

# Spring Bird Communities in the Southern Washington Cascade Range

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## Abstract

Spring bird populations were studied in 1984 and 1985 in 46 Douglas-fir forest stands in the southern Washington Cascade Range. Stands were classified into young (55-80 years), mature (95-190), and old-growth (250-700) age-classes and varied in elevation and latitude. Birds were surveyed by the point-count method, and detection rate (birds/visit) was used as an index of abundance. All birds detected within 75 m of a count station were included in the analysis. Thirty-four species were detected in the study areas. Mean bird species richness varied from 13.6 to 16.4 per stand and differed significantly among age-classes in 1985 but not in 1984, although mean richness was not significantly different between years. Mean richness showed a weak negative relation to increasing elevation and latitude. The nesting avifauna typically consisted of a core group of nine common species and about five uncommon species. Highest pooled detection rates occurred in old-growth wet and old-growth dry sites; lowest rates were in mature and young stands. The five most abundant species in decreasing order of abundance were winter wren, golden-crowned kinglet, hermit/Townsend's warbler, chestnut-backed chickadee, and western flycatcher. Total avian abundance showed a weak negative relation to gain in elevation and

latitude. A correlational analysis was made of vegetation variables associated with bird abundance. Cluster analysis revealed two major groups of forest stands that differed in elevation and latitude. Among birds in which significant relation to vegetation variables were found, live trees and snags typical of late-successional forests were negatively correlated with abundance of the blue grouse and evening grosbeak. These same factors were positively correlated with abundance of the varied thrush, winter wren, and western flycatcher. All but 3 of 17 species analyzed were most abundant in old-growth compared to younger forests. Although many species were most abundant in old growth, the Vaux's swift appears to be the only diurnal bird that may depend on old growth for its continued survival. Cavity nesters and birds that feed on the forest floor may suffer drastic declines in intensively managed monocultures. Bird populations may be most affected by changes in forest structure and fragmentation in the nesting range and by winter habitat availability. The relatively large percentage of permanent residents in Douglas-fir forests makes winter habitat particularly important to their survival.

## Introduction

Until recently, few accounts have been published on bird community studies in naturally occurring, coniferous forests of the Washington Cascade Range. Manuwal and Huff (1987) described spring and winter bird populations in a subset of the stands reported in this paper. Manuwal and others (1987)

discussed the characteristics of subalpine bird communities in the Washington Cascades. The widespread conversion of remaining old-growth coniferous forests of the Pacific Northwest to younger, more intensively managed forests may have an impact on forest bird communities. Sound management of forests to protect bird species richness and rare species is possible only with an understanding of bird communities in natural systems as a baseline.

This report summarizes a study of spring bird populations in different age- and moisture-classes of unmanaged Douglas-fir forests on the west slope of the southern Washington Cascade Range during 1984 and 1985. Objectives of the study were to determine the abundance and species composition of bird populations over a range of forest stand-age and site conditions in the Douglas-fir forests of the southern Washington Cascades; to examine the relation of bird presence to vegetative characteristics at bird-survey locations; and to identify bird species that may depend on old-growth forests for their continued existence.

## Methods

### Field

We surveyed birds by the point-count method (Verner 1985): observers counted all birds detected during an 8-minute count period beginning within 30 minutes of official dawn at each of 12 stations (points) spaced 150 m apart. We did this in 46 stands located from Mount Rainier to the Columbia River (see frontispiece and table 1). Birds were not surveyed during periods of rain, snow, or strong winds. We visited each stand six times from 15 April to 30 June in 1984 and 1985. The abilities of observers to identify birds by both sight and sound and to estimate horizontal distances to within 10 percent of the actual distance were tested. During a given year, most stands were surveyed by more than one observer. Most stands were surveyed in 1985 by different observers from those of the previous year to avoid as much bias as possible. Because of logistical constraints, some stands were surveyed by only one observer during a particular year, so some interstand variability may have resulted from observer differences.

All vegetation sampling was done at all 12 bird-count stations located in each stand. At each station, trees or snags were counted, depending on diameter at breast height (d.b.h.), in either a 13-m-radius (0.05 ha) or a 25-m-radius circular plot (0.2 ha). The total area sampled in a stand was 0.6 ha for 13-m-radius plots and 2.4 ha for 25-m-radius circular plots. In the 13-m plots, small trees (1-10 cm d.b.h.), medium trees (11-50 cm d.b.h.), large trees (51-100 cm d.b.h.), and small snags (10-19 cm d.b.h.) were counted. In the 25-m-radius-plots, very large (>100 cm d.b.h.) live trees, and medium (20-49 cm d.b.h.) and large (>50 cm d.b.h.) snags were counted. Density estimates were then calculated for each species by

**Table 1—Mean elevation, latitude, and age of 46 Douglas-fir stands studied in 1984 and 1985 in the southern Washington Cascades**

	Young	Mature	Old growth		
			wet	Mesic	Dry
Number of stands	10	8	9	12	7
Mean elevation (meters)	757	784	762	736	838
Mean latitude (degrees)	43.39	46.23	46.76	46.35	46.41
Mean age (years)	68	133	520	439	336
Range of age (years)	55-80	95-190	300-730	250-700	210-440

diameter-class. Snags were classified into five decay-classes; class 1 was a hard snag and class 5 a soft, highly decayed snag (Cline and others 1980).

### Data Analysis

Detection rate (birds per visit) was used as an index of abundance. A visit represented the mean number of birds detected at 12 counting stations on a particular day. Detections were used to compare relative abundance of species among age-classes and environmental gradients, assuming that detectability of a given species did not differ among stands and age-classes, observers were equivalent in their ability to detect birds, and all species had the same probability of detection. Several stands were surveyed by two observers instead of one during a particular spring. Furthermore, observers were trained to estimate distances to detected birds to within 10 percent of actual distances and periodically retested themselves to remain accurate. In the gradient analyses, I used bird detection rates and species richness data from all detections within 75 m of a counting station. For the Vaux's swift, all detections of flying birds (within 150 m) judged by the observer to be associated with the stand being surveyed were used. Furthermore, all species detected less than twice during a season were omitted from the analysis because they were probably associated with other habitats. In assessing the relation of birds to vegetation, birds detected <150 m from the counting stations were used.

I used Student's *t* test to compare differences in mean species richness and abundance between years, and the Mann-Whitney U Test (Siegel 1956) to compare differences between two means of small samples. For comparing mean richness and total detection rates among age-classes, I used one-way analysis of variance. Differences in abundance among age-classes for individual bird species were tested by using either analysis of variance or the nonparametric Kruskal-Wallis test (Siegel 1956), depending on whether or not the data were normally distributed. I calculated the

Pearson correlation coefficient ( $r$ ) or Spearman's rank correlation coefficient ( $r_s$ ) to evaluate responses of birds to latitude and elevation and preliminary bird-vegetation relationships.

Associations between habitat variables and counts of each bird species were examined in two different, but related ways. First, Spearman rank correlation coefficients (SPSS, Inc. 1986) were computed to look for significant correlations between tree and snag densities and counts of each bird species. For this analysis, vegetation data were first summarized into the seven most common tree species (or groupings), with four diameter-classes of live trees (1-10 cm, 11-50 cm, 51-100 cm, >100 cm) and three diameterclasses (10-19 cm, 20-49 cm, >50 cm) and decay-classes (hard, composed of classes 1 and 2; and soft, composed of classes 3,4, and 5) of snags.

The large number of variables was reduced to a subset of 22 (appendix table 12) by examining highly significant correlations among vegetation variables. Any pair of variables with correlations of >0.50 (thus explaining >25 percent of each other's variances) was either combined into one, or the more ecologically interpretable variable was retained. Thus variables such as all live trees >100 cm d.b.h., or live western hemlock  $\leq$  50 cm d.b.h., were created.

In computing a large number of correlations, Type I errors may cause some to be judged statistically significant (that is,  $P < 0.05$ ) simply because of random sampling error. Therefore, we focused on those correlations that 'occurred with the same sign (positive or negative) in both years and emphasized those that were significant at the  $P < 0.01$  level. Conflicting results, such as correlations that were positive one year and negative the next, were considered as possible evidence of Type I errors. (Marcot 1984, Meslow and Keith 1971). Even where correlations are consistently significant, however, they demonstrate only numerical association and do not necessarily imply some biologically meaningful cause.

Second, associations between bird abundance and tree and snag densities were investigated by stepwise multiple linear regression (Kleinbaum and Kupper 1978) with SPSSX (SPSS, Inc. 1986). This approach generated equations explaining each bird species' abundance from vegetation variables and was used for descriptive, rather than predictive purposes. The stepwise procedure evaluates each variable to be entered while controlling for variables already in the equation. Because of the sample size ( $n = 46$  stands) and some remaining intercorrelations, a new, smaller set of uncorrelated vegetation variables was generated using factor analysis (Afifi and Clark 1984). The initial factors, each of which was a linear combination of all 22 original variables and explained a known amount of the total variance in vegetation data, were extracted by principal components analysis and rotated with Varimax rotation to ease interpretation. We interpreted the

factors with a minimum eigenvalue of one (Battacharyya 1981) by examining the relative sizes of correlations ("loadings") between the factors and original variables.

Bird counts and vegetation variables were first log-transformed [ $\log_{10}(x+10)$ ] for regression analyses to more closely meet underlying distributional assumptions. Transformed bird counts were regressed on vegetation factor scores separately for 1984 and 1985 data. Because of the large number of equations generated and time limitations, we were unable to search for better fits with polynomial and interaction terms, which may explain some species' distributions more fully (Meents and others 1983). The accuracy of each regression was evaluated by the adjusted coefficient of determination (adjusted  $R^2$ ), an unbiased measure of the percentage of total variation in bird abundance explained by the equation (Zar 1984:336).

Cluster analysis (Afifi and Clark 1984) was used to describe assemblage-level patterns of the similarities of bird species' relative abundances (or simple occurrence). Bird communities were classified with total count data for the spring of 1985 by means of hierarchical, agglomerative cluster analysis. This classification groups species into clusters based on their stand-specific relative abundances and distributions. The properties common to a group of species in a cluster are then used to describe that set of species as a whole. More detailed descriptions of cluster analysis and its applications can be found in Afifi and Clark (1984), Cormack (1971), Gauch (1982) and Sneath and Sokal(1973). Because each distance or similarity measure, as well as each clustering technique, imposes a "structure" on the data, I searched for obvious clusters in the data by comparing results from several of them. Two separate sets of analyses were run. For the first, I converted total counts of the 28 most commonly occurring bird species to presence-absence data and compared sets of clusters formed by several similarity or dissimilarity measures and clustering techniques. I did cluster analyses using similarity measures of presence-absence bird data described by Mueller-Dombois and Ellenberg (1974) and Dice (1945), and the simple-matching equation of Sokal and Michener (1958). The second set of analyses was performed on total bird counts by using squared euclidean distance. After reviewing all the analyses, I decided to present only results from the measures that gave the most definite classification patterns--the simple-matching and squared euclidean measures. They are discussed briefly below:

Simple-matching (Sokal and Michener 1958)

$$S(x,y) = a + b / a + b + c + d,$$

where

a = number of stands in which species x occurred,  
b = number of stands in which species y occurred;

c = number of stands in which both species occurred; and d = number of stands in which neither species occurred.

Squared euclidean:

The second set of analyses was performed on stand-specific total counts of birds. Only birds detected during 8-minute station counts, at distances less than 150 m, and associated with a given stand were counted for these analyses. Bird counts were first log-transformed to reduce the controlling influence of the more abundant species on classification patterns. The formula for the squared euclidean distance is:

$$D(x,y) = \sum_{k=1}^p (x_{ik} - y_{jk})^2 ;$$

I clustered stands by means of average (between groups) and complete linkage techniques for both distance measures and also by Ward's method on the squared euclidean distance. As with the presence-absence data, I compared clusters obtained in all these runs to elucidate apparent clusters.

## Results

### Stand and Age-Class Characteristics

**Live trees--Highest** mean densities of live trees occurred in young stands with very high numbers of western hemlock saplings (1-10 cm d.b.h.) and 11- to 50-cm-d.b.h. Douglas-firs (fig. 1). Not surprisingly, highest densities of the largest diameter trees (>100 cm d.b.h.) were found in old-growth stands, but nearly equal densities of 51- to 100-cm-d.b.h. Douglas-fir were found in young stands. Also, many young stands had some very large (>100 cm) Douglas-fir, hemlock, and western redcedar that had survived previous fires. These trees apparently made the stands more old-growth-like in structure than if the stands were even aged. Although stands varied considerably, old-growth stands had higher densities of hardwood trees than other age-classes.

Among old-growth stands, wet sites had the highest densities of western hemlock and Pacific silver fir, but mesic sites had the highest densities of vine maple and miscellaneous conifers. Highest densities of the *largest live trees*—particularly western redcedar—occurred on old-growth wet sites.

**Deadwood--In** general, snag composition reflected past successional dynamics of the stands. Stem competition in the pioneer species Douglas-fir resulted in early mortality after canopy closure. These trees resulted in relatively high snag densities among boles less than 49 cm d.b.h. in young and mature stands (fig. 2). As western hemlock became more common in the understory and later in the canopy, the number of hemlock snags also increased. Pacific silver fir

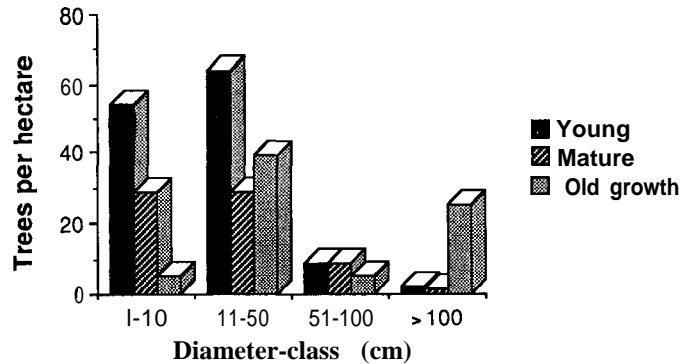


Figure 1—Density of live trees in three diameter-classes among young, mature, and old-growth Douglas-fir forests in the southern Washington Cascades.

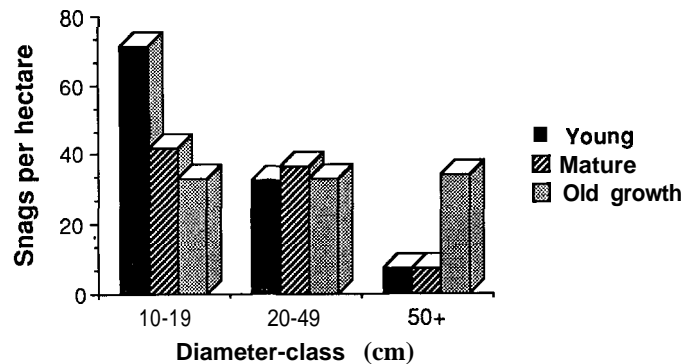


Figure 2—Density of snags in three diameter-classes among young, mature, and old-growth Douglas-fir forests in the southern Washington Cascades.

snags also become more prevalent in later stages of succession. The opposite trend appeared for western white pine, which was present in low densities in all age-classes but did not reach maturity because of blister rust. Highest densities of western white pine snags were in young stands and continued to decrease with stand age. The highest density of snags occurred in young stands where 70 percent of all snags were Douglas-fir and over 40 percent of them were in the small diameter-class (10-19 cm). The 6.2 large snags per ha in young stands reflected the fire history of the stands and probably represented a significant biological resource for cavity-nesting birds and mammals. Predictably, old-growth stands had the highest densities of very large snags. Those of Douglas-fir and western hemlock were most common. Large hardwood snags, primarily bigleaf maple and cottonwood, were most abundant in mature stands.

Snag abundance varied considerably among stands, presumably reflecting fire history and vagaries of successional patterns. Nevertheless, on an age-class basis, the outcome of tree competition followed a predictable pattern (see Cline and

**Table 2—Stand variation in bird species richness in Douglas-fir forests of the southern Washington Cascades**

	Young		Mature		Old growth					
					Wet		Mesic		Dry	
	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985
Total species	27.0	28.0	22.0	23.0	24.0	22.0	26.0	26.0	25.0	23.0
Mean richness	15.2	17.2	13.2	14.0	13.9	13.3	15.1	14.8	15.0	17.7
SD	2.8	3.8	4.1	3.3	2.9	2.1	2.8	3.4	2.1	1.4

**Table 3—Number of species of flycatchers, thrushes, and warblers detected in the 7 lowest and the 7 highest elevation Douglas-fir stands in the southern Washington Cascades in 1985**

Stand	Age	Elevation	Latitude	Bird group		
				Flycatchers	Thrushes	Warblers
302	500	500	46.10	4	3	2
316	500	506	46.09	3	3	2
317	500	529	46.10	3	4	2
340	130	586	46.07	1	5	2
401	500	617	46.99	3	3	1
423	250	644	46.72	2	4	3
365	75	704	46.64	2	3	5
Mean	351	584	46.39	2.6	3.6	2.4
418	550	1037	46.91	2	3	2
332	600	1049	46.67	2	4	3
419	320	1072	46.93	1	3	2
346	190	1124	46.40	2	3	1
468	65	1164	46.98	0	2	1
303	600	1168	46.69	2	2	3
432	300	1217	46.94	1	2	1
Mean	375	1119	46.79	1.4	2.7	1.9

others 1980, Franklin and Dymess 1973) in Douglas-fir forests. Most stands had five to seven conifer species and two to four hardwood species. The large snags (>50 cm d.b.h.) were primarily Douglas-fir, western hemlock, western redcedar, Pacific silver fir, and western white pine. All other species combined usually comprised less than 5 percent of the total snag population.

#### Avian Species Composition and Richness

**General**—In this analysis, I used 27,156 bird detections of 34 species in the study stands. Bird groups in natural Douglas-fir forests (between the ages of 55 and 700 years old) with the largest number of species were the woodpeckers, thrushes, flycatchers, corvids, warblers, and finches. Mean bird species richness was not significantly different between years (in 1984, 14.5, SD = 2.8; in 1985, 15.3, SD = 3.4 ( $t = 1.17, P = 0.24$ ).

**Effect of forest age and moisture**—Mean species richness was 16.2 species per visit in young stands, 13.6 in mature stands, and 15.0 in old-growth stands. It was not significantly different among age-classes in 1984 ( $F = 0.25, P = 0.91$ ) but it was significantly different in 1985 ( $F = 2.63, P < 0.05$ ). Along the moisture gradient, mean species richness was 14.1 in old-growth wet, 14.8 in old-growth mesic, and 16.4 in old-growth dry (table 2). Mean richness was not significantly different along the old-growth moisture gradient in 1984 ( $F = 0.01, P = 0.98$ ), but it was significantly different in 1985 ( $F = 5.67, P < 0.01$ ).

**Effect of elevation**—Bird species richness declined with increasing elevation of study sites in both years ( $r = -0.32; P > 0.05$ ). The lowest seven stands had a mean of 15.4 species, and the highest seven stands, 12.9 species. The difference was not significantly different. Among groups, significantly fewer species of flycatchers ( $t = -2.41, P = 0.03$ ) and thrushes ( $t = 2.57, P = 0.02$ ) but not warblers ( $t = 2.07, P = 0.06$ ) were found in the high-elevation stands compared with low-elevation stands (table 3).

**Effect of latitude**—Richness showed a weak negative relation to latitude (1984:  $r = -0.36, P = 0.013$ ; 1985:  $r = -0.41, P = 0.005$ ). Species richness was highest in the Wind River area and lowest near Mount Rainier. When all 46 stands are considered, however, stand elevation increased with latitude ( $r = 0.63, P < 0.001$ ), so the two factors were interrelated. Nevertheless, the latitudinal effect was probably a real one.

#### Avian Abundance

**General**—A core group of species nesting in natural Douglas-fir forests between the ages of 55 and 700 years old typically consisted of about ten common and widely distributed species, with frequencies of occurrence of at least 85 percent, and four less-common species, with frequencies of occurrence of 46 to 54 percent (table 4). A third group contained an additional 19 relatively rare species. The Vaux's swift was not included in this analysis because of its wide-ranging foraging behavior. In addition to these 34 species detected within 75 m of the counting points, other species,

**Table 4—Frequency of occurrence of birds in 46 Douglas-fir stands in the southern Washington Cascades, 1984 and 1985**

Species	Percentage of stands in which species <sup>a</sup> was recorded		
	1984	1985	Mean <sup>b</sup>
<b>Group 1</b>			
Golden-crowned kinglet	100	100	100
Chestnut-backed chickadee	100	100	100
Winter wren	100	100	100
Varied thrush	100	96	98
Brown creeper	93	98	96
Dark-eyed junco	93	89	91
Western flycatcher	91	89	90
Red-breasted nuthatch	91	89	90
Hermit/Townsend's warbler	89	89	89
Gray jay	87	83	85
<b>Group 2</b>			
Hermit thrush	40	67	54
Pine siskin	41	61	51
Hairy woodpecker	52	48	50
Steller's jay	48	43	46
<b>Group 3</b>			
American robin	36	35	36
Rufous hummingbird	30	39	35
Wilson's warbler	41	26	34
Swainson's thrush	33	26	30
Hammond's flycatcher	15	35	25
Western tanager	26	17	22
Evening grosbeak	15	22	19
Pileated woodpecker	20	9	15
Blue grouse	13	9	11
Red crossbill	11	9	10
Black-throated gray warbler	7	11	9
MacGillivray's warbler	4	11	8
Band-tailed pigeon	11	0	6
Yellow-rumped warbler	7	2	5
Olive-sided flycatcher	0	7	4
Northern flicker	4	4	4
Red-breasted sapsucker	2	4	3
Common raven	4	0	2
Hutton's vireo	0	2	1

<sup>a</sup> Vaux's swift not included because of its wide-ranging habits; it was found in 72 percent of the stands.

<sup>b</sup> Numbers rounded to nearest whole number.

such as raptors and grouse with large territories, were rarely detected within 75 m but were nevertheless members of the avifauna associated with the study stand.

**Effect of forest age and moisture**—Significant differences occurred in mean counts/visit among forest age-classes (1984:  $F = 13.2, P < 0.01$ ; 1985:  $F = 2.50, P = 0.06$ ) and along the moisture gradient (1984:  $F = 18.3, P < 0.01$ ; 1985:  $F = 3.30, P = 0.05$ ) (table 5, fig. 3). Highest detection rates were in old-growth wet and old-growth dry sites, and lowest detection rates were in mature and young sites. The higher numbers in

**Table 5—Mean number of birds detected per visit in Douglas-fir forests in the southern Washington Cascades in 1984 and 1985 (feeding guilds<sup>a</sup> are shown in parentheses)**

Species	Young	Mature	Old-growth		
			Wet	Mesic	Dry
Blue grouse (LUHI)	0.20	0.48	0.28		
Band-tailed pigeon (TS)	.04	.10	.02		
Vaux's swift (AI)	.23	.36	2.56	1.73	0.52
Rufous hummingbird (N)	.11	.22	.19	.35	.36
Red-breasted sapsucker (BI)		.02	.04		
Hairy woodpecker (BI)	.19	.22	.51	.34	.22
Northern flicker (BI)			.04	.03	
Pileated woodpecker (BI)	.09	.11	.07		
Olive-sided flycatcher (AI)	.03				
Hammond's flycatcher (AI)	.06	.25	.13	.27	.43
Western flycatcher (AI)	4.49	3.65	5.28	5.26	3.75
Gray jay (OS)	.94	.83	1.21	1.46	1.31
Steller's jay (OS)	.39	.14	.87	.34	.19
Common raven (OS)			.02		
Chestnut-backed chickadee (TFI)	3.31	3.47	6.51	5.43	3.84
Red-breasted nuthatch (BI)	2.39	1.53	1.67	3.48	4.71
Brown creeper (BI)	1.49	2.88	2.12	3.23	2.10
Winter wren (LUHI)	6.98	8.00	19.45	10.94	8.24
Golden-crowned kinglet (TFI)	6.20	7.27	8.86	6.52	9.02
Swainson's thrush (LUHI)	.18	.15	.22	.43	.36
Hermit thrush (LUHI)	.90	.28	.27	.58	.76
American robin (LUHI)	.24	.17	.48	.16	.28
Varied thrush (LUHI)	2.72	2.48	5.71	4.10	4.68
Hutton's vireo (TFI)	.03				
Yellow-rumped warbler (TFI)	.04	.02	.06	.23	
Black-throated gray warbler (TFI)	.19	.02		.06	
Hermit/Townsend's warbler (TFI)	7.90	5.61	1.59	2.11	6.23
MacGillivray's warbler (LUHI)		.06	.02	.02	.05
Wilson's warbler (LUHI)	.19	.13	.49	.22	.34
Western tanager (TFI)	.25	.22	.06	.06	.13
Dark-eyed junco (LUHI)	3.71	2.28	1.59	2.30	5.30
Red crossbill (TS)	.06	.11	.10	.60	.03
Pine siskin (TS)	1.29	.54	.55	.78	2.03
Evening grosbeak (TS)	.47	.49		.07	.04
<b>Total</b>	<b>45.31</b>	<b>42.09</b>	<b>60.97</b>	<b>51.10</b>	<b>54.92</b>

<sup>a</sup> Guild abbreviations: AI = air-insect, BI = bark insectivore, LUHI = low understory herbivore-insectivore, N = nectarivore, OS = omnivore-scavenger, TFI = timber-foliage-insectivore, TS = timber-seed eater.

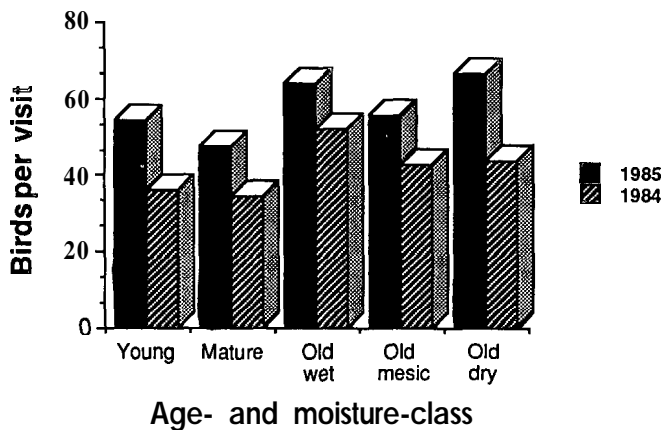


Figure 3—Mean number of birds per visit in young, mature, and old-growth Douglas-fir stands in the southern Washington Cascades.

**Table 6—The 5 most abundant bird species in Douglas-fir forests in the southern Washington Cascades in 1984 and 1985**

Species	Birds per visit					
	1984			1985		
	Mean	SD <sup>a</sup>	CV <sup>b</sup>	Mean	SD	CV
Chestnut-backed chickadee	24.9	12.1	48.5	30.9	17.0	55.1
Golden-crowned kinglet	42.8	19.6	45.7	47.6	20.3	42.7
Hermit/Townsend's warbler	19.2	17.5	90.9	37.3	34.8	93.1
Western flycatcher	23.3	15.2	65.1	32.5	21.4	65.9
Winter wren	55.3	29.9	54.1	77.0	45.1	58.6

<sup>a</sup> Standard deviation.

<sup>b</sup> Percent coefficient of variation ( $100 \text{ SD}/\bar{x}$ ).

old-growth wet sites were due to large counts of Vaux's swifts, winter wrens, chestnut-backed chickadees, and western flycatchers.

**Effect of elevation and latitude**—Although total avian abundance declined with gain in elevation, the relation was not significant and not all species showed a decline. Among the five most abundant species, only the western flycatcher showed a strong relation to elevation ( $r = -0.58$ ,  $P = 0.0001$ ). The response of other species was less obvious: golden-crowned kinglet ( $r = 0.42$ ,  $P = 0.004$ ); chestnut-backed chickadee ( $r = 0.35$ ,  $P = 0.019$ ); hermit/Townsend's warbler ( $r = 0.13$ ,  $P = 0.951$ ); winter wren ( $r = -0.03$ ,  $P = 0.344$ ). Pooled counts of all species did not change with increase in latitude.

**Between-year variation**—The mean detection rate was significantly lower in 1984 than 1985 ( $t = -6.65$ ,  $P < 0.01$ ). The largest differences occurred in young and old-growth dry stands (fig. 3). Of the five most abundant species, only the golden-crowned kinglet was not significantly more abundant

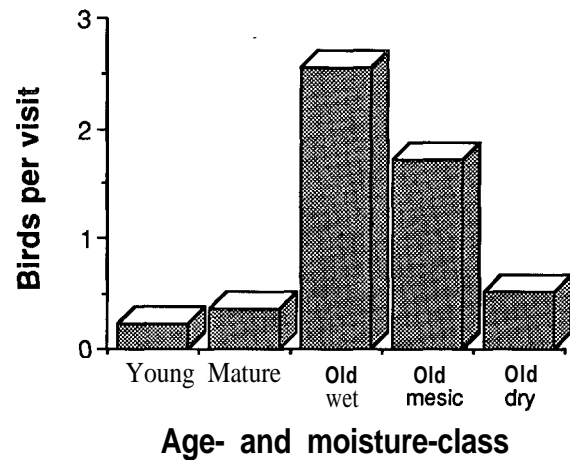


Figure 4—Mean detection rates of the Vaux's swift in young, mature, and old-growth Douglas-fir stands in the southern Washington Cascades, 1984 and 1985 combined.

in 1985 than in 1984 (table 6). The winter wren and hermit/Townsend's warbler showed the largest differences between years.

**Species and species-group abundance patterns**—The data indicate that the Vaux's swift is the only diurnal bird species that may depend on old-growth forests. This species was significantly more abundant in old-growth compared with other age-classes (that is, 7.0 and 4.4 times more abundant in old-growth than in young or mature forests, respectively) (fig. 4). Among the picids, the hairy woodpecker was the most abundant and was found in virtually every stand. It did not show a strong trend in abundance along the age gradient. The northern flicker was missing or uncommon in all stand types. This species uses edges primarily, and apparently found the Douglas-fir forests to be marginal habitat. The red-breasted sapsucker was uncommon and was recorded only in mature and old-growth wet stands, but the sample size was very small. We detected both the red-breasted and yellow-breasted color morphs, the red being by far the most common. About the same number of pileated woodpeckers were found in all age-classes. The rufous hummingbird was substantially more abundant in old-growth mesic and dry stands.

Of the three species of flycatchers, the western was overwhelmingly the dominant one. It was found in all stands and comprised 93 percent of all flycatcher observations. It was most common in old-growth wet sites. The Hammond's flycatcher, the second most commonly detected flycatcher, was found primarily in old-growth mesic and old-growth dry stands.

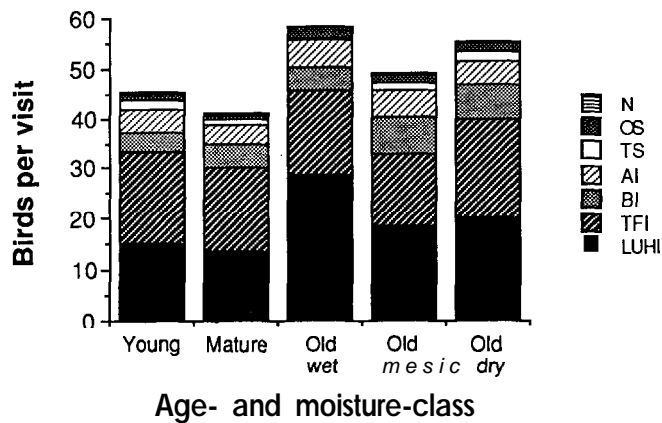


Figure 5-Avian feeding-guild structure based on mean detection rate for 1984 and 1985 in young, mature, and old-growth Douglas-fir forests in the southern Washington Cascades. Guild codes: AI, air-insect; BI, bark insectivore; LUHI, low understory herbivore-insectivore; N, nectarivore; OS, omnivore-scavenger. TFI, timber-foilage insectivore; and TS, timber-seed eater.

Among the corvids, the gray jay was slightly more common than the Steller's. Both species were detected less in mature stands than in either young or old-growth types. Steller's jays were significantly less common at higher than lower elevations. No such change was found for the gray jay. No trends in abundance with environmental gradients were detected for the common raven.

The only **parid** found in Douglas-fir forests was the **chestnut-backed chickadee**. This species was significantly more abundant in old-growth sites, particularly old-growth wet, than in younger stands.

The hermit warbler (and **hermit/Townsend's** hybrids) was by far the most abundant of the six species of warblers. It was the predominant upper canopy warbler in all stands where it occurred. Other upper canopy warblers included the Townsend's and yellow-rumped, but they were far less abundant and had relatively low frequencies of occurrence. The second most abundant warbler was the Wilson's, which was the dominant understory species. The black-throated gray warbler was uncommon but was most often found in young stands with a large broadleaved tree component. **MacGillivray's** warbler seemed to be associated with edges or patches of broad-leaved shrubs growing in tree-fall gaps. The most abundant finches were the pine siskin, evening grosbeak, and red crossbill. The siskin and grosbeak tended to be more abundant in young and mature stands, but the crossbill was more often detected in old-growth stands. The siskin and grosbeak, however, were much commoner than the crossbill.

**Foraging guild structure---**The two dominant foraging guilds in all stand types were the low understory **herbivore-insectivore** and the **timber-foilage insectivore** (fig. 5). The

principal species in the low understory guild were the winter wren, varied thrush, and dark-eyed junco. Birds in this guild were most abundant in old-growth and least abundant in mature stands, except for the junco, which was most common in young and old-growth dry stands. The primary birds in the timber-foilage guild were the chestnut-backed chickadee, golden-crowned **kinglet**, and hermit warbler. The chickadee was most common in old-growth stands. The golden-crowned **kinglet** did not show a strong trend among age-classes, but the winter wren was clearly most abundant in old-growth. Hermit/Townsend's warblers clearly preferred younger forests and responded negatively to moisture. Another obvious difference in guild structure across the age and moisture gradients was that the aerial insectivores were more abundant in old-growth wet and mesic sites than in other stand types because of the high densities of the western flycatcher and Vaux's swift.

#### Habitat Characteristics Associated With Avian Abundance

Correlational analysis between primary live-tree and snag variables (tables 7, 8; appendix table 12) and six **non-cavity-nesting** species showed a significant response to at least one of the six vegetation factors both years of the study. A similar analysis of cavity-nesting species is presented elsewhere in these proceedings (Lundquist and Mariani, this volume).

The six factor scores were correlated with stand-age and moisture values. Factors 1 ( $r_s = 0.55$ ) and 4 ( $r_s = 0.55$ ) were positively correlated, and factor 6 ( $r_s = -0.30$ ) was negatively correlated with stand age ( $P \leq 0.05$ ). Factor 1 ( $r = 0.50$ ) was positively correlated with moisture, but factor 4 ( $r = -0.68$ ) was negatively correlated.

For the blue grouse, the most significant positive relationships (obtained from initial regression analysis) were with vine maple and other hardwoods, and density of small live Douglas-firs. Negative responses were to all very large live trees (>100 cm d.b.h.) and density of true firs (1-10 cm d.b.h.). Blue grouse tended to be negatively correlated with most true fir characteristics. Blue grouse were negatively

correlated with factor 1. The evening grosbeak was also negatively correlated with factor 1, but the varied thrush and winter wren were positively correlated. Factor 2 was significantly correlated with the varied thrush, western flycatcher, and western tanager.

#### Bird Habitat and Community Classification

**Analysis of stands-**Two distinct clusters of stands were produced by the simple matching clustering technique using the 1985 presence-absence data (fig. 6). Two other but similar clusters were produced by using 1985 bird-detection data (squared **euclidean** distance) (table 9). No distinct clustering



**Table 7—Description of vegetation variables comprising 6 factors derived by factor analysis**

Factor	Vegetation variable	Eigenvalue	Percent of variation
Factor 1	Live Douglas-fir <100 cm d.b.h.	6.65	31.7
	Douglas-fir snags 20-49 cm d.b.h.		
	AU live trees >100 cm d.b.h.		
	Live tme firs <100 cm d.b.h.		
	All soft snags		
Factor 2	Hardwood snags 1-49 cm d.b.h.	3.06	14.6
	Western hemlock snags 20-49 cm d.b.h.		
	Western hemlock snags ≥50 cm d.b.h.		
	True firs snags 20-49 cm d.b.h.		
	Live western hemlock 5 l-100 cm d.b.h.		
Factor 3	Live western <b>redcedar</b> 1-50 cm d.b.h.	2.68	12.8
	Live western <b>redcedar</b> 51-100 cm d.b.h.		
	Western <b>redcedar</b> snags 20-49 cm d.b.h.		
	Western <b>redcedar</b> snags ≥50 cm d.b.h.		
Factor 4	Other live conifers <100 cm d.b.h.	1.56	7.4
	Western white pine snags 20-49 em d.b.h.		
	Western white pine snags ≥50 cm d.b.h.		
	Hard Douglas-fit snags ≥50 cm d.b.h.		
Factor 5	Soft Douglas-fir snags ≥50 em d.b.h.	1.30	6.2
Factor 6	Live western hemlock ≤50 cm d.b.h. Stumps and stubs	1.15	5.5

occurred with the 1984 data. Cluster analysis verified the previous conclusions on the importance of elevation, latitude, and forest structural characteristics. Stands that were lower in elevation and more southerly had higher bird species richness and abundance than lower elevation stands in northern sites of the study area (table 9).

Although I did not analyze all bird species in each cluster, differences in bird abundance between clusters were apparent. For example, the flycatchers ( $U = 0, P = 0.0001$ ) were significantly more abundant in low-elevation, lower latitude stands than elsewhere (table 9), but the winter wren was not ( $U = 32.5, P = 0.45$ ). Old-growth wet stands tended to be clustered together in one of the two larger clusters (fig. 6). Stands 401, 403, 410, 411, and 302 were strongly associated with each other. In other words, the bird assemblage associated with each-of those stands was similar. This pattern presumably indicates that the stands themselves were similar and provided nearly equivalent habitat. Stand 402, despite being adjacent to stands 401 and 403, was consistently classified in a different cluster; no reasons for this difference are apparent, although 402 had fewer birds detected. It had hermit warblers, and the others did not, it did not have Wilson's warblers and it had only the western flycatcher, but 401 and

**Table 8—Results of stepwise multiple linear regression of mean total bird counts<sup>a</sup> with vegetation factor<sup>b</sup> analysis scores**

Species and year	Step	Factor	Multiple R	Adjusted R <sup>2</sup>	Significance
Blue grouse	1984	1	-0.46	0.19	0.001
	1985	1	.36	.11	.013
Evening grosbeak	1984	1	-.39	.13	.007
	1985	1	.30	.07	.046
Varied thrush	1984	1	.31	.08	.034
	1985	1	.35	.10	.019
	1984	3	.52	.22	.040
	1985	2	.50	.21	.002
Western flycatcher	1984	2	-.53	.25	.001
	1985	2	-.52	.24	.001
	1984	3	.62	.35	.000
	1985	1	.40	.14	.006
	1984	1	-.38	.13	.008
	1985	3	-.60	.32	.000
Western tanager	1984	1	.35	.11	.015
	1985	4	.72	.47	.000
Winter wren	1984	1	.47	.20	.001
	1985	1	.40	.40	.006

<sup>a</sup> Bird counts and tree and snag densities were. log-transformed.

<sup>b</sup> Vegetation variables comprising the vegetation factors are in table 7.

**Table 9—Some characteristics of stand clusters created by the squared euclidean technique using 1985 bird detections**

	Cluster 1	Cluster 2
Number of stands	26	17
Stand classification		
Young	7	2
Mature	6	2
Old-growth wet	1	7
Old-growth mesic	5	5
Old-growth dry	7	1
Mean elevation	885.5	600.1
Mean latitude	46.6	46.2
Mean age	261.5	350.0
Total detections	454.9	653.4
Total warbler detections	60.0	50.9
Total flycatcher detections	27.1	72.4
Total winter wren detections	71.9	121.6

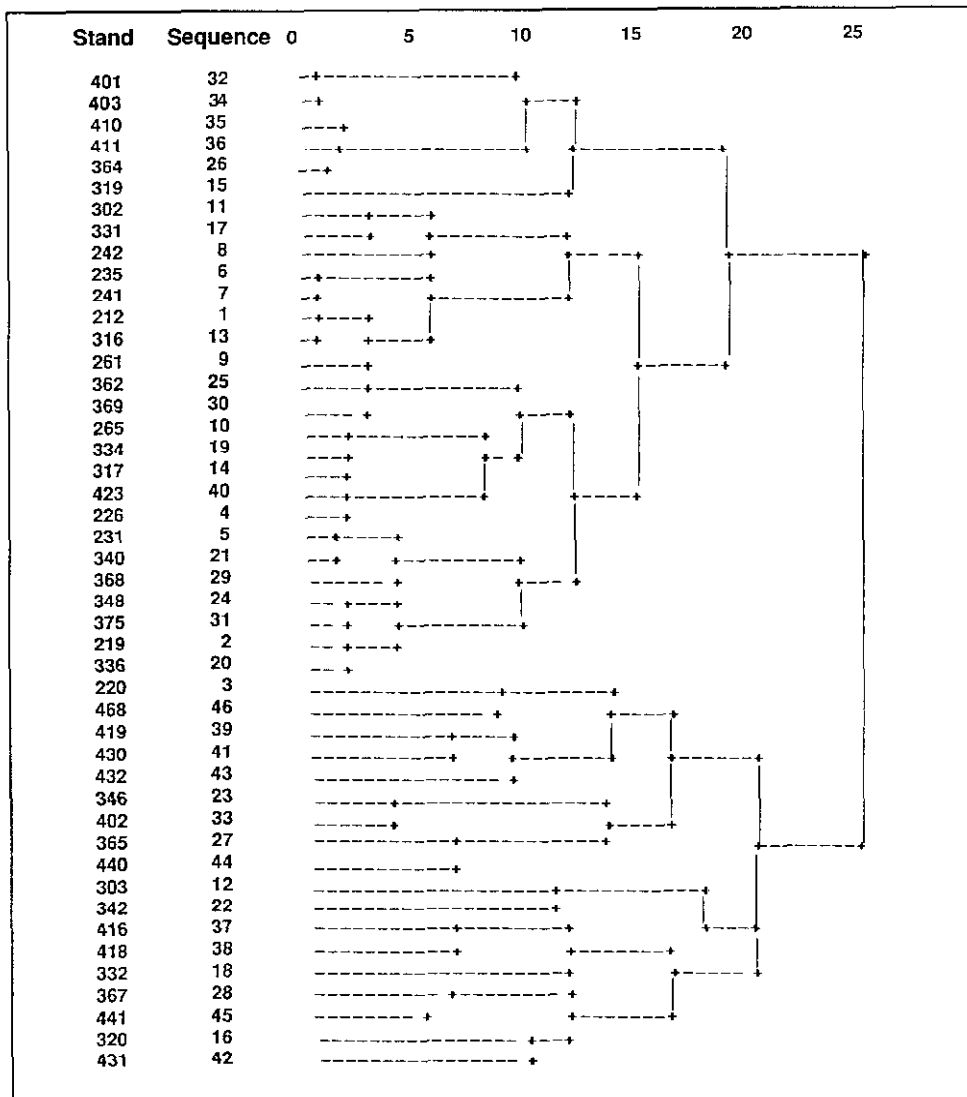


Figure 6—Cluster analysis dendrogram of birds found in 46 Douglas-fir stands derived from the simple-matching technique.

403 had small numbers of Hammond's flycatchers in addition to the westerns. Cluster 1 was also typified by young, mature, and old-growth dry stands. Birds particularly associated with these stands were the red-breasted nuthatch, hermit/Townsend's warbler, dark-eyed junco, and pine siskin.

**Analysis of bird composition**—Cluster analysis revealed that at least one major group of species was identifiable based on either presence-absence or abundance data (fig. 6). Depending on the particular metric used, 8 to 10 bird species consistently clustered together. This group was somewhat analogous to the core group to which I referred earlier. Why this group of species so consistently clustered together is difficult to determine. They did not all share the same feed-

ing or nesting strategies, but they all (except the western flycatcher, which did not occur in stand 468) were detected on each visit to all 46 stands and were abundant species. My tentative conclusion is that birds in cluster 1 simply were abundant and widespread. They were particularly well adapted to resources found in natural Douglas-fir forests over the complete range of environmental conditions that exist. Even though a few other species had high frequencies of occurrence, they were much less abundant (except the hermit/Townsend's warbler) than those species in cluster 1. Much more in-depth analysis of the response of birds to vegetation variables would be required to determine what factors might cause the particular clustering patterns shown in fig. 6.

## Discussion

Because this was only a 2-year study, drawing conclusions on some aspects is difficult. For example, species richness was significantly different among forest age-classes in 1985 but not in 1984. The same was true along the moisture gradient. The 1984 spring was colder and wetter than average (data from U.S. Department of Commerce), and most observers that contributed to this study during both years believed that the cold wet weather depressed bird singing and activity, thus preventing detection. The large difference in abundance between 1984 and 1985 seems unlikely to be because of differences in actual populations. The pilot study year of 1983 was similar to 1985. The spring of 1985 was typical for the southern Washington Cascades, so the relationships exhibited in 1985 probably more accurately reflected ecological relationships than those in 1984.

Abundance patterns were consistent between years even though total bird abundance was significantly lower in 1984 than in 1985. Bird abundance was significantly higher in late-successional forests both years, as was the response of birds to the moisture gradient. The primary reason was the consistently higher numbers of Vaux's swifts, winter wrens, chickadees, and western flycatchers in old-growth wet stands. The high numbers of wrens and chickadees might have been due to the large amounts of standing and forest-floor woody debris common in most wet stands. Those stands were the oldest and more likely to have snags, logs, and canopy openings (tree-fall gaps) that could also have been more conducive to flycatcher foraging.

Elevation gain is ecologically similar to gain in latitude, so presumably similar ecological forces are at work on mountain slopes. The finding that species richness declines with increasing elevation agrees with the study by Able and Noon (1977) in the northeastern United States. Although the reasons for this decline are unclear, some combination of climate, habitat structure, and competition probably shape the response of birds to these gradients. Emlen and others (1986) showed that the abundance of 12 of 41 bird species in the northern Midwest responded significantly to latitude. The remaining species were affected by habitat factors or competition effects. They attributed the latitudinal effect to breeding season length and hours available for adult feeding and feeding of young. I found that some bird species increased with elevation, but others decreased or showed little change, a phenomenon similar to that found by Emlen and others (1986) for latitude.

The analysis of vegetation characteristics associated with bird abundance was inconclusive for all but six species, probably because of inadequate sample size for some uncommon species, complex interactions among habitat variables, and bird response to forest characteristics that were not measured. Sig-

nificant bird responses were related only to variables normally associated with late-successional stages (factors 1, 2, and 5) or with earlier succession (factor 6). Of particular significance may be the large leaf surface area associated with late-successional forests. The most significant variables in factor 1 included all live Douglas-fir, live true firs ~100 cm d.b.h., and all live trees >100 cm d.b.h. This association implies that birds may have responded to large amounts of foliage, which attract insects. Net primary production tends to increase with leaf surface area (Gholz 1982). Studies by Grier and Logan (1977) indicate that greater leaf biomass may allow an increase in insect abundance. Because virtually all songbirds are insectivorous in the spring, they would presumably be more abundant in forests with high insect populations.

I believe that the fact that the mean stand age was not significantly different between groups of stands derived from cluster analysis verified our earlier observations that many young and mature stands had remnant very large live trees and snags that apparently made stand characteristics similar to old-growth sites. Further analysis of the vegetation in these stands might give clues to some of the important habitat features to which some birds responded.

### **Birds Finding Optimal Habitat in Old-Growth Douglas-Fir Forests**

This study was largely based on conventional correlational analyses. Such analyses do not necessarily show causal relationships between avian abundance or occupancy and habitat types or features (Wiens and Rotenberry 1981). Nevertheless, the extensive data set enables us to describe the general relationships between bird abundance and habitat types. Ideally, reproductive success and subsequent information on survival of offspring would be necessary to ascertain whether a particular habitat was optimal for breeding species (Van Home 1983). Such data were unavailable, so avian abundance was used as an indicator of habitat suitability with the knowledge that some stand types may have acted as either source or sink segments of some populations (Wiens and Rotenberry 1981).

Old growth was optimal habitat for all but 3 of 17 species (table 10). These species reached maximum abundance in old growth but were also relatively common in other age-classes. I was unable to assign optimum habitat for other species because the data were either inadequate or no peak in abundance in any stand type was recognizable. Old-growth, particularly old-growth wet stands, appeared important to many species of birds, however.

**Table M-Optimum habitat types for selected bird species nesting in Douglas-fir forests of the southern Washington Cascades**

Bird species	Standtype
Vaux's swift	Old growth <sup>a</sup>
Hairy woodpecker	Old growth (wet)
Pileated woodpecker	Old growth
Hammond's flycatcher	Old growth
Western flycatcher	Old growth (wet)
Gray jay	Old growth
Steller's jay	Old growth (wet)
Chestnut-backed chickadee	Old growth (wet)
Red-breasted nuthatch	Old growth (dry)
Winter wren	Old growth (wet)
American robin	Old growth (wet)
Varied thrush	Old growth (wet)
Hutton's vireo	Young
Black-throated gray warbler	Young
Hermit warbler	Young
Wilson's warbler	Old growth (wet)
Red crossbill	Old growth

<sup>a</sup> Old-growth category means that no trend was evident among the 3 moisture categories.

<sup>b</sup> Includes Townsend's warbler and hybrids between them.

### **Birds Potentially Dependent on Old-Growth Douglas-Fir Forests**

Birds potentially dependent on old-growth Douglas-fir forests are those found almost exclusively in old-growth and that rely on habitat features found primarily in old-growth forests. The Vaux's swift nests colonially in very large, hollow snags—a habitat feature occurring mainly in old-growth forests. Because swifts are aerial insectivores, their food or forest structure are unlikely to have an important bearing on survival—unless, of course, the insects on which they feed depend on old-growth forests. Even though the feeding ecology of this species is poorly known, the nest site is likely to be the critical limiting resource for this species and the species may depend on old-growth for its continued existence.

Other researchers (see Gutierrez and Carey 1985) have tentatively concluded that the northern race of the spotted owl is potentially dependent on old-growth forests for continued survival. Our data, collected opportunistically along with regular bird survey work, also suggest the close association between old growth and spotted owls. We detected five spotted owls in mature and seven in old-growth stands over the 3 years (1983-85). We also detected one barred owl in a young stand and four in old-growth stands. The potential impact of the barred owl on the spotted owl is a concern to many biologists.

### **Ramifications of Changes in Forest Structure and Fragmentation**

**Changes in forest structure**—Many habitat variables such as density of trees or shrubs of various species are correlated with the presence or abundance of some bird species. A more extensive analysis might uncover yet more significant relations. These results support the basic premise that avian diversity, abundance, and species composition are strongly influenced by habitat patchiness. Recent research by Blake and Hoppes (1986), Brokaw (1985), Hartshome (1978), Martin and Karr (1986), Runkle (1981), Whitmore (1978), Willson and others (1982) indicates that canopy gaps are important patches for forest birds. Most research on this topic has been done in tropical forests or in eastern North American hardwood forests, but similar phenomena are likely to exist in Douglas-fir forests. Old-growth Douglas-fir forests often have tree-fall gaps similar to those described by the cited authors. The general conclusions they draw are that these canopy openings provide food or food-getting resources in greater abundance than the forest interior in general. Blake and Hoppes (1986), in particular, have documented the increase in fruit and insect abundance in tree-fall gaps in an Eastern deciduous forest, coincident with an increase in birds and a change in species composition in those areas.

The fundamental differences in canopy structure between young and old-growth Douglas-fir forests undoubtedly account for some of the differences in the avifauna between these age-classes. The vegetation variables in this study were not specifically designed to measure canopy structure, but those that were measured probably gave an indirect measure of some dimensions of the canopy. The different tree species have different geometric shapes and leaf types. These attributes probably affect both resource abundance (mostly insects) and the ability of birds to exploit those resources. Forests composed of different tree species and tree age-classes would presumably differ somewhat in resource availability. If these resources were limiting, differences in avifaunal response would be expected. In fact, such differences apparently existed in Douglas-fir forests, but they appeared to have more impact on winter birds than summer birds (Manuwal and Huff 1987). Even-aged management of Douglas-fir reduces canopy and understory heterogeneity, the same heterogeneity characteristic of natural stands of older Douglas-fir. The primary aspects of heterogeneity reduced by even-aged management will be canopy and understory patchiness and standing and forest-floor dead wood. Bird species affected by these changes are cavity-nesters and birds associated with the forest floor, where coarse woody debris provides habitat for insect prey. The magnitude of these effects in Douglas-fir forests is unknown but may be strongly influenced by effects of fragmentation.

**Table 11—Comparison of the major wintering areas for birds of the Washington Cascades and those from sites in Eastern hardwood forests<sup>a</sup>**

	Permanent residents		Low elevation or Southern United States		Mexico		Central and South America <sup>b</sup>	
	N	%	N	%	N	%	N	%
Washington Cascades	24	42	11	19	7	12	15	26
Eastern hardwoods	14	31	6	15	6	15	16	39

<sup>a</sup> From 3 studies in the Appalachians (Crawford and others 1981), eastern Tennessee (Anderson and Shugart 1974), and West Virginia (Maurer and others 1981).

<sup>b</sup> South of Mexico to South America.

**Fragmentation of nesting habitat**—The effects of forest fragmentation result from many factors, such as the size, dispersion, and structure of the patches, and the natural history characteristics of the birds. The intent here is merely to mention the problem that fragmentation may have on birds in Douglas-fir forests. Birds that have large home ranges or those that are found only in the forest interior are those most affected by fragmentation (Martin 1981, Robbins 1980, Robbins and others 1989, Rosenberg and Raphael 1986, Whitcomb and others 1981). The Douglas-fir forests of the southern Washington Cascades are becoming increasingly fragmented (Morrison 1988). New studies similar to that conducted by Robbins and others (1989) are now needed to understand the relation of patch size and shape to the population size and persistence of birds.

The combined effects of forest fragmentation and simplification of forest structure through even-aged management will probably result in substantial declines in some bird species. Species or groups likely to show declines are all cavity-nesting birds (woodpeckers, nuthatches, chickadees, brown creeper, small owls) and species that are closely associated with the forest floor (winter wren, thrushes) or vertical habitat layering (warblers, chestnut-backed chickadee).

**Fragmentation and changes in winter habitat**—Reductions in breeding bird populations may not result from changes in the nesting habitat. Factors operating outside the nesting season may have consequences during later nesting seasons. Recently, ecologists have become alarmed at the amount of habitat being lost through harvesting of neotropical forests (Powell and Rappole 1986), although many temperate long-distance migrants reach maximum abundance in tropical

second growth (Hutto 1989). A substantial percentage (38-44 percent) of North American nesting birds spend the winter in neotropical forests (table 11). Typical neotropical migrants include the flycatchers, swallows, thrushes, tanagers, vireos, and many species of warblers. The percentage of neotropical migrants in Douglas-fir forests is relatively low compared with other regions of the United States, and a relatively high percentage of permanent residents live in the Cascades Douglas-fir forests (table 11).

One obvious consequence of the large percentage of permanent residents in the Pacific Northwest is the importance of winter habitat. The effects of fragmentation and simplification of forest structure will not only affect breeding birds but also the permanent residents. The ecological bottleneck that so often affects northern temperate wildlife may be more severe if the forest lacks suitable resources to allow birds to survive the winter. Changes in forest structure and reduction in patch (stand) size would be expected to reduce the winter carrying capacity of forests. Previous studies (Manuwal and Huff 1987; Huff and others, this volume) suggest that old-growth forests, with their complex canopy structure and rich tree-species diversity, provide substantially better winter habitat for many bird species than do younger stands. Old growth may actually provide habitat in which a much larger percentage of birds survive the winter than survive in younger stands and therefore are able to replenish stands unable to support winter populations at numbers adequate to maintain the resident population. Studies of the response of birds to intensively managed Douglas-fir forests are now urgently needed, so that new silvicultural prescriptions can be developed to reduce the loss of birds from massive changes in forest structure. More information is particularly needed on habitat needs of permanent residents in the Pacific Northwest.

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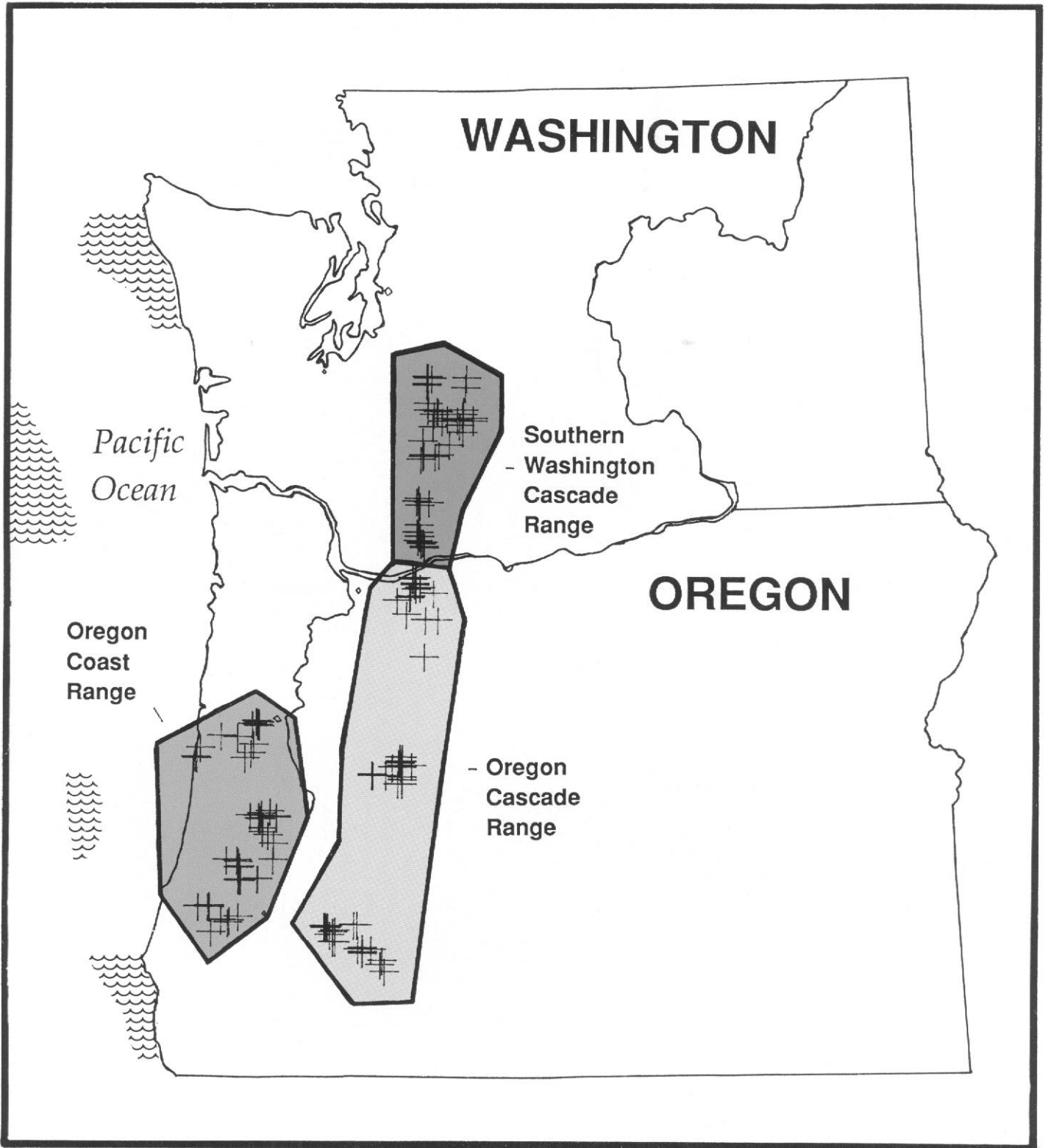
This paper is contribution 112 of the Wildlife Habitat Relationships in Western Washington and Oregon Research Project, Pacific Northwest Research Station, USDA Forest Service. □

## Appendix

**Table 12-Stem count variables for bird and vegetation correlation and regression analyses**

Code	Description
<b>Coarse variables</b>	
LT4	Live trees >100 cm d.b.h.
TSTP	Stumps and stubs (snags <5 m tall, >10 cm d.b.h.)
SS	AU small snags 10-19 cm d.b.h.
<b>Species-specific variables</b>	
<b>DFD13</b>	Live Douglas-fir 1-100 cm d.b.h.
WHD12	Live western hemlock 1-50 cm d.b.h.
WHD3	Live western hemlock 51-100 cm d.b.h.
RCD12	Live western redcedar 1-50 cm d.b.h.
RCD3	Live western redcedar 51-100 cm d.b.h.
ABD13	Live true firs 1-100 cm d.b.h.
CPD13	Live other conifers 1-100 cm d.b.h.
<b>VMD12</b>	Live vine maple 1-50 cm d.b.h.
<b>HDD13</b>	Live other hardwoods 1-100 cm d.b.h.
<b>DFS34</b>	All Douglas-fir snags 20-49 cm d.b.h.
<b>DFS5</b>	Hard Douglas-fir snags $\geq 50$ cm d.b.h.
<b>DFS6</b>	Soft Douglas-fir snags $\geq 50$ cm d.b.h.
<b>WHS34</b>	All western hemlock snags 20-49 cm d.b.h.
WHS56	All western hemlock snags $\geq 50$ cm d.b.h.
RCS34	All western redcedar snags 20-49 cm d.b.h.
RCS56	All western redcedar snags $\geq 50$ cm d.b.h.
ABS34	All true fir snags 20-49 cm d.b.h.
WPS34	All western white pine snags 20-49 cm d.b.h.
WPS56	All western white pine snags $\geq 50$ cm d.b.h.

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Location of study sites within the three physiographic provinces.



# Regional Patterns of Diurnal Breeding Bird Communities in Oregon and Washington

Mark H. Huff and Catherine M. Raley

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## Abstract

Breeding bird communities surveyed in 132 natural fire-regenerated Douglas-fir forest stands were examined for differences in species richness and abundance among forest stand age-classes: young, 35 to 79 years old,  $n = 27$ ; mature, 80 to 190 years old,  $n = 37$ ; and old-growth, 200 to 730 years old,  $n = 68$ , and among physiographic provinces: Oregon Coast Range (1985 and 1986,  $n = 45$ ); Oregon Cascade Range, 1984 and 1985,  $n = 48$  and 15, respectively; and southern Washington Cascade Range, 1984 and 1985,  $n = 39$ . Stands were surveyed six times each spring using 8-minute counts at 12 counting stations spaced 150 or 100 m apart. More than 115,000 birds were detected. We counted 41 species that regularly used Douglas-fir forests >40 years old, after the exclusion of raptorial, nocturnal, and poorly detected species. The most widespread and abundant species were chestnut-backed chickadee, western flycatcher, winter wren, hermit and Townsend's warblers, and golden-crowned kinglet. All bird species significantly more abundant in forests >80 years old in at least two of three regions at  $P \leq 0.10$

were hole or bark nesters: red-breasted sapsucker, brown creeper, chestnut-backed chickadee, red-breasted nuthatch, and Vaux's swift.

Results suggested that patterns of bird abundance were regionally distinct, even though the study design differed between regions. Total bird abundance, species richness, and bird abundance in four spatial-foraging guilds (aerial, bark, canopy, and understory) were significantly higher in the Oregon Coast Ranges than in the southern Washington or Oregon Cascade Range. Aerial and bark guilds showed strong differences among ageclasses: the aerial guild reached its highest abundance in young and old growth and the bark guild was least abundant in young and highest in old growth. Vegetation characteristics used for multiple linear regression models predicted only a small proportion of the variance in bird abundance.

## Introduction

Douglas-fir is the primary tree species of the densely forested slopes of western Oregon and Washington. Old-growth Douglas-fir forests (>200 years old), which once covered large land areas throughout the region (for example, Dodwell and Rixon 1902), are rapidly becoming scarce (Marcot and others, this volume). Most old-growth Douglas-fir forests have been cut on private and industrial holdings; consequently, those that remain are almost exclusively on Federal lands (DeBell and Franklin 1987, Franklin and others 1981).

To meet Federal laws, land managers must decide which old-growth forests to cut and which to preserve, yet the amount of information available to make these decisions as they relate to wildlife populations is often inadequate (Carey 1984).

Converting large forested regions from older to younger age-classes poses specific problems for interpreting and predicting the relation of birds to their habitats. Difficulties arise from, for example, high variability in interregional habitat characteristics (Hamel and others 1986) and scale of measurement, which influences how habitat occupancy by birds is interpreted (Wiens 1981a, Wiens and Rotenberry 1981b). Bird movements resulting from rapid liquidation of old-growth forests, exceeding 20,000 ha per year on Federal land in the Pacific Northwest (Torrence 1986), are poorly understood and could be misleading if bird dispersal from potentially optimal into suboptimal habitat (*sensu* Pulliam 1988) is widespread.

In Finland, where bird populations have been surveyed relative to forestry practices over several decades, researchers found that, in general, species associated with edge and brushy habitats have increased proportionally with the creation of forest openings from cutting (see Stjernberg 1979), but other species closely associated with older coniferous forests have decreased (see Jarvinen and Vaisanen 1978). Similarly, birds associated with mature and old-growth forests in northwestern California have likely declined from the presettlement period to the present because of extensive logging, and especially over the last 20 to 30 years, but ground-brush-foraging birds have increased substantially during the same period (Raphael and others 1988). Species projected to be most significantly affected by rapid and widespread changes in forest composition and structure are those with relatively restricted ranges and habitat requirements (Raphael and others 1988).

In Pacific Northwest forests, 58 percent of the vertebrate fauna consists of bird species (Harris 1984), but, only a few of them regularly use the interior of coniferous forests (Carey 1988, Wiens 1975). Even though birds strongly associated with old-growth Douglas-fir forests seem to be many (*sensu* Brown 1985), the spotted owl and Vaux's swift are suggested as being the most closely associated (Carey 1985, Lundquist 1988, Manuwal and Huff 1987, Meslow and others 1981).

We compared bird species richness and abundance along a forest sere within a large geographic area, throughout the Oregon Coast Ranges and the Oregon and Washington Cascade Ranges, to determine which species consistently are most abundant in old-growth Douglas-fir forests; if old-growth forests have distinct faunal associations; which abundance trends are consistently related to forest age between and

within the study regions; and which vegetative characteristics help to explain the patterns of bird abundance among the study regions. We examined only bird communities of unmanaged, fire-regenerated stands. Wherever plausible, we speculated on how our results might be applied to forested areas intensively managed for timber production.

## Methods

### Study Area

Breeding bird communities were surveyed in Douglas-fir stands of three physiographic provinces, the southern Washington Cascade Range, Oregon Cascade Range, and Oregon Coast Ranges (see frontispiece). The three provinces were divided into subprovinces: three each in the southern Washington and Oregon Cascade Range and two in the Oregon Coast Ranges. A subprovince consisted of study stands within about 60 km of one another and isolated from other subprovinces by varying latitude (see frontispiece). Stands were selected to encompass the range of variation within Douglas-fir forests of each subprovince (table 1).

A study stand was defined as an area relatively homogeneous in structure, disturbance history, vegetational composition, physiography, and soil. Unmanaged, naturally regenerated stands were selected to represent a chronosequence of forest development (young, 35 to 79 years; mature, 80 to 190; and old-growth, 200 to about 730 years). Stand elevation was restricted to the range in which Douglas-fir was a dominant overstorey species (see Franklin and Dyrness 1973) and varied substantially within and among provinces (see frontispiece). Although the experimental design called for stands of at least 40 ha to avoid edge effects, not all stands in the Oregon Coast Ranges met this criterion because few large tracts of unmanaged forest remained. Median size of study stands in the Oregon Coast Ranges was 29 ha, ranging from 14 to 62 ha (Carey and others, this volume).

Avian surveys were done in 151 Douglas-fir stands; 19 stands were excluded from our analysis because they exhibited moisture conditions (either extremely wet or extremely dry) that were outside the range of the young and mature stands sampled. Of the 132 stands suitable for bird community analysis, 39 were in the southern Washington Cascades, 48 in the Oregon Cascades, and 45 in the Oregon Coast Ranges. Because no stand vegetational data were collected from two mature stands in the Oregon Cascades, only 130 stands were analyzed.

Rugged mountains, steep valleys, and high annual precipitation (800 to 3000 mm), which increases rapidly from low to high elevations, characterize the three provinces (Franklin and Dyrness 1973; Spies and Franklin, this volume). Although

**Table 1—Means and range (in parentheses) of environmental variables for young, mature, and old-growth stands sampled in 3 physiographic provinces (n = sample size)**

Variable	Young n = 8	Mature n = 10	Old growth n = 25	All stands n = 43
<b>Oregon Coast Ranges:</b>				
Latitude	43.7 (43.2-44.3)	44.0 (43.0-44.5)	43.7 (43.1-44.5)	43.8 (43.0-44.5)
Longitude	123.7 (123.5-124.0)	123.7 (123.3-124.1)	123.6 (123.3-124.1)	123.6 (123.3-124.1)
Elevation (m)	307.0 (86-473)	487.0 (260-1022)	401.0 (153-909)	403.0 (86-1022)
Percent slope	48.0 (16-73)	50.0 (26-75)	48.0 (19-82)	48.0 (16-82)
Aspect <sup>a</sup>	.96 (.05-1.67)	.84 (.04-1.71)	1.00 (.10-1.89)	.95 (.04-1.89)
Stand age (yr)	59.0 (40-72)	102.0 (80-120)	314.0 (200-525)	213.0 (40-525)
<b>Oregon Cascades:</b>				
	n = 9	n = 17	n = 22	n = 48
Latitude	44.2 (42.8-45.5)	43.9 (42.9-45.4)	43.8 (42.8-45.6)	43.9 (42.8-45.6)
Longitude	122.3 (121.8-122.8)	122.4 (121.9-122.9)	122.4 (122.1-122.9)	122.4 (121.8-122.9)
Elevation (m)	920.0 (520-1428)	812.0 (326-1478)	848.0 (437-1284)	849.0 (326-1278)
Percent slope	42.0 (16-71)	40.0 (3-90)	44.0 (15-80)	43.0 (3-90)
Aspect <sup>a</sup>	1.18 (.07-1.91)	.70 (.03-1.84)	.93 (.02-1.95)	.90 (.02-1.95)
Stand age (yr)	65.0 (35-79)	108.0 (84-180)	355.0 (200-500)	213.0 (35-500)
<b>Southern Washington Cascades:</b>				
	n = 10	n = 10	n = 19	n = 39
Latitude	46.4 (45.8-47.0)	46.3 (45.9-46.8)	46.3 (45.8-47.0)	46.3 (45.8-47.0)
Longitude	121.9 (121.5-123.0)	121.9 (121.7-122.0)	121.8 (121.5-122.0)	121.9 (121.5-123.0)
Elevation (m)	728.0 (476-1168)	749.0 (483-1124)	759.0 (420-1049)	748.0 (420-1168)
Percent slope	41.0 (13-66)	46.0 (19-73)	35.0 (9-80)	39.0 (9-80)
Aspect <sup>a</sup>	1.27 (.29-1.97)	1.02 (.08-1.96)	.89 (.02-1.99)	1.02 (.02-1.99)
Stand age (yr)	67.0 (55-75)	127.0 (80-190)	418.0 (210-700)	253.0 (55-700)

<sup>a</sup> Transformed aspect = cosine (aspect - 45 degrees) + 1.

Douglas-fir dominates the study region, the climax species are western hemlock and Pacific silver fir (Spies, this volume). Forests begin displaying old-growth characteristics at about 200 years, yet rarely approach climax because catastrophic fires occur before shade-tolerant species completely replace the long-lived Douglas-firs (Franklin and Spies 1984, Franklin and others 1981).

### Sampling Methods

**Birds**—Birds were surveyed in each province for two consecutive breeding seasons: 1984 and 1985 in the southern Washington Cascades (Manuwal, this volume), 1984 and 1985 (only 32 percent of the 1984 stands in 1985) in the Oregon Cascades (Gilbert and Allwine, this volume b), and 1985 and 1986 in the Oregon Coast Ranges (Carey and others, this volume). Birds were sampled by using the variable circular plot technique (Reynolds and others 1980). Twelve counting stations were spaced at 150-m intervals in a rectangular pattern placed no closer than 75 m from the edge of the stand.

Stands were surveyed six times from April 26 to July 7. Because the Coast Ranges stands were small, the spacing between stations was reduced to 100 m. Six stands in the Oregon Coast Ranges had fewer than 12 stations: one stand with 7 stations, one stand with 10 stations, and three stands with 11 stations. Additional surveys were done to make the total sample time at these six stands comparable to all other stands. All surveys began no later than 15 minutes after sunrise and were completed within 4 hours. All birds seen or heard during each 8-minute count at each counting station were recorded. Field observers, trained to estimate horizontal distances, recorded horizontal distance for each detection.

**Vegetation**—Vegetation data on snags, logs, live trees, shrubs, and herbaceous vegetation were collected in each stand in five nested, systematically established plots (Spies and Franklin, this volume; Spies and others 1988). Our objective in using this data set was to quantitatively describe the structure and composition of the stand as a whole, rather

than specific points associated with the bird counts as reported in this volume by Manuwal, Gilbert and Allwine, and Carey and others.

### Sampling Biases

Verner (1985) describes five sources of bias in bird counts: observer, habitat, birds, study design, and weather. During this study, attempts to minimize some of these biases included using trained observers, avoiding weather conditions that would interfere with locating and identifying birds, spacing counts throughout the breeding season, and, where possible, rotating observers in each stand. Robbins and Stallcup (1981) suggested rotating observers among plots to help compensate for observer variability. Observers were rotated in all stands surveyed in the Oregon Cascade and Coast Ranges, but logistical problems prevented rotation in more than half of the stands in the southern Washington Cascades. Over all provinces, observers were rotated in 77 percent of the stands surveyed. In general, different observers were used between survey years.

Only birds detected within 50 m of the counting station—representing half of the shortest distance between the stations—were used in the main analysis. Detection distances were truncated so that the area searched would be comparable among stands, and to minimize biases associated with counting the same birds twice. Additionally, we believe that truncating detection at 50 m should help to reduce other biases inherent in bird surveys. Richards (1981) describes three environmental acoustic factors that are distance- and frequency-dependent, and affect the ability of an observer to detect and accurately identify a singing bird in forested habitats: attenuation, the decrease in intensity of sound with distance; random fluctuations in the received level of sound resulting from wind and thermal conditions; and scattering and reverberation of sound by trees, foliage, and the ground. Selecting trained observers can minimize these factors (Richards 1981), but reducing the distance searched further minimizes them as well as differences among observers.

To evaluate whether detectability of bird species changed with location, we compared mean detection distance (60 m radius of the counting station) within each forest age-class among the three physiographic provinces by the Kruskal-Wallis procedure (Zar 1984). We selected 10 common species to evaluate the relative magnitude of differences among the three provinces (table 2). Within young stands, few strong differences were found among the provinces. More strong differences among provinces were found within mature and old-growth stands, as indicated by the P-values, but the mean values were well within the 50-m cut distance and differences among mean values were generally small (<5 m).

**Table 2—For each forest age-class, mean detection distance for 10 common bird species and significance level of Kruskal-Wallis comparisons among 3 provinces**

Bird species	Mean detection distance (m)			P-value
	Oregon Coast Ranges	Oregon Cascades	Southern Washington Cascades	
<b>Young forests:</b>				
Brown creeper	24.0	20.8	24.1	0.5541
Chestnut-backed chickadee	22.9	24.0	24.1	.5619
Dark-eyed junco	21.4	27.6	27.2	.7819
Golden-crowned kinglet	22.0	21.0	22.7	.7143
Hermit thrush	32.6	31.8	32.0	.8135
Hermit/Townsend's warbler	34.2	32.5	34.1	.3142
Red-breasted nuthatch	35.0	34.3	39.6	.0067
Varied thrush	34.8	35.7	31.7	.2018
Western flycatcher	30.1	32.1	31.5	.6390
Winter wren	29.7	29.5	30.8	.4933
<b>Mature forests:</b>				
Brown creeper	25.4	24.4	29.0	.1050
Chestnut-backed chickadee	23.0	23.6	29.2	.0039
Dark-eyed junco	30.6	28.8	26.2	.4058
Golden-crowned kinglet	22.6	21.5	27.4	.0015
Hermit thrush	36.4	27.8	33.0	.0718
Hermit/Townsend's warbler	35.7	33.8	35.1	.1938
Red-breasted nuthatch	35.6	32.0	39.5	.0007
Varied thrush	34.0	33.6	35.7	.6007
Western flycatcher	30.4	32.3	32.8	.4485
Winter wren	30.3	30.8	35.4	.0059
<b>Old-growth forests:</b>				
Brown creeper	24.3	23.1	28.7	.0011
Chestnut-backed chickadee	22.0	23.4	27.3	.0003
Dark-eyed junco	29.4	27.8	26.7	.1880
Golden-crowned kinglet	21.4	21.7	25.6	.0027
Hermit thrush	31.9	34.6	31.5	.4478
Hermit/Townsend's warbler	35.5	33.0	36.4	.0002
Red-breasted nuthatch	37.7	32.3	36.3	.0000
Varied thrush	35.7	32.8	34.1	.1099
Western flycatcher	28.5	29.4	32.8	.0000
Winter wren	29.4	30.9	32.5	.0002

Major biases in the sample design and data collection occurred during this study. First, elevation was not controlled for when study stands were selected; consequently, the degree and magnitude of variation is different within and among provinces. The three provinces were not surveyed during the same two sample years, and in no year were all stands in all provinces surveyed. Also, some stands were surveyed in only one sample year instead of two. The data from these stands represent a mean based on one sample year, whereas data from the remaining stands represent a mean of two sample years. Five stands in the Oregon Coast Ranges had fewer than 12 counting stations (one stand had 7, one had 10, and three had 11 stations). Analyses were conducted to evaluate the effect of fewer counting stations, and differences with and without the five stands were negligible. Finally, observers were different among the three provinces and generally