.1	1.8
Other hardwoods[b]						
Class 1	8	6	2	9	7	2
Class 2	2	10	8	2	3	1
Class 3	0	0		0	0	
Class 4	0	0		0	0	
Total density	8	8	4	9	8	2
Total basal area	8	0.3	0.2	9	0.2	0.1

Appendix 19. continued.

Tree species	Nest site			Random site		
	N	Mean	SE	N	Mean	SE
Other softwoods[c]						
Class 1	0	0		0	0	
Class 2	2	5	3	3	3	1
Class 3	1	4		1	4	
Class 4	2	11	9	4	4	1
Total density	2	18	7	5	5	2
Total basal area	2	9.9	7.4	5	2.9	1.0

[a] Class 1 - 10-27.9 cm dbh; Class 2 - 28.0-53.3 cm dbh; Class 3 - 53.4-78.7 cm dbh; Class 4 - >78.7 cm dbh.

[b] Vine maple, red alder, bigleaf maple, Pacific dogwood, and Pacific yew.

[c] Sitka spruce and Noble fir.