AN ABSTRACT OF THE THESIS OF

Robyn M. S. Vega for the degree of Master of Science in Forest Science presented on August 13, 1993

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Signature redacted for privacy.

Abstract approved: Andrew J. Hansen

Green-tree retention is being implemented on state and federal lands in Oregon. Silvicultural prescriptions with tree and snag retention are thought to mimic natural disturbance patterns in the Pacific Northwest more closely than traditional silvicultural practices, which reduce structural complexity. The effects of green-tree retention on native bird species in the Pacific Northwest are largely unknown. Consequently, this study examined avian communities, individual species abundances, habitat associations, and artificial nest predation in the West-central Oregon Cascade Range. Between May and August 1992, 4 clearcut, 4 green-tree retention, and 4 mature conifer stands were studied. Species diversity was greater in mature stands than in clearcuts. Total bird abundance and species richness did not differ among stand types, but community composition did. Differences in community composition were related to differences in vegetation structure and composition. Species showed individualistic responses to stand types, and individual species abundances were correlated with conifer and snag densities more than with other variables. Green-tree retention stands provided habitat for some birds that are associated with early- and late-seral habitats. Predation on ground nests was greater in clearcuts than retention stands. Shrub nest predation was greater in retention stands than in clearcuts or mature stands. These results support the hypothesis that trees and snags which are retained in harvest units serve as perches which facilitate the location of shrub nests by predators. Retention stands may be sink habitats for species which nest in them unsuccessfully. Open canopy species which are negatively associated with green-tree retention may show further declines in population if green-tree retention stands replace clearcuts on state and federal lands in Oregon. In order to provide habitat for native species, a variety of stand conditions should be maintained across the landscape and management objectives should be tailored to individual species or communities.

BIRD COMMUNITIES IN MANAGED CONIFER STANDS IN THE OREGON CASCADES: HABITAT ASSOCIATIONS AND NEST PREDATION

by

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Typed by researcher for Robyn M. S. Vega

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INTRODUCTION

Changes in the avifauna of eastern deciduous forests have been well documented for the past several decades (Aldrich and Robbins 1965, Terborgh 1989, Finch 1991, Bohning-Gaese et al. 1993). Forest-dwelling species which migrate from the Neotropics have shown the most dramatic declines (Finch 1991). More recently, changes in bird communities of the Western Region have been noted (Raphael et al. 1988, Paige 1990, Sharp 1990, S. Droege, U.S. Fish and Wildlife Service, pers. commun.). Fifty-one migrant and resident species in the Western Region showed negative population trends (Paige 1990:45). The changes in the Pacific Northwest are not characterized by any clear patterns in the abundances of Neotropical migrants or permanent residents (Paige 1990, S. Droege, U.S. Fish and Wildlife Service, pers. commun.). For example, olive-sided flycatchers, which migrate, and chestnut-backed chickadees and golden-crowned kinglets, which are permanent residents, all had negative population trends in Oregon from 1968-1991 (S. Droege, U.S. Fish and Wildlife Service, pers. commun.). Nor are consistent increases or decreases associated with species that breed in early- or late-seral habitats (Paige

1990, S. Droege, U.S. Fish and Wildlife Service, pers. commun.). For example, chipping sparrows and willow flycatchers both live in open habitats, but they showed opposite population trends in Oregon from 1968-1991. The abundance of chipping sparrows decreased, while the abundance of willow flycatchers increased (S. Droege, U.S. Fish and Wildlife Service, pers. commun.). Paige (1990) expressed concern and the need for further investigation into the disproportionate declines of songbirds in the Pacific Northwest.

Changes in the bird populations in both eastern deciduous forests and the Western Region have been attributed to a variety of factors including: habitat loss and fragmentation of breeding grounds (Ambuel and Temple 1983, Terborgh 1989), reduced reproduction as a result of increased nest predation and cowbird (Molothrus ater) parasitism (Brittingham and Temple 1983, Wilcove 1985), alteration of wintering habitats (Terborgh 1980, 1989), pesticide poisoning (Terborgh 1989), and cumulative effects (Askins el al. 1990). Avian populations may express declines in 1, or a combination, of the following ways: contraction of their geographical range, occupation of fewer habitats within a region, or decreased abundance in some, or all, habitats (Wilcove and Terborgh 1984). All of these patterns are evident in the Pacific Northwest. Because different species exhibit population declines in different ways, it is difficult to detect trends and to make comparisons among species (Finch 1991).

In the Pacific Northwest, some avian population changes are related to timber harvesting, which has altered the age class distribution of forests and the natural disturbance regimes (Harris 1984, Franklin and Forman 1987). Norse (1990), estimated that the percent of forested land that was comprised of old-growth west of the Cascade crest has decreased from 60-70% to <25% in the last decade. In Western Oregon, the percentage of land containing closed-canopy conifer forest also has been reduced (Spies et al. in press). An analysis of Landsat imagery from 1972 to 1988 revealed a decline in closed-canopy conifer forest from 71% to 58% (Spies et al. in press). From the 1940's through the 1980's, most stands were clearcut and then burned and planted with Douglas-fir (Pseudotsuga menziesii) seedlings (Swanson and Franklin 1992). This type of management was designed to maximize timber production rather than to maintain native species diversity (Franklin 1989, Gillis 1990).

It has been argued that the aforementioned management activities mimic natural disturbance patterns in the Douglas-fir region. However, Hansen et al. (1991) found that traditionally-managed plantations had less structural complexity than natural forests. Natural disturbances such as fire and windthrow result in removal of varying amounts of the canopy. However, live and dead trees and shrubs remain on site in both cases. These elements of forest structure provide a "legacy" from one stand to the next (Franklin 1989, DeBell 1990), enhancing the structural complexity of stands regenerated by natural disturbances. Traditional silvicultural practices were designed to reduce structural complexity, consequently managed stands often support fewer species than natural stands (Zarnowitz and Manuwal 1985, Schreiber 1988, Hansen et al. 1991, Swanson and Franklin 1992).

As a result of widespread concern over the loss of biodiversity, many forest managers in the Pacific Northwest are attempting to maintain elements of structure (trees, snags, and woody debris) at the time of harvest. For example, the Oregon Forest Practices Act requires that an average of 5 trees, or snags, per ha and 5 downed logs per ha be left on all clearcuts over 4 ha (Oregon Department of Forestry 1991). In addition, at least 15% retention will be mandated on federal lands under "Option 9" as it was developed by the Forestry Ecosystem Management Assessment Team (FEMAT) under the direction of President Clinton (U.S.F.S. Forest Ecosystem Management Assessment Team 1993). Currently, the President favors "Option 9" over the other options. The benefits of green-tree retention are thought to include maintenance of: a) habitat diversity, b) beneficial predator-prey relationships among invertebrates, c) nutrient cycling through the maintenance of habitat for nitrogen-fixing organisms, d) mycorrhizae and invertebrates by acting as refugia and sources of inocula, e) dispersal opportunities for species that avoid non-forested areas, and f) future coarse woody debris inputs for riparian zones and uplands (Swanson and Franklin 1992).

This study examined bird communities and vegetation structure and composition in clearcuts, green-tree retention stands, and mature forest stands in the west Central Oregon Cascades. Specific questions included: 1) Were there differences in bird species diversity, species richness, and total bird abundance among clearcuts, green-tree retention stands, and mature forest stands? 2) How similar were the bird communities in these 3 stand types? 3) Did the abundance of each bird species differ among the 3 stand types? 4) Were there differences in vegetation structure and composition among the 3 stand types? and 5) Were the abundances of bird species correlated, positively or negatively, with vegetation structure and composition?

A second objective of this study was to examine predation on artificial bird nests as a function of canopy structure. Quantification of nest predation compliments the examination of bird species abundances. Both Van Horne (1983) and Yahner and Morrell (1991) warned against using density, or abundance, as a measure of habitat quality because they may not adequately reveal survival or production of individual species. Most often, avian populations are assessed by surveys that measure the densities of species during breeding seasons, when it is easiest to identify singing males. However, densities of breeding birds may be a particularly misleading indicator of habitat quality for several reasons. To begin with, some passerines exhibit site fidelity, so their densities can reflect habitat quality in the past, not the present (Rotenberry and Wiens 1978). Additionally, unknown numbers of singing males that are non-territorial and non-breeding also are included in density estimates (Wilcove and Terborgh 1984). Finally, nest predation and/or parasitism rates can be very high and they have been found to be one of the major factors affecting fledging success (Ricklefs 1969, Gates and Gysel 1978, Yahner and Wright 1985, Martin 1988). Therefore, individual species may have high densities, but low reproduction and fitness, in a particular habitat where predation rates are high. Species which build open cup nests on or near the ground are especially vulnerable to predation (Wilcove 1985, Bohning-Gaese et al. 1993). For example, Gates and Gysel (1978) found that nest predation alone affected 5-45% of nests built by open-nesting passerines. Cowbird parasitism and nest desertion also affected fledging success to a lesser degree (Gates and Gysel 1978).

Previous studies using artificial nests found that small woodlots and forest fragments had greater predation than large forest tracts (Wilcove 1985, Small and Hunter 1988, Yahner and Scott 1988). Other studies have shown that predation on understory nests was greater in forests than in clearcuts or fields (Yahner and Wright 1985, Yahner and Cypher 1987, Ratti and Reese 1988, Rudnicky and Hunter 1993). However, no studies have examined nest predation in the Pacific Northwest, or in open canopy stands with complex vertical structure (such as green-tree retention stands). Because green-tree retention is being encouraged and/or mandated on federal and state lands, it is important to determine its effects on nest predation and success. Furthermore, studies by Hansen and Hounihan (in press) found that some shrub nesting bird species were less abundant in stands with low levels of tree and snag retention than in clearcuts. It is possible that the retention of trees and snags contributed to the reduced abundances of these species. For example, the trees and snags could have led to increased predation on understory bird nests by serving as perches that predators used to locate nests. This idea is supported by Gates' and Gysel's (1978) finding that predation on nests in forests and fields was higher along habitat edges where predators were able to perch.

If predation and/or parasitism rates for some species that nest in retention stands are so high that reproduction fails to compensate for mortality, or if species fail to nest at all, then retention stands would serve as sink habitats for those species (Van Horne 1983, Pulliam 1988). Both Van Horne (1983) and Pulliam (1988) argued that populations which cannot maintain themselves may persist in sink habitats if individuals regularly emigrate from nearby source habitats.

Because songbirds which breed in both open and closed-canopy habitats in the Pacific Northwest are experiencing population declines (Paige 1990, Sharp 1990, S. Droege, U.S. Fish and Wildlife Service, pers. commun.) information on the effects of green-tree retention on nest predation and avian populations is badly needed. Therefore, this study addressed the following question: Did predation rates on artificial ground or shrub nests differ among clearcuts, green-tree retention stands, and mature forest stands?

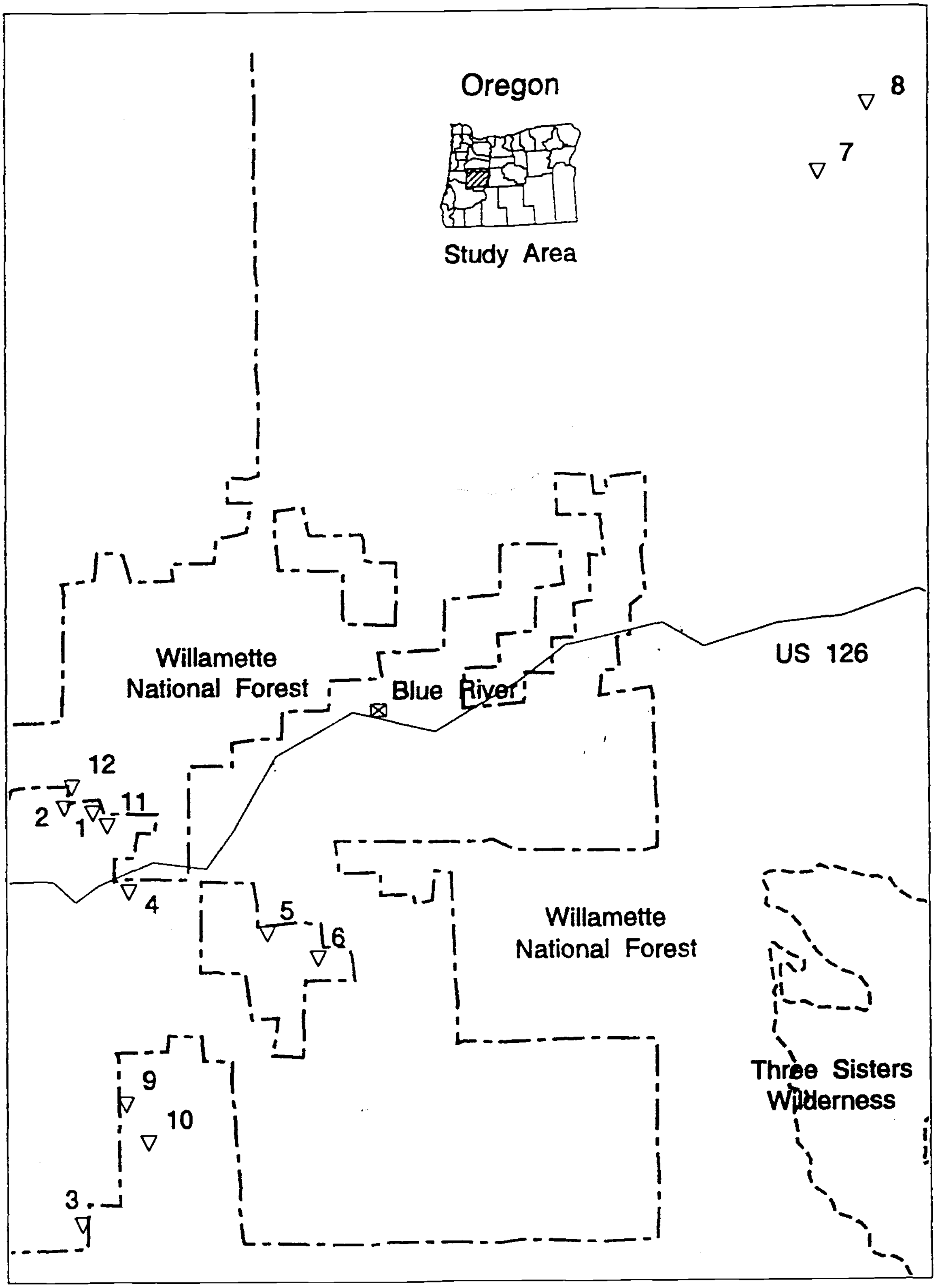
STUDY AREA

Study sites were in the Central Oregon Cascades, from 44° 18' to 44° 02' latitude, Lane County (Figure 1). The local climate is maritime, with wet, mild winters and dry, cool summers (Franklin and Dyrness 1988). The landscape is characterized by steep slopes with a mosaic of different age classes of stands. This mosaic was created by a combination of natural disturbances, ownership boundaries and harvest practices. All study sites were in the Tsuga heterophylla forest zone of the Oregon Cascade Range (Franklin and Dyrness 1988:71-88). Study sites were 2- to 160-years old, and dominated by Douglas-fir (Pseudotsuga mensziesii). Western hemlock (Tsuga heterophylla), mountain hemlock (Tsuga mertensiana), western redcedar (Thuja plicata), true firs (Abies spp.), big-leaf maple (Acer macrophyllum), and golden chinkapin (Castanopsis chrysopylla) also were present in some stands. Common understory shrubs included vine maple (Acer circinatum), ceanothus (Ceanothus velutinus), dwarf Oregon-grape (Berberis nervosa), red huckleberry (Vaccinium parvifolium), rhododendron (Rhododendron macrophyllum) and salal (Gaultheria shallon).

Study sites represented 3 treatments: clearcuts, green-tree retention stands, and natural mature stands. Clearcuts were commercially harvested stands with no tree

Figure 1. Locations of 12 study sites within the Central Oregon Cascades, 1992.

Figure 1.



Oregon
Study Area
8
7
Willamette
National Forest
Blue River
US 126
12
2
1
11
4
5
6
Willamette
National Forest
Three Sisters
Wilderness
9
10
3

retention. All of the clearcuts and retention stands were planted with Douglas-fir. Approximately 12 trees/ha (>30-cm dbh) and 7.5 snags/ha (>30-cm dbh and ≥1.5-m tall) were left in the retention stands after harvest. All of the mature stands were naturally regenerated from fires which occurred 90- to 160-years ago. No trees were harvested from these stands. The ownership, size, elevation, harvest year, site preparation, and planting year for each stand is summarized in Table 1.

Table 1. Ownership, size, elevation, harvest year, site preparation, and planting year for 4 clearcut, 4 green-tree retention, and 4 mature conifer stands in the Central Oregon Cascades, 1992.

	Clearcut				Retention				Forest			
Stand[1]	1	2	3	4	5	6	7	8	9	10	11	12
Ownership[2]	BLM	BLM	WH	RB	FS	FS	FS	FS	FS	FS	BLM	FS
Size (ha)	16	17	25	51	28	33	23	19	N/A	N/A	N/A	N/A
Elevation (m)	870	940	970	320	590	630	670	780	560	540	620	880
Harvest Year	1985	1986	1986-87	1988-89	1989	1989	1990	1990	N/A	N/A	N/A	N/A
Site Preparation[3]	BCB	BCB	N/A	BCB	PTB	BCB	PAB	PTB	N/A	N/A	N/A	N/A
Planting Year	1987	1987-88	1990	1989-90	1991	1990	1991	1991	N/A	N/A	N/A	N/A

[1] Numbers correspond with study site locations shown in Figure 1.

[2] BLM = Bureau of Land Management, WH = Weyerhaeuser, RB = Rosburo Lumber Company, FS = U.S. Forest Service.

[3] BCB = Broadcast burn, PTB = Partial burn, PAB = Pile and burn.

METHODS

Study Site Selection

This study was a comparative mensurative experiment with 3 treatments (Hurlbert 1984). I chose 4 clearcut, 4 green-tree retention, and 4 natural mature forest stands, for a total of 12 study sites. Stands were selected, from those available, using criteria of vegetation structure, age (2-160 years), size (≥12 ha), elevation (<1000 m), vegetation association (*Tsuga heterophylla*), and accessibility.

Bird Surveys

Three sampling stations were located ≥75 m from stand edges at 100-m intervals along each of 2 transects for a total of 6 per stand. Birds were surveyed at these stations using a modification of the variable circular plot method (Reynolds et al. 1980). All surveys took place between May 15, 1992 and June 30, 1992 on days without heavy rain or strong winds. During this time, 5 surveys were conducted in all but 1 mature stand, which received 4 surveys.

All bird counts began 10 minutes before dawn and ended not later than 4 hours after dawn. Upon arrival at each station, observers waited 2 minutes in order to allow birds to resume their normal activities. Then, all birds detected by visual and aural cues during the following 8 minutes were recorded. The information recorded included: weather conditions (cloud cover, precipitation, wind); species; means of detection (song, call, visual, or, aural and visual); distance class from sampling station (5- to 20-m intervals); distance from stand edge; and type of stand edge (clearcut, young plantation, retention stand, mature forest, or, old-growth forest). Observers did not distinguish between hermit and Townsend's warblers because they hybridize in the study area, making them difficult to distinguish in the field (Huff and Raley 1991). Birds observed flying over the stands were recorded, but not included in the analyses. In order to facilitate accurate distance estimations, flagging was placed 40 m from each sampling station in each of the 4 cardinal directions. The observers, order of surveying stands, and the order of visiting sampling stations were systematically rotated to minimize sampling biases.

Habitat Sampling

Vegetation structure and composition was quantified by measuring 45 habitat variables at each bird survey station (Table 2, Figure 2). Slope, aspect, slope position and distance to stand edges were measured at station centers. If streams were present, the distance to the closest stream within a 50-m radius of each station also was noted. Snags were tallied by species, size and decay class within a 30-m radius (0.28-ha circular plot) of station centers. Decay classes of snags follow those defined by Cline et al. (1980). Conifer and hardwood trees were tallied by species and size in 10-m radius (0.03-ha) satellite plots centered 20 m in each cardinal direction from each station. The moosehorn technique (Garrison 1949) was used to measure canopy cover at the center of each of these satellite plots. Since large conifer and hardwood trees in retention stands were widely spaced, there was concern that they would not be adequately sampled in 10-m radius sub-plots. Therefore, all trees in retention stands were also tallied in the same 30-m radius plots as snags. Shrub stems were tallied by species and size class in 5-m radius (0.008-ha) satellite plots centered 20 m in each cardinal direction from each station. Percent cover was estimated for 6 layers of vegetation: 0-1 m, >1-2 m, >2-3 m, >3-4 m, >4-5 m, and 0-2 m combined. These estimates were made in 1-m^2 satellite sub-plots located 5 m in each cardinal direction from the center of each shrub sampling plot.

Table 2. Habitat characteristics measured in plots around bird survey stations in 4 clearcut, 4 green-tree retention, and 4 mature conifer stands in the Central Oregon Cascades, 1992.

Variable	Description
Stand Attributes	
elevation	elevation (m)
slope	average % slope within 20 m of station
aspect	average orientation of slope face in degrees within 20 m of station
slope position	upland, hillslope, footslope, or ravine bottom
distance to water	distance to closest stream $\leq$50 m from station
Vegetation layer (% cover)	
0-1 m	% of ground covered by all vegetation from 0-1 m
>1-2 m	% of ground covered by all vegetation from >1-2 m
>2-3 m	% of ground covered by all vegetation from >2-3 m
>3-4 m	% of ground covered by all vegetation from >3-4 m

Table 2, continued

Variable	Description
>4-5 m	% of ground covered by all vegetation from >4-5 m
0-2 m combined	% of ground covered by all vegetation from 0-2 m
canopy	% of sky covered by all vegetation >2 m
Shrubs by species	
0.5-1 cm dbh[1]	number of stems 0.5-1 cm dbh/0.008 ha
>1-2 cm dbh	number of stems >1-2 cm dbh/0.008 ha
>2-3 cm dbh	number of stems >2-3 cm dbh/0.008 ha
>3-4 cm dbh	number of stems >3-4 cm dbh/0.008 ha
>4-5 cm dbh	number of stems >4-5 cm dbh/0.008 ha
>5 cm dbh	number of stems >5 cm dbh/0.008 ha
Trees by species	
2-10 cm dbh	number of trees 2-10 cm dbh/0.03 ha
>10-20 cm dbh	number of trees >10-20 cm dbh/0.03 ha
>20-30 cm dbh	number of trees >20-30 cm dbh/0.03 ha

Table 2, continued

Variable	Description
>30-40 cm dbh	number of trees >30-40 cm dbh/0.03 ha
>40-50 cm dbh	number of trees >40-50 cm dbh/0.03 ha
>50-60 cm dbh	number of trees >50-60 cm dbh/0.03 ha
>60-70 cm dbh	number of trees >60-70 cm dbh/0.03 ha
>70-80 cm dbh	number of trees >70-80 cm dbh/0.03 ha
>80-90 cm dbh	number of trees >80-90 cm dbh/0.03 ha
>90 cm dbh	number of trees >90 cm dbh/0.03 ha
Snags by species, decay class[2] and height	
2-10 cm dbh	number of snags 2-10 cm dbh/0.28 ha
>10-20 cm dbh	number of snags >10-20 cm dbh/0.28 ha
>20-30 cm dbh	number of snags >20-30 cm dbh/0.28 ha
>30-40 cm dbh	number of snags >30-40 cm dbh/0.28 ha
>40-50 cm dbh	number of snags >40-50 cm dbh/0.28 ha
>50-60 cm dbh	number of snags >50-60 cm dbh/0.28 ha

Table 2, continued

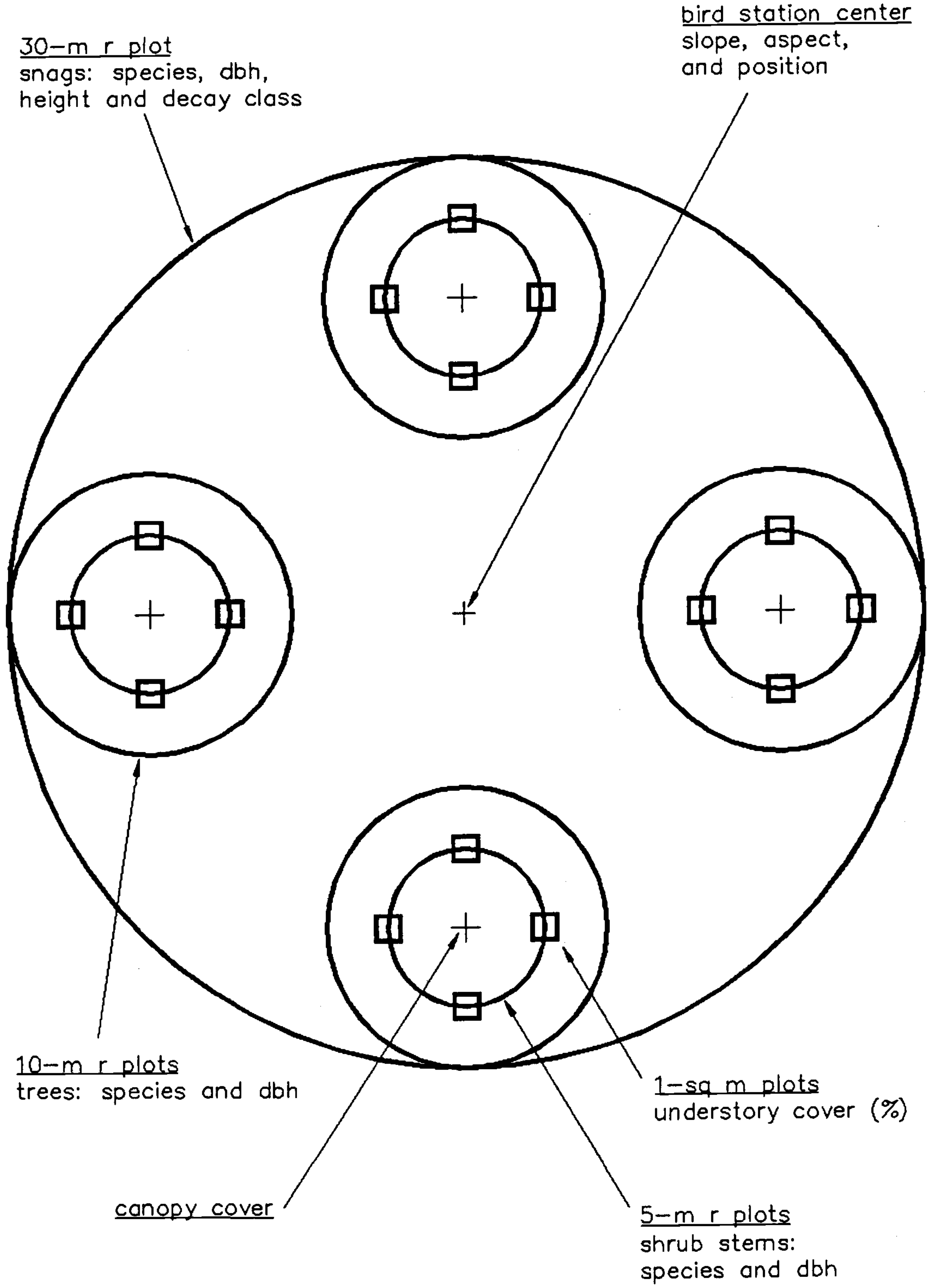
Variable	Description
>60-70 cm dbh	number of snags >60-70 cm dbh/0.28 ha
>70-80 cm dbh	number of snags >70-80 cm dbh/0.28 ha
>80-90 cm dbh	number of snags >80-90 cm dbh/0.28 ha
>90 cm dbh	number of snags >90 cm dbh/0.28 ha

[1] dbh = diameter at breast height

[2] decay classes after Cline et al. (1980).

Figure 2. Habitat sampling scheme used in the 12 study sites in the Central Oregon Cascades, 1992.

Figure 2.


30-m r plot
snags: species, dbh,
height and decay class
bird station center
slope, aspect,
and position
10-m r plots
trees: species and dbh
1-sq m plots
understory cover (%)
canopy cover
5-m r plots
shrub stems:
species and dbh

Nest Predation

To measure relative amounts of predation, 24 artificial open cup nests with 2 Japanese quail (Coturnix coturnix) eggs in each nest were placed in each study site. The nests, which were approximately 6 cm in diameter, were constructed from grass, and were purchased from a craft store. In order to minimize human scent, nests were handled with rubber gloves at all times. In order to minimize the smell of foreign vegetation, nests were placed outdoors for at least 2 weeks prior to use. The eggs, which were purchased from Oregon State University Poultry Science, were approximately 33 mm x 25 mm. They were cream to tan in color and had varying amounts of brown speckles. All eggs were rinsed with well water and handled with rubber gloves (Small and Hunter 1988).

Nests and eggs were placed in study sites from June 3-17, 1992. Four nests, 2 ground and 2 shrub, were placed in separate locations around each bird survey station. All of the nests were within 18-43 m of a station center and nests of the same type (ground or shrub) were placed approximately 180° apart. Shrub nests were wired onto sturdy stems 0.1-2 m from the ground. Ground nests were placed in a variety of locations including: the bases of trees, snags, and stumps, and among coarse woody debris, rocks, and vegetation. In order to minimize the extent to which human scent influenced the activity of predators, observers wore rubber gloves and boots while placing nests and eggs in study sites (Yahner and Cypher 1987, Small and Hunter 1988, Yahner and Scott 1988, Yahner and Voytko 1989, Yahner and Delong 1992, Yahner and Morrell 1991). Observers also made efforts not to tread paths to the nests or destroy vegetation around the nests (Major 1989).

Nest locations were not marked as obvious nest markers have confounded the results of previous nest predation studies (Picozzi 1975, Yahner and Wright 1985). In order to facilitate relocation of nests, the distance and direction from the survey station to each nest was measured and the location was described. Additionally, the height of the nest and the shrub species were recorded for shrub nests.

After 6 days, observers checked the nests and recorded whether or not they were disturbed (Yahner and Wright 1985, Yahner and Scott 1988). Signs of depredation included ≥ 1 broken or missing egg, or a missing nest (Loiselle and Hoppes 1982, Wilcove 1985, Martin 1987). Any indications of predator type, such as peck holes or teeth marks, were noted. The visibility of nests from above was estimated by the percentage of the nest which could be seen by observers from 1 m directly above the nest. Visibility from the sides was quantified by averaging the percentage of the nest visible from 1 m away on 2 opposite sides of the nest.

For shrub nests, the average height and diameter of the shrub, and the distance from the nest to the closest edge of the shrub also was recorded (Major 1989). Nests, eggs, and egg fragments were removed at the end of the experiment (Yahner and Morrell 1991, Yahner and Scott 1988). Upon completion of the field work, all data were entered in the Forest Science Data Bank at Oregon State University (Stafford et al. 1984, 1988).

Data Analysis

Avian Community Analyses

Analyses done on the entire bird community included all birds that were registered within a 50-m radius of sampling stations. Truncation of the data at 50 m ensured that equal areas were sampled in each stand type and minimized biases associated with counting the same bird more than once.

Bird survey data for each species were summed over stations within each stand and averaged among surveys to obtain the mean number of birds/survey. Examination of the residuals showed non-normality and non-constant variance which could not be remedied by appropriate transformations (Sabin and Stafford 1990). Therefore, Kruskal-Wallis 1-way Analysis of Variance (ANOVA) (SAS Institute, Inc. 1985:227-

233) was used to test the hypotheses that there were no differences in bird species diversity, species richness and total bird observations among the treatments. Diversity was calculated by Shannon's Diversity Index (Shannon and Weaver 1949). Total observations for each species also were independent variables in separate ANOVA's. Comparison of means was performed using Distribution-Free Multiple Comparisons based on Kruskal-Wallis rank sums (Hollander and Wolfe 1973:124).

Several measures of community similarity were calculated to assess the resemblance of bird community composition and structure among treatments. The data used in the community analyses above also were used in these calculations. I computed Percentage of Similarity (Wolda 1981), Morisita's Index of Community Similarity, and Horn's Index of Community Overlap (Horn 1966). Percent similarity was determined by calculating the percent of total observations that each species in a community (stand type) contributed. Then, the lowest percent composition of each species from any 2 stand types being compared was summed to obtain the total percent similarity between communities (Brower et al. 1990). Therefore, it is sensitive to rare species. Morisita's Index of Community Similarity, which is based on Simpson's Index of Dominance, is sensitive to abundant species. Horn's Index of Community Overlap is based on information theory. All indices range from 0, when 2 communities have no species in common, to 1, when communities have the same species composition and relative abundances.

Species-Habitat Analyses

To compare the number of observations of individual bird species among stand types it was desirable to account for different detectability distances of each species. For each species, the distance at which ≥75% of the observations occurred was calculated. The observations within this distance then were selected for analysis. Kruskal-Wallis 1-way ANOVA was used to test the hypotheses that there were no differences in the number of observations of each species among treatments. ANOVA's were performed for all species with ≥24 observations. Because all of the bird community analyses were done on the sub-set of observations within a 50-m radius of each sampling station, ANOVA's with those data also were completed. Truncation of the data at 50 m resulted in ≤24 observations of western tanager and red-breasted nuthatch, so they were deleted from these comparisons. However, the results for the remaining species did not change. Therefore, only the results for the ANOVA using the observations at the distance which included ≥75% of the observations for each species are reported. Exact _P_-values for the comparison of means tests are not reported because they are not available in SAS (SAS Institute, Inc. 1985).

Habitat data were averaged across all subplots within each plot. Means and standard deviations were then calculated among plots to obtain the mean value and standard deviation of each variable for each stand. In order to reduce the number of variables without eliminating the importance of tree and snag size, the 10-cm diameter classes of trees and snags were aggregated as follows: 2-10 cm, >10-30 cm, >30-60 cm and >60 cm (Brown 1985). Tree and snag species also were combined into conifers and hardwoods. Snags were divided into hard (decay class 1-3) and soft (decay class 4-5) (after Cline et al. 1980). All shrub stems were placed into 2 size classes, ≥0.5- to 1-cm dbh and >1-cm dbh. Shrub stems of all but the most abundant species (ceanothus, red huckleberry, rhododendron and vine maple) were combined to form a new variable called "non-dominant" shrub stems. Cover estimates of vegetation in the >3- to 4-m layer and >4- to 5-m layer were combined because each species that was highly positively correlated ($\underline{r} \geq 0.7$) with one of those layers was also highly positively correlated with the other. All of these species remained highly positively correlated with vegetation in these 2 layers after they were combined. Standard deviations of habitat variables also were calculated to indicate clumped distributions of habitat features. MANOVA was used to test the hypothesis that there was no difference in the density of trees in >30- to 60-cm dbh or >60-cm dbh size classes in 10-m radius versus 30-m radius plots in retention stands.

Spearman Rank Correlations (SAS institute, Inc. 1982:501-512) were used to describe the relationships between observations of each bird species ($\underline{n} \geq 24$) and habitat characteristics of each stand type. Because of the large number of simple correlations performed, it was necessary to control for the experimentwise error rate. Therefore, only the habitat variables which were highly correlated ($\underline{r} \geq 0.70$, or $\underline{r} \leq -0.70$, $\underline{P} \leq 0.01$) with observations of individual bird species are reported (T. Sabin and W. McComb, Oreg. State Univ., pers. commun.). Kruskal-Wallis 1-way ANOVA tests were used to test the hypotheses that there were no differences in averages or standard deviations of habitat variables among stand types. Only those habitat variables which were highly correlated ($\underline{P} \leq 0.01$) with observations of at least 1 bird species are reported. The 12 residuals for all but 1 habitat variable indicated non-normality and non-constant variance which could not be adequately improved by a single transformation (Sabin and Stafford 1990). Kruskal-Wallis 1-way ANOVA was selected because it had adequate power to detect differences among treatments (T. Sabin, Oreg. State Univ., pers. commun.) and because it could be used for all untransformed habitat variables.

Nest Predation

A split-plot ANOVA (Petersen 1985:134-144) was used to test the hypothesis that there were no differences in predation on ground or shrub nests among stand types. The proportion of ground and shrub nests that were preyed on in each stand was calculated. In order to meet the assumptions of the split-plot ANOVA, an arcsin square-root transformation of the proportions was used (T. Sabin, Oreg. State Univ., pers. commun.). Proportions were weighted by the number of nests which observers were able to relocate after 6 days. The least squares means procedure (SAS Institute, Inc. 1985) was used to determine differences among stand types. Stand type was the whole-plot treatment and nest type was the subplot treatment. Among-stand variation was used to test the effect of stand type. Within-stand variation was used to test for the nest type-by-stand type interaction. Because artificial nests may not reveal actual predation rates, they should be used as an index to the relative magnitude of predation in each stand type (Loiselle and Hoppes 1983, Wilcove 1985).

RESULTS

Avian Communities

During spring 1992, 3,968 birds representing 66 species were recorded. The common and scientific names of all bird species that were observed are listed in Appendix 1. ANOVA of the detection distances (Reynolds el al. 1980) of each species with ≥24 observations indicated that golden-crowned kinglet was the only species for which detectability varied by treatment ($\underline{P}$ = 0.08, df = 2, $\underline{n}$ = 24). For species with ≥12 observations, visual inspection of frequency distributions of the number of observations at each distance revealed that all species, except rufus hummingbird and brown creeper, were adequately detected within a 50-m radius of bird sampling stations. The distances at which ≥75% of all new observations for each species occurred are listed in Appendix 2.

Total bird abundance and species richness did not differ among stand types (Table 3). Species diversity was higher in mature stands than in clearcuts. In order to check for potential bias from a large flock of Brewer's blackbirds ($\underline{n}$ = 45) in 1 clearcut site, differences in total bird abundance, species richness and species diversity were calculated with and without all species of flocking birds. In both cases the results were the same;

Table 3. Community attributes of birds in 4 clearcut, 4 green-tree retention, and 4 mature conifer stands summed over 5[1] breeding season surveys in the Central Oregon Cascades, 1992. Only observations within a fixed-radius plot (50-m radius) are included. Means with similar superscripts do not differ ($P \le 0.10$).

	Clearcut		Retention		Forest			
Community attribute	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	Chi-sq	P[2]
Total abundance	94.3[a]	19.0	76.5[a]	9.8	80.8[a]	17.8	0.46	0.79
Richness	11.3[a]	1.3	16.3[a]	2.3	14.0[a]	1.2	3.05	0.22
Diversity	0.8[a]	0.03	0.9[ab]	0.09	0.9[b]	0.02	5.69	0.06

[1] There were only four counts in one mature forest stand.

[2] Significance level associated with rejection of the null hypothesis that there is no difference between means, Kruskal-Wallis 1-way ANOVA (df = 2). A difference of at least 5.4 between any two values of Mean Scores is needed to show significance at the 0.10 level.

therefore, only the results including flocking birds are reported. All of the community similarity indices indicated that the bird communities in clearcuts and retention stands were the most similar and that the bird communities in clearcuts and mature stands were the least similar (Table 4). However, the magnitude of the similarity values varied among indices.

Species-Habitat Associations

MANOVA of tree densities from data collected in 10-m radius and 30-m radius plots in retention stands indicated that there were no differences in tree densities in either the >30- to 60-cm or >60-cm dbh size classes for conifers or hardwoods ($\underline{P} \geq 0.10$). Because the 10-m radius plots adequately sampled the trees, only the data from 10-m radius plots were used in the analyses.

Of the 17 species with ≥24 observations, 14 of them differed among stand types (Table 5). Lazuli buntings were observed more in clearcuts than in retention or mature stands. Lazuli buntings also were positively correlated with all 0.5- to 1-cm dbh non-dominant shrub stems and negatively correlated with cover from >3-5 m, >30- to 60-cm dbh hardwoods, and >10- to 30-cm dbh conifers (Table 6). Vegetative cover from >3-5 m, >30- to 60-cm dbh hardwoods, and >10- to 30-cm dbh conifers were lower in clearcuts than

Table 4. Similarity indices of the mean number of observations of each bird species in 4 clearcut, 4 green-tree retention, and 4 mature conifer stands in the Central Oregon Cascades, 1992. Only observations within a fixed-radius plot (50-m radius) are included.

	Clearcut-Retention	Retention-Forest	Clearcut-Forest
Similarity index	$\bar{x}$	$\bar{x}$	$\bar{x}$
Percent Similarity	0.26	0.19	0.08
Morisita's Index	0.76	0.20	0.02
Horn's Index	0.61	0.24	0.06

Table 5. Abundance indices (observations/stand) of birds in 4 clearcut, 4 green-tree retention, and 4 mature conifer stands summed over 5[1] breeding season surveys in the Central Oregon Cascades, 1992. Only species with ≥24 observations are included. Means with similar superscripts do not differ ($P \leq 0.10$).

		Clearcut		Retention		Forest			
Species	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	Chi-sq	P[2]
American robin	27	2.8^{a}	1.5	3.3^{a}	1.4	0.8^{a}	0.5	1.97	0.37
Chestnut-backed chickadee	67	0.0^{a}	0.0	5.5^{ab}	4.0	11.6^{b}	2.1	6.61	0.04
Dark-eyed junco	181	27.5^{a}	9.5	16.0^{a}	2.7	2.0^{a}	1.0	4.72	0.09
Golden-crowned kinglet	24	0.0^{a}	0.0	1.0^{ab}	0.6	5.2^{b}	1.0	9.15	0.01
Hammond's flycatcher	58	1.0^{a}	0.7	0.3^{a}	0.3	13.5^{b}	4.1	8.23	0.02
Hermit/Townsend's warbler	130	1.0^{a}	0.7	0.5^{a}	0.3	33.8^{b}	11.5	7.81	0.02
Lazuli bunting	35	8.5^{a}	5.5	0.3^{b}	0.3	0.0^{b}	0.0	9.37	0.01
MacGillivray's warbler	167	20.8^{ab}	9.4	21.0^{a}	3.0	0.0^{b}	0.0	6.12	0.05

Table 5, continued

		Clearcut		Retention		Forest			
Species	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	Chi-sq	P[2]
Red-breasted nuthatch	27	0.0^{a}	0.0	0.5^{ab}	0.5	6.8^{b}	2.1	8.90	0.01
Rufous-sided towhee	63	7.3^{a}	2.4	8.3^{a}	4.6	0.3^{a}	0.3	5.19	0.07
Song sparrow	38	5.0^{a}	1.8	4.5^{a}	1.7	0.0^{b}	0.0	7.71	0.02
Steller's jay	26	0.5^{a}	0.3	5.3^{b}	1.5	0.9^{ab}	0.6	6.92	0.03
Swainson's thrush	33	1.8^{a}	1.4	0.3^{a}	0.3	6.4^{a}	2.9	3.44	0.18
Western tanager	24	0.5^{a}	0.5	4.0^{a}	1.5	1.6^{a}	0.6	4.26	0.12
White-crowned sparrow	69	14.8^{a}	12.8	2.5^{ab}	1.0	0.0^{b}	0.0	6.27	0.04
Willow flycatcher	63	14.8^{a}	2.9	1.0^{ab}	0.6	0.0^{b}	0.0	9.15	0.01
Winter wren	53	0.0^{a}	0.0	0.3^{a}	0.3	13.2^{b}	5.8	9.37	0.009

[1] There were only four counts in one mature forest stand.

[2] Significance level associated with rejection of the null hypothesis that there is no difference between means, Kruskal-Wallis 1-way ANOVA (df = 2). A difference of at least 5.4 between any two values of Mean Scores is needed to show significance at the 0.10 level.

Table 6. Spearman correlation coefficients for bird-habitat associations in 4 clearcut, 4 green-tree retention, and 4 mature conifer stands in the Central Oregon Cascades, 1992.

Bird species	Habitat variable		*r*	*P*
Chestnut-backed chickadee	Cover	canopy	0.79	0.002
	Conifers	>10-30 cm dbh	0.80	0.002
		>30-60 cm dbh	0.84	0.0006
		>60 cm dbh	0.77	0.004
	Hardwoods	>30-60 cm dbh	0.87	0.0002
	Hard snags	>10-30 cm dbh	0.77	0.003
	Soft snags	>10-30 cm dbh	0.77	0.003
		>30-60 cm dbh	0.74	0.006
		>60 cm dbh	0.77	0.003
Dark-eyed junco	Elevation		0.76	0.004
	Hard snags	>30-60 cm dbh	-0.72	0.009
	Soft snags	>60 cm dbh	-0.73	0.007
Golden-crowned kinglet	Cover	>3-5 m	0.79	0.002
		canopy	0.81	0.001
	Conifers	>10-30 cm dbh	0.85	0.0004
		>30-60 cm dbh	0.90	0.0001
		>60 cm dbh	0.71	0.01
	Hardwoods	>30-60 cm dbh	0.86	0.003
	Hard snags	>10-30 cm dbh	0.71	0.01
	Soft snags	>10-30 cm dbh	0.71	0.01
		>30-60 cm dbh	0.78	0.003
		>60 cm dbh	0.75	0.005
Hammond's flycatcher	Shrubs	0.5-1 cm dbh vine maple,SD	-0.73	0.008
	Conifers	>10-30 cm dbh,SD	0.70	0.01
		>30-60 cm dbh	0.70	0.01
		>60 cm dbh	0.71	0.01
	Soft snags	>30-60 cm dbh	0.71	0.01
		>60 cm dbh	0.74	0.006
Hermit/ Townsend's warbler	Cover	canopy	0.76	0.004
	Shrubs	≥0.5 cm dbh red huckleberry	0.74	0.006

Table 6, continued

Bird species	Habitat variable		r	P
	Conifers	>10-30 cm dbh	0.72	0.008
		>30-60 cm dbh	0.70	0.01
		>60 cm dbh	0.76	0.004
	Hard snags	>10-30 cm dbh	0.71	0.009
	Soft snags	>10-30 cm dbh	0.72	0.009
		>30-60 cm dbh	0.72	0.008
		>60 cm dbh	0.71	0.01
Lazuli bunting	Cover	>3-5 m	-0.87	0.003
	Shrubs	0.5-1 cm dbh non-dominant	0.71	0.01
	Conifers	>10-30 cm dbh	-0.86	0.0004
	Hardwoods	>30-60 cm dbh	-0.74	0.006
MacGillivray's warbler	Cover	>1-2 m, SD	0.85	0.0005
	Hardwoods	2-10 cm dbh	0.80	0.002
Red-breasted nuthatch	Cover	>3-5 m	0.72	0.008
		canopy	0.78	0.003
	Conifers	>10-30 cm dbh	0.78	0.003
		>30-60 cm dbh	0.98	0.0001
		>60 cm dbh	0.80	0.002
	Hard snags	>10-30 cm dbh	0.81	0.001
		>30-60 cm dbh	0.89	0.0001
	Soft snags	>10-30 cm dbh	0.89	0.0001
		>30-60 cm dbh	0.85	0.0005
		>60 cm dbh	0.76	0.005
Rufous-sided towhee	Cover	canopy	-0.81	0.002
	Conifers	>30-60 cm dbh	-0.84	0.006
	Hard snags	>10-30 cm dbh	-0.80	0.002
		>30-60 cm dbh	-0.72	0.008
	Soft snags	>10-30 cm dbh	-0.87	0.0002
		>30-60 cm dbh	-0.70	0.01
Song sparrow	Slope (%)		-0.73	0.008
	Cover	>2-3 m	-0.71	0.01
		>3-5 m	-0.75	0.005
		canopy	-0.70	0.01
	Shrubs	≥0.5 cm dbh red huckleberry	-0.86	0.0003
		>1 cm dbh vine maple	-0.71	0.01
	Conifers	>10-30 cm dbh	-0.71	0.01
		>30-60 cm dbh	-0.83	0.001

Table 6, continued

Bird species	Habitat variable		r	P
	Hard snags	>10-30 cm dbh	-0.75	0.005
		>30-60 cm dbh	-0.82	0.001
	Soft snags	>10-30 cm dbh	-0.85	0.0005
		>30-60 cm dbh	-0.77	0.004
White-crowned sparrow	Slope (%)		-0.73	0.008
	Cover	>2-3 m	-0.71	0.01
		>3-5 m	-0.72	0.008
		canopy	-0.79	0.002
	Conifers	>10-30 cm dbh	-0.70	0.01
		>30-60 cm dbh	-0.85	0.0005
	Hard snags	>10-30 cm dbh	-0.73	0.007
		>30-60 cm dbh	-0.79	0.002
	Soft snags	>10-30 cm dbh	-0.86	0.0004
		>30-60 cm dbh	-0.77	0.004
Willow flycatcher	Cover	>3-5 m	-0.78	0.003
	Shrubs	0.5-1 cm dbh non-dominant	0.71	0.01
	Conifers	>10-30 cm dbh	-0.81	0.002
		>30-60 cm dbh	-0.75	0.005
		>60 cm dbh	-0.70	0.01
Winter wren	Cover	>3-5 m	0.76	0.004
		canopy	0.81	0.001
	Shrubs	≥0.5 cm dbh red huckleberry	0.74	0.006
	Conifers	>10-30 cm dbh	0.80	0.002
		>30-60 cm dbh	0.77	0.003
		>60 cm dbh	0.92	0.0001
	Hard snags	>10-30 cm dbh	0.76	0.004
	Soft snags	>10-30 cm dbh	0.74	0.006
		>60 cm dbh	0.84	0.0006

[1] All correlations were performed using mean values except where the standard deviation is indicated by SD.

in mature stands and 0.5- to 1-cm dbh non-dominant shrub stems were more abundant in clearcuts than in retention or mature stands (Table 7).

The number of observations of white-crowned sparrows and willow flycatchers was greater in clearcuts than in mature stands (Table 5). Both species were negatively correlated with cover from >3-5 m and >10- to 60-cm dbh conifers (Table 6). The latter was more abundant in mature stands than in clearcuts or retention stands (Table 7). White-crowned sparrows also were negatively correlated with percent slope, cover from >2-3 m, canopy cover, and >10- to 60-cm dbh hard and soft snags (Table 6). Slope did not differ among stand types, but vegetative cover from >2-3 m, canopy cover, and >10- to 30-cm hard and soft snags were lower in clearcuts than mature stands. Both hard and soft snags >30- to 60-cm dbh were less abundant in clearcuts and retention stands than in mature stands (Table 7). Willow flycatchers also were positively correlated with 0.5- to 1-cm dbh non-dominant shrub stems and negatively correlated with >60-cm dbh conifers (Table 6). The latter was less abundant in clearcuts than in mature stands (Table 7).

Song sparrow observations were greater in clearcuts and retention stands than in mature stands (Table 5) and they were negatively correlated with slope, ≥0.5-cm red huckelberry stems, >1-cm vine maple stems, cover from >2-5 m, canopy cover, and >10- to 60-cm dbh conifers, hard and

Table 7. Habitat characteristics in 4 clearcut, 4 green-tree retention, and 4 mature conifer stands in the Central Oregon Cascades, 1992. Only variables which were correlated with bird species are reported. See Table 1 for a complete list of habitat variables and descriptions. Means with similar superscripts do not differ ($P \leq 0.10$).

	Clearcut		Retention		Forest			
Habitat variable	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	Chi-sq	P[1]
Stand Attributes								
elevation (m)	775.0[a]	153.1	667.5[a]	40.9	650.0[a]	78.5	1.65	0.44
slope (%)	35.7[a]	11.4	25.5[a]	6.4	44.9[a]	7.7	2.81	0.25
Vegetation layer (% cover)								
1-2 m,SD[2]	10.9[a]	5.2	6.0[a]	0.5	4.3[a]	0.5	2.19	0.33
2-3 m	3.0[a]	2.7	1.8[ab]	0.5	12.1[b]	3.5	5.84	0.05
3-5 m	0.05[a]	0.05	1.4[ab]	0.7	14.9[b]	4.4	9.14	0.01
canopy	4.4[a]	3.4	6.7[ab]	1.0	86.8[b]	3.0	8.06	0.02

Table 7, continued

Habitat variable	Clearcut		Retention		Forest		Chi-sq	P[1]
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE		
Shrubs (stems/ha)								
≥0.5 cm dbh red huckleberry	15.6[a]	15.6	93.8[a]	93.8	1196.9[b]	517.2	7.44	0.02
0.5-1 cm dbh vine maple,SD	3850.0[a]	2250.3	2843.8[a]	623.2	731.3[a]	206.9	1.88	0.39
>1 cm dbh vine maple	481.3[a]	394.9	1106.3[ab]	376.4	2656.3[b]	868.5	5.69	0.06
0.5-1 cm dbh non-dominant	975.0[a]	298.4	171.9[ab]	63.2	171.9[b]	115.1	6.60	0.04
Conifers/ha								
>10-30 cm dbh	1.7[a]	1.7	49.2[ab]	11.4	475.8[b]	130.0	9.99	0.007
>10-30 cm dbh,SD	3.3[a]	3.3	45.0[ab]	14.2	196.7[b]	45.3	10.02	0.007
>30-60 cm dbh	0.0[a]	0.0	1.7[a]	1.7	827.5[b]	189.9	9.37	0.009
>60 cm dbh	0.0[a]	0.0	10.8[ab]	4.8	120.0[b]	45.1	9.14	0.01
Hardwoods/ha								
2-10 cm dbh	185.0[ab]	108.5	925.0[a]	668.3	73.3[b]	29.7	5.36	0.07

Table 7, continued

Habitat variable	Clearcut		Retention		Forest			
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	Chi-sq	P[1]
>30-60 cm dbh	0.0[a]	0.0	18.3[ab]	12.9	33.3[b]	16.3	6.79	0.03
Hard snags/ha								
>10-30 cm dbh	4.5[a]	0.8	8.7[ab]	2.5	104.6[b]	41.4	8.00	0.02
>30-60 cm dbh	1.2[a]	0.2	1.5[a]	1.0	13.8[b]	6.5	6.56	0.04
Soft snags/ha								
>10-30 cm dbh	0.9[a]	0.1	1.6[ab]	0.8	16.0[b]	3.9	7.87	0.02
>30-60 cm dbh	1.2[a]	0.2	2.6[a]	1.1	7.6[b]	0.7	7.58	0.02
>60 cm dbh	0.8[a]	0.1	3.6[ab]	1.2	15.6[b]	2.9	8.86	0.01

[1] Significance level associated with rejection of the null hypothesis that there is no difference between means, Kruskal-Wallis 1-way ANOVA (df = 2). A difference of at least 5.4 between any two values of Mean Scores is needed to show significance at the 0.10 level.

[2] All correlations were performed using mean values except where the standard deviation is indicated by SD.

soft snags (Table 6). Red huckleberry stems were less abundant in clearcuts and retention stands than in mature stands. Vine maple stems >1-cm dbh were more abundant in mature stands than in clearcuts (Table 7). Steller's jay observations were greater in retention stands than in clearcuts (Table 5). However, Steller's jays were not highly correlated with any habitat variable. The number of observations of MacGillivray's warblers was greater in retention stands than in mature stands (Table 5). MacGillivray's warblers were positively correlated with the standard deviation of cover from >1-2 m and 2- to 10-cm dbh hardwoods (Table 6). The standard deviation of vegetation from >1-2 m did not differ among stand types and the density of 2- to 10-cm dbh hardwoods was higher in retention stands than in mature stands (Table 7).

More chestnut-backed chickadees, golden-crowned kinglets, and red-breasted nuthatches were observed in mature stands than in clearcuts (Table 5). All were positively associated with canopy cover, >10-cm dbh conifers and soft snags, and >10- to 30-cm dbh hard snags (Table 6). The density of soft snags >60-cm dbh was greater in mature stands than in clearcuts (Table 7). Chestnut-backed chickadees and golden-crowned kinglets also were positively correlated with >30- to 60-cm dbh hardwoods. Golden-crowned kinglets and red-breasted nuthatches also were positively correlated with vegetation from >3-5 m. Additionally, red-breasted nuthatches were positively correlated with >30- to 60-cm dbh hard snags (Table 6).

Species with greater detections in mature stands than in other stand types were Hammond's flycatcher, hermit/Townsend's warbler, and winter wren (Table 5). All were positively correlated with >30-cm dbh conifers, and >60-cm dbh soft snags (Table 6). Hammond's flycatchers also were negatively correlated with the standard deviation of 0.5- to 1-cm vine maple stems and positively correlated with the standard deviation of >10- to 30-cm dbh conifers. The standard deviation of 0.5- to 1-cm dbh vine maple stems did not differ among stand types and the standard deviation of >10- to 30-cm dbh conifers was greater in mature stands than in clearcuts (Table 7). Hammond's flycatchers and hermit/Townsend's warblers also were positively correlated with >30- to 60-cm dbh soft snags. Hermit/Townsend's warblers and winter wrens were positively correlated with canopy cover, ≥0.5-cm red huckelberry stems, and >10- to 30-cm dbh conifers, hard, and soft snags. Winter wrens also were positively correlated with vegetation from >3-5 m (Table 6).

Although observations of dark-eyed juncos ($\underline{n}$ = 181) and rufous-sided towhees ($\underline{n}$ = 63) differed among stand types (Kruskal-Wallis 1-way ANOVA), differences between pairs of means could not be detected (Distribution-Free

Multiple Comparisons test) (Table 5). Failure to detect differences may have been caused by sample size, the conservative Distribution-Free test, or both. Dark-eyed juncos were positively correlated with elevation and negatively correlated with >30- to 60-cm hard snags and >60-cm dbh soft snags (Table 6). There was no difference in elevation among stand types (Table 7). Rufous-sided towhees were negatively correlated with canopy cover, >30- to 60-cm dbh conifers, and >10- to 60-cm dbh hard and soft snags (Table 6).

Observations of American robin, Swainson's thrush, and western tananger did not differ among stand types (Table 5). None of these species were correlated with any habitat variable.

Additionally, there were 4 species with <24 total observations which were consistently observed in only 1 stand type. Red-breasted sapsuckers (n = 9) and western bluebirds (n = 7) were only observed in retention stands. Brown creepers (n = 20) and hermit thrushes (n = 8) were only observed in mature stands.

Nest Predation

Common avian species nesting $\leq$2 m from ground level in open cup nests included American robin, dark-eyed junco, lazuli bunting, MacGillivray's warbler, rufous-sided towhee, song sparrow, Swainson's thrush, white-crowned sparrow, and willow flycatcher (Harrison 1987, Ehrlich et al. 1988).

Of the 283 nests recovered from the experiment, 39 ground (27%) and 36 shrub (26%) nests were disturbed by predators. Potential nest predators included birds, mammals and snakes. Steller's jay, gray jay, common raven, and red-tailed hawk comprised the probable avian predators (A. Hansen, Montana State Univ., pers. commun., and pers. obs.). Potential mammalian predators included Virginia opossum (Didelphis virginiana), shrews (Sorex spp.), Townsend's chipmunk (Tamias townsendii), Douglas' squirrel (Tamiasciurus douglasii), northern flying squirrel (Glaucomys sabrinus), mice (Peromyscus spp.), voles (Microtus spp.), coyote (Canis latrans), black bear (Ursus americanus), red fox (Vulpes vulpes), raccoon (Procyon lotor), striped skunk (Mephitis mephitis), western spotted skunk (Spilogale gracilis), weasels (Mustella spp.) (C. Chambers, Oreg. State Univ., pers. commun. and Ratti and Reese 1988). Gopher snakes (Pituophis melanoleucus catenifer) prey on small birds (Nussbaum et al. 1983). Whether or not they also consume eggs is unknown.

Ground nests were disturbed in all treatments. Predation in clearcut stands ranged from 8-77%. There were no disturbed nests in 2 retention stands and predation rates in the remaining retention stands were 8% and 58%.

Mature stands had predation rates from 8-50%. Eggs from 7 nests had holes or were fragmented and eggs were absent from 33 nests. Twenty-one nests were moved or taken by predators. Percent predation averaged 38% for clearcut stands, 17% for retention stands, and 27% for mature stands (Table 8). Ground nests had a higher predation rate in clearcuts than in retention stands (Table 8).

Shrub nests also were disturbed in all treatments. There were no disturbed nests in 2 clearcuts and predation rates in the remaining clearcut stands were 8% and 91%. Shrub nests in all retention stands were visited by predators (18-83%). Only 1 mature stand had nests that were disturbed (25%). Eggs were missing from 32 nests. Three nests were taken by predators. Percent predation averaged 24% in clearcuts, 47% in retention stands and 6% in mature stands (Table 8). Shrub nests had a higher predation rate in retention stands than in clearcuts or mature stands (Table 8). Clearcuts seemed to experience more predation than mature stands; however, I was unable to detect a difference with the multiple comparison of means test (SAS Institute, Inc. 1985).

Table 8. Relative magnitude of predation on artifical nests in 4 clearcut, 4 green-tree retention, and 4 mature conifer stands in the Central Oregon Cascades, 1992. Means[1] with similar superscripts do not differ ($P \leq 0.05$)[2].

		Clearcut		Retention		Forest		
Nest Predation	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	P[3]
Ground nests	12	0.38[a]	0.07	0.17[b]	0.05	0.27[ab]	0.06	0.006
Shrub nests	12	0.24[a]	0.06	0.47[b]	0.07	0.06[a]	0.04	

[1] Means and standard errors are reported for untransformed variables.

[2] Least-squares Means comparison procedure (SAS Institute, Inc. 1985:148-149).

[3] Significance level associated with rejection of the null hypothesis that there is no difference between means, split-plot ANOVA using transformed means.

DISCUSSION

Avian Communities

Contrary to Hansen and Hounihan (in press), who found that total bird abundance and species richness were positively associated with canopy density, I did not detect differences in mean bird species richness or total bird abundance among stand types. Several factors may have contributed to these differences in findings. Stands that were studied by Hansen and Hounihan (in press) were generally higher in elevation. Also, clearcuts and retention stands in the aforementioned study had less shrub development (P. Hounihan, Oreg. State Univ., pers. commun.). Species diversity was higher in mature stands than in clearcuts. These results are consistent with those of previous studies in the Pacific Northwest, which have found higher bird species diversity in habitats with greater structural complexity (Hansen and Hounihan in press, Ruggiero et al. 1991).

The community structure of the avifauna in each stand type was different. The highest similarity values between clearcuts and retention stands were expected because the green-tree retention stands were only harvested 2- to 3-years prior to the study and they had low numbers of residual trees and snags. Even though retention stands were more similar to clearcuts than mature stands, all of the similarity indices suggest that more species of forest birds used the retention stands than the clearcuts. As retention stands age, or if more trees and snags/ha are retained, the avifauna of retention stands may more closely resemble that of mature stands. Differences in the magnitude of the community similarity values according to each index can be attributed to the fact that the percent similarity index is sensitive to rare species, while Morisita's and Horn's indices are sensitive to abundant species.

Species-Habitat Associations

The 14 species that differed in the number of observations among stand types (Table 5) may have been responding to differences in habitat attributes among stand types. Conifer and snag densities were the variables most frequently correlated with the abundances of individual bird species. The number of observations of each species was used as an index to the abundance of each species in each stand. Lazuli buntings, which were most abundant in clearcuts, and song sparrows, which were more abundant in clearcuts and retention stands than mature stands, were negatively associated with several habitat variables that had highest means in mature stands. These associations also were found for white-crowned sparrows and willow flycatchers, which were more abundant in clearcuts than mature stands. Observations of lazuli buntings, song sparrows, white-crowned sparrows and willow flycatchers are consistent with previous studies, which have shown these species to be associated with early seral stage habitats (Meslow and Wight 1975, Morrison and Meslow 1983, Brown 1985). These results also support the findings of Hansen and Hounihan (in press), which indicate that bird species respond individualistically to tree density. For example, both lazuli buntings and song sparrows were present in clearcuts. However, the abundance of lazuli buntings in retention stands decreased dramatically, while the abundance of song sparrows remained basically unchanged. Marcot (1984) also found lazuli buntings almost exclusively in grass/forb habitats.

MacGillivray's warblers nest and forage near the ground and have been associated with shrubby vegetation (Morrison and Meslow 1983, Brown 1985). MacGillivray's warblers were found to be more abundant in retention stands than mature stands and to be positively associated with 2- to 10-cm dbh hardwoods. These hardwoods also were more abundant in retention stands than mature stands. In the study sites, 2- to 10-cm dbh hardwoods were basically comprised of large clumps of stump-sprouting big-leaf maple. These results are consistent with Marcot (1984), who also found MacGillivray's warblers to be highly positively associated with hardwood, broadleaf, or deciduous foliage in early seral stage habitats. According to Brown (1985) MacGillivray's warblers also inhabit large sawtimber stands (average dbh >21 inches). The less well-developed shrub layer in the mature stands examined in this study may account for the lack of MacGillivray's warblers in this stand type. It may be possible to enhance the number of MacGillivray's warblers in managed stands by increasing hardwood stem densities and foliage volume.

Chestnut-backed chickadees, golden-crowned kinglets, and red-breasted nuthatches were observed in retention and mature stands, but not clearcuts. However, the number of observations only differed between clearcuts and mature stands. All 3 species were correlated with canopy cover, trees, and snags, which were present in retention stands and more abundant in mature stands than in clearcuts. Additionally, all 3 species were positively correlated with 2 variables (>30- to 60-cm dbh conifers and >30- to 60-cm dbh soft snags) that were more abundant in mature stands than in clearcuts or retention stands. Chestnut-backed chickadees and red-breasted nuthatches are cavity nesters (Mannan et al. 1980, Brown 1985, Nelson 1988) and have been positively associated with densities of large conifers (Sturman 1968, Mannan et al. 1980, Manuwal and Huff 1987). Hansen and Hounihan (in press) detected a linear trend in the abundance of red-breasted nuthatches and the abundance of trees. These results are consistent with the findings reported here; however, Hansen and Hounihan's (in press) results for golden-crowned kinglets differed. They did not detect kinglets in stands with <62 trees/ha. The low abundance of golden-crowned kinglets in retention stands is consistent with previous observations of decreased abundance following harvests and the association of kinglets with dense conifer foliage in most seral stages (Mannan and Meslow 1984, Carey et al. 1991). Other researchers also have found golden-crowned kinglets to be strongly associated with conifers (McGarigal and McComb 1992).

Although there were no statistically significant differences in the abundances of chestnut-backed chickadees, golden-crowned kinglets, or red-breasted nuthatches between retention stands and mature stands, they were all less than half as abundant in retention stands. This raises some doubt about whether viable populations of these species could persist in retention stands. For example, Morrison and Meslow (1983) found that chestnut-backed chickadees foraged in open canopy habitats, but nested in adjacent forests. Whether or not this is characteristic of golden-crowned kinglets and red-breasted nuthatches is unknown. Even if these species nest in retention stands, more research is needed to determine if the nests are successful. Retention stands could serve as sink habitats if species are unable to nest in them successfully (Pulliam 1988).

Hammond's flycatchers, hermit/Townsend's warblers and winter wrens, which were associated with mature stands, were correlated with many habitat variables that were most abundant in mature stands. Hammond's flycatchers have been associated with open canopy forests with well developed crowns and few understory trees (Mannan 1984). These characteristics are important because Hammond's flycatchers nest in canopies and forage for aerial insects by sallying into open spaces (Meslow and Wight 1975, Mannan 1984). Hammond's flycatchers foraging habits may account for their negative association with the standard deviation of vine maple stems. Mature stands may have provided suitable habitat for Hammond's flycatchers because there were abundant crowns, as reflected by high percent canopy cover and few understory trees and shrubs. Hermit/Townsend's warblers, which have been positively associated with conifers (Mannan and Meslow 1984, Brown 1985, Ralph et al. 1991), also feed and nest in the canopies of conifer trees (Meslow and Wight 1975, Manuwal 1991). Marcot (1984) found that hermit warblers had greater densities in medium sawtimber stands than in pole stands. These results suggest that hermit warblers are not likely to inhabit retention stands until the regeneration has surpassed the pole stage. Further research is needed to determine if higher levels of tree retention will provide habitat for hermit warblers. Winter wrens were positively associated with several understory (ground cover by vegetation from 3-5 m and red huckelberry stems) and overstory (canopy cover, >10-cm dbh conifers and snags) variables. Other investigators have associated winter wrens with large trees (>30-cm dbh) (Barrows 1986, Gilbert and Allwine 1991) and shrub cover >1.3 m (McGarigal and McComb 1992). These habitat characteristics reflect winter wren's association with forest floor habitats. Marcot (1984) found that winter wrens were positively associated with stands having broken canopies, and consequently, greater shrub development. As they mature, green-tree retention stands may develop the types of canopies and understories that provide habitat for winter wrens.

Although dark-eyed juncos and rufous-sided towhees were not associated with a particular stand type, they were correlated with a few habitat features. Both species were negatively correlated with >30- to 60-cm dbh hard snags, which were most abundant in mature stands. Dark-eyed juncos also were negatively correlated with >60-cm dbh soft snags, which were more abundant in mature stands than in clearcuts. Hansen and Hounihan (in press) found that the abundance of dark-eyed juncos was inversely related to tree density. Rufous-sided towhees were negatively associated with canopy cover and other size classes of trees and snags, which had higher densities in mature stands than in clearcuts or retention stands. These associations are consistent with the general findings that dark-eyed juncos and rufous-sided towhees are open canopy specialists. Morrison and Meslow (1983) and Marcot (1984) found that both species were abundant in early seral stage habitats. However, the presence of dark-eyed juncos in middle and late seral stages also has been documented (Meslow and Wight 1975, Brown 1985).

The results suggest that the structure and composition of vegetation profoundly affected the abundance of individual species and the entire bird community in each stand type. Bird species responded individualistically to the densities of trees and snags. These responses reflect individual habitat requirements and species life histories. Bird community composition, in turn, reflected these collective differences in habitat requirements.

Nest Predation

I found evidence to suggest that the predation rate on shrub nests in retention stands is higher than in both clearcuts and mature stands and that the predation rate on ground nests in retention stands is lower than in clearcuts. I found no evidence that the predation rate on ground nests in retention stands is different from that in mature stands.

The high predation rate on shrub nests in retention stands supports the idea that residual trees and snags serve as perch sites for avian predators (Gates and Gysel 1978, Wilcove 1985, Yahner and Wright 1985). Although there were no direct observations of Steller's jays preying on artificial nests, they were assumed to be predators. Furthermore, Steller's jays were more abundant in retention stands than in clearcuts.

These nest predation results are not applicable to bird species which nest in the canopies of trees because all nests in this study were placed on, or within 2 m of, the ground. However, it is likely that Steller's jays also consume eggs from canopy nests (W. McComb, Oreg. State Univ., pers. commun.). Because canopy volume in green-tree retention stands has been greatly reduced, species which nest in the canopies of retention stands may experience greater predation than those in mature stands. The reduction in canopy volume may make nests more conspicuous, or otherwise reduce the search time of predators (C. Chambers, Oreg. State Univ., pers. commun.).

The higher predation rate on ground nests in clearcuts than retention stands could be confounded with the age of the sites. All of the retention stands were 2- to 3-years beyond harvest, while the clearcuts were 4- to 7-years beyond harvest. Small mammals, which may have been responsible for much of the predation on ground nests (Loiselle and Hoppes 1983, Yahner and Wright 1985, Roper 1992), may have built up larger populations in clearcuts than retention sites.

Previous researchers have attempted to identify predators with little success (Gates and Gysel 1978, Storaas 1988). Rough categorization of predators as avian or non-avian has been possible in some cases (Yahner and Cypher 1987). Because of the relatively small number of times (7) that egg fragments or eggs with holes were found in this study, even a rough categorization of predators was not possible. Avian predators are known to remove eggs from nests and consume them elsewhere; however, missing eggs were not entirely attributed to avian predators. Likewise, all ground predation was not attributed to non-avian predators, as corvids preying on ground nests have been observed (Picozzi 1975, Yahner and Wright 1985). Identification was further complicated because some predators removed nests in addition to, or instead of, eggs. Nest removal was also reported in studies by Loiselle and Hoppes (1983) and Martin (1987). More information on actual predators in the study area and their feeding methods is needed to make identification possible.

Only a few artificial nest predation studies have compared predation rates between early- and late-seral habitats (Yahner and Wright 1985, Yahner and Cypher 1987, Ratti and Reese 1988, Rudnicky and Hunter 1993), and none of these studies examined predation in the Pacific Northwest. In addition, no artificial nest predation studies have examined predation in stands which have structures similar to that created by green-tree retention. Yahner and Wright (1985), Ratti and Reese (1988), and Rudnicky and Hunter (1993) all found that ground nest predation was higher in mature stands than in clearcuts. The results of the aforementioned studies are inconsistent with this study, which found no difference in ground nest predation between clearcuts and mature stands. Yahner and Cypher (1987) and Ratti and Reese (1988) also found that predation on shrub nests was greater in mature stands than in 4- to 6-year old clearcuts. Results from this study indicate no difference in shrub nest predation between clearcuts and mature stands. Yahner and Wright (1985) and Ratti and Reese (1988) suggested that the lower rates of predation in clearcuts corresponded with the lack of perches that predators could utilize while searching for nests. The results of this study, which indicate higher predation on shrub nests in green-tree retention stands than in clearcuts, support the idea that perches facilitate the location of shrub nests by predators. These results are consistent with those from an artifical nest predation study in the East-central Oregon Coast Range (C. Chambers, Oreg. State Univ., pers. commun.). Chambers (Oreg. State Univ. pers. commun.) also found that modified clearcuts and 2-storied stands (both with structures similar to green-tree retention stands) had greater shrub nest predation than mature stands.

The nest predation results from this study are particularly important for several reasons. To begin with, the populations of several species of shrub nesting birds are decreasing in Oregon (Paige 1990, Sharp 1990, and S. Droege, U.S. Fish and Wildlife Service, pers. commun.). In addition, green-tree retention is being mandated on both state and federal lands. This study suggests that the trees and snags which were retained in harvest units served as perches for avian shrub nest predators. Hansen and Hounihan (in press) also found that the abundances of some native bird species decreased in stands with low levels of tree and snag retention. In the interest of conserving native species diversity, it would be prudent to maintain a variety of habitat types across the landscape. The vertical structure provided by green-tree retention may benefit some species, but be detrimental to others.

Overall predation rates for ground (27%) and shrub (26%) nests are lower than predation rates reported for actual nests in other regions (Yahner and Voytko 1989). Actual predation rates for species nesting ≤2 m from ground level in open cup nests in the study area are unknown.

Some studies indicate that predation on artificial nests can be comparable to predation on actual nests (Yahner and Voytko 1989, Major 1989, Gotmark et al. 1990, Yahner and Delong 1992), while other studies indicate that they are not (Martin 1987, Storaas 1988, Yahner and Morrell 1991). Yahner and Voytko (1989) also concluded that there was no difference in predation on nests placed in locations selected by researchers and nests placed in locations where birds had built a nest the previous year. Predation on artificial nests could be higher for the following reasons: 1) artificial nests are easily detected by sight or olfaction (Loiselle and Hoppes 1983, Major 1989, Yahner and Voytko 1989), 2) predators followed researchers to nests (Gotmark et al. 1990, MacIvor et al. 1990), and 3) there are no parents to conceal or defend nests (Loiselle and Hoppes 1983, Gotmark et al. 1990). To the contrary, predation on artificial nests could be lower for several reasons: 1) artificial nests do not fit a predators search image, 2) predators select for nests with larger clutch sizes (Loiselle and Hoppes 1983), 3) predators avoid researchers paths to nests (MacIvor et al. 1990), and 4) small predators are unable to handle quail eggs, which are larger and have thicker shells than some small bird species (Roper 1992).

Scope and Limitations

The scope of this study was restricted to recently harvested clearcuts (4- to 7-years old) and green-tree retention stands (2- to 3-years old), and mature (90- to 160-years old) Douglas-fir dominated stands in the West-central Oregon Cascades. Additional research would be needed to determine if the same patterns hold for other areas of the Cascade Mountains, in other stand age classes, in green-tree retention stands with different tree densities, and in stands dominated by species other than Douglas-fir.

Several limitations should be recognized. First, is the size of the study and the number of replications. The study was limited to 12 sites based on the availability of time, money and desirable site attributes. Although 4 replicates is often considered good in ecological studies (Hurlbert 1984), more replicates would greatly increase the ability to detect differences in bird communities, species abundances and nest predation rates in different site types.

The primary limitation of the bird sampling method was the location of survey stations at 100-m intervals. In the bird community analyses, this resulted in elimination of all observations which were greater than 50 m from the sampling station in order to prevent overlap in birds sampled in adjacent areas. This design works well for some common species, but it results in elimination of more widely distributed species from the analysis because it is difficult to obtain ≥24 observations within 50 m. Other researchers have reported the same problem in studies with similar designs (J. Hagar and K. McGarigal, Oreg. State Univ., pers. commun.). For example, birds such as olive-sided flycatchers, northern flickers and red-breasted sapsuckers were observed in stands, but almost never occurred within 50 m of a sampling station. These birds also can be accurately detected at great distances (≥300 m) because of their unique songs, habits and markings (personal observation). Therefore, increasing the distance between sampling stations to at least 200-300 m, or using a non-point centered method of sampling is recommended. If this were done, the assumption that all species could be adequately detected within the entire sampling area would no longer be valid. It would be necessary to calculate an effective detectability distance (Reynolds et al. 1980) for each species and then account for it in all of the analyses. Some trade-offs of such a design include the smaller number of survey stations that could be included in stands and increased walking time between stations. Also, there would be less overlap in the areas in which birds were surveyed and the area in which habitat was sampled. Finally, because the sampling was designed to study diurnal birds during the breeding season, nocturnal birds, and seasonal changes in the avifauna were not assessed.

Limitations of the nest predation experiment must also be recognized. The extent to which predation on artificial nests mimics predation on real nests in the Pacific Northwest has not been studied.

Conclusions and Management Implications

Mature forest stands had greater bird species diversity than clearcuts. Total bird abundance and species richness did not differ among clearcuts, green-tree retention stands, and mature forest stands. However, there were differences in the compositions of the bird communities in each stand type. The communities in clearcuts and green-tree retention stands were the most similar.

The absence of trees and presence of a well-developed shrub layer in clearcuts seemed to provide better habitat for lazuli buntings. Red-breasted sapsuckers and western bluebirds were only observed in green-tree retention stands. Mature stands provided better habitat for brown creepers, Hammond's flycatchers, hermit/Townsend's warblers, hermit thrushes, and winter wrens. Chestnut-backed chickadees, golden-crowned kinglets, and red-breasted nuthatches were only present in green-tree retention and mature forest stands, while MacGillivray's warblers, song sparrows, white-crowned sparrows, and willow flycatchers were only present in clearcuts and retention stands. It is clear that the vegetation structure and composition of each stand type had strong impacts on the bird communities and their component species. Bird species responded individualistically to tree and snag retention and even low levels of retention corresponded with changes in bird community composition.

Stand conditions also affected nest predation. Ground nest predation was greater in clearcuts than in mature stands and shrub nest predation was highest in retention stands.

The Breeding Bird Survey trend data from 1968-1991 (Paige 1990, Sharp 1990, S. Droege, U.S. Fish and Wildlife Service, pers. commun.) indicates that the populations of many Oregon songbirds are declining. Both open canopy associates, such as dark-eyed juncos and white-crowned sparrows, and closed-canopy associates, such as brown creepers and golden-crowned kinglets, have declined. In addition, many other migratory and resident species also have experienced population changes during this period (S. Droege, U.S. Fish and Wildlife Service, pers. commun.). Because both open and closed-canopy associates, as well as migrants and residents, are showing declines in population, it would be wise to provide a variety of stand conditions across the landscape. The individualistic responses of bird species to green-tree retention emphasize the need to maintain an array of stand types in the Pacific Northwest. Also, it is important that management goals be specifically tailored to individual species or communities.

Green-tree retention may be a valuable tool for management. It has the potential to allow for some commodity extraction while mimicking natural disturbance patterns more closely than traditional management practices. Leaving trees and snags in harvest units increases the structural diversity of managed stands and may provide habitat for some wildlife species. For example, the populations of western tanagers and olive-sided flycatchers have been declining in Oregon (S. Droege, U.S. Fish and Wildlife Service, pers. commun.), but they were both present in green-tree retention stands. However, other species such as lazuli buntings and willow flycatchers were absent from, or less abundant, in retention stands.

Clearly, mandates such as 15% retention in all harvest units on federal lands, as is recommended under "option 9" of the Forestry Ecosystem Management Assessment Team, would be detrimental to some open canopy species which respond negatively to green-tree retention. This is especially true if species that nest in shrubs in retention stands suffer from greater predation rates than species which nest in clearcuts or mature stands. If green-tree retention provides perches which facilitate the location of shrub nests by predators, or if the reduction in canopy volume leads to increased predation on canopy nests, then reproduction in retention stands may not compensate for mortality. In this case, green-tree retention stands would serve as sink habitats for some species. Management activities which rely on data about species abundances would be misleading if green-tree retention stands were indeed sink habitats for some species.

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APPENDICES

Appendix 1. Common and scientific names of bird species observed in 4 clearcut, 4 green-tree retention, and 4 mature conifer stands in the Central Oregon Cascades, 1992.

Common Name	Scientific Name
American crow	Corvus brachyrhynchos
American goldfinch	Carduelis tristis
American robin	Turdus migratorius
Black-headed grosbeak	Pheucticus melanocephalus
Black-throated grey warbler	Dendroica nigrescens
Blue grouse	Dendragapus obscurus
Brewer's blackbird	Euphagus cyanocephalus
Brown creeper	Certhia americana
Bushtit	Psaltriparus minimus
California quail	Callipepla californica
Cedar waxwing	Bombycilla cedrorum
Chestnut-backed chickadee	Parus rufescens
Chipping sparrow	Spizella passerina
Common nighthawk	Chordeiles minor
Common raven	Corvus corax
Dark-eyed junco	Junco hyemalis
Dusky flycather	Empidonax oberholseri
European starling	Sturnus vulgaris
Evening grosbeak	Coccothraustes vespertina
Golden-crowned kinglet	Regulus satrapa

Appendix 1, continued

Common Name	Scientific Name
Grey jay	*Perisoreus canadensis*
Hairy woodpecker	*Picoides villosus*
Hammond's flycather	*Empidonax hammondii*
Hermit warbler	*Dendroica occidentalis*
Hermit thrush	*Catharus guttatus*
House wren	*Troglodytes aedon*
Hutton's vireo	*Vireo huttoni*
Lazuli's bunting	*Passerina amoena*
MacGillivary's warbler	*Oporornis tolmiei*
Mountain quail	*Oreortyx pictus*
Mourning dove	*Zenaida macroura*
Northern flicker	*Colaptes auratus*
Northern pygmy owl	*Glaucidium gnoma*
Olive-sided flycatcher	*Contopus borealis*
Orange-crowned warbler	*Vermivora celata*
Osprey	*Pandion haliaetus*
Pacific-slope flycatcher	*Empidonax difficilis*
Pileated woodpecker	*Dryocopus pileatus*
Pine siskin	*Carduelis pinus*
Purple finch	*Carpodacus purpureus*
Red crossbill	*Loxia curvirostra*
Red-winged blackbird	*Agelaius phoeniceus*
Red-breasted nuthatch	*Sitta canadensis*

Appendix 1, continued

Common Name	Scientific Name
Red-breasted sapsucker	Sphyrapicus ruber
Rufous hummingbird	Selasphorus rufus
Ruffed grouse	Bonasa umbellus
Red-tailed hawk	Buteo jamaicensis
Rufous-sided towhee	Pipilo erythrophthalmus
Song sparrow	Melospiza melodia
Steller's jay	Cyanocitta stelleri
Swainsons thrush	Catharus ustulatus
Townsend's solitaire	Myadestes townsendi
Townsend's warbler	Dendroica townsendi
Tree swallow	Tachycineta bicolor
Turkey vulture	Cathartes aura
Varied thrush	Ixoreus naevius
Violet-green swallow	Tachycineta thalassina
Western bluebird	Sialia mexicana
Western wood pewee	Contopus sordidulus
Western tanager	Piranga ludoviciana
White-crowned sparrow	Zonotrichia leucophrys
Willow flycatcher	Empidonax traillii
Wilson's warbler	Wilsonia pusilla
Winter wren	Troglodytes troglodytes

Appendix 2. Distance at which ≥75% of all observations of each species with ≥12 observations at known distances occurred.

Species	n[1]	Effective Detectability Distance (m)
American robin	33	160
Black-headed grosbeak	17	100
Brewer's blackbird	54	60
Brown creeper	19	30
Chestnut-backed chickadee	81	50
Dark-eyed junco	190	100
Golden-crowned kinglet[2]	27	50
Hammond's flycatcher	59	100
Hairy woodpecker	22	70
Hermit/Townsend's warbler	146	100
House wren	26	70
Lazuli bunting	39	100
MacGillivaray's warbler	181	100
Northern Flicker	20	120
Pine siskin	15	60
Pacific-slope flycatcher	15	100
Red-breasted nuthatch	32	100
Rufous-sided towhee	84	100
Song sparrow	40	100
Steller's jay	26	>200

Appendix 2, continued

Species	n[1]	Effective Detectability Distance (m)
Swainson's thrush	38	100
Western tanager	28	100
White-crowned sparrow	87	80
Willow flycatcher	69	100
Winter wren	65	80

[1] Number of observations recorded at known distances for each species, ≥75% of these observations occured within the effective detectability distance.

[2] Golden-crowned kinglet was the only species for which detectability varied by treatment (*P* = 0.08, df = 2, *n* = 24). 50 m was the minimum effective detectability distance.