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BREEDING BIRD RESPONSES TO THREE SILVICULTURAL TREATMENTS IN THE OREGON COAST RANGE

Carol L. Chambers,[1,4] William C. McComb,[2,5] and John C. Tappeiner II[3]

[1]*Department of Forest Resources, Oregon State University, Corvallis, Oregon 97331 USA*
[2]*Department of Forest Science, Oregon State University, Corvallis, Oregon 97331 USA*
[3]*U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, 3200 Jefferson Way, Corvallis, Oregon 97331 USA*

Abstract. Silvicultural alternatives to clear-cutting have been suggested to promote development, retention, or creation of late-successional features such as large trees, multilayered canopies, snags, and logs. We assessed bird response to three silvicultural alternatives to clear-cutting that retained structural features found in old Douglas-fir (*Pseudotsuga menziesii*) forests and that imitated natural disturbance regimes more closely than did traditional clear-cutting: (1) small-patch group selection treatment representing a low-intensity disturbance; (2) two-story treatment, representing a moderate to high-intensity disturbance; and (3) modified clear-cut treatment, representing a high-intensity disturbance. We counted diurnal breeding birds 1 yr prior to and 2 yr after harvest to estimate effects of the silvicultural treatments on bird communities compared with uncut controls. The small-patch group selection treatment was most similar in species composition to control stands. The two-story treatment was more similar to the modified clear-cut treatment. Ten bird species remained abundant following the small-patch group selection treatment. They declined in abundance in modified clearcuts and two-story stands. These species included four neotropical migratory species and five species with restricted geographic ranges and habitat associations. Nine species increased in response to moderate and/or high-intensity disturbances. This group included a larger proportion of species that were habitat generalists. Silvicultural treatments imitating low-intensity disturbances were most effective in retaining bird communities associated with mature forest; high-intensity disturbances such as the two-story and modified clear-cut treatments greatly altered bird community composition. Bird responses to the silvicultural treatments that we studied indicate that a variety of stand types is needed to meet needs of all species.

Key words: bird communities; forest management; green tree retention; natural disturbance regimes; neotropical migratory birds; new forestry; Oregon Coast Range; Pseudotsuga menziesii; *silviculture; uneven-aged management.*

Introduction

Mature and old-growth forests once dominated large areas of the Pacific Northwest. Landscape changes were initiated by natural disturbances such as windthrow, insect damage, and fires that varied in spatial extent, frequency, and intensity. Small, localized events such as the death of an individual tree created fine-scale changes in species composition, whereas large disturbances such as wildfires and prolonged droughts caused reorganization of the entire species assemblage (Urban et al. 1987, Spies et al. 1990). Disturbances affecting large patches on the landscape (100–10 000 ha) recurred only every 300–700 yr in western Oregon. Return intervals were 100–200 yr for smaller disturbances that created gaps of 0.01–0.1 ha (Spies and Franklin 1989). Presumably, the animal species occupying Douglas-fir (*Pseudotsuga menziesii*) forests persisted within disturbance patterns of the pre-European settlement period.

The extensive use of clear-cutting in the Pacific Northwest over the past 50 yr has affected the forest landscape by rescaling natural disturbances both temporally and spatially. Large areas have been harvested on rotations that were much shorter than the life-span of the original trees. Much of the landscape is now dominated by second-growth, even-aged stands of Douglas-fir that differ greatly in stand density, edge length, patch size, and stand configuration from primeval landscapes (Harris 1984, Franklin and Forman 1987). This change from natural disturbance levels may be expected to favor behaviorally plastic species (Urban et al. 1987) and may eventually lead to decrease or extirpation of some animal species (Mannan and Meslow 1984, Forest Ecosystem Management Assessment Team 1993).

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[4] Present address: School of Forestry, College of Ecosystem Science and Management, P.O. Box 15018, Northern Arizona University, Flagstaff, Arizona, 86011 USA.

[5] Present address: Department of Forestry and Wildlife Management, Holdsworth Natural Resources Center, P.O. Box 34210, University of Massachusetts, Amherst, Massachusetts 01003 USA.

Silvicultural alternatives to clear-cutting have been proposed for Federal lands (USDA Forest Service and USDI Bureau of Land Management 1994). These silvicultural systems are to promote development, retention, or creation of late-successional features (large trees, diverse plant species, multilayered stands, snags, and large logs) (USDA Forest Service and USDI Bureau of Land Management 1994), and they may more closely mimic presettlement disturbance regimes. Long-rotation, even-aged (e.g., green-tree retention with live trees retained in either uniform spacing or aggregated in clumps) and uneven-aged (e.g., group selection) silvicultural systems have been suggested as management options (USDA Forest Service and USDI Bureau of Land Management 1994).

Uneven-aged silvicultural systems may most closely mimic the fine-scale disturbances that once predominated in these Douglas-fir forests and benefit wildlife species associated with mature forests (McComb et al. 1993). Long-rotation, even-aged systems simulate more intense disturbances (e.g., windthrow), but may provide habitat for species associated with mature forests because some attributes of old-growth forests would be retained (e.g., large trees, snags, logs).

As alternative management techniques are applied to forested landscapes, resource managers need to be able to assess effects of changing conditions on wildlife populations. We hypothesized that the degree of timber removal (or disturbance) would cause the abundance of various bird species to decline, increase, or show no response to the disturbance. These responses might occur immediately after harvest, or there might be a lag effect, with bird abundance changing in response to harvest only after several years. The response would be dependent on the degree of habitat change caused by disturbance and niche breadth of the bird species.

Our objective was to compare the immediate (1–2 yr postharvest) response of bird communities to three silvicultural treatments representing a range of disturbance levels applied to mature Douglas-fir forests with uncut control stands in the east Central Oregon Coast Range.

Methods

Study area

We selected 29 stands in Oregon State University's 4800-ha McDonald-Dunn Forest (Fig. 1), located on the eastern edge of the Coast Range, north and northwest of Corvallis, Oregon, United States. Replicates consisting of 7–11 stands each were located at Lewisburg Saddle (T11S, R5W, Sec. 44, 8, 9, 16, 17), Peavy (T10S, R5W, Sec. 25, 35, 36), and Dunn (T10S, R5W, Sec. 14, 22, 23, 27). Replicates were ~3–5 km apart. Elevation ranged from 120 to 400 m.

Prior to treatment, stands were similar in species composition and habitat characteristics (Chambers 1996). Douglas-fir basal area averaged 38 m^2/ha in each stand prior to harvest; grand fir (*Abies grandis*) basal area averaged 1 m^2/ha. Hardwoods, including bigleaf maple (*Acer macrophyllum*), Oregon white oak (*Quercus garryana*), Pacific madrone (*Arbutus menziesii*), Pacific dogwood (*Cornus nuttallii*), red alder (*Alnus rubra*), Oregon ash (*Fraxinus latifolia*), and bitter cherry (*Prunus emarginata*), made up the remaining basal area (14 m^2/ha). Live tree densities (trees $\geq$20 cm dbh) averaged 537 trees/ha for conifers and 165 trees/ha for hardwoods. Snag densities (hardwood and/or conifer snags $\geq$30 cm dbh) averaged $\leq$1.9 snags/ha prior to treatment. Stands were 80–120 yr old, and were the outcome of natural regeneration following Euro-American settlement and the subsequent elimination of prairie and hillside burning by Native Americans. We selected an average stand size of 10 ha because it was large enough to sample diurnal breeding birds (most species have home ranges that would allow several individuals to occupy stands of this size; Brown 1985), but small enough to replicate within the same forest type (similar species composition, size, and age class) on McDonald-Dunn Research Forest. This size was similar to the 10–12 ha stand sizes typically managed on public lands. Our stands ranged from 5.5 to 17.8 ha in size; however, different sizes were equally represented among treatments and replicates.

Each replicate included at least one stand per silvicultural treatment (Table 1). Treatments were (1) small-patch group selection (one-third of the wood volume was removed in 0.2-ha circular patches; in an 8-ha stand, for example, we created ~13 0.2-ha patches); (2) two-story (three-quarters of the wood volume was removed, with remaining green trees [20–30/ha] scattered uniformly throughout the stand); and (3) modified clearcut, with 1.2 green trees/ha retained (Fig. 2). One control (unharvested) stand was designated in each replicate. One replicate was harvested each year for 3 yr. Harvesting began in fall 1989 and was completed by early spring 1991. Snags were created at an average density of 3.8 snags/ha in all but control stands (Chambers et al. 1997).

Bird sampling

We sampled diurnal breeding birds one year prior to harvest and for two years after harvest on all replicates. Birds were sampled from early May through mid-July 1989–1993, using the modified variable circular-plot (VCP) method described by Reynolds et al. (1980). Three VCPs were established in each stand, with plot centers $\geq$100 m from the stand edge and from other VCP centers. Bird counts began at sunrise and continued through mid-morning (0500 to 1000) on calm mornings. Each VCP was visited six times during the breeding season. Order of visitation was alternated among stands to account for seasonal variation in breeding phenology and hourly variation in bird activity. Counts were halted by rain or by winds >15 km/h.

Counts began 2 min after arrival at the VCP station

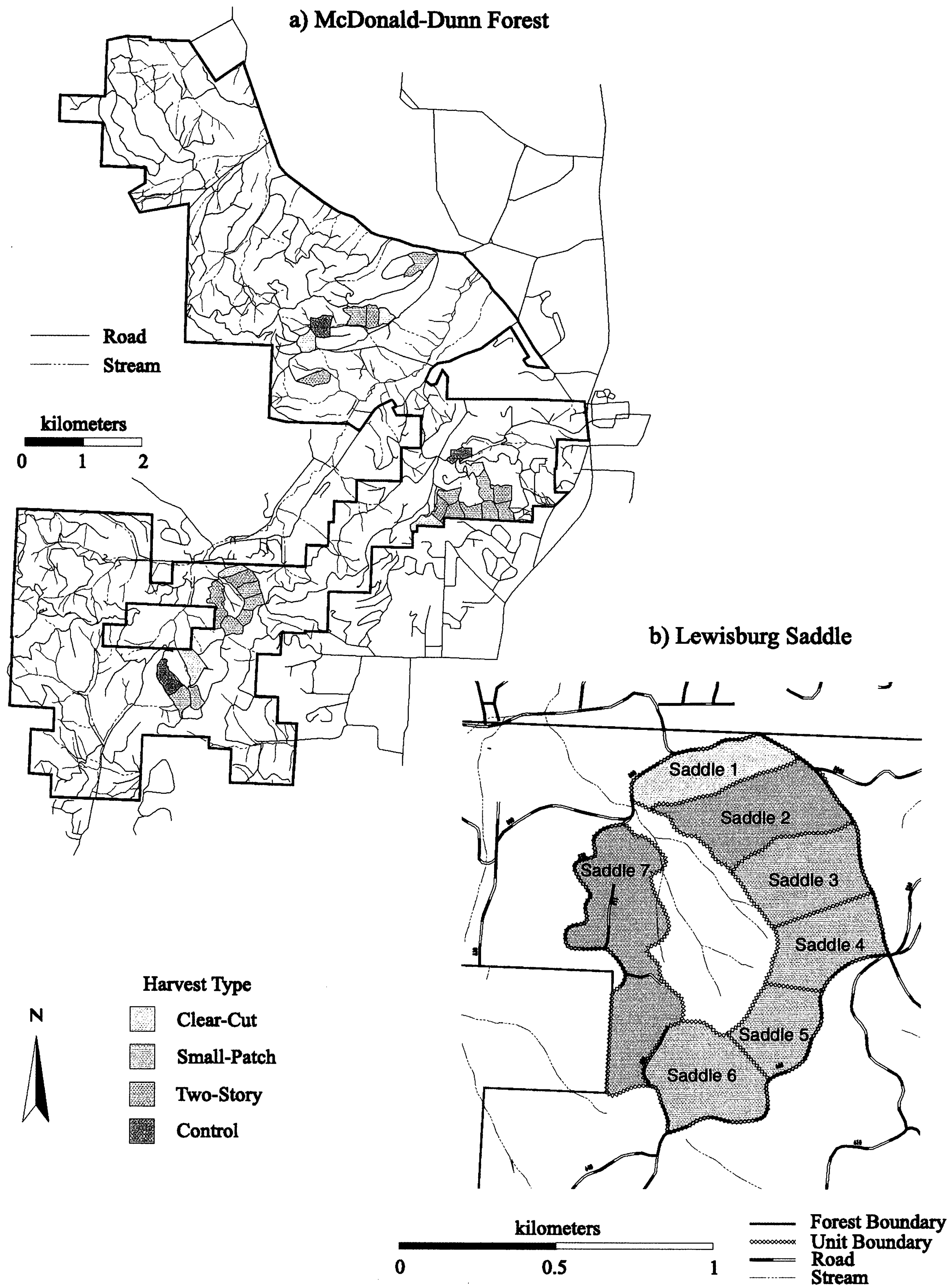

FIG. 1. (a) Layout of Lewisburg Saddle, Peavy, and Dunn replications in the McDonald-Dunn Research Forest, Corvallis, Oregon, United States. Silvicultural treatments are designated for each stand. (b) Layout of part of the Lewisburg Saddle replication in the McDonald-Dunn Research Forest, Corvallis, Oregon.

TABLE 1. Number of stands for each silvicultural and snag treatment by replicate.

Replicate	Control	Silvicultural treatment: Small-patch CL	Small-patch S	Two-story CL	Two-story S	Clear-cut CL	Clear-cut S
Lewisburg Saddle	1	3	3	1	1	1	1
Peavy	1	3	3	1	1	1	1
Dunn	1	1	1	1	1	1	1
Total	3	7	7	3	3	3	3

Notes: Silvicultural treatments were small-patch group selection (n = 14), two-story (n = 6), and modified clear-cut (n = 6). Snag treatments were clumped (CL) and scattered (S). Control stands were unharvested. No snags were created in control stands. Replicates were established in the McDonald-Dunn Research Forest, Corvallis, Oregon, United States, between 1989 and 1991.

to allow for resumption of normal bird activity. Each count lasted 8 min, during which time birds seen or heard singing in the stand were identified to species, their distance (in meters) from the VCP center was estimated, and their approximate location was mapped. Distances were recorded to the nearest meter for birds ≤10 m from VCP station, and to the nearest 5 m for birds >10 m. Locations of active bird nests found during bird counts or while walking between VCP stations also were recorded.

Four trained observers participated in sampling. Three of these conducted sampling throughout all four years, whereas the fourth sampled in two of the four years. Each observer sampled all VCPs 1–4 times.

Abundance (number of observations per 5 ha) for each species was averaged among VCPs within stands each year. Species richness (total number of species) was averaged among stands within each treatment by year. Similarity of bird communities in harvested stands was compared with pretreatment communities using a percentage similarity index (Brower et al. 1990).

Statistical analyses

We compared average detection distance (in meters) using individuals ≤75 m from the VCP station for each bird species ($n \geq 30$ observations) to insure that we did not eliminate a high percentage (e.g., >10%) of individuals and bias results of species analyses by underreporting observations. We analyzed data for bird species that had home ranges or territories small

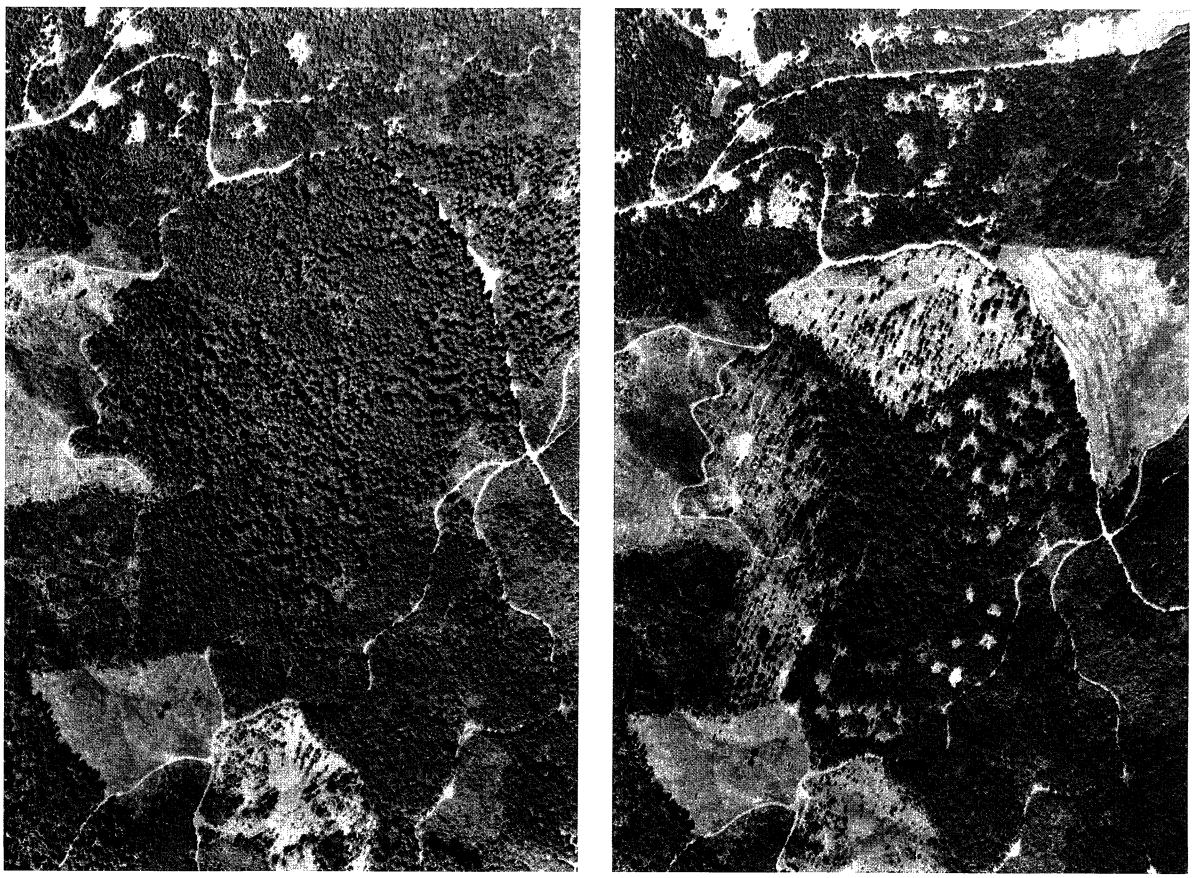

FIG. 2. Layout of part of the Lewisburg Saddle replication pre-harvest (left) and postharvest (right). The postharvest photo shows examples of small-patch group selection, two-story, and clear-cut treatments after harvest.

TABLE 2. Mean detection distance, in meters (with 1 SE in parentheses), from bird count point (VCP, variable circular plot) for bird species ($n \geq 30$ observations per species for individuals detected ≤ 75 m from VCP), at the McDonald-Dunn Research Forest, Oregon, 1989–1993.

Species†	Silvicultural treatment‡				Probability (*P*)§		
	Control	Small-patch	Two-story	Clear-cut	Year × Trt	Trt	Year
Pacific-slope Flycatcher	37 (2)	37 (1)	58 (3)	51 (5)	0.3	0.0001	0.03
Steller's Jay	50 (2)	51 (1)	48 (3)	59 (3)	0.2	0.2	0.03
Gray Jay	39 (4)	35 (3)	55 (8)	60‖	0.04	NA	NA
Chestnut-backed Chickadee	24 (1)	24 (1)	33 (3)	40 (3)	0.05	NA	NA
Bushtit	15 (2)	28 (3)	23 (4)	16 (10)	0.07	0.2	0.03
Golden-crowned Kinglet	25 (1)	23 (1)	28 (4)	36 (11)	0.003	NA	NA
Swainson's Thrush	42 (2)	43 (1)	41 (5)	43 (4)	0.002	NA	NA
Orange-crowned Warbler	40 (2)	36 (1)	35 (3)	44 (2)	0.3	0.2	0.02
Hermit Warbler	42 (1)	43 (1)	47 (4)	58 (5)	0.4	0.002	0.003
American Goldfinch	40‖	36 (10)	37 (4)	34 (3)	0.08	0.3	0.0001
Purple Finch	46 (5)	50 (2)	48 (2)	46 (3)	0.4	0.1	0.01

Note: NA indicates that interpretation of statistics is not appropriate, given the year by treatment interaction.

† Scientific names for birds are listed in the text.

‡ ANOVA was used to detect differences among treatments. Data represent detections for pretreatment, 1 yr post-treatment, and 2 yr post-treatment. Treatments were control (no harvest treatment); small-patch (one-third of the volume harvested by removing 0.2-ha patches); two-story (three-quarters of the volume removed uniformly); and clear-cut (1.2 green trees/ha retained).

§ *P* is the probability associated with differences in average detection distance for year by treatment interaction effect (Year × Trt), treatment effect (Trt), and year effect (Year).

‖ Standard error could not be calculated because there was only one observation.

enough to be included in our stands (≤8 ha). We used ANOVA for an unbalanced design (SAS Institute 1989) to detect differences in detection distances among treatments and years. For species with treatment by year interaction ($P \leq 0.05$), treatment effects ($P \leq 0.05$), or year effects ($P \leq 0.05$), we calculated 95% confidence intervals for treatment means. If the 95% CI placed some individuals at detection distances >75 m, we omitted the species from analyses to avoid biasing the sample (e.g., if Red Crossbills, *Loxia curvirostra,* averaged 65 m from VCP, but 95% confidence intervals placed individuals within a 50–80 m range of VCPs, <95% of individuals were probably being counted using a 75-m cutoff distance, and this species would be eliminated from statistical analyses).

Bird abundance (number of detections per 5 ha) and species richness were compared among treatments for the 3-yr period (pretreatment, 1 yr post-treatment, and 2 yr post-treatment). We calculated bird community similarity (percentage similarity) for pretreatment vs. 1 yr post-treatment and for pretreatment vs. 2 yr post-treatment, and used ANOVA to detect treatment differences. We used least squares means tests to detect differences among treatments (SAS Institute 1989).

Abundance of each species was compared among treatments over the 3-yr period (pretreatment, 1 yr post- and 2 yr post-treatment). Only birds ($n \geq 30$ observations) observed ≤75 m from each VCP station were used in analyses. Repeat observations were eliminated from analyses. Birds observed flying over stands were recorded, but were not used in analyses. Bird data were transformed using a log transformation [$\log_{10}$(bird abundance + 1)] because data were non-normal or had unequal variance (Sabin and Stafford 1990).

We used multivariate analysis of variance, MANOVA (SAS Institute 1989), to detect treatment and time effects for bird community measures (abundance and species richness) and for abundance of each species. We used Mauchly's criterion (SAS Institute 1989) to test the appropriateness of a univariate analysis for time effects. If Mauchly's criterion was not significant ($P > 0.10$), we used results from the univariate repeated-measures ANOVA, RMA (SAS Institute 1992). If Mauchly's criterion was significant, indicating that we could only use the MANOVA, we used the Wilks' lambda statistic to test hypotheses of: (1) no treatment by year interaction, (2) no treatment effects, and (3) no year effects.

In any case, if we detected a treatment by year interaction ($P < 0.05$), we included results of orthogonal profile contrasts to compare differences between successive years for each treatment (SAS Institute 1989). These values indicated bird response to treatment. We only used as many contrasts as were allowed by degrees of freedom. If there were no detectable interaction effects ($P > 0.05$), we still used profile orthogonal contrasts of treatments vs. control for successive years.

We used nonparametric analyses to detect differences in treatments when the assumptions for MANOVA or RMA were not met. We averaged bird data by treatment and year within each block (control, $n = 3$; small-patch, $n = 3$; two-story, $n = 3$; clear-cut, $n = 3$). We compared only two years: pretreatment vs. 2 yr post-treatment. We calculated differences between pretreatment and 2 yr post-treatment, ranked these data using PROC RANK (SAS Institute 1990), and used ANOVA to detect treatment differences based on ranks (SAS Institute 1990). Multiple-comparisons tests based on Friedman rank sums were used to detect differences among treatments (Hollander and Wolfe 1973:151).

TABLE 3. Means (with 1 SE in parentheses) for bird abundance (number of observations/5 ha over six visits), species richness (number of species), and percentage community similarity (Brower et al. 1990) by treatment and year.

Bird community measure	Control			Small-patch		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Abundance	192 (12)	192 (3)	198 (32)	212 (7)	202 (6)	199 (9)
Richness	21.7 (1.2)	21.3 (1.9)	20.7 (1.8)	23.7 (0.8)	23.1 (0.7)	23.1 (0.8)
Percentage similarity		74 (1)	75 (4)		73 (1)	67 (2)

Notes: Year 1 = pretreatment year; Year 2 = 1 yr post-treatment; Year 3 = 2 yr post-treatment. The table presents results for birds ($n \geq 30$ individuals per species) observed ≤ 75 m from the VCP, at the McDonald-Dunn Research Forest, Oregon, 1989–1993. Percentage similarity is a comparison between pretreatment and post-treatment years. For percentage similarity, Year 2 is the pretreatment vs. 1 yr post-treatment comparison; Year 3 is the pretreatment vs. 2 yr post-treatment comparison.

RESULTS

Detection distance differences

Detection distances differed among treatments, or there were significant year by treatment interactions, for 11 bird species (see Table 2): Pacific-slope Flycatcher (*Empidonax difficilis*), Steller's Jay (*Cyanocitta stelleri*), Gray Jay (*Perisoreus canadensis*), Chestnut-backed Chickadee (*Poecile rufescens*), Bushtit (*Psaltriparus minimus*), Golden-crowned Kinglet (*Regulus satrapa*), Swainson's Thrush (*Catharus ustulatus*) Orange-crowned Warbler (*Vermivora celata*), Hermit Warbler (*Dendroica occidentalis*), American Goldfinch (*Carduelis tristis*), and Purple Finch (*Carpodacus purpureus*). Upper 95% CIs were within 75 m for all species, regardless of detection distance differences. Based on these results, we concluded that a 75-m maximum distance criterion included ≥95% of individuals likely to be encountered in each stand.

Community responses to treatment

We recorded 69 breeding bird species, representing 17 391 observations, within 75 m of VCP stations during three years of observation. Bird abundance declined in two-story and clear-cut stands in the first year following harvest ($P \leq 0.04$). Bird abundance in small-patch stands decreased between 1 yr post-treatment and 2 yr post-treatment ($P = 0.05$; Tables 3 and 4). We were unable to detect differences in species richness among treatments (Table 4), although richness appeared to be higher in two-story stands (25.9 ± 1.2 species, all data expressed as mean ± 1 SE) than in control (21.2 ± 1.2 species), clear-cut (21.9 ± 1.2 species), and small-patch stands (23.3 ± 1.2 species).

Percentage similarity differed among treatments for pretreatment vs. 1 yr post-treatment ($P = 0.0001$; Fig. 3a) and for pretreatment vs. 2 yr post-treatment comparisons ($P = 0.0001$; Fig. 3b). We did not detect changes in bird communities in small-patch group selection stands after harvest ($P = 0.07$), but bird communities changed in two-story and clear-cut stands.

Differences in percentage similarity reflected changes in dominant bird species following harvest. The six most abundant bird species in each treatment accounted for 38–59% of observations recorded. In control stands, Winter Wrens, *Troglodytes troglodytes* (13.9% of observations in control stands), Pacific-slope Flycatchers (11.2%), Hermit Warblers (10.8%), Chestnut-backed Chickadees (9.8%), Wilson's Warblers, *Wilsonia pusilla* (7.1%), and Swainson's Thrushes (6.1%) made up 58.9% of the bird community. In small-patch stands, Hermit Warblers (12.7% of observations in small-patch stands) were most abundant and, with Wilson's Warblers (8.8%), Chestnut-backed Chickadees (7.8%), Dark-eyed Juncos, *Junco hyemalis* (7.4%), Winter Wrens (7.1%), and Pacific-slope Flycatchers (5.1%), represented 48.9% of the observations. Dark-eyed Juncos (8.8% of observations in two-story stands), Chestnut-backed Chickadees (6.9%),

TABLE 4. Repeated-measures ANOVA tests of hypothesis for measures of bird community structure (birds ≤ 75 m from the VCP center, for species with $n \geq 30$ observations, at the McDonald-Dunn Research Forest, Oregon, 1989–1993).

Bird community measure	Year × Trt		Year		Trt		*P* values for Year 1–Year 2 contrast†					*P* values for Year 2–Year 3 contrast†				
									Contrast of CN with:					Contrast of CN with:		
	df	*P*	df	*P*	df	*P*	Cst	Cst × Trt	SP	TS	CC	Cst	Cst × Trt	SP	TS	CC
Abundance	6, 8	0.007		NA		NA	0.003	0.008	0.9	0.04	0.02	0.1	0.02	0.05	0.8	1.0
Richness	6, 16	0.4	2, 16	0.7	3, 6	0.1	0.7	0.2	0.9	0.2	0.8	0.5	0.8	0.7	0.8	0.8

Notes: Year 1 = pretreatment; Year 2 = 1 yr post-treatment; Year 3 = 2 yr post-treatment. Treatments are: CN, control; SP, small-patch; TS, two-story; and CC, clear-cut. *P* is the probability associated with differences among treatment (Trt), year (Year), or year by treatment interaction (Year × Trt) effects. NA indicates that interpretation of statistics is not appropriate, given the year by treatment interaction.

† For abundance, df = 1, 5 for Cst (contrast); df = 3, 5 for Cst × Trt (contrast by treatment interaction); and df = 1, 5 for contrast of CN with SP, TS, and CC. For richness, df = 1, 6 for Cst (contrast); df = 3, 6 for Cst × Trt (contrast by treatment interaction); and df = 1, 6 for contrast of CN with SP, TS, and CC.

TABLE 3. Extended.

Two-story			Clear-cut		
Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
230 (11)	167 (19)	180 (13)	211 (11)	140 (19)	157 (14)
23.5 (0.6)	27.2 (1.8)	27.0 (1.3)	22.8 (1.5)	22.2 (2.0)	20.8 (1.7)
	42 (4)	32 (3)		29 (3)	23 (5)

White-crowned Sparrows, *Zonotrichia leucophrys* (6.5%), Wilson's Warblers (6.5%), House Wrens, *Troglodytes aedon* (5.1%), and Spotted Towhees, *Pipilo maculatus* (4.6%) made up 38.4% of the bird community in two-story stands. White-crowned Sparrows (12.6% of observations in modified clearcuts), Dark-eyed Juncos (9.3%), House Wrens (7.3%), Chestnut-backed Chickadees (6.7%), Hermit Warblers (4.8%), and Spotted Towhees (4.5%) accounted for 45.2% of the observations in modified clear-cut stands.

In general, control and small-patch stands were similar in bird species composition and abundance. Two-story and clear-cut stands were also similar to each other with respect to bird composition and abundance.

Individual species responses to treatment

Within treatments, 19 bird species differed in abundance among years: 10 species decreased and nine species increased. We were unable to detect differences in abundance for 12 species (Table 5).

Decrease in response to treatment. We found two patterns of response to harvest (Fig. 4a and b). In both patterns, there was little change in bird abundance in control and small-patch stands following harvest (Tables 5 and 6). Two species, Brown Creeper (*Certhia americana*) and Chestnut-backed Chickadee (Fig. 4a), continued to use two-story and clear-cut stands, although in lower abundance than prior to treatment (Table 5). Brown Creepers foraged on retained trees and snags, but were not observed nesting in two-story or clear-cut stands. Chestnut-backed Chickadees nested in small-patch, two-story, and clear-cut stands (C. Chambers, *personal observation*). Eight bird species, including Steller's Jay, Red-breasted Nuthatch (*Sitta canadensis*), Winter Wren, Golden-crowned Kinglet,

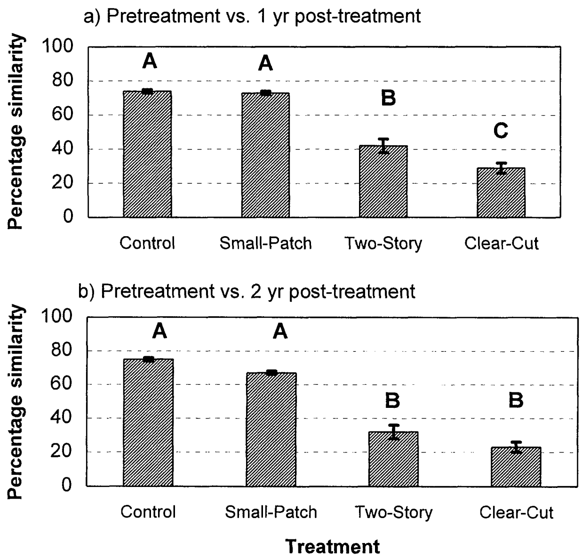

FIG. 3. Mean (± 1 SE) percentage similarity (Brower et al. 1990) for comparisons of (a) 1 yr post-treatment and (b) 2 yr post-treatment with pretreatment bird community. Significant treatment differences ($P \leq 0.05$) are indicated by different letters. Bird data were collected in the McDonald-Dunn Research Forest, 1989–1993.

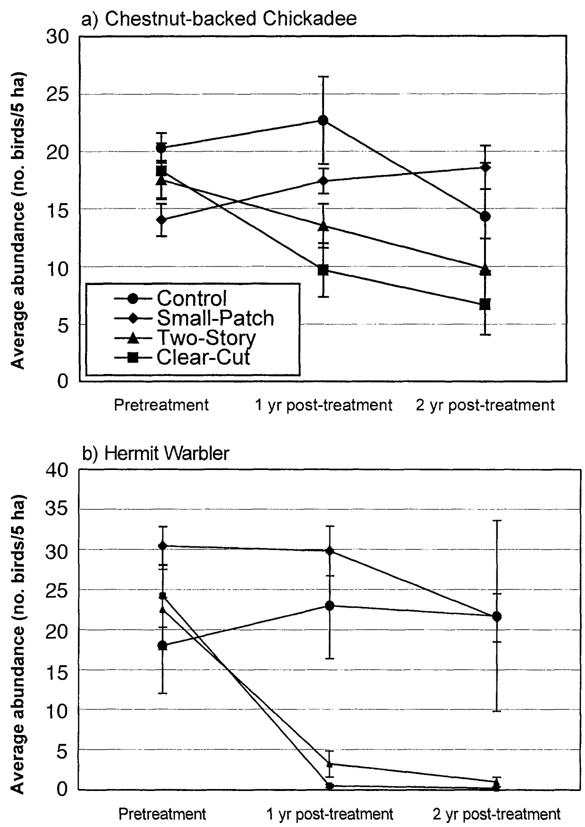

FIG. 4. Examples of decrease in bird abundance in response to treatment depicting (a) Chestnut-backed Chickadee and (b) Hermit Warbler. Average abundance (number of Chesnut-backed Chickadee or Hermit Warbler observations/5 ha, mean ± 1 SE) is shown for control, small-patch, two-story, and clear-cut treatments for three years (pretreatment, 1 yr post-treatment, 2 yr post-treatment). Bird data were collected in the McDonald-Dunn Research Forest, 1989–1993.

TABLE 5. Repeated-measures ANOVA and orthogonal contrasts for pretreatment vs. 1 yr post-treatment (Year 1–Year 2 contrast), and 1 yr post-treatment vs. 2 yr post-treatment (Year 2–Year 3 contrast) for bird species abundances (birds ≤ 75 m from VCP center; $n \geq 30$ observations, at the McDonald-Dunn Research Forest, Oregon, 1989–1993).

	Year × Trt		Year		Trt	
Species	df	*P*	df	*P*	df	*P*
Decrease in response to treatment						
Chestnut-backed Chickadee	6, 10	0.0008	NA		NA	
Brown Creeper	6, 16	0.0	NA		NA	
Steller's Jay	6, 10	0.03	NA		NA	
Red-breasted Nuthatch	6, 16	0.0002	NA		NA	
Winter Wren	6, 16	0.0003	NA		NA	
Golden-crowned Kinglet	6, 22	0.01	NA		NA	
Swainson's Thrush	6, 16	0.0001	NA		NA	
Hermit Warbler	6, 16	0.0004	NA		NA	
Wilson's Warbler	6, 16	0.0002	NA		NA	
Western Tanager	6, 16	0.0005	NA		NA	
Increase in response to treatment						
Willow Flycatcher	6, 16	0.02	NA		NA	
House Wren	6, 22	0.001	NA		NA	
MacGillivray's Warbler	6, 22	0.02	NA		NA	
Spotted Towhee	6, 22	0.005	NA		NA	
White-crowned Sparrow	6, 16	0.0	NA		NA	
American Goldfinch	6, 16	0.01	NA		NA	
Olive-sided Flycatcher‡	6, 16	0.2	2, 16	0.1	3, 8	0.02
Brown-headed Cowbird‡	6, 16	0.3	2, 16	0.003	3, 6	0.05
Purple Finch‡	6, 16	0.07	2, 16	0.0	3, 6	0.05
No detectable response to treatment						
Rufous Hummingbird	6, 24	0.8	2, 24	0.2	3, 24	0.3
Northern Flicker	6, 24	0.7	2, 24	0.9	3, 24	0.006
Red-breasted Sapsucker	6, 16	0.2	2, 16	0.4	3, 8	0.3
Hairy Woodpecker	6, 24	0.2	2, 24	0.9	3, 24	0.08
Pacific-slope Flycatcher	6, 10	0.3	2, 5	0.02	3, 6	0.0001
Gray Jay	6, 22	0.3	2, 22	0.2	3, 22	0.5
Bushtit	6, 16	0.2	2, 16	0.7	3, 6	0.7
American Robin	6, 22	0.8	2, 22	0.3	3, 22	0.1
Orange-crowned Warbler	6, 24	0.6	2, 24	0.02	3, 24	0.5
Black-throated Gray Warbler	6, 16	0.8	2, 16	0.0007	3, 8	0.6
Black-headed Grosbeak	6, 24	0.9	2, 24	0.4	3, 24	0.3
Dark-eyed Junco	6, 16	0.2	2, 16	0.003	3, 6	0.2

Notes: Abundances were log-transformed ($\log_{10}$[abundance + 1]) for analyses. Treatments are: CN, control; SP, small-patch; TS, two-story; and CC, clear-cut. *P* is the probability associated with differences among treatment (Trt), year (Year), or year by treatment interaction (Year × Trt) effects. Species are arranged in categories of decreasing, increasing, or no response to treatment. NA indicates that interpretation of statistics is not appropriate, given the year by treatment interaction.

† For contrasts; df = 1, 6 for Cst (contrast); df = 3, 6 for Cst × Trt (contrast by treatment interaction); and df = 1, 6 for contrast of CN with SP, TS, and CC.

‡ Results of nonparametric statistical tests to detect differences among treatments: (1) Olive-sided Flycatcher ($P = 0.04$) increased in two-story stands compared with control stands ($P = 0.05$), and no differences were detected between two-story and clear-cut stands, two-story and small-patch stands, control and small-patch stands, or control and clear-cut stands ($P \geq 0.05$); (2) Purple Finch ($P = 0.0007$) increased in abundance in two-story stands compared with control and clear-cut stands ($P = 0.05$), and no difference was detected between two-story and small-patch stands ($P > 0.05$); and (3) Brown-headed Cowbird ($P = 0.004$) increased in two-story stands ($P = 0.05$), but no detectable difference was observed between control and small-patch, control and clear-cut, two-story and small-patch, or two-story and clear-cut stands ($P \geq 0.05$).

Swainson's Thrush, Hermit Warbler, Wilson's Warbler, and Western Tanager (*Piranga ludoviciana*), were only rarely observed in two-story and clear-cut stands (Tables 5 and 6, Fig. 4b).

One species showed a lag response to small-patch harvesting (Tables 5 and 6). Swainson's Thrushes declined in small-patch stands 2 yr postharvest, perhaps due to changes in breeding habitat (e.g., vegetation composition and structure) or other factors (e.g., increased predation).

Increase in response to treatment.—Nine species increased in one or more treatments following harvest (Tables 5 and 6). Abundances of four species (House Wren, Spotted Towhee, White-crowned Sparrow, and American Goldfinch) increased in two-story and clear-cut stands 1 yr postharvest and again 2 yr after harvest. Birds were absent, or there was no detectable change in abundance, in control and small-patch stands (Tables 5 and 6, Fig. 5). These species probably responded to the increase in shrub density in two-story and clear-cut stands (Chambers 1996).

MacGillivray's Warblers (*Oporornis tolmiei*) ap-

TABLE 5. Extended.

P values for Year 1–Year 2 contrast†					*P* values for Year 2–Year 3 contrast†				
		Contrast of CN with:					Contrast of CN with:		
Cst	Cst × Trt	SP	TS	CC	Cst	Cst × Trt	SP	TS	CC
0.0001	0.0001	0.03	0.04	0.0004	0.005	0.4	0.5	0.8	0.6
0.0008	0.001	0.4	0.02	0.001	0.1	0.2	0.8	0.1	0.3
0.005	0.002	0.2	0.006	0.001	0.7	0.9	1.0	0.8	0.8
0.0003	0.002	0.9	0.02	0.004	0.1	0.8	0.5	0.9	0.8
0.0004	0.008	0.6	0.1	0.02	0.3	0.2	0.2	0.04	0.2
0.002	0.07	0.9	0.1	0.09	0.4	0.6	0.2	0.3	0.3
0.0001	0.0003	0.6	0.002	0.004	0.8	0.01	0.03	0.6	0.1
0.0008	0.003	0.4	0.01	0.003	0.04	0.8	0.7	0.6	0.9
0.0007	0.002	0.2	0.009	0.002	0.8	0.8	0.4	0.4	0.5
0.09	0.01	0.5	0.04	0.009	0.5	0.1	0.05	0.3	0.1
0.2	0.6	1.0	0.6	0.4	0.02	0.03	0.9	0.03	0.3
0.002	0.02	0.6	0.02	0.03	0.3	0.7	0.3	0.3	0.3
0.09	0.2	0.08	0.1	0.4	0.03	0.5	0.9	0.3	0.4
0.006	0.04	0.4	0.02	0.06	0.09	0.7	0.3	0.4	0.3
0.0001	0.0001	0.2	0.0001	0.0001	0.004	0.08	0.3	0.02	0.2
0.009	0.02	0.6	0.06	0.01	0.5	0.6	0.8	0.4	0.8
0.03	0.2	0.5	0.07	0.5	0.3	1.0	0.7	0.7	0.9
0.0002	0.05	1.0	0.05	0.9	0.3	0.3	0.3	0.9	0.8
0.005	0.1	0.8	0.1	0.1	0.03	0.3	0.3	0.07	0.2
0.4	0.3	0.1	0.1	0.5	0.04	0.8	0.5	0.8	0.9
0.0001	0.02	0.9	0.02	0.05	0.2	0.4	0.9	0.5	0.3
0.02	0.5	0.2	0.1	0.3	0.7	0.2	0.08	0.06	0.08

peared to increase in small-patch stands (Tables 5 and 6). The 0.2-ha openings in small-patch stands may have provided additional vegetative structure for nest or foraging sites for these species. Willow Flycatcher (*Empidonax traillii*) abundance increased significantly only in two-story stands (Tables 5 and 6). This may have been caused by an increase in shrub cover in combination with overstory retention.

We did not detect a response for six species using RMA (we did not detect a year by treatment interaction; Table 5), although there appeared to be a response to stand management (treatment effects: $P \leq 0.10$). This could have been caused by low power of the statistical test, because transformed data did not meet assumptions of RMA (i.e., unequal variance), or because some bird species were consistently more abundant in some stands.

We used nonparametric statistical tests to detect differences among treatments for three species. Olive-sided Flycatcher, *Contopus cooperi* ($P = 0.04$), Purple Finch ($P = 0.0007$), and Brown-headed Cowbird, *Molothrus ater* ($P = 0.004$) abundances increased following harvest (Tables 5 and 6). Olive-sided Flycatchers, Purple Finches, and Brown-headed Cowbirds increased in two-story stands ($P = 0.05$).

No detectable response to treatment. Twelve species, Rufous Hummingbird (*Selasphorus rufus*), Northern Flicker (*Colaptes auratus*), Red-breasted Sapsucker (*Sphyrapicus ruber*), Hairy Woodpecker (*Picoides villosus*), Pacific-slope Flycatcher, Gray Jay, Bushtit, American Robin (*Turdus migratorius*), Orange-crowned Warbler, Black-throated Gray Warbler (*Dendroica nigrescens*), Black-headed Grosbeak (*Pheucticus melanocephalus*), and Dark-eyed Junco, did not appear to respond to treatments ($P \geq 0.08$). Dark-eyed Junco response is depicted as an example of the "no trend" response in Fig. 6.

Although we did not detect a difference in Pacific-slope Flycatcher abundance following stand management, we suspect that this was due to low power of our statistical tests ($1 - \beta < 0.5$). Over the 3-yr study period, observations decreased to two bird observations per 5 ha in two-story stands and one bird observation per 5 ha in clearcuts, while remaining constant

TABLE 6. Mean bird abundance (number of observations/5 ha, with 1 SE in parentheses) by treatment and year.

Species	n	Control			Small-patch		
		Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Decrease in response to treatment							
Chestnut-backed Chickadee	1325	20.3 (1.3)	22.7 (3.8)	14.3 (4.7)	14.0 (1.4)	17.4 (1.1)	18.6 (1.9)
Brown Creeper	665	8.3 (2.7)	9.0 (0.0)	10.7 (1.5)	10.0 (1.4)	8.3 (0.8)	8.9 (1.2)
Steller's Jay	543	3.7 (2.0)	5.7 (2.4)	5.7 (1.9)	5.6 (1.1)	6.3 (1.0)	7.2 (0.9)
Red-breasted Nuthatch	740	13.7 (5.4)	8.7 (1.5)	8.0 (2.1)	15.4 (2.8)	9.4 (0.7)	7.3 (1.2)
Winter Wren	1146	28.0 (9.5)	21.0 (9.8)	32.0 (10.0)	18.9 (2.2)	15.2 (1.5)	11.7 (1.5)
Golden-crowned Kinglet	716	15.0 (7.2)	9.0 (3.5)	11.7 (4.3)	15.1 (2.4)	7.9 (0.9)	7.6 (1.8)
Swainson's Thrush	747	12.0 (4.4)	10.7 (6.7)	13.3 (5.2)	12.4 (1.6)	10.6 (1.5)	7.2 (1.2)
Hermit Warbler	1641	18.0 (6.0)	23.0 (6.6)	21.7 (11.9)	30.4 (2.4)	29.8 (3.1)	21.5 (3.0)
Wilson's Warbler	1287	11.7 (3.3)	16.0 (4.4)	13.7 (5.8)	20.4 (1.8)	17.4 (1.8)	18.8 (1.6)
Western Tanager	687	3.0 (1.5)	7.0 (3.5)	10.3 (3.7)	9.6 (2.2)	10.4 (1.9)	9.9 (2.6)
Increase in response to treatment							
Willow Flycatcher	30	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.2)	0.2 (0.2)	0.1 (0.1)
House Wren	462	0.7 (0.7)	0.7 (0.7)	0.0 (0.0)	0.1 (0.1)	0.3 (0.2)	3.1 (1.3)
MacGillivray's Warbler	357	1.3 (0.7)	1.0 (1.0)	1.3 (0.7)	1.1 (0.6)	3.1 (0.9)	6.0 (1.3)
Spotted Towhee	575	1.0 (0.6)	0.7 (0.3)	0.7 (0.7)	3.3 (1.0)	4.6 (1.3)	10.9 (2.9)
White-crowned Sparrow	645	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.2)	1.4 (0.9)
American Goldfinch	179	0.3 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)
Olive-sided Flycatcher	75	0.3 (0.3)	0.3 (0.3)	0.0 (0.0)	0.2 (0.2)	0.1 (0.1)	0.1 (0.1)
Brown-headed Cowbird	56	0.0 (0.0)	0.0 (0.0)	0.3 (0.3)	0.0 (0.0)	0.5 (0.4)	0.4 (0.1)
Purple Finch	280	0.0 (0.0)	0.7 (0.3)	0.3 (0.3)	2.0 (0.9)	3.4 (1.0)	4.0 (0.8)
No detectable response to treatment							
Rufous Hummingbird	38	0.0 (0.0)	0.3 (0.3)	0.3 (0.3)	0.3 (0.1)	0.5 (0.3)	0.1 (0.1)
Northern Flicker	83	0.0 (0.0)	0.3 (0.3)	0.3 (0.3)	0.9 (0.3)	0.5 (0.3)	0.6 (0.3)
Red-breasted Sapsucker	194	3.0 (1.5)	0.3 (0.3)	2.0 (1.0)	2.4 (0.6)	2.5 (0.6)	3.2 (0.8)
Hairy Woodpecker	124	2.0 (1.0)	0.7 (0.3)	0.3 (0.3)	1.1 (0.4)	0.6 (0.3)	1.4 (0.4)
Pacific-slope Flycatcher	852	24.3 (2.4)	20.7 (5.8)	20.3 (2.6)	12.9 (1.7)	9.9 (1.8)	9.9 (1.8)
Gray Jay	94	0.3 (0.3)	1.3 (1.3)	1.0 (0.6)	1.8 (0.5)	1.6 (0.6)	1.1 (0.4)
Bushtit	34	2.0 (2.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.2 (0.2)	0.1 (0.1)
American Robin	549	4.0 (0.6)	3.0 (1.0)	4.3 (2.3)	8.4 (1.8)	6.1 (0.9)	6.0 (1.0)
Orange-crowned Warbler	550	4.3 (1.9)	3.3 (2.4)	4.7 (1.2)	4.0 (1.0)	7.8 (1.3)	8.9 (1.3)
Black-throated Gray Warbler	251	3.7 (2.7)	1.3 (0.9)	0.3 (0.3)	6.1 (1.3)	3.4 (0.9)	1.2 (0.3)
Black-headed Grosbeak	199	1.3 (0.7)	2.0 (1.2)	2.0 (1.0)	3.2 (0.6)	2.4 (0.7)	2.1 (0.3)
Dark-eyed Junco	1354	4.7 (1.7)	9.7 (7.8)	13.0 (7.5)	9.9 (1.3)	19.9 (1.3)	17.9 (1.6)

Notes: Year 1 = pretreatment; Year 2 = 1 yr post-treatment; Year 3 = 2 yr post-treatment. The table presents results for birds ($n \geq 30$ observations per species) observed ≤ 75 m from the VCP center, at the McDonald-Dunn Research Forest, Oregon, 1989–1993. Abundances are untransformed data. Species are arranged in categories of decreasing, increasing, or no response to treatment; n is the total number of birds observed.

in control and small-patch stands (Table 6). The small number of control stands and variability associated with means from these stands probably prevented detection of significant treatment differences for Pacific-slope Flycatcher.

DISCUSSION

Applying silvicultural prescriptions that were based on natural disturbance regimes offered benefits to bird species associated with late-successional or old-growth forests, e.g., Brown Creeper, Chestnut-backed Chickadee, Olive-sided Flycatcher, Red-breasted Nuthatch, Pacific-slope Flycatcher (Carey et al. 1991). Although not all bird species associated with late-successional forests nested in each of our silvicultural treatments, these treatments provided foraging and/or roosting habitat that would not have been available in traditional clear-cut harvest units.

We monitored artificially created snags for indications of use (presence of excavated cavities) by cavity nesters. Created snags in all treatments contained more excavated cavities 5 yr after snag creation. Snags in clear-cut and two-story stands contained more excavated cavities (1.8 and 2.1 excavated cavities per snag, respectively) than snags in small-patch stands (0.6 excavated cavity per snag) (Chambers et al. 1997). Creating snags increased potential habitat for primary and secondary nesters in all treatments.

In general, small-patch group selection stands were most similar in vegetation (Chambers 1996) and bird community composition to control stands, whereas two-story stands were more similar to modified clear-cut stands. All treatments affected bird communities, although two-story and clear-cut treatments had the most pronounced effect. Most harvesting treatments probably have greater impact (higher level of disturbance) than our small-patch group selection treatment. If the intent is to extract some timber, but to retain species associated with late successional forests, silvicultural treatments like our small-patch group selection treatment are more effective than two-story or clear-cut treatments.

TABLE 6. Extended.

Two-story			Clear-cut		
Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
17.5 (1.7)	13.5 (1.9)	9.8 (2.6)	18.3 (2.4)	9.7 (2.3)	6.7 (2.6)
13.8 (1.6)	6.8 (2.2)	2.7 (1.0)	8.7 (1.7)	1.0 (0.5)	0.2 (0.2)
11.8 (7.5)	2.5 (0.9)	6.0 (2.6)	11.3 (3.6)	2.5 (1.0)	4.3 (3.6)
15.2 (3.6)	2.2 (0.9)	1.8 (0.8)	13.8 (2.7)	0.3 (0.2)	0.0 (0.0)
19.0 (2.2)	5.0 (1.8)	0.7 (0.3)	17.5 (2.3)	1.2 (0.6)	0.3 (0.2)
15.8 (4.3)	1.8 (0.8)	1.2 (0.8)	10.7 (2.7)	0.5 (0.3)	0.0 (0.0)
16.2 (1.4)	0.8 (0.4)	2.3 (0.8)	14.5 (2.5)	1.3 (0.6)	0.8 (0.5)
22.5 (5.0)	3.2 (1.6)	1.0 (0.6)	24.2 (3.9)	0.5 (0.2)	0.2 (0.2)
24.5 (2.1)	7.5 (2.3)	6.5 (0.8)	18.3 (1.7)	2.5 (1.3)	2.5 (1.3)
10.2 (3.8)	5.2 (1.8)	5.5 (2.0)	10.7 (4.0)	1.8 (0.7)	1.3 (0.6)
0.2 (0.2)	0.3 (0.2)	2.0 (0.6)	0.0 (0.0)	0.3 (0.3)	1.0 (0.6)
0.0 (0.0)	12.5 (4.4)	18.2 (1.8)	0.5 (0.3)	15.5 (6.9)	21.5 (5.6)
1.7 (0.9)	4.5 (1.9)	13.2 (2.5)	2.7 (1.5)	3.0 (1.4)	9.0 (2.8)
1.8 (1.1)	10.0 (2.3)	15.5 (2.5)	2.2 (1.0)	8.2 (2.5)	13.0 (1.4)
0.0 (0.0)	13.5 (3.2)	25.3 (3.9)	0.0 (0.0)	27.3 (5.5)	37.5 (6.4)
0.0 (0.0)	3.7 (1.6)	6.3 (2.3)	0.2 (0.2)	9.2 (4.5)	10.0 (4.4)
0.3 (0.3)	2.2 (1.1)	3.0 (0.5)	1.3 (1.1)	2.2 (0.9)	2.0 (1.1)
0.2 (0.2)	2.7 (1.2)	2.7 (1.0)	0.0 (0.0)	0.8 (0.8)	0.8 (0.4)
1.7 (0.8)	6.3 (1.7)	6.3 (2.1)	2.7 (1.2)	4.7 (1.7)	2.7 (1.2)
0.0 (0.0)	1.2 (0.5)	0.8 (0.8)	0.5 (0.2)	0.7 (0.2)	0.8 (0.5)
2.0 (0.6)	2.0 (0.9)	0.8 (0.3)	0.8 (0.3)	1.3 (0.5)	1.7 (0.6)
2.8 (1.4)	2.3 (1.6)	2.3 (1.2)	0.8 (0.5)	1.7 (1.1)	0.7 (0.3)
2.7 (0.9)	2.8 (1.3)	1.7 (0.4)	0.7 (0.3)	2.2 (0.8)	1.8 (0.3)
13.7 (2.9)	2.0 (0.7)	1.3 (0.8)	14.0 (5.2)	1.0 (0.4)	0.8 (0.5)
1.7 (1.2)	0.5 (0.3)	0.2 (0.2)	1.5 (0.6)	0.0 (0.0)	0.2 (0.2)
0.0 (0.0)	0.3 (0.3)	2.7 (1.9)	0.3 (0.3)	0.2 (0.2)	0.0 (0.0)
6.7 (1.3)	9.7 (4.2)	6.7 (2.0)	7.5 (1.6)	3.7 (2.0)	3.8 (1.6)
2.3 (0.8)	5.2 (1.4)	8.5 (1.8)	7.0 (3.5)	5.2 (1.6)	9.0 (2.4)
7.3 (1.9)	1.3 (0.7)	1.0 (0.4)	3.5 (1.1)	0.5 (0.5)	0.5 (0.3)
3.2 (1.1)	2.3 (0.9)	2.2 (1.0)	3.2 (1.7)	1.0 (0.4)	0.7 (0.4)
10.1 (1.9)	26.3 (2.5)	16.3 (1.3)	9.8 (1.6)	22.2 (3.8)	16.0 (2.8)

Two-story stands

In the Pacific Northwest, green-tree retention is replacing clear-cutting as a harvest treatment on Federal lands (Forest Ecosystem Management Assessment Team 1993). Two-story stands may provide habitat for more species. Although neither our study nor Vega's (1993) detected a change in bird species richness, both studies detected more species in two-story stands than other treatments. Vega (1993) compared bird communities in clear-cut, green-tree retention (two-story), and mature conifer stands (n = 4 stands each) in the Oregon Cascades. Richness averaged 16.3 ± 2.3 species in her retention units, 14.0 ± 1.2 species in mature conifer, and 11.3 ± 1.3 species in clear-cut stands (all values mean ± 1 SE). Two-story stands provided breeding habitat for early seral stage associates, but the retention of large trees apparently provided foraging substrates and, in some cases, breeding sites for some species associated with mature forest (Red-breasted Nuthatch, and Chestnut-backed Chickadee; C. Chambers, *personal observation*). Nichols and Wood (1993) compared two-story, clear-cut, and unharvested stands in the Monongahela National Forest in West Virginia. They observed highest species richness in two-story stands. Their two-story and clear-cut stands had been harvested 12 yr prior to study, so understory plants had more of an opportunity to develop or recover from disturbance than did our stands.

We found that two-story stands offered benefits (foraging and nesting habitat), compared with clear-cutting, to some of the species associated with old-growth forests (e.g., Brown Creeper, Chestnut-backed Chickadee, Red-breasted Nuthatch, and Olive-sided Flycatcher; Carey et al. 1991). Feen (1997) found that although northern flying squirrel (*Glaucomys sabrinus*) winter den sites were more common in 80–130-yr old Douglas-fir stands in the southern Oregon Cascades Mountains, six of 162 winter den sites were found in green-tree retention stands.

Olive-sided Flycatcher abundance increased in two-story stands. Carey et al. (1991) found that Olive-sided Flycatchers were associated with old-growth forests in the Oregon Coast Range. We found that they used large, open areas such as our two-story and modified clear-cut stands for breeding habitat, but they were rarely observed using 0.2-ha patches in small-patch or control stands. McGarigal and McComb (1995) found that Olive-sided Flycatchers were affected by the arrangement

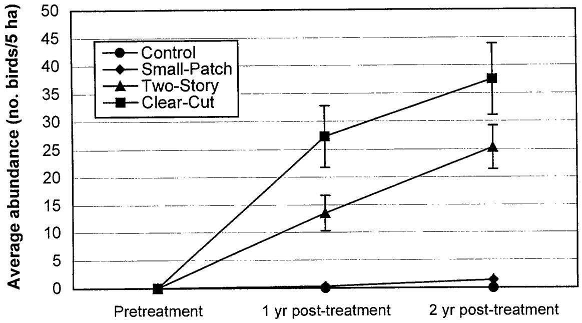

FIG. 5. Example of an increase in bird abundance in response to treatment, depicting results for the White-crowned Sparrow. Average abundance (number of White-crowned Sparrow observations/5 ha, mean ± 1 SE) is shown for control, small-patch, two-story, and clear-cut treatments for three years (pretreatment, 1 yr post-treatment, 2 yr post-treatment). Bird data were collected in the McDonald-Dunn Research Forest, 1989–1993.

and types of stands in a landscape rather than just stand type. Olive-sided Flycatchers were more abundant in fragmented landscapes with high-contrast edges (mature forest with early seral stage). We detected the highest numbers of Olive-sided Flycatchers in two-story stands. The type of stand adjacent to two-story stands may have been critical in determining use.

Although two-story stands provided additional foraging or nesting habitat to some birds associated with old-growth forests, some species were never observed nesting in these stands (e.g., Brown Creeper). Forest-associated birds that we observed using two-story stands were probably incorporating some of the two-story stands within larger home ranges that were composed of mature forest adjacent to two-story stands.

Our study was based on avian abundance rather than reproductive success. Chambers (1996) found that artificial nests placed in shrubs in two-story stands were more likely to be preyed upon than shrub nests placed in other treatments. In addition, we found that Brown-headed Cowbirds reached highest abundance in two-story stands. Nichols and Wood (1993) also found cowbirds to be more abundant in two-story stands than in clearcuts and uncut forest. Because Brown-headed Cowbirds parasitize nests, they can contribute to population declines of bird species (Harrison 1979, Robinson et al. 1992, Martin 1992). If Brown-headed Cowbird populations and levels of parasitism are monitored and found to pose a threat to bird populations, use of this harvest treatment should be carefully considered. In our study, however, Brown-headed Cowbirds were present only in low abundance (0–2.7 cowbirds/5 ha). At this time, Brown-headed Cowbirds may not have a significant effect on bird communities in the Oregon Coast Range.

Small-patch stands

Most bird species associated with mature and old-growth forests were able to incorporate small-scale disturbances caused by small-patch group selection into their home ranges. Medin and Booth (1989) documented bird community response to a low-intensity harvest. They found that only two species (Red-breasted Nuthatch and Western Tanager) declined in response to single-tree selection logging (29% reduction in wood volume) in Idaho. A moderate-intensity harvest had a greater effect on birds. Keller and Anderson (1992) found that Brown Creepers avoided strip-cut and spot-cut areas in fragmented stands interrupted with strip or patch clearcuts. Birds were probably affected by the reduction in resources for foraging and nesting. Apparently, they needed a minimum number of foraging sites per territory before habitat was suitable for use. These observations were from mixed conifer forests in Wyoming and Idaho; however, they indicate the types of responses to be expected from different intensities of selective logging.

Small-patch harvest may have negative effects for some species. The first year after harvest, Swainson's Thrushes declined in clear-cut and two-story stands by 90%. There was no detectable change in abundance in small-patch stands. However, the second year after harvest, Swainson's Thrushes declined to 60% of their original population size in small-patch stands. Winter Wrens showed a similar tendency, although the decline in abundance in small-patch stands was not statistically significant 2 yr postharvest. Harvesting and associated effects (e.g., creation of skid roads and logging corridors, increased numbers of openings in the stand, alteration of microclimate) may have increased the permeability of these stands to predators, or may have introduced levels of disturbance that affected animal abundance. To determine whether this effect reflects a trend in population response that may persist, populations should be monitored in small-patch stands over a longer time period.

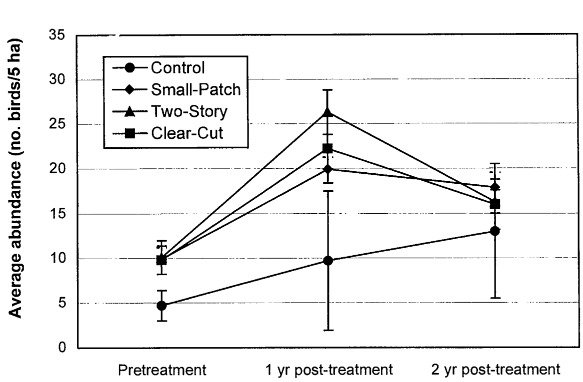

FIG. 6. Dark-eyed Junco as an example of a species showing no detectable response to treatment. Average abundance (number of Dark-eyed Junco observations/5 ha, mean ± 1 SE) is shown for control, small-patch, two-story, and clear-cut treatments for three years (pretreatment, 1 yr post-treatment, and 2 yr post-treatment). Bird data were collected in the McDonald-Dunn Research Forest, 1989–1993.

Species not responding to treatments

Twelve bird species showed no noticeable response to silvicultural treatment, perhaps because habitat upon which they relied or to which they were sensitive (e.g., shrub density) was not strongly impacted by harvest. Sample size was small for some species (e.g., Rufous Hummingbird, $n = 38$; Bushtit, $n = 34$), so they may have been inadequately sampled to detect change among treatments. Some species differed in abundance among years, but not in treatment response, perhaps because habitat sampled was marginal, species were habitat generalists and were insensitive to harvest (e.g., Dark-eyed Junco), or our 3-yr study period was inadequate to detect change.

Neotropical migrants

Concern for neotropical migrants has increased over the past 15 yr as declines in some forest-breeding species have been noted. Loss of habitat, area sensitivity, and vulnerability to nest predation were cited as causes in the eastern United States (Therres 1992), and it is possible that effects of edges created by timber harvest in western states could create fragmented landscapes that result in population declines (Thompson et al. 1992).

In our study, seven of the 19 bird species responding to silvicultural treatment were neotropical migratory species. Four species (Swainson's Thrush, Hermit Warbler, Wilson's Warbler, and Western Tanager) declined following harvest. Swainson's Thrushes were sensitive to all harvest treatments, including small-patch harvesting. Hermit Warblers, Wilson's Warblers, and Western Tanagers decreased in two-story and clear-cut treatments, but seemed to be unaffected by small-patch harvesting.

Those increasing after harvest included Olive-sided Flycatcher, Willow Flycatcher, and MacGillivray's Warbler. Olive-sided Flycatchers and Willow Flycatchers increased in two-story stands, and MacGillivray's Warblers increased in small-patch stands. Both MacGillivray's Warbler and Olive-sided Flycatcher populations are reported in decline by analyses of Breeding Bird Survey (BBS) data (Robbins et al. 1992). Olive-sided Flycatchers have been in continuous decline over the past 26 yr, whereas MacGillivray's Warblers have been in decline over the past 10 yr (Robbins et al. 1992). Olive-sided Flycatchers were identified by McGarigal and McComb (1995) as associated with high-contrast edges. This juxtaposition of open stands (e.g., clearcuts or two-story stands) with older forest may decrease if more Pacific Northwest mature and old-growth forests are converted to younger age classes. In addition, rotations may be so shortened that stands that could serve as "mature," in creating high-contrast edges with harvested units, no longer develop.

Management Implications

If the needs of all wildlife species are to be met, then forest management that more closely imitates natural stand disturbances should be considered. Our silvicultural treatments are alternatives to traditional clearcut regeneration systems, and provide for both timber extraction and retention of habitat features important for wildlife.

Single-tree or group selection, uneven-aged management can be used to imitate fine-scale disturbances in Douglas-fir stands, and may allow mature-forest associates to persist in managed stands. In other forest types, the creation of small openings, such as that caused by the death of a single tree or small groups of trees, increased bird abundance but did not affect species diversity (Kilgore 1971, McComb and Rumsey 1983, Blake and Hoppes 1986). Gaps created by these treatments, or through natural tree mortality, apparently increased habitat heterogeneity and resource levels through greater primary productivity, fruit production, and insect abundance.

Two-story stands appear to provide habitat for many of the same species that occur in clear-cut stands. Retaining some overstory, however, provides benefits for some forest-associated species (e.g., nest sites for Western Tanager, foraging sites for Brown Creeper, and song posts for many species). Structure in these stands will become more complex than in developing clearcut stands, and may recover the characteristics of mature forest well in advance of clearcuts.

The retention and creation of snags in all treatments provides nesting habitat for cavity-nesting birds (Chambers et al. 1997). The retention of green trees helps to insure snag recruitment in the future, although stand conditions may not favor use by all cavity-nesting species (e.g., the Pileated Woodpecker (*Dryocopus pileatus*) is associated with mature and old-growth forests, and probably would not nest in young stands even though snags of adequate size were available).

A mosaic of stand types using a variety of silvicultural treatments across the landscape will maintain bird species diversity. However, arrangement of those stands on the landscape will be critical to maintaining viable populations (e.g., connectivity among populations and adequate habitat patch sizes).

Scope and limitations

We examined short-term (1–2 yr) effects of several alternative silvicultural systems on bird communities associated with mature Douglas-fir forests of the Oregon Coast Range. Our analyses were stand-level and do not account for landscape-level effects of silvicultural treatments on bird populations.

We used bird abundance as a treatment response variable, rather than using a measure of bird fitness (e.g., nest predation rates, number of successful nesting attempts, or fledgling survival). Density or abundance estimates can be misleading indicators of habitat quality (Van Horne 1983). To determine effects of treatments on bird survival and reproduction, nest searches and territory mapping, in conjunction with VCP counts, would be better indicators of bird response.

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