AN ABSTRACT OF THE THESIS OF

Kelly Anne Bettinger for the degree of Master of Science in Wildlife Science presented on February 5, 1996. Title: Bird Communities in 5- to 34-Year-Old Managed Douglas-fir Stands on the Willamette National Forest, Oregon Cascades.

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Breeding bird communities were examined in 18 managed Douglas-fir stands in 6 age classes from 5 to 34 years old in spring and early summer, 1993 on the Detroit Ranger District, Willamette National Forest, Oregon. The range of seral stages included early shrub/sapling, late shrub/sapling, and pole. In general, the 9 younger stands were open-canopy while the 9 older stands were closed-canopy. Of the 50 bird species recorded, 21 had large enough sample sizes for analysis. Of these 21, 8 showed a pattern of increasing abundance with increasing stand age (chestnut-backed chickadee, golden-crowned kinglet, hermit thrush, hermit warbler, Pacific-slope flycatcher, Swainson's thrush, Wilson's warbler, winter wren). Six species showed a pattern of decreasing abundance with increasing stand age (American robin, dark-

eyed junco, rufous hummingbird, white-crowned sparrow) and 4 species peaked in abundance in age class 2 (10 - 14 years old) before decreasing with increasing stand age (dusky flycatcher, MacGillivray's warbler, orange-crowned warbler, rufous-sided towhee). Two species did not exhibit any particular pattern associated with stand age (warbling vireo, western tanager). Three species were dropped from analysis because their average territory size is larger than the smallest stand surveyed. Abundance indices for species which showed an increasing pattern were positively associated with habitat variables describing conifer basal area, percent cover of live conifer crown between 4 m and the height of the tallest conifer tree, number of conifer stems/ha between 20- and 30- cm dbh, and/or percent cover of live hardwood crown between 4 m and the height of the tallest hardwood tree. Abundance indices for species which showed a decreasing or peaked abundance were negatively associated with the same variables, excluding percent cover of hardwood crown. Total abundance, species richness, and species diversity did not differ ($P<0.05$) among the age classes. However, bird community composition changed with increasing stand age. Open-canopy stands were dominated by species preferring open-canopy habitats (top 5 species in order of abundance: dark-eyed junco, MacGillivray's warbler, rufous hummingbird, dusky flycatcher, rufous-sided towhee) while closed canopy-stands were dominated by species preferring closed-canopy habitats, (hermit warbler, dark-eyed junco, chestnut-backed chickadee, golden-crowned kinglet, Swainson's thrush); the dark-eyed junco was an exception. The rate of bird community change was rapid along the gradient of open-canopy stands but appeared to reach a plateau once canopy closure was reached.

Bird Communities in 5- to 34-Year-Old Managed Douglas-fir Stands on the Willamette National Forest, Oregon Cascades

by

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

Kelly Anne Bettinger, Author

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BIRD COMMUNITIES IN 5- TO 34-YEAR-OLD MANAGED DOUGLAS-FIR STANDS ON THE WILLAMETTE NATIONAL FOREST, OREGON CASCADES

INTRODUCTION

Background

The widespread use of clearcut regeneration over the past 40 years in the Pacific Northwest has resulted in a greater proportion of forest habitat being converted to early seral stages than has occurred in the previous 100 years (Brown 1985, Raphael et al. 1988). Forest planners recently have modified the Willamette National Forest Land and Resource Management Plan (USDA Forest Service 1990) using FORPLAN (Johnson and Stuart 1987) to be in accordance with the Record of Decision for the Final Supplemental Environmental Impact Statement on Management of Habitat and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl (USDA Forest Service and USDI Bureau of Land Management 1994). This recent planning effort indicates that 52,177 hectares of land on the Willamette National Forest classified as suitable and available for timber harvest is in the 0- to 40-year age class (A. Reger, Willamette National Forest, pers. comm.). In 100 years 50,447 hectares will be in that age class. With 148,240 hectares classified as suitable and available for timber management on the Willamette National Forest, this represents 35% of the managed land base now and 34% of the area in the future in early seral stages. The future estimate is likely to be higher as it does not include natural disturbances such as fire. These figures also do not include another 224,291 hectares of the forest categorized as Managed/Late-Successional Reserves and Adaptive Management Areas that are considered tentatively suitable for timber production, or any estimate of the amount of area to be harvested under the new Public Law 140.19 (Rescission/salvage logging bill).

Land managers need to consider the contribution of young stands to large-scale patterns of bird diversity. The National Forest Management Act of 1976 (which amended the Forest and Rangeland Renewable Resources Planning Act of 1974) directs the Forest Service to "...provide for diversity of plant and animal communities..." (Sec. 6.). In addition, current concern about the population trends of many neotropical migrants warrants investigating how birds are using these stands (Finch 1991). In the early 1980's Marcot (1984) recorded several early seral stage species (fox sparrow, western bluebird, and dusky flycatcher; see Appendix 1 for scientific names of birds) as being abundant that were previously not present or only present in low numbers when the same area of Douglas-fir (Pseudotsuga menziesii) forests in northwestern California was surveyed by Hagar (1960) in the 1950's. Raphael et al. (1988) also noted substantial increases in ground- and brush-foraging birds over the past 20-30 years in northwestern California. Though there are no past studies for comparison, similar trends likely have occurred in the western Oregon

Cascades. Data from Breeding Bird Surveys (BBS) for Oregon as a whole, however, list individual species of ground- and brush-foraging birds as either showing a significant 10- and/or 23-year decline or no significant trend (Andelman and Stock 1994). When only BBS routes on National Forest lands are considered, some of the same species do show increasing trends between 1968 and 1990 (Sharp 1992).

Rationale for present study

Meslow (1978) listed bird species that he expected to occur in grass/forb (1- to 7-year-old stands), shrub/sapling (8 to 15 years old), and young forest (16 to 40 years old) stages of Douglas-fir forests based on knowledge of species requirements and the personal experience of a variety of field biologists. A similar but expanded effort was conducted by Bruce et al. (1985) as part of the USDA Forest Service publication Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington. But actual research on bird communities in stands 5 to 40 years old in the Oregon Cascades or Coast Ranges has been limited: Gilbert and Allwine (1991) included 1 35-year-old stand in their study of bird communities in the Oregon Cascades; Skirvin (1981) included 1 28-year-old stand in a preliminary study of bird communities in the Cascades; and Morrison and Meslow (1983) surveyed 11 stands from 6 to 9 years old in the Coast Range. A more recent study by McGarigal and McComb (1995) on avian landscape structure relationships included 30 300-ha landscapes in the Coast Range where grass/forb, shrub, sapling, and pole seral stages made up 49.5% of the area within 50 m of each sampling point (n = 1046 sampling points). Other studies in the region that included stands from 5 to 35 years old dealt primarily with primary and secondary cavity nesters and have little or no data on non-cavity nesting birds (Mannan et al. 1980, McCullough 1991).

In contrast, bird communities in stands younger than 5 years old or older than 35 have been studied in greater detail. McComb and Hunter (in prep.) surveyed bird communities in 3- to 5-year-old clearcuts in the Cascades. Hansen and Hounihan (in press) also surveyed bird communities in several clearcuts under 5 years old in the Cascades and Schreiber (1987) and Schreiber and deCalesta (1992) surveyed primary and secondary cavity nesters (with some references to non-cavity nesting birds) in 2- to 4-year-old clearcuts in the Coast Range. Several studies also have been conducted in both the Coast and Cascade Ranges in stands 35 years and older (Anderson 1970, Mannan et al. 1980, Skirvin 1981, Nelson 1988, Gilbert and Allwine 1991, Hagar 1992, McGarigal 1993, McComb and Tappeiner, ongoing study, Oregon State Univ.). A recent study by Hansen et al. (1995) included both clearcuts and mature and old-growth stands in the western Cascades. The purpose of my study is to provide information on bird communities in young seral stage managed stands from 5 to 35 years old in the Central Cascades of Oregon.

Bird communities and succession following clearcutting

Marcot (1984) surveyed bird communities in northwestern California Douglas-fir stands over a range of stand conditions from grass/forb to medium sawtimber. The grass/forb stage had the lowest number of bird species and lowest total bird density; highest numbers of species and density occurred in the late shrub/sapling stage (average age 14 years). A similar pattern was noted by Peterson (1982) in western hemlock (Tsuga heterophylla) and grand fir (Abies grandis) forests in northern Idaho. Conner and Adkisson (1975) found the lowest species richness of breeding birds in their youngest clearcut stand (1 year old), and the highest species richness in a 7-year-old clearcut, when they studied several clearcut, pole, and mature mixed oak (Quercus spp.) stands in southwestern Virginia. In a study of a successional sequence of stands (shrub/forb clearcuts to old-growth) in southeastern Alaska, Kessler and Kogut (1985) found the lowest species richness occurred in the grass/forb stage clearcuts and young sawtimber. Highest species richness occurred in a riparian sapling/shrub stage stand.

All studies of forest bird communities along a sere show a shift in bird community composition from younger to older stands that is typically reflected by losses and additions of species based on availability of nesting or foraging sites. Another common pattern among these studies is that individual species typically exhibit a peak in numbers in one particular seral stage even though they occur in more than one seral stage. Each successional stage then has a characteristic and often predictable bird community (Titterington et al. 1979, Crawford et al. 1981).

When stands are viewed on a continuum from recent clearcuts to old-growth, the general pattern is for species diversity to steadily rise through the grass/forb and shrub stages until canopy closure is achieved in pole or sawtimber stage (about 35 years for intensively managed Douglas-fir and about 60 years for naturally regenerating Douglas-fir; Mitchell 1983) (Meslow 1978, Wiens 1989:134-135). At this time most undergrowth is shaded out and bird species diversity may decline (Meslow and Wight 1975). Diversity rises again as natural mortality of individual trees provides breaks or "gaps" in the canopy, where understory growth can again become established.

Bird communities and habitat characteristics

The changes in bird communities discussed above can be associated with stand habitat (structural) diversity. The more complex or diverse the stand, the more diverse the bird community (Bond 1957). A number of habitat characteristics are associated with bird community composition, abundance, and diversity. Anderson (1981) recognized two types of habitat characteristics - "macro" habitat characteristics are major features of a stand that are associated with the bird community as a whole (i.e., associated with many bird species), and "micro" habitat characteristics are those associated with fewer, individual bird species. Examples of macro habitat characteristics that have been of particular importance in various studies reviewed by Balda (1975) and Anderson (1981) include foliage height diversity, percent cover of shrubby and herbaceous species, foliage volume, plant species diversity, dbh (diameter at breast height) and tree density. Roth (1976) also found that patchiness (based on measurements of distances to patches such as shrub clumps) was an important predictor of bird species diversity. Down woody debris and individual tree species are examples of microhabitat characteristics. Hagar (1960) reported a close relationship between winter wrens and down woody debris in northwestern California, and McGarigal (pers. comm., Oregon State Univ.) suggested a strong association between red-breasted sapsuckers and the presence of bigleaf maple (*Acer macrophyllum*) in Oregon Coast Range stands.

All of the previously mentioned habitat characteristics can be altered by forest management practices. Management for timber can result in stands with less habitat diversity than might naturally occur (Hansen et al. 1991). However, creative active management also can be used to create stands with the necessary habitat characteristics for the bird species (or group of species) a land manager wishes to enhance (Mannan and Meslow 1984).

OBJECTIVES

My goal was to better understand patterns of bird communities among young seral stage, managed Douglas-fir stands in the west Central Oregon Cascades of the Pacific Northwest. I examined bird communities and habitat conditions in 18 stands ranging in age from 5 to 33 years old on the Detroit Ranger District of the Willamette National Forest. Specifically, I estimated if:

1) There were differences in the relative abundances of individual bird species among age classes of young seral stage stands studied.

2) There were differences in the total bird abundance, species richness, and species diversity among age classes of young seral stage stands studied.

3) There were differences in the vegetation structure and other habitat characteristics among age classes of young seral stage stands studied.

4) Stand habitat characteristics could be used to predict individual bird species abundance, total bird abundance, species richness, and species diversity.

STUDY AREA

The study area is located on the west side of the central Oregon Cascades in Marion and Linn Counties (Figure 1). All study sites are on the Detroit Ranger District of the Willamette National Forest and fall between 44° 35′ and 44° 46′ latitude.

The area is part of the extensive western hemlock vegetation zone as classified by Franklin and Dyrness (1973). Major tree species of this zone include Douglas-fir, western hemlock, and western red-cedar (Thuja plicata). Pacific yew (Taxus brevifolia) occurs as a subdominant tree throughout the zone. Red alder (Alnus rubra), bigleaf maple and chinqapin (Castanopsis chrysophylla) are the most common hardwoods but occur mainly on disturbed or riparian sites. Much of the area is dominated by Douglas-fir forests because of extensive logging and/or burning over the past 150 years (Franklin and Dyrness 1973). The study sites are all within the "general forest" Forest Service classification (as opposed to wilderness or other special areas) and therefore the surrounding landscape is a mosaic of seral stages.

The climate is described as wet, mild maritime (Franklin and Dyrness 1973). Average annual temperature at Detroit, Oregon is 9.3° C, with a July average of 17.9° C. The average annual precipitation at Detroit is 193 cm and occurs primarily as winter rainfall (Franklin and Dyrness 1973:72).

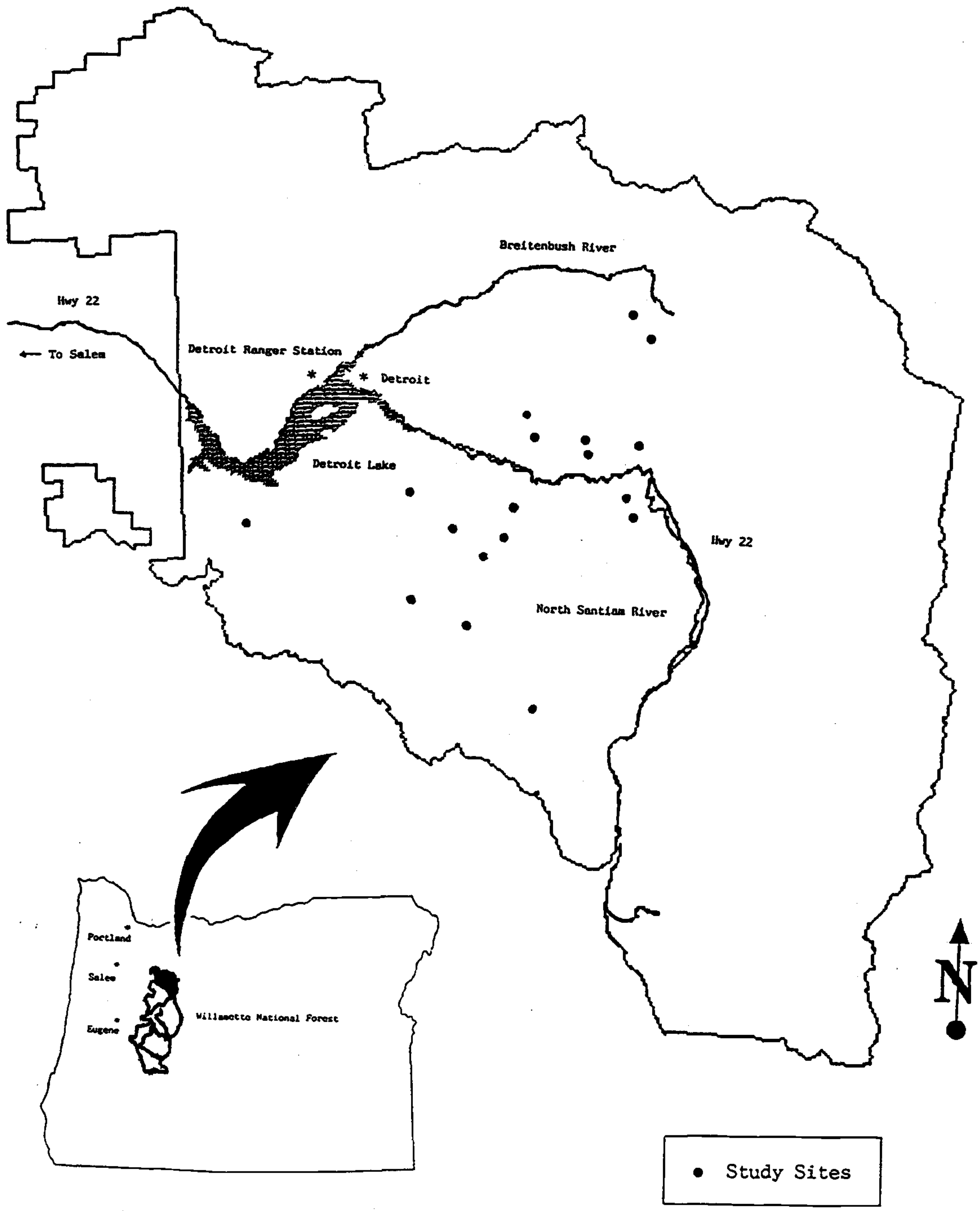


Figure 1. Location of study sites on the Detroit Ranger District, Willamette National Forest, Oregon.

METHODS

Study site selection

I randomly chose 3 managed stands from those available in each 5-year age category from age 5 to 34 years old for a total of 18 stands (3 replications, 6 age classes) (Table 1). Criteria used to determine if stands were available included elevation ($\leq$ 1,220 m), size ($\geq$ 12 ha), shape (avoided long, linear stands), and road accessibility. The 1,220 m elevational cutoff was chosen because snow often prevented access to higher elevations until late May or later. The seral stages represented in this range of stand ages included early shrub/sapling, late shrub/sapling, and pole. In general, the 9 younger stands were open-canopy and the 9 older stands were closed-canopy, though the 2 stands in the middle (19 and 20 years old) had both open- and closed-canopy portions.

All stands had been regenerated by clearcutting, broadcast burning, and replanting with Douglas-fir or a mix of Douglas-fir, western red-cedar, western hemlock, Engelmann spruce (Picea engelmannii), western white pine (Pinus monticola), noble fir (Abies procera), and/or Pacific silver fir (Abies amabilis). Where mixed species were planted, Douglas-fir still made up 40% to 80% of the total. All but 1 of the stands 14 years and older had been pre-commercially thinned to about 745 merchantable trees per hectare (range 437 to 813). Younger stands ranged from 1039 to 1311 merchantable trees per hectare. All but 1 of the stands $\geq$ 20 years

Table 1. Age (as of 1993), number of bird survey plots, exposure, size, and elevation for 18 stands on the Detroit Ranger District, Willamette National Forest, Oregon.

Stand name	Age (yrs)	# Bird plots	Exposure	Size (ha)	Elev (m)
Leone U-1a	33	4	E	14.2	829
Tom Ck U-4	31	5	NE-W	23.5	914
Cooper's Ridge	30	4	NE	14.6	829
Hawkin's Ck U-10	28	4	W	13.4	884
Straight Ck U-2	28	3	SW	13.0	1216
North Santiam	27	4	NE	16.2	780
Central Blowout U-5	24	3	NE	12.2	671
McCoy Creek U-5	23	4	SW	14.6	860
Log Creek U-8	20	5	SW	16.6	1116
Box Canyon #1 U-1	19	5	NW	17.0	914
McCoy #3 U-22	18	3	E	12.2	1097
McCoy #4 U-4	15	4	all	12.5	1036
Cub Point	14	5	all	16.6	1049
Rainbow Ridge U-4	12	3	NE	12.5	945
Boulder Patch U-2	10	4	S-SW	14.2	850
Tunnel Creek U-2	8	5	SW	23.5	1039
Riverside West U-1	6	4	E	17.4	768
SEF U-2	5	5	N	19.4	951

old had been fertilized. Competing hardwood vegetation was controlled by hand cutting in 2 stands (Table 2).

Bird surveys

Birds were censused in spring and early summer 1993 using the variable circular-plot method as described by Reynolds et al. (1980). Three to 5 point count stations were located in each stand, depending on stand size and shape, so that survey intensity was proportional to stand area. Using aerial photographs and a grid overlay (30 m by 30 m), stations were established randomly (but with the condition that they were > 100 m from both stand edges and other stations) by choosing pairs of numbers from a random numbers table that corresponded to the x and y coordinates on the grid. Thirteen of the 18 stands had spur roads or main forest roads passing through them. Point count stations that fell on or near roads within stands were not relocated, because I felt that roads were part of the stand in that they contributed to patchiness and stand heterogeneity.

I visited each stand 4 times during the breeding season between 3 May and 16 July, 1993. The order in which stands were visited was chosen randomly, and the order in which point count stations within a stand were surveyed was either reversed or rearranged (by randomly choosing a count station to begin at and continuing through the rest of

Table 2. Management activity and year completed for 18 Douglas-fir stands on the Detroit Ranger District, Willamette National Forest, Oregon.

Stand name	Cut	Burned	Planted	PCT[a]	Fert	Released[b]
Leone U-1a	1957	1958	1960	1979	----	----
Tom Creek U-4	1960	1960	1962	1976	1990	----
Cooper's Ridge	1962	1962	1963	1976	1979&1986	----
Hawkin's Ck U-10	1963	1964	1965	1982	1985	----
Straight Ck U-2	1964	1964	1965	1983	1991	----
North Santiam	1964	1965	1966	1981	1985	----
Central Blowout U-5	1966	1966	1969	1981	1983	----
McCoy Creek U-5	1964	1964	1970	1979	1988	1979
Log Creek U-8	1971	1972	1973	1985	1986	----
Box Canyon #1 U-1	1971	1971	1974[c]	1988	----	----
McCoy #3 U-22	1972	1972	1975	1988	----	1975
McCoy #4 U-4	1977	1977	1978	----	----	----
Cub Point	1976	1978	1979	1990	----	----
Rainbow Ridge U-4	1979	1980	1981	----	----	----
Boulder Patch U-2	1983	1983	1983	----	----	----
Tunnel Creek U-2	1983	1984	1985	----	----	----
Riverside West U-1	1986	1986	1987	----	----	----
SEF U-2	1987	1987	1988	----	----	----

[a] Pre-commercial thin
[b] Manual brush control
[c] 4 hectares of this unit were replanted in 1977

the count stations in an orderly fashion) for each visit. Depending on driving distances between stands, 1 to 3 stands could be surveyed in 1 morning. Visits started any time after 0530 and were completed by 0930 most mornings unless weather delayed the start time (no visit lasted beyond 1030). At each point count station, I recorded all birds seen or heard for 8 minutes and estimated the horizontal distance in meters to each bird where it was first observed. Because there is no maximum distance limitation with this method, I occasionally detected birds whose songs or calls carry great distances that seemed to be at the edge of the stand (olive-sided flycatchers, for example) or in adjacent stands (Steller's jays, for example). In these cases I noted whether I thought the bird was at the edge of or outside of the stand, and attempted to confirm the location visually whenever possible at the end of the count period. Additional notes were taken regarding whether the detection was aural, visual or both, and whether the same bird had been detected from previous point count stations on the same visit to avoid double counting individuals (tallied as a new or repeat detection). Birds flushed from the ground (common nighthawks, ruffed grouse) while walking between point count stations were counted and their distance estimated to the nearest point count station. All birds flying over stands also were recorded, however, only species likely to be using the stand, such as red-tailed hawks hunting in clearcuts, were used in the analyses.

Surveys were not conducted on mornings when the rain was judged to be heavy enough to affect bird surveys. On several mornings I waited to begin surveys until after heavy ground fog had lifted when it appeared that the fog was suppressing bird activity (i.e., no birds were singing).

Habitat surveys

I measured habitat characteristics on 30-m radius (0.28-ha) plots and 4 fixed-area subplots of 5-m (0.01-ha) radius (adapted from Hagar 1992 and McGarigal 1993, see Figure 2). Habitat survey plots were centered on the point count (bird survey) stations in each stand and on 3 to 5 additional randomly located points chosen using the same method used to select the bird survey stations, with the exception that stations needed to be at least 50 m from other stations or the stand edge. The total number of habitat survey plots was related to stand size and shape, with twice as many habitat survey plots as bird point count stations in each stand.

At each plot center, the following were estimated: distance to nearest permanent and intermittent streams, distance to nearest habitat patch edge, and live crown to bole ratio. Habitat patches were defined as any feature that stood out in contrast to the overall surroundings, and included hardwood clumps, logging roads, patches of snags killed by root rot diseases, cliff faces, etc. I used the average number of habitat

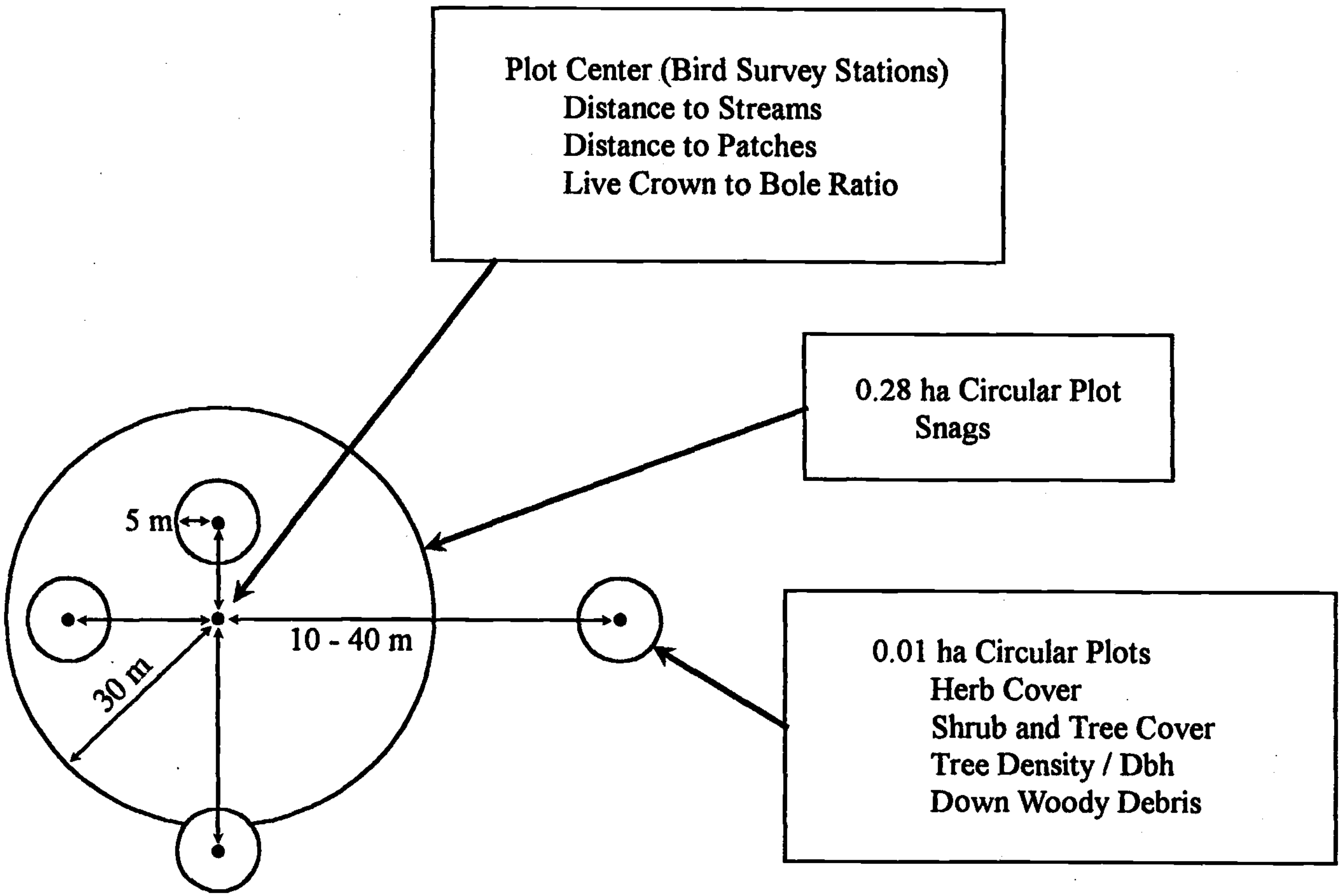


Figure 2. Habitat sampling layout centered on bird survey stations (Adapted from Hagar (1992) and McGarigal (1993)).

patches within 50 m of survey stations as an index of stand heterogeneity. All snags within each 30-m radius plot were counted in the pole stage stands ($\geq$ 18 years old), and complete snag counts were performed in the grass/forb and shrub/sapling stage stands ($\leq$ 15 years old). Snags were classified into height class (< 2 m, 2 - 6 m, > 6 m tall), dbh class (10 - 30 cm dbh, 30 - 51 cm dbh, > 51 cm dbh), and decay class (1, 2 - 3, 4 - 5; see Cline et al. 1980). Results were averaged over plots in each stand and reported as snags/ha.

Subplots were located at randomly chosen distances between 10 and 40 m from plot center in order to sample vegetation in the area in which most bird observations occurred. The compass direction for the first subplot was chosen randomly and the other 3 then were placed at 90° intervals from the first subplot. In the 5-m radius plots, live trees (including hardwoods) were tallied by 10-cm dbh classes and results reported as stems/ha. Percent cover and average height estimates for up to 3 layers of vegetation (low shrub/sapling, 0 - 1.3 m; tall shrub/sapling, 1.4 - 4 m; pole trees 4 - 20 m) were made using the method described by McGarigal and McComb (1992). Percent cover estimates of herbs, ferns, moss, and bare soil/leaf litter also were visually estimated in the 5-m radius plots.

I used two procedures to measure down woody debris in the 5-m radius plots: First, a visual estimate of percent cover of slash (pieces < 3 cm in diameter) was made. Bark debris, very decayed class 5 logs, branches from pre-commercial thinning, and dead, collapsed shrubs caused by shading in older stands were included as part of this estimate. Second, lengths of all logs in 3 diameter classes (3 - 20 cm dbh, 20 - 41 cm dbh, > 41 cm dbh) were measured for an average total length (m/ha) for each stand.

Basal area of hardwoods and conifers was calculated mathematically from measurements of individual tree dbh and stems/ha in the 5-m radius plots.

The area of forest roads in each stand was calculated by measuring road lengths on aerial photographs and measuring the road width in the field. The area of landings/road junctions in each stand was calculated by measuring the approximate radius of each landing in the stand. Road and landing areas were combined for a total non-vegetated area and reported as a percentage of the total stand area.

I used maps from the Forest Service's Geographic Information System (GIS) and aerial photos to calculate the percentage of each stands' perimeter that was roaded and/or bordered by permanent streams, and to calculate the total length of intermittent and permanent streams within each stand.

An index of seral stage contrast for each study stand was calculated by assigning contrasts between 0 and 1 (0 meaning no contrast, 1 meaning extreme contrast of clearcut adjacent to old-growth) to the study stands and all stands immediately adjacent to them (modified from McGarigal 1993). Using the 6 seral stage categories from Hall et al. (1985:26), I developed a matrix of all possible contrasts. The grass/forb stage next to old-growth received a contrast of 1.0; next to large sawtimber a contrast of 0.8; next to closed sapling/pole and small sawtimber, 0.6; next to open sapling/pole, 0.4; next to shrub, 0.2; and next to grass/forb, 0.0. This was repeated for the rest of the seral stages. The contrasts between each study stand and its adjacent stands were then weighted by the percentage that each adjacent stand made up of the total perimeter of the study stand; these weighted contrasts were then summed and divided by 100 to estimate the contrast index for the study stand.

Elevations at the lowest and highest points in each stand were read from USGS topographic maps and averaged to get a mid-point elevation for the stand. Stand area measurements were obtained from the GIS database. In all, a total of 59 variables describing the habitat characteristics and some landscape characteristics was measured or derived (Table 3).

Statistical analysis

I tested the hypothesis that bird abundance did not differ among stand age classes for each of the 18 species with $>$ 12 detections (Objective 1). This cutoff point is more liberal than some studies (Hagar 1992, $>$ 28 detections; Sanders 1995, $>$ 20 detections) because I did

Table 3. Description of habitat variables from 18 managed Douglas-fir stands on the Detroit Ranger District, Willamette National Forest, Oregon.

Variable	Description
Age	Stand age in years as of 1993
Slash	Percent cover of slash
DWD1	Meters/ha of logs 3 - 20 cm dbh
DWD2	Meters/ha of logs 20 - 41 cm dbh
DWD3	Meters/ha of logs >41 cm dbh
Bare	Percent cover of bare ground
Moss	Percent cover of moss
Ground	Percent cover of bare ground + moss
Herb	Percent cover of herbaceous species
Grass	Percent cover of grasses
Fern	Percent cover of ferns
Conlow	Percent cover of conifer seedlings and/or live conifer tree branches between 0 - 1.3 m high
Hwdlow	Percent cover of hardwood shrubs and trees between 0 - 1.3 m high
Contall	Percent cover of conifer seedlings and/or live conifer tree branches between 1.4 - 4.0 m high
Hwdtall	Percent cover of hardwood shrubs and trees between 1.4 - 4.0 m high
Contree	Percent cover of live conifer crown between 4 m and the height of the tallest tree
Hwdtree	Percent cover of live hardwood crown between 4 m and the height of the tallest tree
Herbht	Average height of herbaceous species
Grassht	Average height of grasses
Fernht	Average height of ferns
Conlowht	Average height of conifer cover between 0 - 1.3 m high
Hwdlowht	Average height of hardwood cover between 0 - 1.3 m high
Contallht	Average height of conifer cover between 1.4 - 4.0 m high
Hwdtallht	Average height of hardwood cover between 1.4 - 4.0 m high
Contreeht	Average height of conifer trees above 4.0 m high
Hwdtreeht	Average height of hardwood trees above 4.0 m high
Ctree1	Number of stems/ha of conifers <10 cm dbh
Ctree2	Number of stems/ha of conifers 10 - 20 cm dbh
Ctree3	Number of stems/ha of conifers 20 - 30 cm dbh
Ctree4	Number of stems/ha of conifers 30 - 40 cm dbh
Ctree5	Number of stems/ha of conifers 40 - 50 cm dbh
Conba	Conifer basal area, m^2/ha
Conbole	Percent live crown
Htree1	Number of stems/ha of hardwoods <10 cm dbh
Htree2	Number of stems/ha of hardwoods 10 - 20 cm dbh

Table 3, continued

Variable	Description
Htree3	Number of stems/ha of hardwoods 20 - 30 cm dbh
Hwdba	Hardwood basal area, m^2/ha
Snag1	Number of snags/ha, 10 - 30 cm dbh, decay class 1
Snag2	Number of snags/ha, 10 - 30 cm dbh, decay class 2 & 3
Snag3	Number of snags/ha, 10 - 30 cm dbh, decay class 4 & 5
Snag4	Number of snags/ha, 30 - 51 cm dbh, decay class 1
Snag5	Number of snags/ha, 30 - 51 cm dbh, decay class 2 & 3
Snag6	Number of snags/ha, 30 - 51 cm dbh, decay class 4 & 5
Snag7	Number of snags/ha, >51 cm dbh, decay class 1
Snag8	Number of snags/ha, >51 cm dbh, decay class 2 & 3
Snag9	Number of snags/ha, >51 cm dbh, decay class 4 & 5
Ssnag	Number of snags/ha, 10 - 30 cm dbh, all decay classes
Msnag	Number of snags/ha, 30 - 51 cm dbh, all decay classes
Lsnag	Number of snags/ha, >51 cm dbh, all decay classes
Snagsha	Total snags/ha, all snags >10 cm dbh
Prcntrd	Percentage of total stand area in road and/or landing
Rdedge	Percentage of total stand perimeter roaded
Stream	Average number of permanent and/or intermittent streams within 50 m of survey plots
Streamin	Total length in m of permanent and/or intermittent streams within stand boundary
Ckedge	Percentage of total stand perimeter made up of permanent stream
Patch	Average number of habitat patches (hardwood clumps, root rot patches, log piles, spur roads, streams, etc.) within 50 m of survey plots
Contrast	Index of seral stage contrast between study stand and those stands immediately adjacent to it
Stndarea	Stand area in hectares
Elevation	Midpoint elevation of the stand in meters

not want to ignore species that clearly were breeding in stands that fall into the 5- to 34-year-old range, but were perhaps able to use only the youngest or oldest stands studied. Three additional species, hairy woodpecker, northern flicker, and Steller's jay, had > 12 detections but were dropped from analysis because their average territory size is larger than the smallest stand in my study and the birds may have been nesting outside of the study stand. I used an analysis of variance (ANOVA, SAS Institute, Inc. 1993) to compare bird abundance among the stand age classes. If these analyses indicated that there were differences in bird abundance among stand age classes ($P \leq 0.05$), then I used Fisher's Protected Least Significant Difference (LSD) to identify specific differences in bird abundance between pairs of stand age classes.

Based on findings by McGarigal and McComb (1995) in the Coast Range of Oregon, individual species abundance estimates were calculated using detections at any distance, so long as they were within the study stand, rather than computing effective detection distances in the different habitat types.

Thirty-four percent of new detections of western tanagers and 12% of new detections of warbling vireos occurred at the stand edge ("new" detections being the first time an individual bird was recorded on a particular visit; subsequent detections of the same bird were tallied as "repeat"). Male tanagers in particular frequently sang from a large tree at the very edge of an adjacent mature stand. These edge detections were dropped from the database so that only new detections of birds actually within the stand boundary were analyzed.

Examination of the residuals showed that transformation was necessary for 5 of the 18 bird species in order to meet the assumptions of ANOVA for normality and constant variance (Steel and Torrie 1980:167-170). Average detection rates of hermit warblers, rufous hummingbirds, and Wilson's warblers were square root-transformed before analysis, and the average detection rates of golden-crowned kinglets and western tanagers were log-transformed (log(Y + 0.01) for variables with zero values). Seven species did not show improvement with any method of transformation. For these species, the non-parametric Friedman's Two-way test was used to compare bird abundance among age classes (Manugistics, Inc. 1993).

I calculated the statistical power (1 - beta, the probability of rejecting the null hypothesis when there is an effect) of the *F* test for those bird species where differences in abundance among age classes seemed biologically apparent, but differences were not statistically significant at the 0.05 level (Cohen 1988).

I tested the hypothesis that total bird abundance, species richness, and species diversity did not differ among stand age classes (Objective 2) using the process outlined above for individual species. For total abundance estimates, only species detected >1 visit per stand were used. It was assumed that species detected on only one visit to a stand were migrants, transients, or rare breeders (Gilbert and Allwine 1991). Total abundance was estimated as birds per plot per visit by summing all new bird detections over the 4 visits and dividing by the number of bird survey plots in each stand and by the number of visits. All species were used to estimate species richness and diversity, in order to include the rarer species or those with very large territories.

The COMMUN program (McComb 1994, adapted from Brower et al. 1990) was used to calculate Shannon's diversity (Shannon and Weaver 1949) for each stand and to calculate Percent of Similarity comparisons of each stand with the oldest and youngest stands surveyed. The Percent of Similarity index is zero when bird communities in two stands have no species in common and reaches a maximum of 1 when species composition and relative abundance are identical (McGarigal and McComb 1992). I chose the Percent of Similarity index to help describe the changes in bird community composition that occurred with increasing stand age when I found no significant differences among ages classes for total abundance, species richness, and diversity.

I tested the hypothesis that there were no differences in the vegetation structure and other habitat characteristics among stand age classes (Objective 3) using the procedure outlined for individual bird species above. Examination of the residuals revealed that the mean values of 26 habitat characteristics needed transformation to meet the assumptions of ANOVA for normality and constant variance (Steel and

Torrie 1980:167-170). An additional 12 habitat characteristics could not be improved by any method of transformation. For these variables, the non-parametric Friedman's Two-way test was used to compare mean values among age classes (Manugistics, Inc. 1993).

In order to test whether specific stand habitat characteristics could be used to predict individual bird species abundance, total bird species abundance, species richness, and diversity (Objective 4), Spearman correlation coefficients were calculated between bird abundances for all 21 bird species and the bird community parameter variables and the habitat variables at the stand (not age class) level. Five habitat variables had missing values (Grassht, Fernht, Htallht, Ctreeht, Htreeht) and were not used in the analysis. I used the Draftsman plot option in Statgraphics (Manugistics, Inc. 1993) to plot the average detection rate of each individual bird species and the community parameter variables at the stand level against all the habitat variables significantly associated with them (T. Sabin, Oregon State Univ., pers. comm.). All variables were plotted untransformed, log-transformed, and square-root-transformed in order to determine where transformation could be used to help linearize relationships between dependent and explanatory variables. Then I used stepwise linear regression to select final models for predicting bird abundance, total bird abundance, species richness, and diversity using only those habitat variables which were significantly ($P \leq 0.05$) associated with the bird species and bird community parameter variables and using transformed dependent and explanatory variables where necessary. The variable age was not used in regression analysis because birds were likely responding to habitat variables and not the actual stand age. Regression analysis was performed only on the 11 species with 35 or more detections. Species with fewer detections could not be transformed and therefore violated the assumptions of constant variance. Plots of the residuals from each final model were examined to ensure the assumptions of normality and constant variance were met.

A posteriori review of the data suggested that many of the bird species were more abundant in either the younger 3 age classes (open-canopy stands) or the older 3 age classes (closed-canopy stands). Therefore, I compared differences in mean detection rates of individual bird species and bird community parameters between the 9 open-canopy and the 9 closed-canopy stands using Student's t-test in Statgraphics (Manguistics, Inc. 1993). This approach also was appropriate because all of the species showing a decreasing, increasing, or peaked pattern were associated, either positively or negatively, with habitat variables that were characteristic of open- or closed-canopy stands. Total abundance was log-transformed and the mean detection rates of hermit warbler, rufous hummingbird, and Wilson's warbler were square root-transformed in order to meet the assumptions of normality and constant variance (Steel and Torrie 1980:167-170). Twelve species were not improved by any method of transformation. For these species the non-parametric Mann-Whitney U-test (rank-sum analysis) was used (Manugistics, Inc. 1993).

To further identify which habitat variables differed between open-canopy and closed-canopy stands, Student's t-test also was performed on the habitat variables. Examination of the residuals revealed that the mean values of 15 habitat characteristics needed transformation in order to meet the assumptions of normality and constant variance (Steel and Torrie 1980:167-170). An additional 17 habitat characteristics could not be improved by any method of transformation. For these variables, the non-parametric Mann-Whitney U-test (rank-sum analysis) was used to compare mean values between open-canopy and closed-canopy stands (Manugistics, Inc. 1993).

Spearman correlation coefficients were calculated again between bird abundances and the community parameter variables and the habitat variables, but this time separating the open-canopy and closed-canopy stands to see if there was a difference in importance of habitat variables related to canopy closure.

RESULTS

A total of 2,094 observations of 50 species was recorded during the 1993 breeding season. Sixty-five percent (1,361) of the observations were of new birds (Appendix 1). Seven species of birds made up 64% of the total number of new observations (dark-eyed junco 18%, hermit warbler 14%, MacGillivray's warbler 9%, rufous hummingbird 7%, chestnut-backed chickadee 6%, Steller's jay 5%, dusky flycatcher 5%). Of the 50 species, 36 were detected on more than one visit. Only one species, the dark-eyed junco, was detected in all 18 stands.

Habitat characteristics

Twenty-four of the measured or derived habitat variables were significantly (positively or negatively) associated with stand age (Table 4). Twenty-five of the habitat variables showed significant differences among age classes (Table 5).

Amounts of slash and the 3 classes of down woody debris varied widely over the age classes and did not show any clear pattern associated with stand age. Stands in the youngest 2 age classes tended to have remnant snags of all size and decay classes persisting from the stands that existed prior to harvest. Small (10 to 30 cm dbh) decay class 1 snags were present in all age classes. Large (> 51 cm dbh) decay class

Table 4. Habitat characteristic mean, standard error, F, and *P*-value from ANOVA for 6 age classes of managed Douglas-fir stands ranging in age from 5 to 34 years old on the Detroit Ranger District, Willamette National Forest, Oregon.

	Age Class (years)							
Variable[a]	5-9	10-14	15-19	20-24	25-29	30-34	F	*P*-value
Slash	11.1[b]	13.8	10.6	24.1	24.7	11.1	0.74	0.607
	(3.3)	(2.0)	(0.9)	(13.7)	(10.9)	(2.6)		
DWD1	1520.73[b]	751.18	428.82	1311.11	1747.92	933.96	1.96	0.158
	(279.54)	(204.77)	(130.39)	(669.51)	(835.02)	(234.62)		
DWD2	150.10	105.94	54.24	97.99	59.38	130.21	1.25	0.360
	(48.41)	(16.34)	(28.86)	(30.20)	(40.79)	(33.09)		
DWD3	132.19	80.52	124.44	188.75	105.90	129.38	0.38	0.852
	(81.39)	(4.76)	(58.57)	(81.72)	(54.96)	(22.98)		
Bare	25.7[b]	11.2	11.0	32.8	29.3	36.8	2.03	0.146
	(9.1)	(4.2)	(2.7)	(16.5)	(8.6)	(7.00)		
Moss[c]	0.2[b]	0.4	0.6	3.7	5.2	16.5	8.74	0.001
	(0.2)	(0.4)	(0.2)	(2.0)	(0.8)	(6.0)		
Ground[c]	25.9[b]	11.5	11.7	36.4	34.5	53.4	3.43	0.037
	(9.2)	(4.1)	(2.5)	(18.1)	(9.2)	(2.7)		
Herb[c]	17.5	29.6	22.1	44.1	47.9	35.2	1.60	0.234
	(5.7)	(3.5)	(11.3)	(16.1)	(10.2)	(2.9)		
Grass[c]	9.4[b]	8.8	5.3	2.0	1.3	0.1	2.04	0.144
	(4.3)	(6.1)	(3.9)	(1.5)	(0.6)	(0.1)		
Fern	17.1[b]	0.7	2.3	3.5	8.0	3.3	0.38	0.851
	(16.4)	(0.7)	(1.9)	(2.1)	(7.1)	(1.7)		
Conlow	9.9[d]	35.4	38.3	9.9	6.1	5.2	6.03	0.005
	(4.6)	(8.8)	(9.2)	(6.1)	(3.3)	(0.7)		

Table 4, continued

Variable	Age Class (years) 5-9	10-14	15-19	20-24	25-29	30-34	F	*P*-value
Hwdlow[c]	20.3[b]	14.0	20.4	4.1	2.2	3.0	5.21	0.009
	(9.6)	(2.3)	(1.5)	(0.6)	(1.5)	(1.7)		
Contall	1.6[d]	13.7	25.8	28.9	16.2	5.4	7.30	0.002
	(1.5)	(5.0)	(4.3)	(11.3)	(3.1)	(0.3)		
Hwdtall	0.3[d]	1.9	2.4	2.7	2.0	1.4	1.86	0.176
	(0.2)	(1.02)	(0.6)	(1.4)	(0.5)	(0.9)		
Contree[c]	0.0[d]	4.3	10.9	47.3	48.6	40.4	42.16	0.000
	(0.0)	(2.4)	(3.7)	(6.2)	(1.7)	(4.3)		
Hwdtree[c]	0.0[b]	0.1	0.2	3.3	1.7	1.1	7.94	0.002
	(0.0)	(0.0)	(0.1)	(2.7)	(0.6)	(0.7)		
Herbht[c]	0.50[b]	0.38	0.31	0.23	0.20	0.12	6.17	0.005
	(0.09)	(0.11)	(0.03)	(0.04)	(0.05)	(0.01)		
Grassht	0.41	0.92	0.42	0.55	0.29	0.10	9.15	0.004
	(0.04)	(0.05)	(0.12)	(0.12)	(0.01)	--[e]		
Fernht	0.49[b]	0.50	0.51	0.78	0.89	0.51	0.90	0.531
	(0.11)	--[e]	(0.01)	(0.20)	(0.23)	(0.07)		
Conlowht	1.27	1.30	1.26	1.15	1.15	1.27	na[f]	0.124
	(0.08)	(0.00)	(0.04)	(0.07)	(0.06)	(0.02)		
Hwdlowht	1.04	1.20	1.24	1.20	1.19	1.23	2.44	0.095
	(0.10)	(0.038)	(0.02)	(0.03)	(0.02)	(0.02)		
Contallht	2.13	3.69	3.97	3.99	3.98	3.71	21.52	0.000
	(0.22)	(0.29)	(0.03)	(0.01)	(0.02)	(0.12)		
Hwdtallht	1.85	2.51	2.25	3.71	3.22	3.28	22.54	0.000
	(0.33)	(0.08)	(0.16)	(0.06)	(0.11)	(0.07)		

Table 4, continued

Variable	Age Class (years) 5-9	10-14	15-19	20-24	25-29	30-34	F	*P*-value
Contreeht	--[g]	6.0	8.2	13.2	15.2	16.0	33.80	0.000
	--	(0.4)	(1.0)	(0.8)	(0.9)	(0.5)		
Hwdtreeht	--[g]	5.0[d]	5.5	8.1	7.2	9.7	6.60	0.012
	--	(0.0)	(0.6)	(0.7)	(0.6)	(1.0)		
Ctree1	912.3	1019.6	1219.2	482.8	737.2	590.8	1.04	0.438
	(279.9)	(266.2)	(301.4)	(294.4)	(309.4)	(128.6)		
Ctree2[c]	0.0[d]	11.7	163.9	336.0	180.6	104.0	13.06	0.000
	(0.0)	(11.67)	(70.7)	(72.6)	(68.7)	(1.2)		
Ctree3[c]	0.0	0.0	0.8	109.2	251.4	315.6	na[f]	0.014
	(0.0)	(0.0)	(0.8)	(78.6)	(73.5)	(11.8)		
Ctree4[c]	0.0	0.0	0.0	1.4	57.6	102.3	na[f]	0.026
	(0.0)	(0.0)	(0.0)	(1.4)	(33.7)	(18.3)		
Ctree5[c]	0.0	0.0	0.0	0.0	1.4	8.3	na[f]	0.022
	(0.0)	(0.0)	(0.0)	(0.0)	(1.4)	(2.8)		
Conba[c]	0.17[b]	2.28	6.41	13.84	24.94	32.59	77.59	0.000
	(0.07)	(0.42)	(0.67)	(3.09)	(5.45)	(2.01)		
Conbole[c]	100.0	100.0	98.3	82.3	80.3	47.7	57.96	0.000
	(0.0)	(0.0)	(1.7)	(3.8)	(3.2)	(3.8)		
Htree1[c]	0.0[b]	97.8	41.9	686.2	153.5	96.5	4.05	0.022
	(0.0)	(86.8)	(23.2)	(551.2)	(12.6)	(56.6)		
Htree2[c]	0.0	0.0	0.0	2.4	0.0	12.9	na[f]	0.117
	(0.0)	(0.0)	(0.0)	(1.3)	(0.0)	(9.4)		
Htree3	0.0	0.0	0.0	0.0	0.0	6.3	na[f]	0.416
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(6.3)		
Hwdba[c]	0.00[b]	0.09	0.05	1.63	0.37	0.77	5.18	0.009
	(0.00)	(0.09)	(0.05)	(1.37)	(0.09)	(0.62)		

Table 4, continued

	Age Class (years)							
Variable	5-9	10-14	15-19	20-24	25-29	30-34	F	*P*-value
Snag1[c]	5.5[d]	0.7	1.2	6.0	4.1	5.3	1.08	0.418
	(5.2)	(0.4)	(0.9)	(4.1)	(0.6)	(1.4)		
Snag2	0.6[d]	0.0	0.2	1.0	0.7	1.0	1.15	0.388
	(0.5)	(0.0)	(0.2)	(0.8)	(0.4)	(0.3)		
Snag3[c]	0.2	0.2	0.0	0.0	0.0	0.0	na[f]	0.032
	(0.1)	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)		
Snag4[c]	0.1	0.0	0.0	0.0	0.0	0.0	na[f]	0.075
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)		
Snag5	0.2	0.0	0.0	0.4	0.2	0.2	1.05	0.432
	(0.1)	(0.0)	(0.0)	(0.2)	(0.2)	(0.2)		
Snag6	0.9[d]	0.1	0.7	0.0	0.2	0.4	1.00	0.456
	(0.7)	(0.1)	(0.4)	(0.0)	(0.2)	(0.4)		
Snag7[c]	0.2	0.0	0.0	0.0	0.0	0.0	na[f]	0.075
	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)		
Snag8[c]	0.4	0.1	0.0	0.1	0.0	0.0	na[f]	0.164
	(0.2)	(0.1)	(0.0)	(0.1)	(0.0)	(0.0)		
Snag9	1.1	0.2	1.5	1.3	1.3	1.4	na[f]	0.164
	(0.6)	(0.1)	(0.1)	(0.5)	(0.9)	(0.8)		
Ssnag[c]	6.3[d]	0.9	1.5	7.0	4.7	6.3	1.37	0.304
	(5.6)	(0.5)	(0.9)	(3.8)	(0.8)	(1.3)		
Msnag	1.1[d]	0.2	1.5	1.3	1.3	1.4	0.51	0.763
	(0.6)	(0.1)	(0.1)	(0.5)	(0.9)	(0.8)		
Lsnag	1.6[d]	0.3	1.5	1.4	1.3	1.4	0.66	0.663
	(0.83)	(0.2)	(0.1)	(0.4)	(0.9)	(0.8)		

Table 4, continued

Variable	5-9	10-14	15-19	20-24	25-29	30-34	F	*P*-value
	Age Class (years)							
Snagsha[c]	9.0[b]	1.4	3.7	8.8	6.3	8.2	3.87	0.026
	(4.7)	(0.6)	(1.2)	(4.0)	(0.8)	(0.4)		
Prcntrd	2.1	2.6	1.6	2.3	0.8	1.6	0.66	0.661
	(0.7)	(1.0)	(0.9)	(0.2)	(0.8)	(1.0)		
Rdedge	19.0	15.0	34.0	16.7	47.3	22.7	0.70	0.632
	(10.2)	(5.0)	(11.1)	(10.1)	(21.8)	(22.7)		
Stream	0.2	0.8	0.0	0.2	0.1	0.4	6.13	0.005
	(0.2)	(0.2)	(0.0)	(0.1)	(0.0)	(0.1)		
Streamin	330.0	968.0	176.0	484.0	110.0	880.0	1.72	0.204
	(330.0)	(188.0)	(176.0)	(267.6)	(110.0)	(440.0)		
Ckedge	0.0	17.7	0.0	10.7	2.3	10.7	na[f]	0.480
	(0.0)	(9.8)	(0.0)	(10.7)	(2.3)	(10.7)		
Patch	0.8	1.5	0.6	1.9	1.1	1.4	4.71	0.013
	(0.2)	(0.3)	(0.3)	(0.3)	(0.2)	(0.0)		
Contrast	0.5	0.4	0.4	0.4	0.3	0.3	1.51	0.257
	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.0)		
Stndarea	20.1	14.4	13.9	14.5	14.2	17.4	1.97	0.156
	(1.8)	(1.2)	(1.6)	(1.3)	(1.0)	(3.0)		
Elev	919.3	948.0	1015.7	882.3	960.0	857.3	0.41	0.832
	(79.8)	(57.5)	(53.8)	(129.0)	(131.5)	(28.3)		

[a] See Table 3 for a description of habitat variables
[b] Means are untransformed data; F values and *P*-values are from analysis on LOG- (or LOG+0.01 or 1.0) transformed data
[c] Habitat variable significantly ($P \leq 0.05$) correlated (positively or negatively) with stand age
[d] Means are untransformed data; F values and *P*-values are from analysis on square-root-transformed data
[e] Height data measured in only 1 out of 3 stands in the age class; no SE to report
[f] Friedman Two-way test comparing sample medians used; no F to report
[g] No trees $\geq$4.0 m in this age class

Table 5. Habitat variables in managed Douglas-fir stands ranging in age from 5 to 34 years old on the Detroit Ranger District, Willamette National Forest, Oregon, that differed ($P \leq 0.05$) among age classes.

	Age Class (years)					
Habitat Variable	5-9	10-14	15-19	20-24	25-29	30-34
Moss[a]	A[b]	AB	AB	BC	CD	D
Ground	AB	A	A	AB	B	B
Conlow	A	B	B	A	A	A
Hwdlow	AB	AB	A	BC	C	C
Contall	A	BC	C	C	BC	AB
Contree	A	B	C	D	D	D
Hwdtree	A	A	AB	C	C	BC
Herbht	A	AB	ABC	BCD	CD	D
Grassht	AB	C	AB	B	AB	A
Contallht	A	B	B	B	B	B
Hwdtallht	A	B	AB	C	D	CD
Contreeht	--[c]	A	A	B	BC	C
Hwdtreeht	--	A	A	BC	AB	C
Ctree2	A	A	BC	B	BC	C
Ctree3	A	A	A	A	B	B
Ctree4	A	A	A	A	B	B
Ctree5	A	A	A	A	A	B
Conba	A	B	C	D	DE	E
Conbole	A	A	A	B	B	C
Htree1	A	AB	AB	B	B	B
Hwdba	A	AC	A	B	BC	BC
Snag3	A	A	B	B	B	B
Snagsha	A	B	AB	A	A	A
Stream	AC	B	A	AC	AC	C
Patch	AB	CD	A	D	ABC	BCD

[a] See Table 3 for a description of habitat variables
[b] Means with the same letter code are not significantly different
[c] No trees >4.0 m in this age class

5 snags were present at about the same level in all age classes, with the exception of age class 2 where fewer snags were present. Total snags/ha was highest in age class 1, lowest in age class 2, and tended to increase with increasing stand age from age class 2-6.

Average percent cover of moss and herbaceous species increased with increasing stand age, while the percent cover of grass decreased. The percent cover of bare ground was highest in age classes 1 and 4-6. Average cover (foliage density) between 0 and 1.3 m high was greatest for both conifers and hardwoods in the youngest 3 age classes, with hardwood cover dominant in age class 1 and conifer cover dominant in age classes 2-3. Average cover between 1.4 and 4.0 m tall was greatest in age classes 3 and 4 for both conifers and hardwoods, though conifer cover was about 11 times greater than hardwood cover. Conifer trees > 4.0 m tall were absent from age class 1, with average crown foliage density fairly low in age classes 2 and 3 (4.3% to 10.9%), and considerably higher in age classes 4-6 (40.4% to 48.6%). Hardwood trees > 4.0 m tall also were absent from age class 1, and average crown cover was very low in all age classes.

The average height of herbaceous species decreased over the 6 age classes. Conifer tree heights increased from an average of 6.0 m tall in age class 2 to 16.0 m tall in age class 6, while average hardwood tree heights ranged from 5.0 m tall to 9.7 m tall.

Total number of conifer stems/ha was high (900 - 1400 stems/ha, all dbh classes combined) in all age classes, though larger diameter trees made up an increasingly larger proportion of total stems as stand age increased. The average number of stems/ha of conifers < 10 cm dbh was highest in the youngest 3 age classes, with amounts about twice those in age classes 4-6. Conifer trees 10- to 20-cm dbh were present in and increased in number of stems/ha from age class 2-6. Conifer trees 20- to 30-cm dbh were present in and increased in number of stems/ha from age class 3-6. Conifer trees 30- to 40-cm dbh were present in and increased in number of stems/ha from age class 4-6, and conifer trees 40- to 50-cm dbh were present in and increased in number of stems/ha from age class 5-6. The average number of stems/ha of hardwoods < 10 cm dbh did not show any pattern among age classes. Hardwood trees 10- to 20-cm dbh were present in age classes 4 and 6, and hardwood trees 20- to 30-cm dbh were present only in age class 6.

The basal area of conifers increased with increasing stand age while the basal area of hardwoods did not show any pattern among age classes. The percentage of individual conifer tree boles having live limbs from crown to base decreased from 100.0% in age classes 1 and 2 to 47.7% in age class 6.

Variables measuring amounts of logging roads and streams within stands and bordering stands were not significantly associated with stand age and did not show any pattern among the age classes. The percent of stand area made up of logging roads was less than 2.6% for all age classes. The index to habitat patchiness was lowest in age class 3, and contrast between study stands and adjacent stands appeared lowest in age class 1. Average stand elevation and area did not show any pattern among age classes.

Patterns of bird abundance

No pattern was evident for either total abundance, species richness, or species diversity of birds among the 6 age classes (Figure 3). The mean total abundances of birds, species richness, and species diversity were not significantly different among the 6 age classes (Appendix 2). Though not statistically significant ($P=0.450$), total abundance appeared highest in age class 2 (4.9 birds per plot, per visit, per stand), and lowest in age class 3 (3.1). Species richness ($P=0.196$) appeared highest in age class 4 (18.3 species), and lowest in age class 3 (13.3). Species diversity ($P=0.438$) also appeared highest in age class 4 (1.11) and lowest in age class 3 (0.98).

The abundance of each of 18 bird species analyzed using ANOVA fell into one of four general patterns. Eight species (chestnut-backed chickadee, golden-crowned kinglet, hermit thrush, hermit warbler, Pacific-slope flycatcher, Swainson's thrush, Wilson's warbler, and winter wren) increased in abundance with increasing stand age (Figure 4). Four species (American robin, dark-eyed junco, rufous hummingbird, and white-

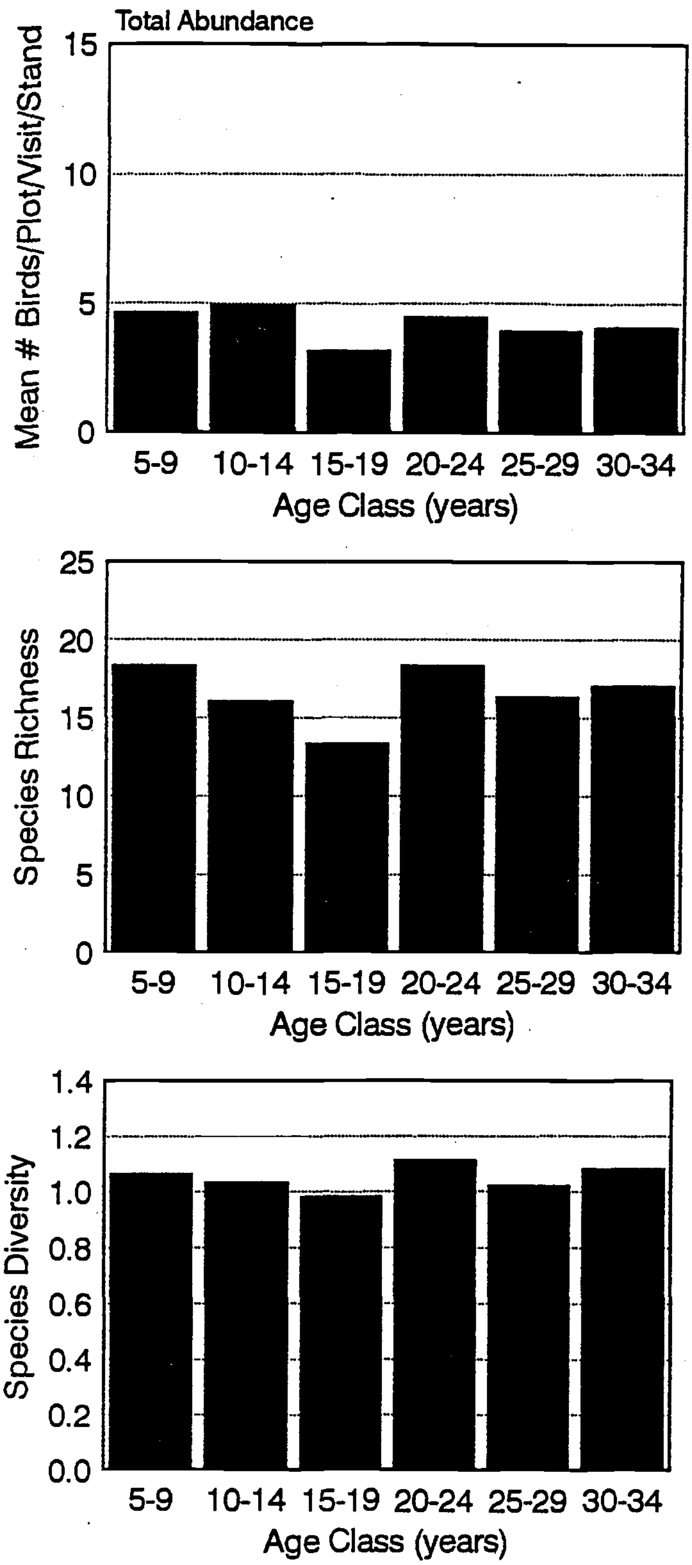


Figure 3. Bird community parameters by age class in managed Douglas-fir stands ranging in age from 5 to 34 years old on the Detroit Ranger District, Willamette National Forest, Oregon.

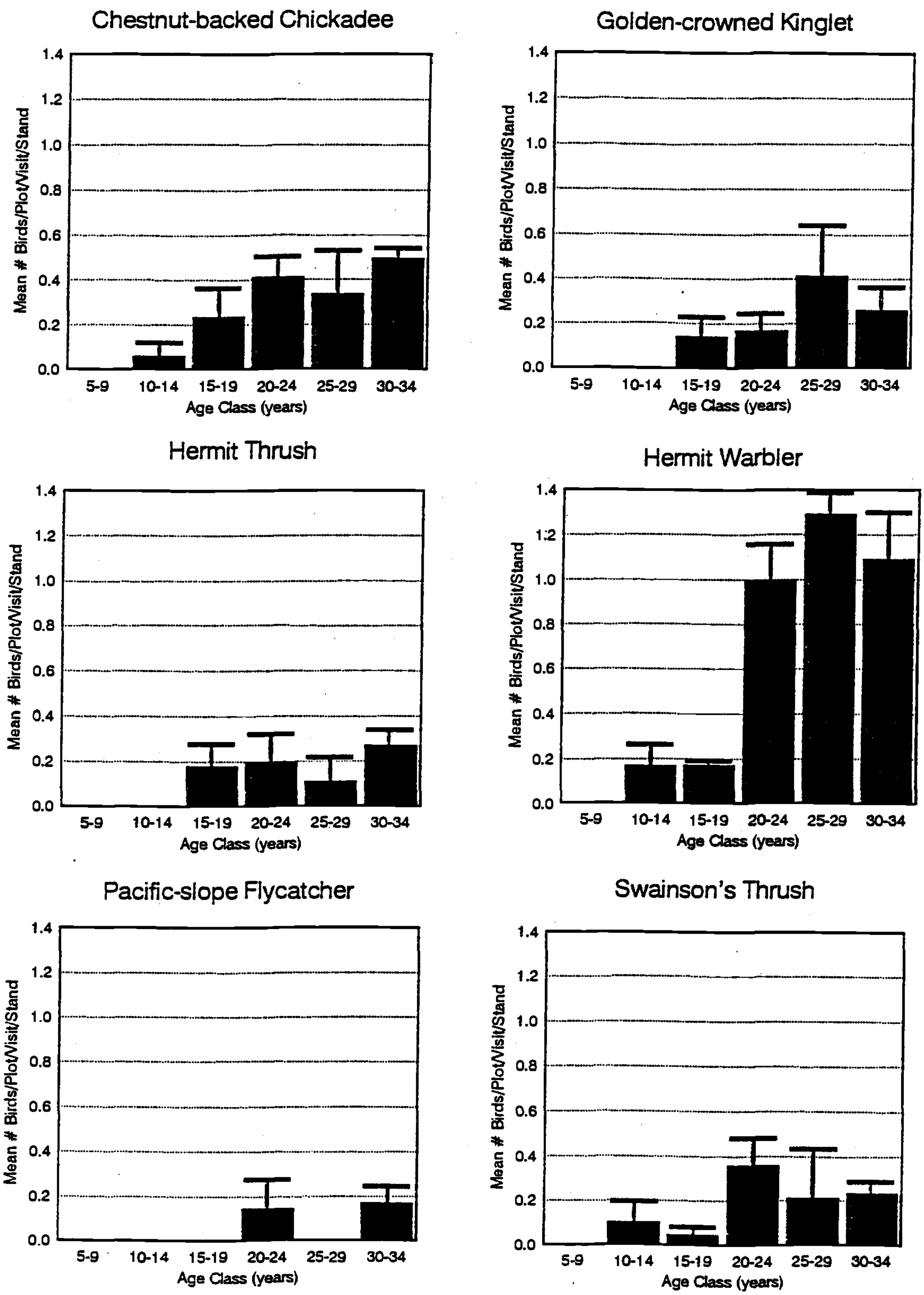
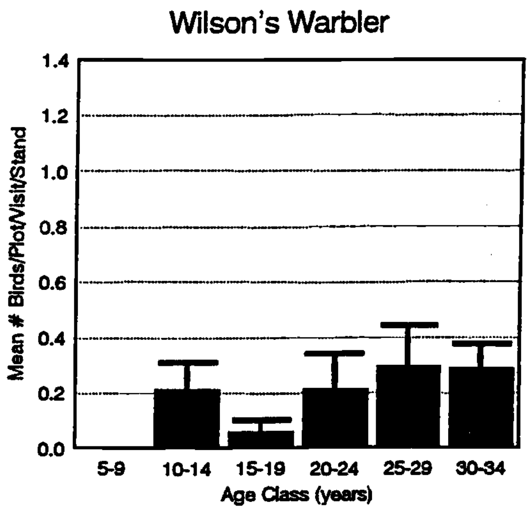


Figure 4. Species showing an increase in abundance with increasing stand age in managed Douglas-fir stands ranging in age from 5 to 34 years old on the Detroit Ranger District, Willamette National Forest, Oregon.



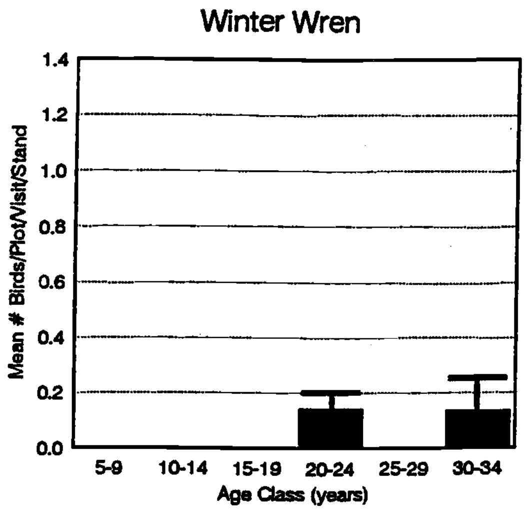


Figure 4, continued

crowned sparrow) decreased in abundance with increasing stand age (Figure 5). Four species (dusky flycatcher, MacGillivray's warbler, orange-crowned warbler, and rufous-sided towhee) peaked in abundance in age class 2 (stand age 10 to 14 years old), with abundance then decreasing over age classes 3-6 (Figure 6). The remaining 2 species (warbling vireo and western tanager) did not show any discernible pattern among age classes (Figure 7).

Only 4 species - dark-eyed junco, dusky flycatcher, hermit warbler, and MacGillivray's warbler - differed significantly in abundance among the age classes (Table 6). Power (1 - beta) was only 0.05 - 0.06 for the rest of the species.

Correlation analysis

Spearman correlation coefficients for 18 individual bird species and the bird community parameters are shown in Table 7 (only correlations significant at the 0.05 level are reported). Species richness and diversity were negatively associated with the number of conifer stems/ha < 10 cm dbh (Ctree1), and the percent cover of hardwood shrubs and trees < 1.3 m high (Hwdlow). Richness and diversity were positively associated with the number of streams within 50 m of survey plots (Stream) and the total length of streams within stands (Streamin). Total abundance was significantly associated (positively) with only one variable, Patch, which

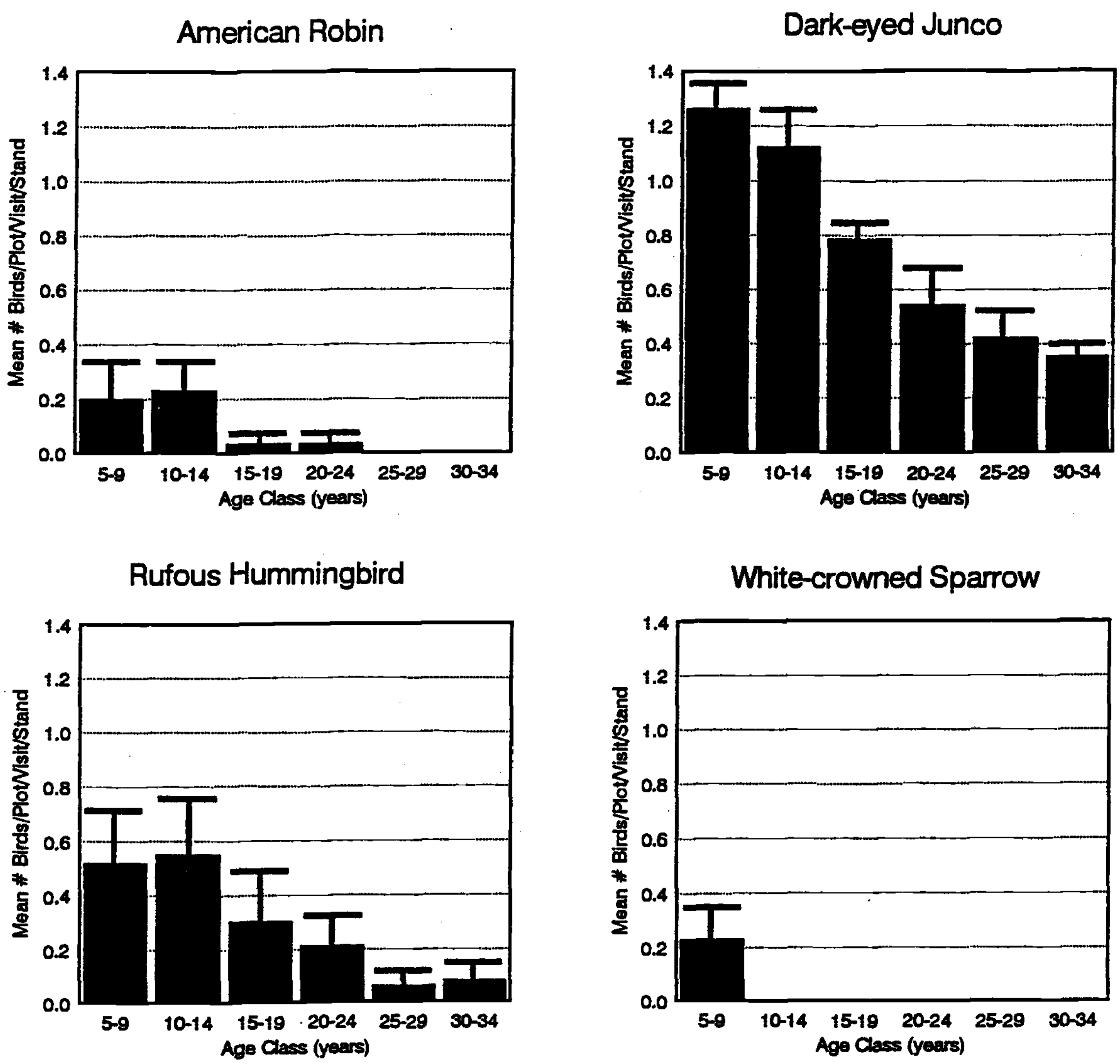


Figure 5. Species showing a decrease in abundance with increasing stand age in managed Douglas-fir stands ranging in age from 5 to 34 years old on the Detroit Ranger District, Willamette National Forest, Oregon.

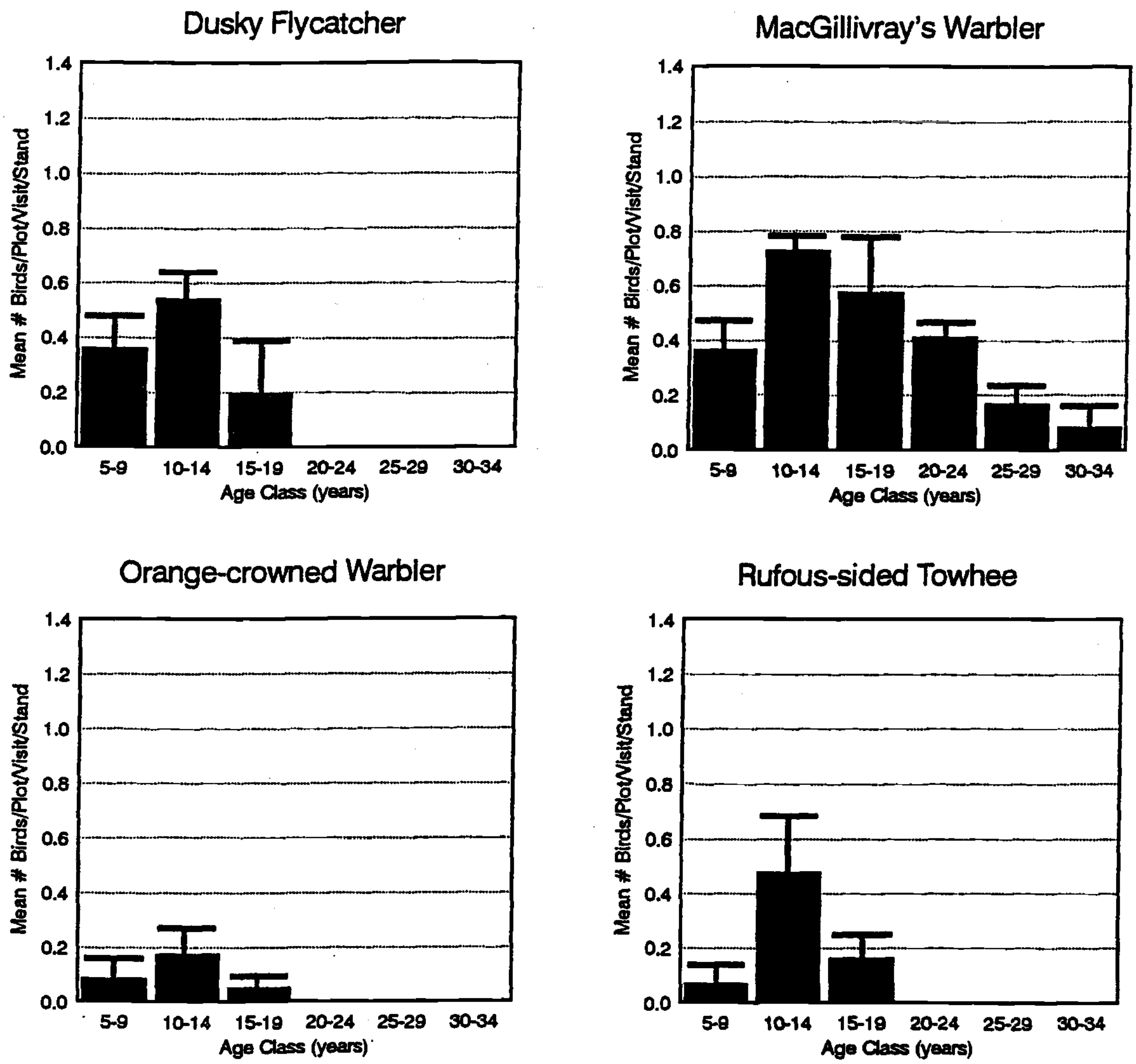


Figure 6. Species showing a peak in abundance in age class 2 (10 to 14 years old) in managed Douglas-fir stands ranging in age from 5 to 34 years old on the Detroit Ranger District, Willamette National Forest, Oregon.

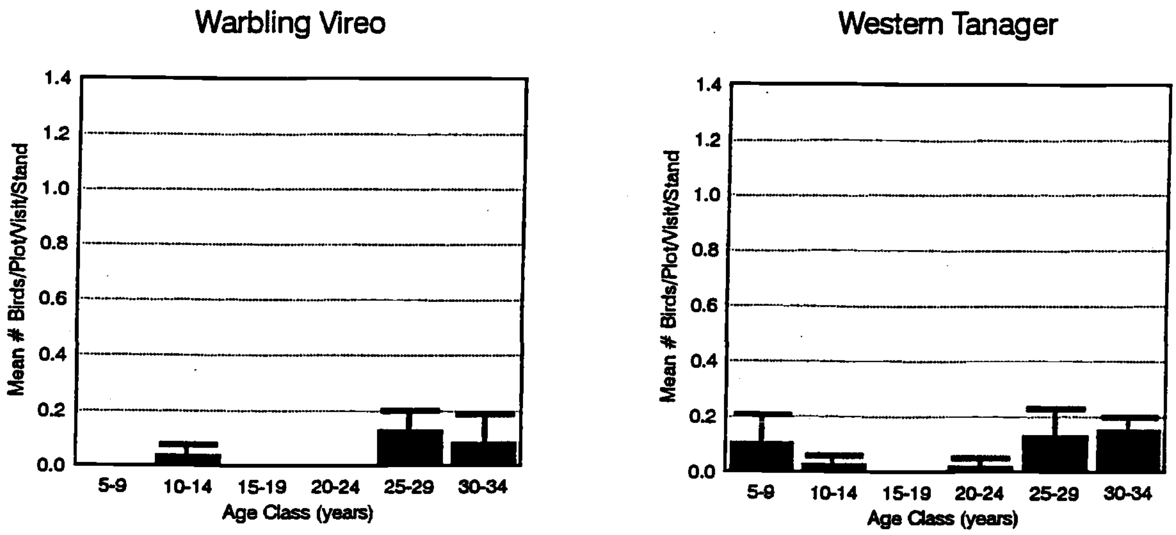


Figure 7. Species showing no apparent pattern with increasing stand age in managed Douglas-fir stands ranging in age from 5 to 34 years old on the Detroit Ranger District, Willamette National Forest, Oregon.

Table 6. Bird species in managed Douglas-fir stands ranging in age from 5 to 34 years old on the Detroit Ranger District, Willamette National Forest, Oregon, that differed ($P \leq 0.05$) in the mean number of birds per plot per visit per stand among age classes.

	Age Class (years)					
Species	5-9	10-14	15-19	20-24	25-29	30-34
Dark-eyed junco	A[a]	A	B	BC	C	C
Dusky flycatcher	AB	A	BC	C	C	C
Hermit warbler	A	B	B	C	C	C
MacGillivray's warbler	AB	C	BC	ABC	A	A

[a] Means with the same letter code are not significantly different

Table 7. Spearman correlation coefficients for individual bird species abundance indices with habitat variables in 18 managed Douglas-fir stands ranging in age from 5 to 34 years old on the Detroit Ranger District, Willamette National Forest, Oregon. Only significant ($P \leq 0.05$) correlations are shown.

Habitat Variables[b]	Bird Species[a]									
	AMRO	CBCH	DEJU	DUFL	GCKI	HETH	HEWA	MAWA	OCWA	PSFL
Age	-0.59	0.70	-0.89	-0.77	0.67	0.51	0.87	-0.56		
Slash										
DWD1										
DWD2										0.56
DWD3										0.49
Bare	-0.58		-0.59					-0.61	-0.72	
Moss	-0.60	0.76	-0.84	-0.67	0.47	0.52	0.77	-0.57		
Ground	-0.62		-0.67					-0.66	-0.72	
Herb				-0.46	0.54		0.58			
Grass		-0.66	0.69	0.58	-0.51		-0.57	0.55	0.47	
Fern										
Conlow			0.54							
Hwdlow			0.61	0.59	-0.56		-0.68	0.48		
Contall										
Hwdtall						0.48				
Contree	-0.52	0.70	-0.77	-0.80	0.62		0.88	-0.49		0.46
Hwdtree		0.76	-0.79	-0.70		0.55	0.78			
Herbht	0.64		0.81	0.54	-0.61	-0.41	-0.64	0.50	0.52	
Conlowht										
Hwdlowht						0.56				
Ctallht				-0.50						
Ctree1										
Ctree2		0.70	-0.62	-0.70		0.66	0.58			

Table 7, continued

Habitat Variables[b]	Bird Species[a] AMRO	CBCH	DEJU	DUFL	GCKI	HETH	HEWA	MAWA	OCWA	PSFL
Ctree3	-0.52	0.65	-0.83	-0.77	0.70		0.83	-0.65		0.51
Ctree4	-0.48		-0.69	-0.53	0.74		0.70	-0.62		0.58
Ctree5			-0.60		0.51			-0.50		0.51
Conba	-0.59	0.63	-0.89	-0.79	0.75		0.86	-0.55		0.52
Conbole	0.59	-0.58	0.64	0.77	-0.50		-0.60	0.74	0.49	-0.56
Htree1		0.58	-0.59			0.48	0.64			
Htree2		0.47	-0.47							0.88
Htree3										0.50
Hwdba	0.67	-0.68	-0.57			0.69				
Snag1							0.54			
Snag2										
Snag3		-0.59	0.67	0.75	-0.57	-0.52	-0.55			
Snag4			0.51	0.50			-0.48			
Snag6							-0.47			
Snag7							-0.48			
Snag8		-0.51	0.57	0.46						
Snag9										
Ssnag							0.56			
Snagsha				-0.48						0.51
Rdedge										
Stream									0.53	
Streamin									0.49	
Ckedge										
Patch		0.46					0.54			0.46
Contrast			0.51		-0.58		-0.61			
Stndarea									0.60	
Elev		-0.54								

Table 7, continued

Habitat Variables[b]	Bird Species[a]										
	RSTO	RUHU	SWTH	WAVI	WETA	WCSP	WIWA	WIWR	Rich	Abund	Div
Age	-0.55	-0.59	0.53			-0.48	0.54				
Slash				0.55							
DWD1				0.48							
DWD2											
DWD3	-0.63										
Bare		-0.62									
Moss	-0.47	-0.62					0.60	0.48			
Ground		-0.67									
Herb	-0.51										
Grass		0.54	-0.54					-0.46			
Fern		-0.56									
Conlow	0.70				-0.48						
Hwdlow	0.52	0.47	-0.54		-0.72				-0.55		-0.56
Contall						-0.48					
Hwdtall						-0.55					
Contree	-0.56	-0.60	0.65			-0.51	0.57				
Hwdtree	-0.63	-0.50	0.62				0.56				
Herbht		0.59	-0.49	-0.48							
Conlowht	0.68										
Hwdlowht						-0.47					
Ctallht						-0.48					
Ctree1	0.54				-0.46				-0.63		-0.51
Ctree2	-0.57		0.47								
Ctree3	-0.70	-0.58	0.58		0.47		0.49				
Ctree4	-0.47				0.63						
Ctree5					0.63						
Conba	-0.54	-0.62	0.53			-0.48					

Table 7, continued

Habitat Variables[b]	RSTO	RUHU	SWTH	WAVI	WETA	WCSP	WIWA	WIWR	Rich	Abund	Div
	Bird Species[a]										
Conbole	0.52	0.64	-0.50								
Htree1											
Htree2		-0.50	0.61					0.77			0.48
Htree3											
Hwdba	-0.47		0.56				0.55				
Snag1	-0.64				0.47		0.46				
Snag2	-0.60				0.66				0.51		
Snag3	0.60										
Snag4						0.99					
Snag6			-0.52								
Snag8											
Snag9								0.48			
Ssnag	-0.70				0.51						
Snagsha	0.77				0.55						
Rdedge								-0.49			
Stream									0.51		0.48
Streamin									0.58		0.61
Ckedge							0.46				
Patch			0.57				0.56	0.54		0.59	0.49
Contrast				-0.66		0.51					

[a] AMRO = American robin, CBCH = Chestnut-backed chickadee, DEJU = Dark-eyed junco, DUFL = Dusky flycatcher, GCKI = Golden-crowned kinglet, HETH = Hermit thrush, HEWA = Hermit warbler, MAWA = MacGillivray's warbler, OCWA = Orange-crowned warbler, PSFL = Pacific-slope flycatcher, RSTO = Rufous-sided towhee, RUHU = Rufous hummingbird, SWTH = Swainson's thrush, WAVI = Warbling vireo, WETA = Western tanager, WCSP = White-crowned sparrow, WIWA = Wilson's warbler, WIWR = Winter wren, Rich = Species richness, Abund = Total abundance, Div = Species diversity

[b] See Table 3 for habitat variable descriptions

describes how many habitat patches (roads, streams, hardwood clumps etc.) were within 50 m of survey plots. Thirteen of the 18 species in this study were significantly (either positively or negatively) associated with stand age, while total abundance, species richness, and diversity were not. Most species showing increasing abundance with increasing stand age were positively associated with variables describing the amount of bare and/or moss covered ground (Bare, Moss, Ground), conifer basal area (Conba), percent cover of live conifer crown (Contree), and number of stems per hectare of conifers > 10 cm dbh (Ctree2 - Ctree5). Species showing a pattern of decreasing abundance or a peak in abundance before decreasing with increasing stand age were negatively associated with one or more of the same variables. Of the species that did not exhibit any clear pattern among age classes, the western tanager was positively associated with variables describing the number of stems per hectare of conifers > 30 cm dbh (Ctree4, Ctree5) and the warbling vireo was negatively associated with contrast and positively associated with the amount of slash. Variables describing elevation, stand area, slash, down woody debris amounts, and vegetation heights in the different layers (except herb height) were not significantly associated with many species in this study. Four variables - the number of 30- to 51-cm dbh snags/ha in decay class 2 and 3 (Snag5), the number of 30- to 51-cm dbh snags/ha in all decay classes (Msnag), the number of >51-cm dbh snags/ha in all decay classes (Lsnag), and the percentage of total stand area in roads and landings (Prcntrd), - were not significantly associated with any species or community parameters.

Regression analysis

Adjusted R^2 values for predicting the mean number of birds per plot per visit per stand ranged from 0.36 for hermit and Swainson's thrushes to 0.90 for the hermit warbler (Table 8). Total length of streams (Streamin) within a stand was an important predictor variable for both species richness and diversity. The number of habitat patches within 50 m of survey stations was the best predictor of total abundance.

The abundances of those species which increased with increasing stand age had positive relationships with conifer basal area (Conba), percent cover of live conifer crown between 4 m and the height of the tallest tree (Contree), the number of 20- to 30-cm dbh conifer stems/ha (Ctree3), or percent cover of live hardwood crown between 4 m and the height of the tallest tree (Hwdtree). Species which decreased in abundance, or peaked in age class 2 before decreasing in abundance, had negative relationships with the same variables, excluding the percent cover of live hardwood crown between 4 m and the height of the tallest tree. The abundance of western tanagers, which exhibited no pattern among the age classes, had a negative relationship with percent cover of hardwood shrubs and trees 0 to 1.3 m high (Hwdlow).

Table 8. Regression models for individual bird species (mean number of birds per plot per visit per stand), total abundance, species richness, and species diversity in 18 managed Douglas-fir stands ranging in age from 5 to 34 years old on the Detroit Ranger District, Willamette National Forest, Oregon.

Bird Species	Habitat Variable[a]	Coefficient	*P*-value	R^2	Adjusted R^2
Chestnut-backed	constant	0.387	0.000		
chickadee	LOG(hwdtree)	0.082	0.001	0.52	0.49
Dark-eyed junco	constant	1.130	0.000		
	SQRT(conba)	-0.146	0.000		
	grass	0.016	0.045	0.85	0.83
LOG (Dusky	constant	-1.291	0.005		
flycatcher)	contree	-0.073	0.000	0.70	0.68
SQRT (Golden-	constant	0.029	0.686		
crowned kinglet)	conba	0.018	0.000	0.59	0.56
Hermit thrush	constant	0.196	0.000		
	LOG(hwdtree)	0.044	0.005	0.40	0.36
Hermit warbler	constant	0.002	0.972		
	contree	0.021	0.000		
	moss	0.021	0.010	0.91	0.90
SQRT (Mac-	constant	0.726	0.000		
Gillivray's warbler)	ctree3	-0.002	0.000	0.58	0.56
SQRT (Rufous	constant	1.160	0.000		
hummingbird)	LOG(fern)	-0.046	0.017		
	LOG(conba)	-0.073	0.013		
	LOG(bare)	-0.218	0.006	0.74	0.69
Swainson's thrush	constant	0.012	0.855		
	contree	0.006	0.005	0.39	0.36
Western tanager	constant	0.174	0.000		
	LOG(hwdlow)	-0.059	0.001	0.54	0.51

Table 8, continued

Wilson's warbler	constant	0.042	0.421		
	LOG(ctree3)	0.034	0.021		
	LOG(ckedge)	0.055	0.040	0.49	0.42
Richness	constant	14.610	0.000		
	streamin	0.002	0.054		
	snag2	1.547	0.054	0.45	0.38
LOG (Total abundance)	constant	1.057	0.000		
	patch	0.281	0.011	0.34	0.30
Diversity	constant	1.043	0.000		
	streamin	0.0001	0.018		
	hwdlow	-0.003	0.047	0.54	0.48

[a] See Table 3 for a description of habitat variables

Community similarity

When compared to the 5-year-old stand, bird communities in the other 8 youngest (open-canopy) stands had higher Percent of Similarity values (0.40 - 0.63) than the 9 older (closed-canopy) stands (0.19 - 0.53) (Figure 8). After removing the two transitional stands in the middle (ages 19 and 20, parts of the stands had reached canopy closure while the rest had not), the range of Percent of Similarity values becomes 0.19 to 0.31 for the older stands. When compared to the 33-year-old stand, bird communities in the other 8 older (closed-canopied) stands had higher percent similarity values (0.56 - 0.79) than the 9 younger (open-canopied) stands (0.15 - 0.43). Again, by removing the two transitional stands in the middle, the range of Percent of Similarity values becomes 0.15 to 0.38 for the younger stands and 0.63 to 0.79 for the older stands.

Overall, 15 species were lost and 33 species were gained as stand age increased (Figure 9). The rate of bird community change (cumulative number of species lost and gained) was greatest in the open-canopy stands. The rate of change appeared to reach a plateau after canopy closure occurred.

Open- versus closed-canopy stands

Open-canopy stands had less percent cover of bare ground, moss, and herbaceous species than closed-canopy stands (Table 9). Most of the

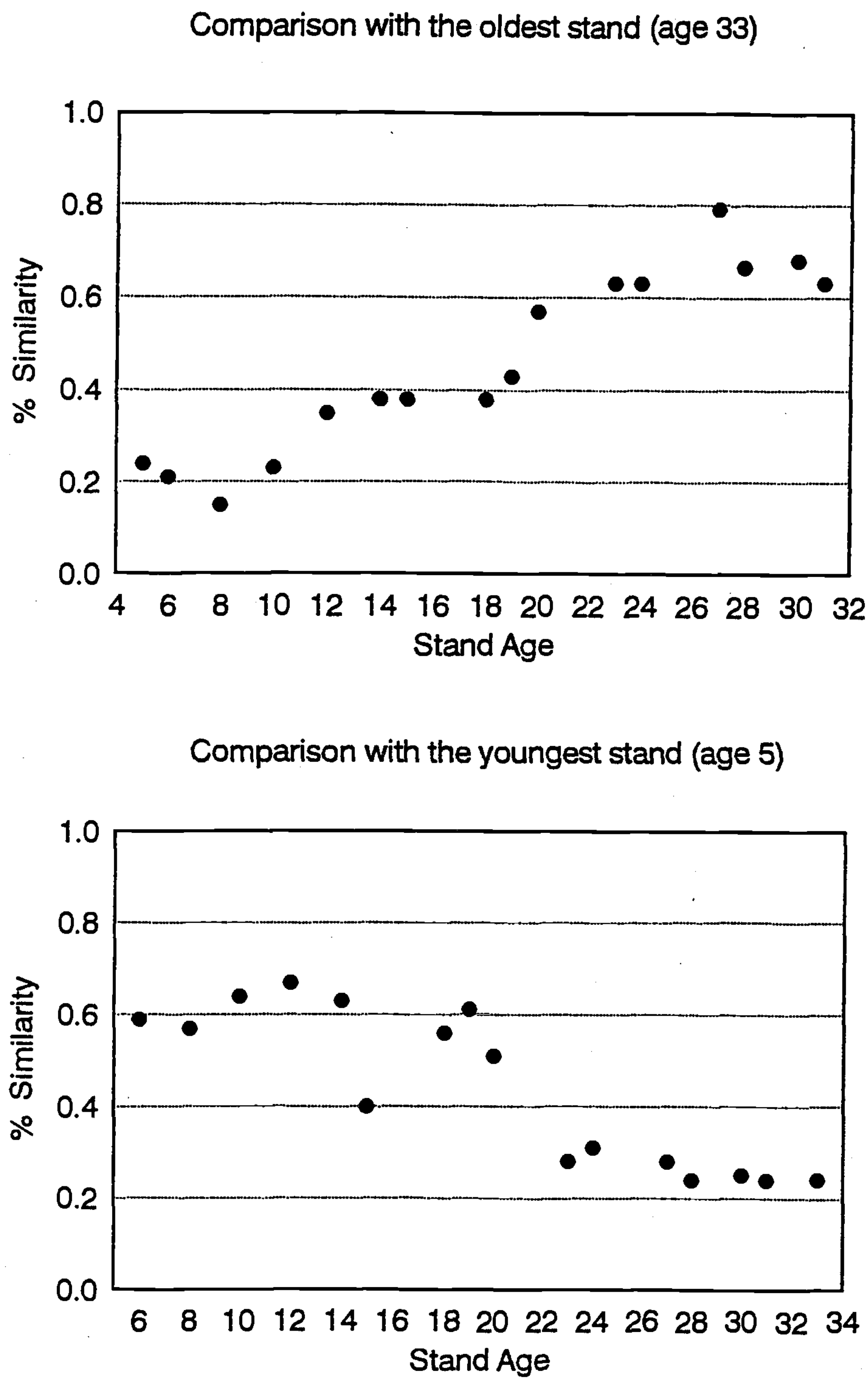
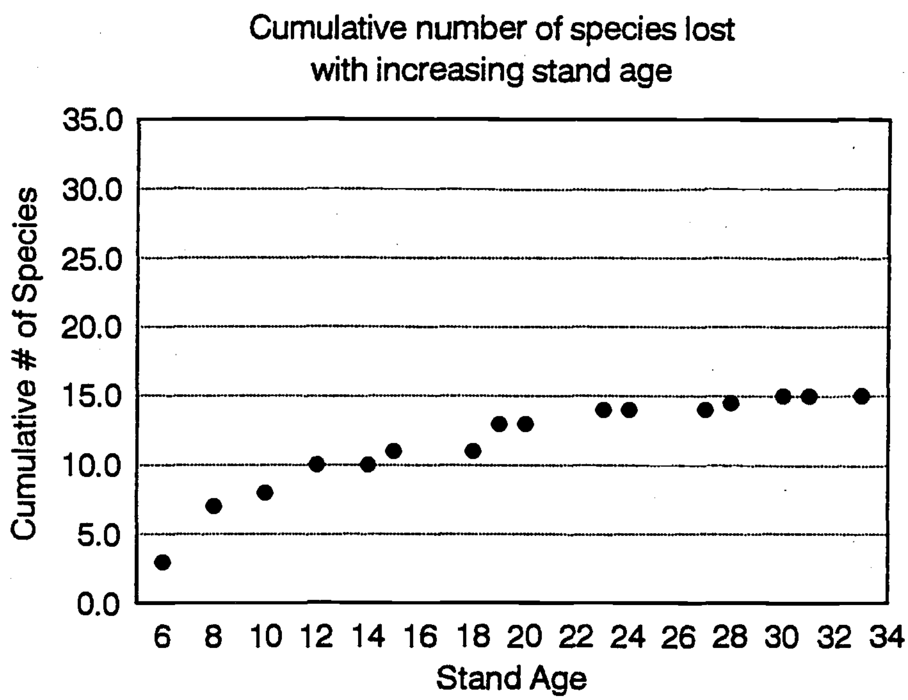


Figure 8. Percent similarity comparison of bird communities between individual managed Douglas-fir stands and the oldest (age 33) and youngest (age 5) stands surveyed. The percent similarity value for the two 28-year-old stands is shown as an average.



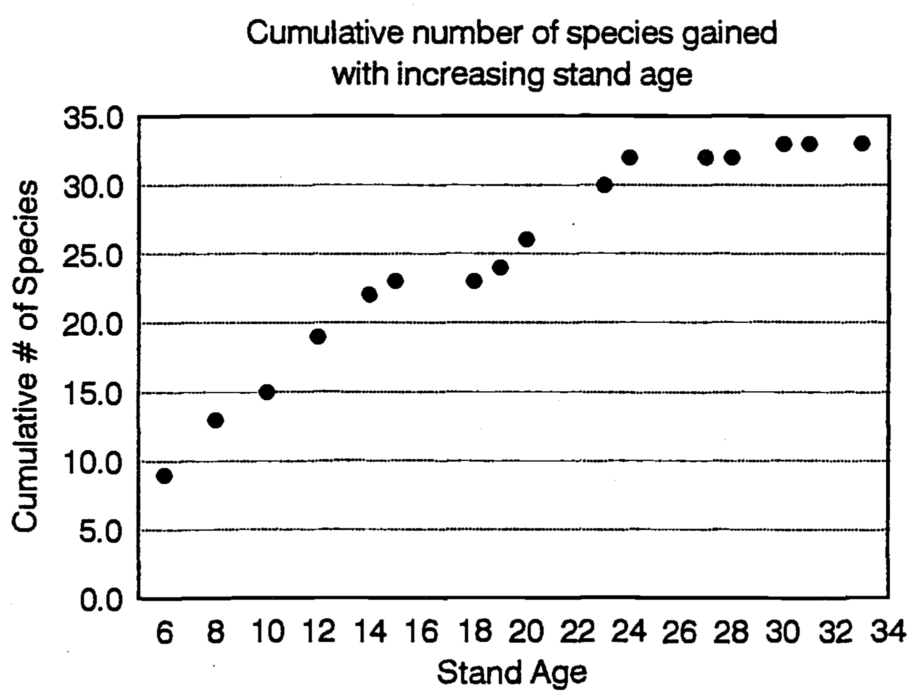


Figure 9. Rate of bird community change with increasing stand age in managed Douglas-fir stands on the Detroit Ranger District, Willamette National Forest, Oregon. The cumulative number of species lost or gained in the two 28-year-old stands is shown as an average.

Table 9. Habitat characteristics in 9 open-canopy (5 to 19 years old) and 9 closed-canopy (20 to 34 years old) managed Douglas-fir stands on the Detroit Ranger District, Willamette National Forest, Oregon.

	Open-canopy		Closed-canopy		
Habitat Variables[a]	Mean	SE	Mean	SE	*P*-value
Slash	11.8	1.3	20.0	5.6	0.172[b]
DWD1	900.24	194.04	1331.00	337.45	0.285[b]
DWD2	103.43	21.88	95.86	20.26	0.803[b]
DWD3	112.38[c]	30.07	141.34	31.69	0.917[b]
Bare	16.0[c]	3.9	33.0	5.8	0.015[b]
Moss	0.4[d]	0.1	8.5	2.7	0.000[b]
Ground	16.4[d]	3.8	41.4	6.6	0.003[b]
Herb	23.0	4.2	42.4	5.9	0.016[b]
Grass	7.9[d]	2.5	1.1	0.6	0.007[b]
Fern	6.7[d]	5.4	4.9	3.3	0.711[b]
Conlow	27.9[c]	6.0	7.0	2.1	0.004[b]
Hwdlow	18.2[d]	3.1	3.1	0.7	0.000[b]
Contall	13.7	4.0	16.8	4.8	0.623[b]
Hwdtall	1.5	0.5	2.0	0.5	0.487[b]
Contree	5.1	2.0	45.4	2.6	0.000[b]
Hwdtree	0.1[d]	0.0	2.0	0.9	0.001[b]
Herbht	0.40[d]	0.05	0.18	0.03	0.001[b]
Grassht	0.58[c]	0.09	0.36	0.10	0.100[b]
Fernht	0.50	0.04	0.72	0.11	0.341[e]
Conlowht	1.23	0.04	1.19	0.03	0.438[b]
Hwdlowht	1.16	0.04	1.21	0.01	0.306[b]
Contallht	3.26	0.31	3.89	0.06	0.345[e]
Hwdtallht	2.25	0.14	3.40	0.09	0.000[b]
Contreeht	7.1	0.7	14.8	0.57	0.000[b]
Hwdtreeht	5.3	0.3	8.3	0.5	0.004[b]
Ctree1	1050.4	148.4	603.6	133.9	0.040[b]
Ctree2	58.5[d]	33.5	206.8	44.7	0.003[b]
Ctree3	0.3	0.3	225.4	43.7	0.000[e]
Ctree4	0.0	0.0	53.8	18.3	0.005[e]
Ctree5	0.0	0.0	3.2	1.6	0.034[e]
Conba	2.96[d]	0.94	23.79	3.32	0.000[e]
Conbole	99.4	0.6	70.1	5.9	0.000[e]
Htree1	46.6[d]	29.5	312.0	185.5	0.027[b]
Htree2	0.0	0.0	5.1	3.4	0.034[e]
Htree3	0.0	0.0	2.1	2.1	0.374[e]
Hwdba	0.05[d]	0.03	0.92	0.47	0.005[b]
Snag1	0.1	0.1	0.0	0.0	0.169[e]
Snag2	0.1	0.1	0.0	0.0	0.034[e]

Table 9, continued

Snag3	1.7	1.3	0.6	0.3	0.558[b]
Snag4	0.2	0.5	0.4	0.3	0.558[b]
Snag5	0.1	0.0	0.0	0.0	0.033[e]
Snag6	0.8	0.5	4.6	1.4	0.011[e]
Snag7	0.0	0.0	0.4	0.2	0.022[e]
Snag8	0.0	0.0	0.0	0.0	0.374[e]
Snag9	0.0	0.0	0.0	0.0	0.374[e]
Ssnag	2.9	1.9	6.0	1.2	0.031[b]
Msnag	0.6	0.3	0.4	0.1	0.424[b]
Lsnag	1.2	0.3	1.4	0.4	0.657[b]
Snagsha	4.7	1.8	7.8	1.2	0.178[b]
Prcntrd	2.1	0.4	1.6	0.4	0.399[b]
Rdedge	22.7	5.4	28.9	10.6	0.609[b]
Stream	0.3	0.1	0.2	0.1	0.527[b]
Streamin	491.3	171.2	491.3	188.3	1.000[b]
Ckedge	5.9	4.1	7.9	4.6	0.737[e]
Patch	0.9	0.2	1.5	0.1	0.039[b]
Contrast	0.5	0.0	0.3	0.1	0.100[b]
Stndarea	16.1	1.3	15.4	1.1	0.650[b]
Elevation	961.0	35.4	899.9	56.0	0.370[b]

[a] See Table 3 for description of habitat variables

[b] *P* = the significance level associated with rejection of the null hypothesis that there is no difference between means, Student's t-test

[c] Means are untransformed data; analysis performed on LOG-transformed data

[d] Means are untransformed data; analysis performed on square-root-transformed data

[e] *P* = the significance level associated with rejection of the null hypothesis that there is no difference between medians, Mann-Whitney U-test (rank-sum analysis)

cover under 1.3 m high in open-canopy stands was hardwood shrubs, conifer seedlings, and grass and herbaceous species. Herbaceous species were more than twice as tall in open-canopy stands as in the closed canopy stands. While the percent cover of both conifer and hardwood tree canopy was significantly higher in closed-canopy stands, hardwoods never accounted for more than a small fraction of total canopy foliage density. Hardwood tree species such as vine maple (Acer circinatum), elderberry (Sambucus sp.), and cherry (Prunus sp.) were always shorter than conifer trees in the stand and had very few leaves. Conifer and hardwood trees were nearly twice as tall in closed-canopy than open-canopy stands. The number of conifer stems/ha < 10 cm dbh in open-canopy stands was nearly twice the amount in closed-canopy stands, while the number of hardwood stems/ha < 10 cm dbh in closed-canopy stands was almost 7 times greater than in open-canopy stands. The number of conifer stems/ha 10 to 20 cm dbh was 3.5 times greater in closed-canopy than open-canopy stands. Conifer trees 20 to 50 cm dbh and hardwood trees 10 to 30 cm dbh were found almost exclusively in the closed-canopy stands. Conifer and hardwood basal area was greater in closed-canopy than open-canopy stands. In open-canopy stands, even the lowest limbs on the bole were live, while in closed canopy-stands only an average of 70.1% of the bole had live limbs. Total small snags/ha (10 to 30 cm dbh, all decay classes) was 2 times greater in closed-canopy stands. Closed-canopy stands had about 1.5 times as many habitat patches (log piles, roads, hardwood clumps, root rot clumps etc.) within 50 m of survey points than open-canopy stands.

Seven species were significantly more abundant in the open-canopy stands (American robin, dark-eyed junco, dusky flycatcher, MacGillivray's warbler, orange-crowned warbler, rufous hummingbird, and rufous-sided towhee) while 5 species were significantly more abundant in the closed-canopy stands (chestnut-backed chickadee, golden-crowned kinglet, hermit warbler, Swainson's thrush, and Wilson's warbler) (Table 10). None of the community parameters differed significantly between open- and closed-canopy stands. Three species (dusky flycatcher, orange-crowned warbler, and white-crowned sparrow) were unique to the open-canopy stands. Two species (Pacific-slope flycatcher and winter wren) were unique to the closed-canopy stands.

The most abundant 5 species (in order of decreasing abundance) in the open-canopy stands (5 to 19 years old) were dark-eyed junco, MacGillivray's warbler, rufous hummingbird, dusky flycatcher, and rufous-sided towhee. The most abundant 5 species in the closed-canopy stands (20 to 33 years old) were hermit warbler, dark-eyed junco, chestnut-backed chickadee, golden-crowned kinglet, and Swainson's thrush.

Habitat associations were significant for 6 of the 7 species that were more abundant in the open-canopy stands (Table 11). American robins were positively associated with total length of streams within a stand. Dark-eyed juncos were negatively associated with conifer basal

Table 10. Abundance indices of individual species (mean number of birds per plot per visit per stand), total abundance, species richness, and species diversity in 9 open-canopy (5 to 19 years old) and 9 closed-canopy (20 to 34 years old) managed Douglas-fir stands on the Detroit Ranger District, Willamette National Forest, Oregon.

	Open-canopy		Closed-canopy		
Bird Species	Mean	SE	Mean	SE	*P*-value
American robin	0.2	0.1	0.0	0.0	0.040[a]
Chestnut-backed chickadee	0.1	0.1	0.4	0.1	0.004[b]
Dark-eyed junco	1.1	0.1	0.4	0.1	0.000[b]
Dusky flycatcher	0.4	0.1	0.0	0.0	0.002[a]
Golden-crowned kinglet	0.1	0.0	0.3	0.1	0.018[a]
Hermit thrush	0.1	0.0	0.2	0.1	0.110[a]
Hermit warbler	0.1[c]	0.0	1.1	0.1	0.000[b]
MacGillivray's warbler	0.6	0.1	0.2	0.1	0.006[b]
Orange-crowned warbler	0.1	0.0	0.0	0.0	0.034[a]
Pacific-slope flycatcher	0.0	0.0	0.1	0.1	0.077[a]
Rufous hummingbird	0.5[c]	0.1	0.1	0.1	0.014[b]
Rufous-sided towhee	0.2	0.1	0.0	0.0	0.005[a]
Swainson's thrush	0.1	0.0	0.3	0.1	0.016[a]
Warbling vireo	0.0	0.0	0.1	0.0	0.434[a]
Western tanager	0.0	0.0	0.1	0.0	0.133[a]
White-crowned sparrow	0.1	0.1	0.0	0.0	0.169[a]
Wilson's warbler	0.1[c]	0.1	0.3	0.1	0.050[b]
Winter wren	0.0	0.0	0.1	0.1	0.077[a]
Total abundance	4.2[d]	0.5	4.1	0.2	0.860[b]
Richness	15.9	1.1	17.2	0.6	0.306[b]
Diversity	1.02	0.03	1.07	0.02	0.230[b]

[a] *P* = the significance level associated with rejection of the null hypothesis that there is no difference between medians, Mann-Whitney U-test (rank-sum analysis)

[b] *P* = the significance level associated with rejection of the null hypothesis that there is no difference between means, Student's t-test

[c] Means are untransformed data; analysis performed on square-root-transformed data

[d] Means are untransformed data; analysis performed on LOG-transformed data

Table 11. Spearman correlation coefficients for individual bird species abundance indices with habitat variables in 9 open- canopy (5 to 19 years old) managed Douglas-fir stands on the Detroit Ranger District, Willamette National Forest, Oregon. Only significant ($P \leq 0.05$) correlations are shown.

Habitat Variables[b]	Bird Species[a]									
	AMRO	CBCH	DEJU	DUFL	GCKI	HETH	HEWA	MAWA	OCWA	PSFL[c]
Age			-0.74			0.71				
DWD1			0.74				-0.73			
DWD3										
Bare									-0.86	
Moss		0.72								
Ground									-0.86	
Fern								-0.71		
Conlow							0.86			
Hwdlow									-0.68	
Contall		0.70			0.71		0.68			
Hwdtall							0.87			
Contree		0.72			0.72		0.69			
Hwdtree						0.78		0.79		
Grassht									0.71	
Conlowht							0.67			
Hwdlowht			-0.84							
Ctallht		0.67					0.80			
Ctree1		0.67								
Ctree2			-0.68			0.78				
Conba		0.70	-0.71		0.71					
Htree1							0.68	0.77		
Hwdba						0.71	0.76			
Snag2							-0.78			
Snag4										

Table 11, continued

Habitat Variables[b]	Bird Species[a]									
	AMRO	CBCH	DEJU	DUFL	GCKI	HETH	HEWA	MAWA	OCWA	PSFL[c]
Snag5							-0.70			
Snagsha										
Stream									0.80	
Streamin	0.72								0.88	
Ckedge				0.69						
Patch										
Contrast								-0.83		

Table 11, continued

Habitat Variables[b]	RSTO	RUHU[d]	SWTH[d]	WAVI[d]	WETA[d]	WCSP	WIWA	WIWR[c]	Rich[d]	Abund	Div[d]
					Bird Species[a]						
Age											
DWD1											
DWD3	-0.76										
Bare											
Moss											
Ground											
Fern							-0.70				
Conlow											
Hwdlow											
Contall											
Hwdtall						-0.73	0.73				
Contree											
Hwdtree											
Grassht											
Conlowht	0.81										
Hwdlowht											
Ctallht											
Ctree1											
Ctree2											
Conba											
Htree1							0.73				
Hwdba						0.74					
Snag2						0.67	-0.70				
Snag4						0.97					
Snag5											
Snag9	-0.66										

Table 11, continued

Habitat Variables[b]	Bird Species[a]									
	RSTO	RUHU[d]	SWTH[d]	WAVI[d]	WETA[d]	WCSP	WIWA	WIWR[c]	Rich[d]	Abund	Div[d]
Snagsha	-0.93										
Stream										0.77	
Streamin										0.78	
Ckedge	0.75										
Patch										0.73	
Contrast						0.66					

[a] AMRO = American robin, CBCH = Chestnut-backed chickadee, DEJU = Dark-eyed junco, DUFL = Dusky flycatcher, GCKI = Golden-crowned kinglet, HETH = Hermit thrush, HEWA = Hermit warbler, MAWA = MacGillivray's warbler, OCWA = Orange-crowned warbler, PSFL = Pacific-slope flycatcher, RSTO = Rufous-sided towhee, RUHU = Rufous hummingbird, SWTH = Swainson's thrush, WAVI = Warbling vireo, WETA = Western tanager, WCSP = White-crowned sparrow, WIWA = Wilson's warbler, WIWR = Winter wren, Rich = Species richness, Abund = Total abundance, Div = Species diversity

[b] See Table 3 for habitat variable descriptions

[c] This species was not detected in open-canopied stands

[d] No habitat variables were significantly associated with this species in open-canopied stands

area. Dusky flycatchers were positively associated with the percent of stand perimeter made up of permanent streams. MacGillivray's warblers were negatively associated with the percent cover of ferns. Orange-crowned warblers were negatively associated with percent cover of bare ground. Rufous-sided towhees were negatively associated with total snags/ha. No habitat variables were significantly associated with the abundance of rufous hummingbirds in open-canopy stands.

Habitat associations were significant for all 5 of the species that were more abundant in closed-canopy stands (Table 12). Golden-crowned kinglets were negatively associated with percent cover of hardwood shrubs 1.4 to 4.0 m tall. Hermit warblers were negatively associated with total length of streams within a stand. Swainson's thrushes were positively associated with the amount of dwd >41 cm dbh. Wilson's warblers were positively associated with the number of stems/ha of conifers <10 cm dbh. The abundance of chestnut-backed chickadees in closed-canopy stands was only correlated with one variable, elevation. This negative relationship was probably because younger stands tended to be at higher elevations, reflecting a recent trend toward sale planning at higher elevations because most available timber at lower elevations has been harvested.

Table 12. Spearman correlation coefficients for individual bird species abundance indices with habitat variables in 9 closed- canopy (20 to 34 years old) managed Douglas-fir stands on the Detroit Ranger District, Willamette National Forest, Oregon. Only significant ($P \leq 0.05$) correlations are shown.

Habitat	Bird Species[a]									
Variables[b]	AMRO	CBCH[c]	DEJU	DUFL[d]	GCKI	HETH	HEWA	MAWA	OCWA[d]	PSFL
Age								-0.82		
Slash			-0.68							-0.73
DWD1			-0.88							
DWD2										0.81
DWD3					0.70	-0.66				0.68
Ground			-0.71							
Herb						-0.90				
Fern										
Conlow			0.79							
Contall								0.69		
Hwdtall					-0.71					-0.81
Contree										
Herbht			0.68							
Hwdlowht						0.71				
Ctallht								0.76		
Ctree1										
Ctree2										
Ctree3								-0.86		
Ctree4										
Ctree5										
Htree1										-0.81
Htree2										0.85
Snag1										
Snag5										

Table 12, continued

Habitat Variables[b]	Bird Species[a]									
	AMRO	CBCH[c]	DEJU	DUFL[d]	GCKI	HETH	HEWA	MAWA	OCWA[d]	PSFL
Snag8	1.00									
Snagsha										0.68
Prcntrd										
Rdedge										
Stream							-0.67			
Streamin							-0.88			
Ckedge							0.80			
Patch										
Contrast								0.73		

Table 12, continued

Habitat Variables[b]	Bird Species[a] RSTO[d]	RUHU	SWTH	WAVI	WETA	WCSP[d]	WIWA	WIWR	Rich	Abund	Div
Age											
Slash											
DWD1				0.67							
DWD2											
DWD3			0.67								
Ground											
Herb											
Fern		-0.78									
Conlow											
Contall					-0.66						
Hwdtall											
Contree									-0.68		
Herbht					-0.76						
Hwdlowht		-0.76									
Ctallht											
Contreeht					0.80						
Ctree1							0.91		-0.84		
Ctree2					-0.83						
Ctree3											
Ctree4					0.86						
Ctree5					0.82						
Htree1											
Htree2											
Snag1							0.67		-0.89		
Snag5										0.76	
Snag8											

Table 12, continued

Habitat Variables[b]	Bird Species[a]										
	RSTO[d]	RUHU	SWTH	WAVI	WETA	WCSP[d]	WIWA	WIWR	Rich	Abund	Div
Ssnag									-0.73		
Msnag							0.72	0.73		0.87	
Snagsha											
Prcntrd								0.72			0.70
Rdedge										-0.72	
Stream									0.70		0.67
Streamin				-0.71					0.69		0.75
Ckedge							0.76		-0.75	0.75	
Patch			0.67					0.66			
Contrast				-0.76	-0.82						

[a] AMRO = American robin, CBCH = Chestnut-backed chickadee, DEJU = Dark-eyed junco, DUFL = Dusky flycatcher, GCKI = Golden-crowned kinglet, HETH = Hermit thrush, HEWA = Hermit warbler, MAWA = MacGillivray's warbler, OCWA = Orange-crowned warbler, PSFL = Pacific-slope flycatcher, RSTO = Rufous-sided towhee, RUHU = Rufous hummingbird, SWTH = Swainson's thrush, WAVI = Warbling vireo, WETA = Western tanager, WCSP = White-crowned sparrow, WIWA = Wilson's warbler, WIWR = Winter wren, Rich = Species richness, Abund = Total abundance, Div = Species diversity

[b] See Table 3 for habitat variable descriptions

[c] No habitat variables were significantly associated with this species in closed-canopied stands

[d] This species was not detected in closed-canopied stands

DISCUSSION

Habitat characteristics

The differences seen in many of the habitat characteristics among the age classes are consistent with what would be expected under normal successional processes following a major disturbance, in this case harvest by clearcutting, in managed stands up to about 34 years old. In another Oregon study, hardwood shrubs were dominant for the first 10 years after harvesting and slash burning occurred (Steen 1966). In my study shrubs were dominant in age class 1, which included 5- to 9-year-old stands. Long and Turner in Mitchell (1983) described rapid reductions in understory vegetation that occurred in Douglas-fir stands 22 to 42 years old. Hardwood shrubs and tall herbaceous species made up a large part of the understory in all of the open-canopy stands (up to 19 years old) in my study, but in stands that had achieved canopy closure (20 to 34 years old) the shrubs were dead from lack of sun and the tall herbaceous species had been replaced by shade-tolerant mat-forming species, mosses, and bare ground. Average conifer tree heights, diameters, canopy closure, and shrub conditions in my study were consistent with descriptions given by Bruce et al. (1985:26) and Hall et al. (1985:27-28) for shrub, open sapling-pole, and closed sapling-pole stand conditions following clearcut regeneration treatment with broadcast burning of slash in temperate coniferous forests of Oregon.

Some of the habitat characteristics measured in my study are not influenced as much by successional processes as by stand treatment after harvest such as site preparation burning. Slash, down woody debris amounts and most snag variables fall into this category. Small, decay class 1 snags (10 to 30 cm dbh) are probably influenced by both stand treatment and succession over the range of stand ages examined in my study. High abundance of these snags in age class 1 is probably attributable to remnant snags persisting from the stands that existed prior to harvest. These snags probably fall and decrease in abundance during age classes 2-3, and then begin to increase again as recruitment by suppression mortality and root rot occurs in age classes 4-6.

Bird community parameters

The lack of any pattern for total abundance, species richness, and diversity may be caused by low sample sizes and the high variability in habitat conditions over the range of stand ages, which in turn resulted in high variability for total abundance estimates (2.6 to 7.1 birds per plot per visit per stand) and species richness estimates (12 to 23 species) for individual stands. In 2- to >30-year-old Douglas-fir stands of northwestern California, Marcot (1984) reported the highest numbers of species and highest densities in stands of the late shrub/sapling stage. In my study, both the highest and lowest estimates of total abundance and species richness occurred in the late shrub/sapling stage, though the differences were not statistically different.

It was more informative to examine how the overall bird community composition changed over the range of stand ages studied. There appeared to be a threshold of community change at the point of canopy closure, a pattern also noted by Marcot (1984) in young Douglas-fir stands in northwestern California. Stands between ages 5 and 19 were dominated by bird species characteristic of open-canopy habitats while stands between ages 20 and 33 were dominated by species characteristic of closed-canopy habitats. The rapid rate of bird community change that occurred in the open-canopy stands suggests that over the relatively short range of stand ages making up the early and late shrub seral stages the bird community experiences a far more rapid turnover than occurs in closed canopy stands. Therefore, an 8-year-old stand will not have the same bird community as a 14-year-old stand. But once canopy closure occurs, the bird community varies little and a 26-year-old stand will have roughly the same species as a 32-year-old stand.

The list of the 5 most abundant species found in the closed-canopy stands is similar to that found in young closed-canopy stands in several recent studies in western Oregon and Washington, with the exception that most of those studies listed the winter wren and Pacific-slope flycatcher (Table 13). These 2 species generally replaced the dark-eyed junco and Swainson's thrush on the list in my study. The fact that stands in my

Table 13. Comparison of the 5 most abundant bird species in young managed Douglas-fir stands (20 to 80 years old) among recent studies in western Oregon and Washington.

OR Cascades			OR Coast Range	WA Cascades		
Age (years)			Age (years)	Age (years)		
20-34[a]	32-53[b]	30-80[c]	40-72[d]	30-40[e]	50-70[e]	55-80[f]
HEWA[g]	HEWA	HEWA	CBCH	WIWR	WIWR	HEWA
DEJU	WIWR	WIWR	WIWR	PSFL	PSFL	WIWR
CBCH	SWTH	CBCH	HEWA	GCKI	CBCH	GCKI
GCKI	GCKI	HAFL	GCKI	CBCH	GCKI	PSFL
SWTH	HETH	PSFL	PSFL	HEWA	WIWA	DEJU

[a] This study, 1993 results
[b] McComb and Tappeiner, Oregon State Univ., ongoing study, 1992-1993 results
[c] Gilbert and Allwine 1991
[d] Carey et al. 1991
[e] Aubry et al., USDA Forest Service, PNW Research Sta., Seattle, WA, ongoing study, 1993-1995 results
[f] Manuwal 1991
[g] HEWA = hermit warbler, DEJU = dark-eyed junco, CBCH = chestnut-backed chickadee, GCKI = golden-crowned kinglet, SWTH = Swainson's thrush, WIWR = winter wren, HETH = hermit thrush, PSFL = Pacific-slope flycatcher, HAFL = Hammond's flycatcher, WIWA = Wilson's warbler

study were younger than most of those in the comparison studies probably explains why juncos and Swainson's thrushes (both of which tend to be associated with young stands) were more abundant than winter wrens and Pacific-slope flycatchers (both of which tend to also be associated with mature and old-growth conditions).

In studies of mature and old-growth stands in the region, species that commonly occurred on the list of the 5 most abundant species (varied thrush, brown creeper, and red-breasted nuthatch) were noticeably scarce or missing from closed-canopy stands in my study (Carey et al. 1991, Gilbert and Allwine 1991, Manuwal 1991). I tallied 2 detections of varied thrushes in 2 of my oldest stands and 6 detections of red-breasted nuthatches in several of the closed-canopy stands. I did not detect any brown creepers in this study.

It is also notable that I had few detections of western bluebirds (6 detections, 3 stands), house wrens (1 detection), and lazuli buntings (1 pair of birds seen twice in one stand) in the youngest stands in my study, and no detections of these species in stands > 8 years old. Marcot (1984) listed both the western bluebird and the house wren as 2 of the 5 most abundant species in grass/forb seral stage stands in northwestern California; McComb and Hunter (in prep.) found the house wren to be the most abundant secondary cavity nester in 3- to 5-year-old clearcuts in the western Oregon Cascades; and Vega (1993) recorded 34 detections of lazuli buntings in four 2-to 6-year-old clearcuts in the western Oregon

Cascades. I also recorded just 1 detection of a song sparrow in a 14-year-old stand, while Morrison and Meslow (1983) listed the song sparrow as one of the 5 most abundant species in 4- to 9-year-old clearcuts in the Oregon Coast Range and Vega (1993) recorded 38 detections in 8 2-to 6-year-old clearcuts. The low abundance of western bluebirds and house wrens, both secondary cavity nesters, is probably caused by a lack of snags. A study by Schreiber and deCalesta (1992) in the Oregon Coast range found snags used by house wrens were in decay classes 3 and 4 and averaged 77.1 cm dbh; snags used by western bluebirds were in decay classes 3 and 4 and averaged 71.3 cm dbh. The average total snags/ha in the 3 youngest age classes ranged from 1.4 to 9.0, with the majority of snags measuring 10 - 30 cm dbh and classified as decay class 1. Where snags > 51 cm dbh were available they tended to be mostly decay class 5.

For most of the species examined in my study, Meslow's (1978) assignment of breeding birds into five seral stages of Douglas-fir communities is corroborated by my results. For example, he predicted rufous-sided towhees and orange-crowned warblers would nest primarily in the 8- to 15-year-old shrub sapling stage, and peak abundances of both species did occur in the 10- to 14-year-old stands in age class 2. Differences in expected breeding species included the chestnut-backed chickadee, which Meslow listed as present but not breeding in second growth 16- to 40-year-old stands and the rufous-hummingbird, which he listed as present but not breeding in shrub-sapling 8- to 15-year-old stands. Observations from my study indicate both of these species may have been breeding in those age stands. In addition, Meslow listed the varied thrush as present but not breeding in 1- to 7-year-old stands, and as a breeder in 8- to 15- and 16- to 40-year-old stands. However, I recorded only 2 detections of varied thrushes during the entire survey season.

The effort by Bruce et al. (1985) also was largely supported by the results of my study. The only notable exceptions include the Pacific-slope flycatcher, western tanager, and hermit warbler, which they listed as not breeding in stands younger than large sawtimber. Observations from my study indicate that these species may be breeding in much younger stands. And like Meslow (1978), they listed the varied thrush as breeding in closed sapling-pole conditions, whereas my observations did not support this.

Species with increasing abundance

The 8 species showing a pattern of increasing abundance with increasing stand age (chestnut-backed chickadee, golden-crowned kinglet, hermit thrush, hermit warbler, Pacific-slope flycatcher, Swainson's thrush, Wilson's warbler, and winter wren) belong to 2 foraging guilds (canopy gleaners, ground gleaners) (de Graff et al. 1985) and 3 nesting guilds (conifer tree nesters, hole nesters, ground/low shrub nesters) (Ehrlich et al. 1988). The percent cover of bare ground, moss, and herbaceous species, percent cover of conifer tree canopy, and densities of trees > 10 cm dbh all increased with increasing stand age, providing habitat for these species in the older stands.

Marcot (1984) and Raphael et al. (1988) reported similar patterns for chestnut-backed chickadees, golden-crowned kinglets, hermit warblers, Pacific-slope flycatchers, and winter wrens in northwestern California over a range of seral stages from grass/forb to medium sawtimber (Marcot 1984) and brush/sapling to mature (Raphael et al. 1988). McGarigal (1993), McGarigal and McComb (1995, Oregon Coast Range), Manuwal and Huff (1987, western Washington Cascades), and Hansen et al. (1995, western Oregon Cascades) reported a similar pattern for chestnut-backed chickadees and winter wrens.

Though present, none of the species listed above appear to reach their peak abundance in young seral stages. Peak abundances of hermit warblers occurred in medium sawtimber (roughly 45 to 80 years old) in studies by Marcot (1984) and Manuwal and Huff (1987). Hansen et al. (1995), however, recorded about equal peak abundances in young (30 to 50 years old), mature, and old-growth stands. The other 4 species are all reported as reaching peak abundances in either mature and/or old-growth stands, though in a study by Hansen et al. (1995) golden-crowned kinglets showed a much greater abundance in young stands (30 to 50 years old), and in a study by Manuwal and Huff (1987) kinglets were slightly higher in abundance in young stands (42 to 75 years old).

Studies in the region have shown varying abundance patterns for hermit thrushes and Swainson's thrushes. All reported an increase in abundance from the youngest stands studied, but the seral stage in which peak abundance occurred differed. Peak abundances of hermit thrushes occurred in late shrub/sapling stands in a study by Marcot (1984) (though he did not examine old-growth stands), and in mature stands (150+) in a study by Raphael (1988). Manuwal and Huff (1987) reported peak abundances of both thrush species in old-growth (250+); and Hansen et al. (1995) reported peak abundances of both thrush species in young stands (30 to 50 years old).

Species with decreasing abundance

The 4 species showing a pattern of decreasing abundance with stand age (American robin, dark-eyed junco, rufous hummingbird, and white-crowned sparrow) are ground and/or brush-foragers (de Graff et al. 1985). The junco and white-crowned sparrow nest on the ground, the robin and hummingbird nest in shrubs or small trees (Ehrlich et al. 1988). The percent cover of hardwood shrubs decreased greatly with increasing stand age, eliminating feeding and nesting habitat for the robins and hummingbirds. The percent cover of grasses and the height of herbaceous species also decreased with increasing stand age, eliminating food sources for the juncos and white-crowned sparrows. Though the percent cover of herbaceous species increased, the types of species changed with increasing stand age. Tall species such as fireweed (Epilobium angustifolium) whose flowers are utilized by hummingbirds (pers. obs.) and whose seeds are probably eaten by juncos and sparrows, were replaced by low, mat-forming species such as whipplevine (Whipplea modesta).

All 4 species may reach peak abundance in the earliest seral stages though they tend to be present in all seral stages, with the exception of the white-crowned sparrow which is limited to the earliest seral stage. Peak abundances of dark-eyed juncos have been reported in 2- to 6-year-old clearcuts (Hansen et al. 1995); in 3- to 7-year-old brushy clearcuts (Hagar 1960); in 1- to 20-year-old stands (Raphael et al. 1988); and in the early shrub/sapling stage (Marcot 1984). For the rufous hummingbird, Hansen et al. (1995) found equal peak abundances in clearcuts and clearcuts with green trees, while Manuwal and Huff (1987) found peak abundances in old-growth stands. Both Marcot (1984) and Raphael et al. (1988) recorded peak abundances for American robins in sawtimber stands, while peak abundances occurred in clearcuts and clearcuts with green retention trees in a study by Hansen et al. (1995). Robins were found in equal abundance in young (42 to 75 years old), mature (105 to 165 years old), and old-growth (250+) stands by Manuwal and Huff (1987). White-crowned sparrows were limited to 1- to 2-year-old weedy clearcuts and 3- to 7-year-old brushy clearcuts in a study by Hagar (1960). Hansen et al. (1995) only recorded white-crowned sparrows in clearcuts and clearcuts with green retention trees, though they were significantly more abundant in clearcuts without green trees.

Species with peaked abundance

The 4 species that appeared to have peak abundances in age class 2 (10- to 14-year-old stands) (dusky flycatcher, MacGillivray's warbler, orange-crowned warbler, and rufous-sided towhee) represent 3 foraging and 2 nesting guilds (de Graff et al. 1985, Ehrlich et al. 1988). Dusky flycatchers are classified as aerial foragers. MacGillivray's and orange-crowned warblers are shrub foragers. All 3 species are obligate shrub or shrub/tree nesters. Rufous-sided towhees are both ground foragers and nesters. Among the 3 open-canopy age classes, total shrub cover was actually lowest in age class 2, but this age class had the highest number of < 10 cm dbh hardwood stems/ha. Marcot (1984) reported identical patterns of abundance for all 4 species. Peak abundances of all 4 species occurred in 1- to 20-year-old stands in a study by Raphael et al. (1988), but because they did not analyze their results on a finer scale there is no way to know if a peak occurred in similar aged stands. Hansen et al. (1995) found higher abundances of MacGillivray's warblers in 2- to 6-year-old clearcuts with green retention trees than in clearcuts without green trees, and a few birds present in 30- to 50-year-old stands, but they did not include any stands between 6 and 29 years old.

Species not showing a pattern in abundance

The 2 species not showing a pattern in abundance over the range of stand ages studied - warbling vireo and western tanager - represent 1 nesting and 1 foraging guild (de Graff et al. 1985, Ehrlich et al. 1988). Both nest in trees and are canopy gleaners. Average conifer tree height and the number of larger diameter trees were greatest in age classes 5 and 6 where both species were most abundant. It is possible that the western tanagers detected in the younger age classes (1-2, 4) were using the stands for feeding only (Bruce et al. 1985).

Warbling vireos and western tanagers have been associated with young stands in western Oregon and Washington in studies by Carey et al. (1991) and Gilbert and Allwine (1991). Hansen et al. (1995) observed peak abundances of western tanagers in clearcuts with green retention trees. Several studies, however, have reported peak abundances in large sawtimber stage stands (Raphael et al. 1988, McGarigal 1993, McGarigal and McComb 1995). Manuwal and Huff (1987) found equal peak abundances of tanagers in young (42 to 75 years old) and mature (105 to 165 years old) stands. For warbling vireos, peak abundance estimates have been reported as occurring in mature stands (150+) (Raphael et al.

1988), young stands (42 to 75 years old) (Manuwal and Huff 1987), and in the late shrub/sapling stage (Marcot 1984).

CONCLUSION

Species that appear to reach their peak abundance in young open-canopy seral stages include American robin, dark-eyed junco, dusky flycatcher, orange-crowned warbler, MacGillivray's warbler, rufous hummingbird, rufous-sided towhee, and white-crowned sparrow and their abundances can be expected to remain steady or decrease on the Willamette National forest in future years if cutting continues as projected in the modified Forest Plan. It could be argued that these species would merely be moving back toward more historic population levels that existed before widespread harvesting began to change landscape patterns (Raphael et al. 1988). One possible source of concern for these species, however, is the shortened period of time that stands remain in an open-canopy stage when intensively managed. According to Long and Turner in Mitchell (1983), canopy closure should occur between 35 years of age for intensively managed Douglas-fir and 60 years for naturally regenerating Douglas-fir. Given that stands in my study reached full canopy closure at about 20 to 25 years old, the amount of time any one stand is available to species preferring open-canopy stands is truncated by up to 40 years. Ten additional species - chestnut-backed chickadee, golden-crowned kinglet, hermit thrush, hermit warbler, Pacific-slope flycatcher, Swainson's thrush, warbling vireo, western tanager, Wilson's warbler, winter wren - analyzed in my study were present in young closed-canopy stands but reach peak abundances in later seral stages. Though Raphael et al. (1988) concluded that none of the 60 species of birds they analyzed would be extirpated if all mature timber were eliminated from the Pacific Northwest, they did express particular concern for the hermit warbler and chestnut-backed chickadee whose breeding ranges are mostly limited to the Pacific Northwest. Some of these species may be benefitting from the fact that canopy closure is reached much sooner than in naturally regenerating stands.

The bird community changes rapidly over the course of the open-canopy seral stages from age 5 to about 19 or 20 years old, but remains relatively constant in the early closed-canopy seral stage from about 20 to 33 years old.

Scope and limitations

The method of survey used and stand level approach taken in this study limited analysis to diurnal songbirds. An important part of the avian community - hawks, owls, and woodpeckers - was therefore excluded from study as the point count method is not well suited to sampling these species. Because I also limited data analysis to that subset of the data that included only birds detected within the stand boundaries, even some songbirds which are associated with edge habitat, such as olive-sided flycatchers and western wood pewees, were not addressed in this study. Observations in the field also suggested that western tanagers and warbling vireos may be associated with edge habitat. Therefore, in spite of eliminating detections of these 2 species that occurred at the stand edge from the database, they did not exhibit a clear pattern of abundance and analysis at the interior stand level (versus landscape) may not have been sufficient to determine habitat associations. In addition, an ongoing study in west-central Idaho has shown that Swainson thrush densities were greatly under-estimated using the point count method versus spot mapping on a known population of birds, possibly caused by several unusual behaviors (such as "whisper" songs) exhibited by the species (J. C. Bednarz, pers. comm., Arkansas State Univ.).

One of the most important limitations of this study was that nest success and fecundity were not examined. For those species typically associated with older seral stages, for example, which were present and seemed to be breeding in 30- to 34-year-old stands in this study, it would be important to determine if they were breeding successfully. Additionally, Wolff (1995) has asserted that if individuals are surviving and producing at the same rate in habitats other than what has been identified as preferred habitat, then measures of habitat associations are superfluous. A related issue that was not examined because no nest searches were undertaken, was the degree of brown-headed cowbird parasitism. Brown-headed cowbirds were detected in 3 of the stands, including along a main forest road in a closed-canopy stand with no other adjacent open-canopy habitat.

This study was limited to 1 breeding season of data collection, with spring and early summer 1993 being cooler and wetter than usual. Though this may have affected actual abundance estimates, I believe the overall patterns of species abundance would be the same in spite of weather conditions. Results from avian monitoring that occurred in 1992 and 1993 on the Willamette National Forest seem to support this, as relative abundances stayed the same but total abundance decreased slightly in 1993 (DeSante et al. 1994). Because this study was limited to the breeding season, it is an incomplete picture of year-long habitat needs for resident songbirds. Marcot (1984) found seasonal changes in abundance patterns of birds among different young seral stage habitats which suggested changes in habitat requirements depending on the time of year.

Because this was an observational study and the "treatment" of age was not randomly applied, no cause and effect conclusions can be made. The results are not transferable to unmanaged, naturally regenerating stands. Higher and lower elevations are probably not comparable, both because of differences in stand growth rates and in avian community composition. For example, an open-canopy managed Douglas-fir stand in the foothills of the Oregon Coast Range may have bushtits (Psaltriparus minimus) and wrentits (Chamaea fasciata), while a young closed-canopy stand may have black-capped chickadees (Parus atricapillus) in place of, or in addition to, chestnut-backed chickadees.

Management implications

Obviously, no one seral stage provides preferred breeding habitat for all species of diurnal breeding birds in the western Oregon Cascades. Forest managers should be particularly concerned with those species that have been identified as showing significant long-term statewide declines according to Breeding Bird Survey (BBS) data (though see discussion on Raphael et al. below), species that are restricted to particular seral stages such as the white-crowned sparrow and house wren, and guilds of species such as cavity nesters which have specific habitat requirements. Species with sufficient sample sizes to analyze in my study and also showing a significant 23-year statewide decline according to BBS data include dark-eyed junco, orange-crowned warbler, rufous hummingbird, white-crowned sparrow, and western tanager (Andelman and Stock 1994). Species showing a significant 10-year decline, which is either indicative of a long-term decline or natural population fluctuations, include Swainson's thrush and Wilson's warbler. In some cases there are differences in species' trends between statewide BBS data and BBS data from only National Forest routes; species such as the rufous-sided towhee and dark-eyed junco are increasing on National Forest lands but decreasing statewide. Because only one species, the willow flycatcher, showed the reverse trend of decreasing on National Forest lands but stable or increasing statewide, I would suggest that National Forests have an important role to play in maintaining those species which are declining statewide, even if increasing on National Forests. While the declines shown by the BBS data may be a result of changing habitat conditions along migration corridors and on wintering grounds rather than on breeding grounds, or in addition to changes on breeding grounds, it is critical to still maintain preferred breeding habitats. An additional 5 species analyzed in my study had non-significant BBS trends - decreasing for American robin, hermit thrush, and MacGillivray's warbler, and stable or increasing for dusky flycatcher and warbling vireo. Two species, the hermit warbler and Pacific-slope flycatcher, were listed as not adequately sampled by BBS routes.

It is interesting that in spite of the fact that the total area of early seral stage habitat has increased in the past 100 years, many of the species listed above as declining over the past 10 to 23 years are ones that prefer such habitat. Raphael et al. (1988) provide a possible explanation for this when they suggest that the significant increases seen in populations of species associated with early seral habitats has reached a peak in northwestern California and will now fall as stands in early seral conditions age into young forest. Because harvesting in Oregon and Washington has gone on longer and at a greater level than in northwestern California, this may explain the decreases being observed in the region now.

At the time this study was initially proposed, the justification used was that 25% of the land tentatively suitable for timber harvest (418,016 ha) was currently in the 0- to 40-year age class and that in 150 years this would increase to 35%. With the Willamette Forest Plan now modified by the Record of Decision (USDA Forest Service 1994), the total area considered tentatively suitable for timber harvest has dropped from 418,016 ha to 148,240 ha. Of these 148,240 ha, 35% is currently in the 0- to 40-year age class and the 100 year projection is 34%. The original intent of this study was to describe the bird communities in these young stands because they would be making up such a large proportion of the area, now the concern may very well be their potential scarcity. The fact that intensive management truncates the time a stand remains in the early seral stage which some species prefer, and speeds up the change to closed canopy conditions which others prefer, creates a dilemma for land managers. Pre-commercial thinning is one tool that can be used to create or maintain open sapling-pole conditions if the objective is to manage for open-canopy species (Hall et al. 1985). To maintain and promote hardwood shrubs and trees, control of competing vegetation should be limited to those immediately adjacent to conifer seedlings. Another objective may be to provide habitat for species such as Swainson's thrushes and Wilson's warblers which are associated with hardwood trees in closed-canopy stands. Stand treatment prescriptions could include only light control of hardwoods during the re-establishment stage as mentioned above, and retaining hardwood trees in 0.1-ha plots scattered throughout the stand (Marcot 1984). For stands that are already near or in the early closed-canopy stage where the hardwoods are being shaded out, it would be worthwhile to try releasing several clumps of hardwoods scattered throughout the stand from the conifers that are overtopping them. Total bird abundance was best predicted by patchiness, which can be manipulated by the design of pre-commercial thin treatments. Thinning some portions of a stand more heavily than others, and leaving some portions unthinned would help contribute to overall patchiness. Leaving log piles, root rot patches, and groups of hardwood trees also would contribute to patchiness. Root rot patches could be planted with resistant conifer and hardwood species, while leaving the existing snags. Overall richness and diversity were best predicted by the total length of streams within stands, which is not under management control.

Stand prescriptions that retain or create 14 snags/ha 28 - 128 cm dbh and 6.4 - 25 m tall to provide for 2 nests of secondary cavity nests per hectare would benefit both the chestnut-backed chickadee and western bluebirds and house wrens which were nearly absent from study stands and may be restricted to breeding in young seral stages (McComb and Hunter, in prep; Schreiber and deCalesta 1992). All of the stands in my study had been harvested prior to 1990 when the current Forest Plan (which requires 3.77 - 4.82 snags/ha $\geq$ 46 cm dbh, 6 m tall, and in decay classes 2 - 4 to maintain population levels of primary cavity nesters at 100% of the potential) was adopted and only rarely had an average of 1 snag/ha in decay classes 2 - 4 and > 30 cm dbh; most had < 0.5 snags/ha (USDA Forest Service 1990).

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APPENDICES

Appendix 1

Total number of new detections summed over 4 visits for all species detected during point-count surveys, May - July, 1993, in 18 managed Douglas-fir stands ranging in age from 5 to 34 years old on the Detroit Ranger District, Willamette National Forest, Oregon. Stands listed in order of increasing stand age.

Species	SEF	Riven	Tunn	Boul	Rain	Cub	Mc4	Mc22	Box	Log	Mc5	Cent	Nort	Stra	Hawk	Coop	Tom	Leon	Total
American robin (*Turdus migratorius*)	3	7	2	1	4	7			2	2	1		1			1	1	1	33
black-headed grosbeak (*Pneucticus melanocephalus*)											1							1	2
brown-headed cowbird (*Molothrus ater*)		1				1					1								3
chestnut-backed chickadee (*Parus rufescens*)	1		1	2	2	3	4	1	9	5	9	5	12		4	8[a]	7	10	83
chipping sparrow (*Spizella passerina*)		8[a]																	8
common nighthawk (*Chordeiles minor*)				1															1
dark-eyed junco (*Junco hyemalis*)	22	22	26	16	12	27	14	8	16	14	4	8	10	3	6	7	6	5	226
dusky flycatcher (*Empidonax oberholseri*)	11	2	8	11[a]	7	7	1	7											54
fox sparrow (*Passerella iliaca*)				1			3							1					5
golden-crowned kinglet (*Regulus satrapa*)						1	5		2	5	1	3	3	5	13	3	9	2	52

Appendix 1, continued

Species	SEF	Riven	Tunn	Boul	Rain	Cub	Mc4	Mc22	Box	Log	Mc5	Cent	Nort	Stra	Hawk	Coop	Tom	Leon	Total
gray jay (*Perisoreus canadensis*)			4				4	2		4	1	2							17
hairy woodpecker (*Picoides villosus*)	6[a]	3	1	1		1				1	2	2	1				1		19
Hammond's flycatcher (*Empidonax hammondii*)											1		4			1	1	3	10
hermit thrush (*Catharus guttatus*)							2	4	4	3	7		5	1	3	3	6	5	43
hermit warbler (*Dendroica occidentalis*)					3	5	3	2	3	17	13	16	18	15	24	13	19	24	175
house wren (*Troglodytes aedon*)		1																	1
lazuli bunting (*Passerina amoena*)		4																	4
MacGillivray's warbler (*Oporornis tolmiei*)	10	7	3	10	9	16	3	10	14	8	8	4	4	3		1	5	1	116
mountain bluebird (*Sialia currucoides*)			1																1
Nashville warbler (*Vermivora ruficapilla*)										1									1
northern flicker (*Colaptes auratus*)	5	2	4[a]			1			1	3	1				1				18
northern pygmy-owl (*Glaucidium gnoma*)					1														1

Appendix 1, continued

Species	SEF	Riven	Tunn	Boul	Rain	Cub	Mc4	Mc22	Box	Log	Mc5	Cent	Nort	Stra	Hawk	Coop	Tom	Leon	Total
orange-crowned warbler (*Vermivora celata*)	1	4			2	7			3										17
olive-sided flycatcher (*Contopus borealis*)	2			3	1				3								1		10
Pacific-slope flycatcher (*Empidonax difficilis*)												5	1			4	5		15
pileated woodpecker (*Dryocopus pileatus*)		1																	1
pine siskin (*Carduelis pinus*)		6												1					7
purple finch (*Carpodacus purpureus*)									1					2					3
red-breasted nuthatch (*Sitta canadensis*)			1								2			1		1		2	7
red-breasted sapsucker (*Sphyrapicus ruber*)											1				2				3
red-tail hawk (*Buteo jamaicensis*)			1																1
ruffed grouse (*Bonasa umbellus*)												1		1	1	2	2		7
rufous hummingbird (*Selasphorus rufus*)	14	12	2	4	12	8	1	3	13	9		2	1	2	1	1		4	89
rufous-sided towhee (*Pipilo erythrophthalmus*)	1	1	4	13[a]	5	4	5	2											35

Appendix 1, continued

Species	SEF	Rive	Tunn	Boul	Rain	Cub	Mc4	Mc22	Box	Log	Mc5	Cent	Nort	Stra	Hawk	Coop	Tom	Leon	Total
song sparrow (*Melospiza melodia*)						1													1
Steller's jay (*Cyanocitta stelleri*)	3	5		1	5	6	3	3	2	5	5	5	4	5	4		8	4	68
Swainson's thrush (*Catharus ustulatus*)						6	2			3	8	5	2	1	10	5	5	2	49
Townsend's solitaire (*Myadestes townsendi*)		3	2							1				1					7
tree swallow (*Tachycineta bicolor*)		7[a]																	7
varied thrush (*Ixoreus naevius*)																1	1		2
violet-green swallow (*Tachycineta thalassina*)	2	5																	7
warbling vireo (*Vireo gilvus*)	2			3	1	2				1				3	2	1	1	4	20
western bluebird (*Sialia mexicana*)	1	3	2																6
western tanager (*Piranga ludoviciana*)	6	7			2			1	1	2	2	2	1	3	2	3	4	2	38
white-crowned sparrow (*Zonotrichia albicollis*)		6	6																12
willow flycatcher (*Empidonax traillii*)		1			4														5

Appendix 1, continued

Species	SEF	Riven	Tunn	Boul	Rain	Cub	Mc4	Mc22	Box	Log	Mc5	Cent	Nort	Stra	Hawk	Coop	Tom	Leon	Total
Wilson's warbler (*Wilsonia pusilla*)					4	6		2			2	6	7		7	2	6	7	49
winter wren (*Troglodytes troglodytes*)					1					1	4	2	1		1	1	8		19
yellow-rumped warbler (*Dendroica coronata*)											1				2				3

[a] Nest and/or flightless young found within boundaries of study stand

Appendix 2

Mean number of birds per plot per visit per stand, F, and *P*-value from ANOVA on individual bird species in 6 age classes of managed Douglas-fir stands on the Detroit Ranger District, Willamette National Forest, Oregon.

	Age Class (years)							
Species	5-9	10-14	15-19	20-24	25-29	30-34	F	*P*-value
American robin	0.2	0.2	0.0	0.0	0.0	0.0	na[a]	0.326
	(0.1)	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)		
Chestnut-backed chickadee	0.0	0.1	0.2	0.4	0.3	0.5	2.76	0.069
	(0.0)	(0.1)	(0.1)	(0.1)	(0.2)	(0.1)		
Dark-eyed junco	1.3	1.1	0.8	0.5	0.4	0.4	14.20	0.000
	(0.1)	(0.1)	(0.1)	(0.2)	(0.1)	(0.1)		
Dusky flycatcher	0.4	0.5	0.2	0.0	0.0	0.0	4.98	0.011
	(0.1)	(0.1)	(0.2)	(0.0)	(0.0)	(0.0)		
Golden-crowned kinglet	0.0[b]	0.0	0.1	0.2	0.4	0.3	2.61	0.081
	(0.0)	(0.0)	(0.1)	(0.1)	(0.2)	(0.1)		
Hermit thrush	0.0	0.0	0.2	0.2	0.1	0.3	1.84	0.179
	(0.0)	(0.0)	(0.1)	(0.1)	(0.1)	(0.0)		
Hermit warbler	0.0[c]	0.2	0.2	1.0	1.3	1.1	27.76	0.000
	(0.0)	(0.1)	(0.0)	(0.2)	(0.1)	(0.2)		
MacGillivray's warbler	0.4	0.7	0.6	0.4	0.2	0.1	5.10	0.010
	(0.1)	(0.1)	(0.2)	(0.1)	(0.1)	(0.1)		
Orange-crowned warbler	0.1	0.2	0.1	0.0	0.0	0.0	na[a]	0.297
	(0.1)	(0.1)	(0.1)	(0.0)	(0.0)	(0.0)		

Appendix 2, continued

Species	Age Class (years)						F	*P*-value
	5-9	10-14	15-19	20-24	25-29	30-34		
Pacific-slope flycatcher	0.0	0.0	0.0	0.1	0.0	0.2	na[a]	0.221
	(0.0)	(0.0)	(0.0)	(0.1)	(0.0)	(0.1)		
Rufous hummingbird	0.5[c]	0.6	0.3	0.2	0.1	0.1	1.83	0.182
	(0.2)	(0.2)	(0.2)	(0.1)	(0.1)	(0.1)		
Rufous-sided towhee	0.1	0.5	0.2	0.0	0.0	0.0	na[a]	0.055
	(0.1)	(0.2)	(0.1)	(0.0)	(0.0)	(0.0)		
Swainson's thrush	0.0	0.1	0.0	0.4	0.2	0.2	1.52	0.255
	(0.0)	(0.1)	(0.0)	(0.1)	(0.2)	(0.1)		
Warbling vireo	0.0	0.0	0.0	0.0	0.1	0.1	na[a]	0.263
	(0.0)	(0.0)	(0.0)	(0.0)	(0.1)	(0.1)		
Western tanager	0.1[b]	0.0	0.0	0.0	0.1	0.2	1.70	0.210
	(0.1)	(0.0)	(0.0)	(0.0)	(0.1)	(0.2)		
White-crowned sparrow	0.2	0.0	0.0	0.0	0.0	0.0	na[a]	0.075
	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)		
Wilson's warbler	0.0[c]	0.2	0.1	0.2	0.3	0.3	1.54	0.250
	(0.0)	(0.1)	(0.1)	(0.2)	(0.2)	(0.1)		
Winter wren	0.0	0.0	0.0	0.1	0.0	0.1	na[a]	0.203
	(0.0)	(0.0)	(0.0)	(0.1)	(0.0)	(0.1)		
Total abundance[d]	4.6	4.9	3.1	4.5	3.9	4.0	0.85	0.450
	(1.3)	(0.6)	(0.3)	(0.5)	(0.4)	(0.5)		

Appendix 2, continued

Species	Age Class (years)						F	P-value
	5-9	10-14	15-19	20-24	25-29	30-34		
Species richness	18.3	16.0	13.3	18.3	16.3	17.0	1.76	0.196
	(2.3)	(1.5)	(0.7)	(1.8)	(0.3)	(0.6)		
Species diversity	1.06	1.03	0.98	1.11	1.02	1.08	1.04	0.438
	(0.08)	(0.06)	(0.01)	(0.02)	(0.03)	(0.03)		

[a] Friedman Two-way test comparing sample medians used; no F to report
[b] Means are untransformed data; F values and *P*-values are from analysis on LOG+0.1-transformed data
[c] Means are untransformed data; F values and *P*-values are from analysis on square-root-transformed data
[d] Total abundance = Total # of detections per plot per visit per stand for all bird species detected on > 1 visit combined