AN ABSTRACT OF THE THESIS OF

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Signature redacted for privacy.

Abstract approve(

William C. McComb

Growing concerns over maintaining animal and plant biodiversity have led to significant changes in forest management policies in the Pacific Northwest. Silvicultural alternatives to clearcutting are being suggested to promote development, retention, or creation of late-successional features such as large trees, multilayered canopies, snags and logs. As alternative management techniques are applied to forested landscapes, land managers need to assess their effects on wildlife.

I systematically sampled diurnal breeding bird and small mammal populations in the eastern Central Oregon Coast Range 1 year prior to and 2- to 4-years after harvest to determine effects of 3 silvicultural treatments: modified clearcut, two-story, and small patch group selection harvest on wildlife species compared with uncut controls. Based on measures of community similarity and responses of individual bird species, the small patch treatment (a silvicultural treatment representing a light intensity disturbance) was most similar in species composition to controls, while the two-story treatment (two-aged silvicultural treatment representing a moderate to heavy disturbance) was most similar to the modified clearcut treatment (even-aged management treatment representing a heavy intensity disturbance). Communities in control and group selection treatments were represented by different bird species than two-story and clearcut treatments.

Ten bird species associated with mid- to late-successional forests declined after intensive harvest. Nine bird species responded positively to harvesting and increased in 1 or more treatments. Only 1 taxonomic group of small mammals showed a significant response to treatment; shrews (*Sorex* spp.) declined in two-story and clearcut treatments.

I used artificial nests placed on the ground and in shrubs to compare nest predation rates among treatments. Artificial shrub nest predation rates were higher ($\underline{P} \leq 0.10$) in two-story and clearcut treatments compared with control and small patch group selection stands.

Animal responses to the silvicultural treatments I studied indicate a variety of stand types are needed to meet needs of all species. Placement of these stand types on the landscape should be considered so as to maintain well-distributed populations. I examined only a limited number of silvicultural options. As new treatments are implemented, animal response to them should be monitored.

RESPONSE OF TERRESTRIAL VERTEBRATES TO THREE SILVICULTURAL TREATMENTS IN THE CENTRAL OREGON COAST RANGE

by

Carol L. Chambers

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CONTRIBUTION OF AUTHORS

Drs. William C. McComb and John Tappeiner, III developed the silvicultural treatments and initiated the study on McDonald-Dunn Forest. They contributed to the design of the vertebrate response experiment and assisted in preparation of Chapter 2 of this document.

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CHAPTER 1

RESPONSE OF TERRESTRIAL VERTEBRATES TO THREE SILVICULTURAL TREATMENTS IN THE CENTRAL OREGON COAST RANGE - INTRODUCTION

INTRODUCTION

During the last 3 decades, environmental concerns and growing dissatisfaction with the scale and intensity of land management triggered changes in federal, state, and private forest management (National Forest Management Act of 1979, Oregon Forest Practices Act, Washington Forest Practices Act, Thomas et al. 1993). The designation of the northern spotted owl (*Strix occidentalis caurina*) as a threatened species under the Endangered Species Act focused the controversy on the logging of mature and old-growth forests in the Pacific Northwest. In addition to the spotted owl, 38 bird, 26 mammal, and 16 amphibian species were identified as closely associated with late-successional forests (Thomas et al. 1993). Concerns for plant, invertebrate, and vertebrate species unique to old-growth forest ecosystems led to acceptance of a broader array of management options that range from no management to use of even-aged, two-aged, or uneven-aged management techniques (Forest Ecosystem Management Assessment Team 1993). Although sometimes referred to as "new forestry," these silvicultural techniques were derived from European methods (Smith 1986, Forest Ecosystem Management Assessment Team 1993). They are now being reconsidered as alternative silvicultural options to clearcutting because they can be used to retain structural features found in old forests and more closely imitate natural disturbance regimes (Forest Ecosystem Management Assessment Team 1993).

To provide habitat for the over 400 terrestrial vertebrate species in forests of western Oregon and Washington (Brown 1985b), understanding their uses of habitat components, stand and landscape-level conditions are needed. Some animals are adapted to a variety of forest seral stages while optimum habitat for other wildlife species may be a single seral stage (e.g., a fire-created opening or an old-growth forest) (Brown 1985a, Brown 1985b). Additionally, within-stand structures such as logs or snags may be necessary for breeding or feeding (e.g., western bluebirds [*Sialia mexicana*] require cavities for nesting but feed in open areas) (Brown 1985a). Species with large home ranges (e.g., red-tailed hawk [*Buteo jamaicensis*]), may use more than 1 stand condition and respond to landscape-level patterns as well (Brown 1985b). With the interest in using alternatives to clearcutting, identifying wildlife response to alternative silvicultural techniques is also critical to retaining habitat or habitat features important to terrestrial vertebrates.

I studied the response of diurnal breeding birds and small mammals to 3 alternative silvicultural treatments and compared them with uncut controls. As a study site, I used McDonald-Dunn Research Forest which is located on the eastern edge of the Oregon Coast Range. The 5261-ha experimental forest was acquired in parcels by purchase or donation to Oregon State University between 1925 and 1962. Most parcels had been recently harvested prior to acquisition and because it has been actively managed by College of Forestry foresters, it consists primarily of second-growth forest. It is used as a teaching and research forest for the College of Forestry (Oregon State University College of Forestry 1993).

My study characterized animal and habitat use response to harvest. I focused on stand level associations and did not attempt to identify landscape-level patterns that influenced abundance of the species I documented. In Chapter 2, I identified species that were positively or negatively sensitive to disturbance caused by different intensities of logging: light intensity (uneven-aged small group selection treatment), moderate to heavy intensity (two-storied harvest treatment), and heavy intensity (modified clearcut even-aged treatment). Because I studied only 3 treatments representing a limited range of harvesting alternatives, I developed an index of habitat use versatility for birds based on geographic range, migratory status, and life history data. The versatility index (VI6) used the 6 most abundant species in a stand as an indicator of disturbance. It was developed for species whose home ranges were inclusive in stand sizes I studied (5 to 18 ha). The index could be used to identify disturbance intensity of alternative silvicultural treatments or to prioritize bird species when making management decisions.

I compared responses of vegetation and habitat variables among the 3 alternative silvicultural treatments in Chapter 3. I examined habitat selection by 5 bird species (winter wren [*Troglodytes troglodytes*], Swainson's thrush [*Catharus ustulatus*], Wilson's warbler [*Wilsonia pusilla*], orange-crowned warbler [*Vermivora celata*], and MacGillivray's warbler [*Oporornis tolmiei*]) using multiple regression analysis. I selected these species because they represented a range of responses to silvicultural treatments (from mature forest-associates to early seral stage-associates), were shrub or understory nesting species and so might be expected to indirectly reflect changes in overstory resulting from logging, showed sensitivity to all treatments (e.g., Swainson's thrush, winter wren), or were long-distance migrants and might be more vulnerable to habitat disturbance because they generally raise fewer young per year. Winter wren and Wilson's warbler were considered old-growth associates (Thomas et al. 1993).

In Chapter 4, I examined reproductive success in the silvicultural treatments and control stands using artificial nest predation rates to detect treatment responses since bird abundance or density can be misleading indicator of habitat quality (Van Horne 1983). Although artificial nests may not experience the same rate of predation as real nests, they may provide an estimate of the effect of avian or mammalian predators on bird productivity.

Logging in the Pacific Northwest in the 19th and early 20th centuries has varied from selective removal of large trees (small, unmerchantable species, snags, and logs were left on site) to clearcutting (Lord 1938, Forest Ecosystem Management Assessment Team 1993). Clearcutting and planting Douglas-fir (*Pseudotsuga menziesii*) has usually resulted in more uniform forest structure and composition than naturally regenerated forests, and the rotation lengths selected are often insufficient for recreating some mature or old-growth characteristics (e.g., snags, logs, large diameter trees) (Brown 1985a). Developing silvicultural prescriptions that produce more structurally complex managed forests may help meet needs of wildlife species, particularly those associated with mature or old-growth forests (Brown 1985b, Thomas et al. 1993).

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CHAPTER 2

DIURNAL BREEDING BIRD AND SMALL MAMMAL COMMUNITY RESPONSES TO THREE SILVICULTURAL TREATMENTS

Carol L. Chambers[1]
William C. McComb[2]
John Tappeiner, III[1]

[1]Department of Forest Resources
[2]Department of Forest Science
Oregon State University
Corvallis, OR 97331

INTRODUCTION

Mature and old-growth forests once dominated the landscape of the Pacific Northwest. Forests west of the Cascade Mountains, occupying over 28 million acres, were mixtures of Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and other conifers and were characterized by uneven-age diameter distributions, multilayered canopies, standing snags, broken top trees, and large logs. These forests reached old-growth status at about 150 to 250 years of age and stands with trees as old as 750 years have been documented (Harris 1984, Spies and Franklin 1988).

Landscape changes were initiated by natural disturbances such as windthrow, insect damage, and fires that varied in spatial extent, recurrence interval, and intensity. Small localized events such as the death of an individual tree created fine-scale changes in species composition, while large disturbances such as wildfires and prolonged droughts caused reorganization of the entire species assemblage (Spies et al. 1990, Urban et al. 1987). Disturbances affecting large patches on the landscape (100 to 10,000 ha) recurred only every 300 to 700 years. Return intervals were 100 to 200 years for smaller disturbances that created gaps of 0.01 to 0.1 ha (Spies and Franklin 1989).

The extensive use of clearcutting in the Pacific Northwest over the past 50 years has affected the forest landscape by rescaling natural disturbances both temporally and spatially and may eventually lead to a decrease or extirpation of some animal species (Mannan and Meslow 1984). Large areas have been harvested on rotations that were much shorter than the lifespan of the original trees. This change from natural disturbance levels may be expected to favor behaviorally plastic species (Urban et al. 1987) or early successional species. Silvicultural systems that mimic fine-scale disturbances through the use of uneven-aged regeneration systems may favor species that require continuous canopy cover. If structural legacy (e.g., snags, logs, green trees) is retained, the cutting cycle is appropriately long, and the target tree size appropriately large, then many mature forest species may benefit from uneven-age or long rotation even-aged management (McComb et al. 1994).

Uneven-aged silvicultural systems, which might mimic fine-scale disturbances, have been largely ignored as a basis for regeneration of Douglas-fir because such systems are not as economically efficient as clearcutting and Douglas-fir seedlings may develop more slowly in the more shaded conditions associated with uneven-age management. Consequently clearcutting has been the primary method of regeneration, and much of the landscape is currently dominated by second-growth even-aged stands of Douglas-fir that differ greatly in connectiveness of mature forest, edge length, patch size, and stand configuration from primeval landscapes (Harris 1984, Franklin and Forman 1987). Forty percent of mature stands have now been harvested, and until recently, Federal forest plans called for up to 85% of mature stands to be cut in the next 50 years (Raphael et al. 1988). Replacement stands were scheduled for harvest on much shorter rotations (e.g., 60 to 80 years) than the lifespan of the original trees.

Presumably the animal communities occupying Douglas-fir forests have persisted within disturbance patterns of the pre-European settlement period. Their fitness and/or abundance may be more greatly affected by human-induced disturbances of large tracts of forest. As the size of the opening or amount of harvested timber increases, the ability of old-forest associates to exist in the changed conditions may be affected detrimentally. Other species may not be affected, while habitat may be improved for those species favoring larger openings or disturbed sites.

Growing concerns over maintaining animal and plant biodiversity, preserving habitat for threatened and endangered species, and/or providing recreational opportunities (Thomas et al. 1993, Forest Ecosystem Management Assessment Team, 1993) have caused significant changes in Federal forest management policies. Federal guidelines now designate portions of national forests in the Pacific Northwest as reserve (Congressionally Reserved, Late-Successional Reserves, Riparian Reserves), withdrawn (Administratively Withdrawn), or management (Adaptive Management, Managed Late-Successional, Matrix) areas (USDA Forest Service and USDI Bureau of Land Management 1994). Managed areas are to be used to develop and test new management approaches that incorporate ecological and social objectives, to develop old-growth forest characteristics, to prevent large-scale disturbances (e.g., high intensity, high severity fire, insect and disease epidemics), to produce commercial yields of wood, and/or to increase ecological diversity by providing early-successional habitat (USDA Forest Service and USDI Bureau of Land Management 1994).

Silvicultural alternatives to clearcutting have been suggested to promote development, retention, or creation of late-successional features (large trees, diverse plant species, multilayered stands, snags and large logs). Under proposed Federal guidelines, snags and large down logs would be retained to provide appropriate habitat for organisms that use these structures. Single or groups of green trees would be distributed to provide future supplies of dead wood and patches of late-successional forest structure throughout the landscape (USDA Forest Service and USDI Bureau of Land Management 1994).

Silvicultural alternatives include even-aged, two-aged, and uneven-aged management techniques. Retaining snags and 3 to 5 green trees per ha while removing the remaining overstory produces a modified even-aged clearcut. A two-aged green tree retention (or two-story) system removes as much as two-thirds to three-fourths of the trees in the stand. Old trees are left behind to provide seed to regenerate the stand, and/or additional structure and dead wood resources. A new stand grows beneath these larger trees, providing two structural layers (Smith 1986). An uneven-aged group selection harvest removes patches of trees from the stand (e.g., oldest/largest trees in small groups), leaving the rest of the stand intact until the next entry (Smith 1986). Since these systems maintain some of the structure and components of the old stand, they presumably provide habitat for at least some animal species associated with old forests.

As alternative management techniques are applied to forested landscapes, resource managers need to be able to assess effects of changing conditions on wildlife populations. Some animal populations may benefit from the post-settlement changes in landscape pattern and structure, but others may lose important breeding or foraging habitat and decline in number (Mannan and Meslow 1984, Thomas 1988, Small and Hunter 1988, Renken and Wiggers 1989, McGarigal and McComb 1993).

I viewed timber removal as a type of disturbance that could be measured by variables such as percent overstory, basal area, or wood volume removed. I hypothesized that the degree of timber removal (or disturbance) would affect animal abundance in 1 of 3 ways: species might decline, increase, or show no response to the disturbance (Figure 2.1). Response would be dependent on the degree of habitat change caused by disturbance and the animal's versatility to those habitat changes.

Species associated with mature or old-growth forests would likely decline with timber removal; however, I predicted there could be 3 patterns of decline: linear decrease, early threshold, and late threshold (Figure 2.1A). Densities of some species might decline in direct proportion to amount of overstory removed, exhibiting a "linear decrease." Other species may tolerate a small amount of disturbance but show rapid declines in density after this "early threshold" disturbance level (e.g., removal of 10 to 30% of overstory) is reached. "Late threshold" species might tolerate a large amount of disturbance (e.g. removal of 50 to 70% of overstory) before densities decline.

Some animal species are associated with early seral stages or frequent and/or intense disturbances. These species should increase in density with overstory removal (Figure 2.1B). "Linear increasing" responses would indicate proportionate increases in species densities with overstory removal. Species increasing in density after a small percentage of wood volume was removed (e.g., 10 to 30%) would be considered "early threshold" species. Those increasing in density after a high percentage of overstory was removed (e.g., 70 to 90%) would be considered "late threshold" species.

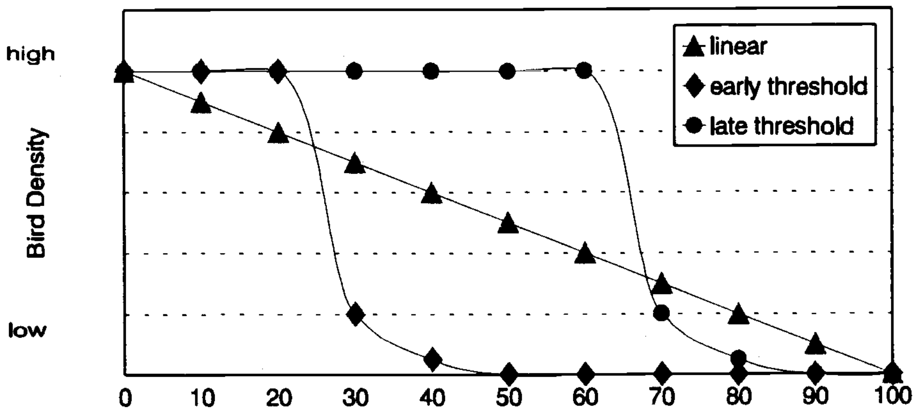
Figure 2.1. Hypothetical responses of animal species (e.g., birds) to disturbance. In this case, disturbance represents a silvicultural treatment that removes > 0 to 100% of overstory trees.

A. Birds associated with mature or old-growth forests may be affected detrimentally and decline in density. I predict there could be 3 patterns of decline: linear decrease, early threshold, and late threshold. Densities of some species might decline in direct proportion to amount of overstory removed, exhibiting a "linear decrease." Other species may tolerate a small amount of disturbance but show rapid declines in density after this "early threshold" disturbance level (e.g., removal of 10 to 30% of overstory) is reached. "Late threshold" species might tolerate a large amount of disturbance (e.g. removal of 50 to 70% of overstory) before densities decline.

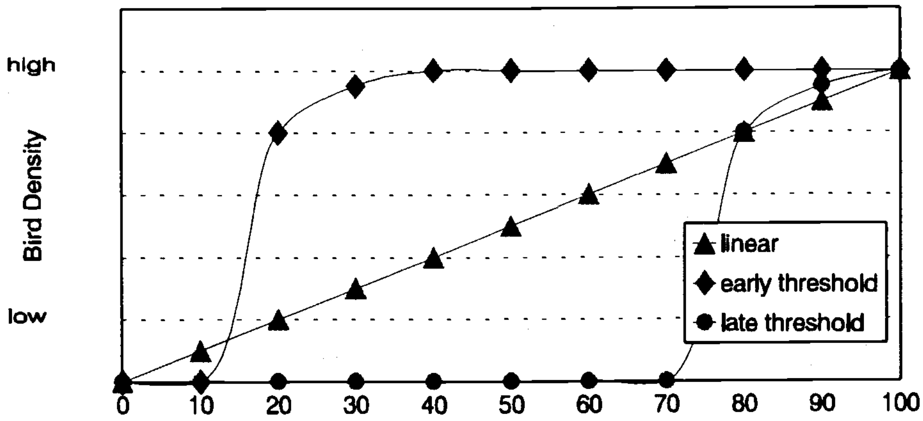
B. Species favoring large openings or disturbed sites may be affected positively, and increase in density as overstory is removed. "Linear increasing" responses would indicate proportionate increases in species densities with overstory removal. Species increasing in density after a small percentage of wood volume is removed (e.g., 10 to 30%) could be considered "early threshold" species. Those increasing in density after a high percentage of overstory is removed (e.g., 70 to 90%) would be considered "late threshold" species.

C. Other species may not be affected because they use features of habitat not affected by overstory removal.

A. Decreasing response



B. Increasing response



C. No response

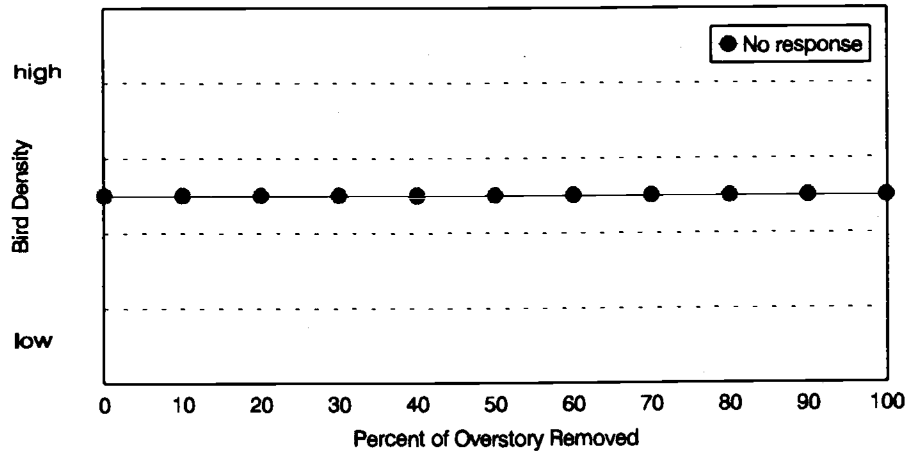


Figure 2.1.

There are some species that might not respond to overstory removal. They might instead be sensitive to changes in other habitat features (e.g., shrub density, snag or log density) (Figure 2.1C).

Monitoring animal responses to alternative silvicultural treatments can provide more detailed information about critical habitat components and identify degree of sensitivity to habitat change. Risk (or vulnerability ratings), viability assessments (Lehmkuhl and Ruggiero 1991, Thomas et al. 1993, Holthausen et al. 1995), or versatility indices (Thomas 1979, Brown 1985a, Brown 1985b) are all tools suggested to measure species sensitivity to habitat change.

Risk ratings define conditions required for stability of a population, and generally focus on sensitive, threatened, or endangered species or ecosystems. Lehmkuhl and Ruggiero's (1991) risk rating attempted to define dependency of old-growth associated vertebrate species on late-successional forest, using life history (e.g., migratory status, body size, vagility) and habitat use information (e.g., structural foliage layer used, requirement for special features such as snags).

Viability assessments evaluate population stability over time. They may include qualitative information about the species (e.g., dispersal capability, migratory status, habitat use, riparian associations, microhabitat associations), information on amount and distribution of habitat, population trends, abundance, degree of endemism, and potential effects of disturbance events on population persistence. For example, the viability assessment conducted by the Scientific Analysis Team (Thomas et al. 1993) evaluated viability of species closely associated with old-growth forests under 5 forest planning alternatives.

Versatility indices define a species adaptability to changing conditions and often consider a broader animal community than risk ratings or viability assessments. Versatility indices prepared by Thomas (1979) and Brown (1985a and 1985b) described the degree of adaptability of wildlife species based on the number of different plant communities and successional stages they use for feeding and breeding. These indices are indicators of sensitivity of each species to habitat change. Versatility indices were created for all forest-associated species (all seral stages) while vulnerability or risk ratings have usually addressed only one seral stage (e.g., old-growth).

Although versatility indices often consider more species, those developed in the Pacific Northwest for terrestrial vertebrate species of the Blue Mountains and western Oregon and Washington (Thomas 1979, Brown 1985b) were based on the number of forest plant communities and the number of successional stages (or stand conditions) used by the species as primary or secondary reproduction and/or feeding habitat. Neither index included use of special and unique habitats (e.g., riparian, talus), nor did they incorporate life history information. Versatility indices were simple numerical ratings with ranges of from 2 to 42, categorized as low (index rating of 2 - 15), medium (16 - 30), and high versatility (> 30). Brown (1985a) pointed out that this versatility rating system could rate 2 species the same when their habitat associations and sensitivity to habitat change varied considerably. Because the versatility rating sums the number of successional stages and number of plant communities used by a species, a species that uses 5 plant communities but only 1 successional stage within each community will receive the same rating as a species that uses 3 plant communities and 3 successional stages within each community. These species have the same versatility rating; however, habitat alterations may have very different effects on these 2 species.

Risk ratings, viability assessments, and versatility indices are somewhat artificial, but elements of all of them may be useful in creating an index of species response to habitat change. Knowing whether species respond negatively (e.g., old-growth associates) or positively (e.g., dark-eyed juncos [*Junco hyemalis*]) to different levels of disturbance (e.g., alternative silvicultural treatments) can be useful in landscape-level forest planning to help maintain appropriate distribution of species across the landscape. An index sensitive to habitat disturbance could be tested on a range of alternative silvicultural treatments representing a range of disturbance levels, then used to assess habitat suitability for species of interest. I hypothesized that higher intensities of disturbance (e.g., larger amounts of timber removed) would result in bird communities represented by highly versatile species; therefore, the modified clearcut treatment should have species with the highest versatility indices, species abundant in the two-story treatment should have the second highest versatility indices, those in the small patch group selection stands should have lower versatility indices, and those in controls should have lowest indices.

My objective was to determine the immediate (1- to 2-years post-harvest) response of bird and small mammal communities to 3 silvicultural treatments representing a range of disturbance levels applied to mature Douglas-fir forests to uncut control stands in the east Central Oregon Coast Range. I also developed a versatility to disturbance index to quantify bird community change as a result of harvest. I used it to test bird community response to the silvicultural treatments and control stands in my study.

STUDY AREA

Thirty-three stands were selected for study within Oregon State University's McDonald-Dunn Forest, a 5261-ha experimental forest located on the eastern of edge of the Coast Range, north and northwest of Corvallis. Three blocks of 11 stands each were located near (1) Lewisburg Saddle: Township 11S, Range 5W, Willamette Baseline and Meridian, portions of Sections 4, 8, 9, 16, 17; (2) Peavy: Township 10S, Range 5W, Willamette Baseline and Meridian, portions of Sections 25, 35, 36; and (3) Dunn: Township 10S, Range 5W, Willamette Baseline and Meridian, portions of Sections 14, 22, 23, 27. Stands were 5 to 18 ha in size. Douglas-fir comprised ≥ 64% basal area prior to harvest; in most stands (25 of 33 stands), it represented ≥ 80% total basal area. Species including grand fir (*Abies grandis*), 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*) comprised the remaining basal area (Table 2.1).

Treatments applied to both the Lewisburg Saddle and Peavy blocks consisted of 1 control (uncut), 6 small patch group selection (1/3 volume removed in 0.2-ha circular patches), 2 two-story (3/4 volume removed uniformly), and 2 modified clearcut (1.2 green trees/ha retained) stands. Treatments applied to the Dunn block included 1 control, 2 two-story, 2 modified clearcut, 2 small patch group selection, 2 large patch group selection (1/3 volume removed in 0.6-ha circular patches), 1 wedge cut (0.8- to 2-ha wedge cuts removing approximately 1/3 volume), and 1 strip cut (linear strips removing approximately 1/3 volume in 0.8- to 2-ha strips) stands. For statistical analyses I used replicated treatments: control: n = 3; small group selection: n = 14, two-story: n = 6, modified clearcut: n = 6. Harvesting began in fall 1989, and was completed by early spring 1991. One block was cut per year: Lewisburg Saddle block: 1989; Peavy block: 1990; Dunn block: 1991.

METHODS

Bird Sampling

I sampled diurnal breeding birds on the Lewisburg Saddle block for 5 years (1989 - 1993), on the Peavy block for 4 years (1990 - 1993), and on the Dunn block for 3 years (1991 - 1993). I conducted pretreatment sampling during the bird breeding season 1 year prior to harvest, and post-treatment sampling 2 to 4 years after harvest. Because only pretreatment and 1-year and 2-years post-treatment data were replicated among all blocks, I did not use data collected 3-years and 4-years post-harvest in statistical analyses.

Table 2.1. Stand size, age, species composition (pre-harvest), and harvest treatment applied for stands in McDonald-Dunn Forest.

Block Name		Average	Harvest	Snag	Pre-Harvest Species Basal Area (m^2/ha)[3]		
Stand Number	Size (ha)	Age (years)	Treatment[1]	Treatment[2]	PSME	ABGR	HWDS
Lewisburg Saddle[4]							
1	6.9	119	Clearcut	scattered	50 (84)	2 (3)	7 (13)
2	11.6	119	Two-Story	scattered	50 (84)	2 (3)	7 (13)
3	9.6	119	Small Patch	scattered	50 (84)	2 (3)	7 (13)
4	7.6	96	Small Patch	scattered	39 (84)	1 (3)	6 (13)
5	6.1	73	Small Patch	scattered	42 (83)	1 (1)	8 (16)
6	10.4	108	Small Patch	clumped	48 (82)	1 (2)	9 (16)
7	17.8	117	Two-Story	clumped	52 (86)	2 (2)	7 (12)
8	15.0	144	Clearcut	clumped	52 (88)	2 (4)	5 (8)
9	8.0	95	Small Patch	clumped	36 (89)	2 (5)	2 (6)
10	12.5	136	Small Patch	clumped	35 (85)	2 (4)	4 (11)
11	12.0	88	Control	no treatment	31 (91)	1 (1)	3 (8)

Table 2.1, continued.

Block Name Stand Number	Size (ha)	Average Age (years)	Harvest Treatment[1]	Snag Treatment[2]	Pre-Harvest Species Basal Area (m^2/ha)[3] PSME	ABGR	HWDS
Peavy[4]							
1	8.3	131	Control	no treatment	44 (80)	5 (10)	5 (10)
2	9.7	134	Clearcut	scattered	38 (93)	0 (0)	3 (7)
3	11.1	130	Small Patch	scattered	39 (85)	0 (0)	7 (15)
4	10.3	111	Two-Story	scattered	42 (94)	1 (1)	2 (5)
5	9.6	109	Small Patch	scattered	36 (93)	0.5 (1)	3 (6)
6	9.8	109	Small Patch	scattered	41 (90)	1 (2)	4 (8)
7	9.9	104	Small Patch	clumped	39 (89)	1 (1)	4 (10)
8	8.1	114	Small Patch	clumped	27 (64)	0 (0)	15 (36)
9	8.4	127	Small Patch	clumped	60 (79)	1 (1)	15 (20)
10	7.8	124	Two-Story	clumped	35 (83)	1 (1)	7 (16)
11	5.5	118	Clearcut	clumped	35 (83)	1 (2)	6 (15)

Table 2.1, continued.

Block Name Stand Number	Size (ha)	Average Age (years)	Harvest Treatment[1]	Snag Treatment[2]	Pre-Harvest Species Basal Area (m^2/ha)[3] PSME	ABGR	HWDS
Dunn[4]							
1	16.1	77	Two-Story	clumped	33 (77)	1 (1)	9 (22)
2	11.4	70	Large Patch	clumped	31 (73)	0.5 (1)	11 (26)
3	10.7	124	Clearcut	clumped	37 (81)	1 (2)	8 (17)
4	7.9	76	Strip	clumped	25 (77)	1 (2)	7 (21)
5	13.5	141	Control	no treatment	36 (76)	2 (5)	9 (19)
6	7.3	67	Wedge	scattered	30 (81)	1 (2)	7 (17)
7	11.7	59	Small Patch	scattered	33 (80)	0.5 (1)	8 (19)
8	9.0	58	Two-Story	scattered	29 (81)	0.5 (1)	7 (18)
9	6.7	45	Clearcut	scattered	18 (75)	0 (0)	6 (25)
10	9.8	58	Large Patch	scattered	21 (68)	1 (3)	9 (29)
11	10.9	60	Small Patch	clumped	26 (70)	1 (2)	10 (28)

[1] Treatments: (1) control: no treatment; (2) small patch: group selection with 0.2-ha circular patches removing 1/3 of the stand volume; (3) two-story: 3/4 volume removed with residual trees scattered uniformly through the stand; (4) clearcut: 1.2 green trees/ha retained; (5) large patch: group selection with 0.8-ha circular patches removing 1/3 of the stand volume; (6) wedge: group selection with 0.8- to 2.0-ha wedge cuts removing 1/3 of the stand volume, (7) strip: group selection with 0.8- to 2.0-ha linear strips removing 1/3 of the stand volume.

[2] 3.8 snags/ha created by topping green trees in scattered or clumped pattern; no snags created in control stands.

[3] Data are m^2/ha with percent of total basal area indicated in parentheses. Tree species are: PSME = Douglas-fir (*Pseudotsuga menziesii*); ABGR = grand fir (*Abies grandis*); HWDS = all hardwoods including Pacific madrone (*Arbutus menziesii*), Pacific dogwood (*Cornus nuttallii*), red alder (*Alnus rubra*), Oregon ash (*Fraxinus latifolia*), and bitter cherry (*Prunus emarginata*).

[4] Lewisburg Saddle harvested in 1990, Peavy harvested in 1991, Dunn harvested in 1992.

Diurnal breeding 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 centers a minimum of 100 m from the stand edge and 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 winds > 15 km/h.

Counts began 2 minutes after arrival at the VCP station to allow for resumption of normal bird activity. Each count lasted 8 minutes, during which time birds seen or heard singing in or adjacent to the stand were identified to species, their distance (m) from the VCP center estimated, and their approximate location mapped. Distances were recorded to the nearest meter for birds ≤ 10 m from VCP station, nearest 5 m for birds > 10 m but ≤ 50 m, nearest 10 m for birds > 50 m. Locations of active bird nests found during bird counts or while walking between VCP stations also were recorded.

Four observers participated in sampling. Three of these conducted sampling throughout all 4 years, while the fourth sampled in 2 of the 4 years. Each observer sampled all VCPs 1 to 4 times during the breeding season.

Abundance (number of observations/5 ha) for each species was averaged by stand within treatments (control: n = 3; group selection: n = 14; two-story: n = 6; modified clearcut: n = 6). Species richness (total number of species), Simpson species diversity and equitability indices (Brower et al. 1990) were averaged among stands within each treatment by year. Similarity of bird communities in harvested stands was compared with pretreatment communities using a percent similarity index, Morisita's Index, and the Jaccard coefficient (Brower et al. 1990).

Percent similarity compares the proportional composition of species in 2 communities. For each species, the percentage of individuals present in both communities is summed. The higher the value, the greater the similarity between communities. Morisita's index measures the probability that 2 randomly selected individuals from a community will be of the same species (probability of encounter). The Jaccard coefficient is a comparison of species common to 2 communities. This coefficient does not take into account the relative abundance of species (Brower et al. 1990).

Small Mammal Trapping

Capture efficiency differs among trap types, so I used a combination of pitfall and Sherman traps for small mammal mark-recapture live-trapping. Pitfall traps sample insectivores and nonjumping rodents more effectively than Sherman traps which capture jumping mice (*Zapus* spp.) and large rodents more effectively (Williams and Braun 1983, McComb et al. 1991).

VCP stations in each stand were used as center points for mammal sampling. Ten traps were placed at each VCP station, with 1 each Sherman live trap (8 x 9 x 23 cm) and pitfall trap (double-deep number 10 tin cans) at the VCP and at each of the four cardinal directions 10- to 15-m from the VCP (30 traps per stand). Pitfall traps were buried flush with the ground along logs, snags, or other natural drift "fences" when available. Sherman traps also were placed along natural drift fences.

Traps were opened for 1 week per block during the summer (July-August). Traps were opened on Monday, checked daily for 4 days, then closed on Friday (4 trap nights (TN) x 10 traps/VCP station x 3 VCP stations/stand = 120 TN per stand) with the exception of the Lewisburg Saddle block. During the first year for this block, 9 pitfall traps per stand only were used to sample small mammals (3 traps per VCP, 3 VCPs per stand). Capture rate for each species was standardized by calculating number of individuals per 1000 trap nights (TN) for each stand and year.

I used polyester bedding to help prevent hypothermia and I baited traps with rolled oats and peanut butter-covered hamster chow. To keep pitfall traps free of water accumulation, I punched 4 drain holes in the pitfalls and placed a metal cover approximately 10-15 cm above each pitfall. Sherman traps were covered with a milk carton sleeve (half-gallon unformed milk carton) for insulation and protection from rain. All animals captured were identified to species, and sexed, weighed, and aged when possible. Individuals were marked by toe clipping, then released.

During breeding bird counts, I noted activity (calling) or sightings of Douglas' squirrels (*Tamisciurus douglasii*) and Townsend's chipmunks (*Tamias townsendii*). Squirrel and chipmunk detections were compared among treatments to determine the effect of disturbance on a mature forest associate (Douglas' squirrel) and a less specialized species (Townsend's chipmunk).

Statistical Analyses

I compared average detection distance (m) using individuals ≤ 75 m from VCP station for each bird species and for 3 mammal species (vocalizations and/or sightings of Douglas' squirrel, Townsend's chipmunk, and black-tailed deer [*Odocoileus hemionus columbianus*]) (n ≥ 30 observations) to insure that I did not eliminate a high proportion (e.g., > 10%) of individuals and bias results of species analyses by underreporting observations. I used analysis of variance (PROC GLM, SAS Institute Inc. 1989) to determine if there were differences in detection distances among treatments and years. For species with significant treatment*year interaction ($\underline{P} \leq 0.05$), significant treatment effects ($\underline{P} \leq 0.05$), or significant year effects ($\underline{P} \leq 0.05$), I calculated 95% confidence intervals for treatment means. If the 95% confidence interval placed some individuals at detection distances > 75 m, I 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- to 80-m range of VCPs, not all individuals were being counted using a 75 m cutoff distance, and this species would be eliminated from statistical analyses).

Bird abundance (total number of birds per 5 ha, excluding red crossbill and evening grosbeak [*Coccothraustes vespertinus*] observations since these birds were mostly in foraging flocks), diversity, equitability, and richness were compared among treatments for the 3-year period (pretreatment, 1-year post-treatment, and 2-years post-treatment). I calculated bird community similarity values (percent similarity, Jaccard coefficient, Morisita's index) for pretreatment v. 1-year post-treatment and for pretreatment v. 2-years post-treatment and used analysis of variance to detect treatment differences. I used LSMeans tests to detect differences among treatments (SAS Institute Inc. 1989).

Bird abundance was averaged for individual species by year and compared among treatments over the 3-year period (pretreatment, 1-year post- and 2-years post-treatment). Only birds ($n \geq 30$ observations) mapped ≤ 75 m from each VCP station were used in data analyses. Repeat observations were eliminated from data analyses. Birds observed flying over stands were recorded but 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).

Douglas' squirrel, Townsend's chipmunk, and black-tailed deer observations and vocalizations (average number of observations per 5 ha) were compared among treatments for the 3-year period. Data were transformed using a log transformation [$\log_{10}$(variable+1)] to reduce variance (Sabin and Stafford 1990). If data could not be normalized (e.g., nonsignificant treatment*year interaction effect but significant treatment effect), I calculated differences between pretreatment and 2-years post-treatment data, averaging by treatment within each block (control: $n = 3$, small patch: $n = 3$, two-story: $n = 3$, clearcut: $n = 3$). I ranked these differences with PROC RANK (SAS Institute 1990) and used analysis of variance 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 ($\underline{P} \leq 0.05$) (Hollander and Wolfe 1973:151).

Capture rates (number of individuals captured/1000 TN/stand) were calculated for each mammal species and for 4 mammal groups. These were 3 groups of taxonomically related species ([1] rodents: western red-backed vole [*Clethrionomys californicus*], northern flying squirrel [*Glaucomys sabrinus*], Oregon vole [*Microtus oregoni*], dusky-footed woodrat [*Neotoma fuscipes*], deer mouse [*Peromyscus maniculatus*], red tree vole [*Phenacomys longicaudus*], and Townsend's chipmunk; [2] insectivores: shrew-mole [*Neurotrichus gibbsii*], coast mole [*Scapanus orarius*], Townsend's mole [*Scapanus townsendii*], Pacific water shrew [*Sorex bendirii*], Pacific shrew [*Sorex pacificus*], Trowbridge's shrew [*Sorex trowbridgii*], and vagrant shrew [*Sorex vagans*]; and (3) shrews: Pacific water shrew, Pacific shrew, Trowbridge's shrew, and vagrant shrew), and 1 functionally-related group of potential bird nest predators including Townsend's chipmunk and deer mouse. Capture rates of species ($n \geq 30$ observations) or species groups were compared among treatments for 2 time periods (pretreatment and 1-year post-treatment). Only new captures were used in analyses and data were transformed using a log transformation [$\log_{10}$(capture rate+1)] to meet the assumptions of equal variance and normally distributed residuals (Sabin and Stafford 1990). In analyzing small mammal community measures (abundance, Simpson diversity, Simpson equitability, richness), I used capture rates (number of individuals per 1000 trap nights) for all new individuals trapped.

For other community similarity values (percent similarity, Jaccard coefficient, Morisita's index) for pretreatment v. 1-year post-treatment and for pretreatment v. 2-years post-treatment, I used analysis of variance to detect treatment differences. I used LSMeans tests to detect differences among treatments (SAS Institute Inc. 1989).

Two blocks (Lewisburg and Peavy), were live-trapped for 3 years; the Dunn block was live-trapped for 2 years. The Lewisburg Saddle and Peavy blocks were trapped 1 year prior to harvest and for 2 consecutive years post-harvest. The Dunn block was trapped preharvest and 1-year post-harvest. The Lewisburg Saddle block was trapped using only pitfalls the first year, so I eliminated it from analysis except for comparisons of Trowbridge's shrews based on pitfall capture rates.

I used SAS repeated measures analysis (RMA) (SAS Institute Inc. 1989) to detect treatment and time effects for bird and mammal community measures (abundance, Simpson diversity, Simpson equitability, species richness) and for individual bird and mammal species. I used Mauchly's criterion to test the appropriateness of a univariate analysis for time effects. If Mauchly's criterion was significant ($\underline{P} \leq 0.10$), I interpreted results for RMA using the Wilks' Lambda statistic for MANOVA tests of hypotheses of: (1) no treatment by year interaction, (2) no treatment effects, and (3) no year effects.

If I detected a significant treatment by year interaction ($\underline{P} \leq 0.05$) I did not report results of Wilks' Lambda tests for treatment or for year tests but included results of RMA orthogonal contrasts of treatments v. control using profile contrasts which compare successive years (e.g., compare year 1 to year 2 and year 2 to year 3) (SAS Institute Inc. 1989). These values indicated animal response to treatment.

If Mauchly's Criterion was significant and there were no detectable interaction effects ($\underline{P} > 0.05$), I reported results for Wilks' Lambda tests for year and treatment effects, as well as profile orthogonal contrasts of treatments v. control for successive years. If Mauchly's Criterion was not significant ($\underline{P} > 0.10$), I used results from the univariate repeated measures analysis of variance using the procedure PROC MIXED (SAS Institute 1992). If Mauchly's Criterion was not significant ($\underline{P} > 0.10$) and the univariate analysis resulted in significant year by treatment interactions ($\underline{P} \leq 0.05$), I included results of RMA orthogonal contrasts of treatments v. control for successive years (SAS Institute Inc. 1989). These values can be used as indicators of trends in animal response.

I used nonparametric analyses to detect differences in treatments when the assumptions for RMA were not met. I averaged animal data by treatment and year within each block (control: n = 3, small patch: n = 3, two-story: n = 3, clearcut: n = 3). I compared only 2 years: pretreatment v. 2-years post-treatment. I calculated differences between pretreatment and 2-years post-treatment, ranked these data using PROC RANK (SAS Institute 1990) and used an 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).

Bird Versatility / Disturbance Index

I developed a versatility index (VI) to examine response of Oregon Coast Range bird communities to habitat change caused by timber harvest. I followed the example of Lehmkuhl and Ruggiero (1991) and incorporated versatility ratings created by Brown (1985b) in creating indices for birds whose home ranges were generally < 20 ha. I collected information on species' life history (e.g., migratory status) and habitat relationship information that might indicate sensitivity to habitat disturbance. I included geographic range as an indicator of overall population responses, assuming that populations distributed across broader geographic ranges might be less strongly affected by disturbances since dispersing individuals might rescue failing populations, and assuming geographic range could serve as an indicator of a species' ability to adapt to a broader array of ecosystems and climatic zones. Information for species found in forests west of the Oregon Cascades Range (geographic range, habitat distribution, migratory status, reproductive capacity, and special habitat features [dead wood]) is listed in Table 2.2. The index and variables used in its calculation are defined in Table 2.3. The versatility index I developed which may also serve as an index of habitat disturbance is listed in Table 2.4. Variables and points assigned to ranges or categories of the variables are defined below. I developed the indices primarily for species whose home ranges were inclusive in the stand sizes I studied (5 to 18 ha).

Table 2.2. Summary of life history data, habitat use, and geographic range in North America (breeding and winter) of bird species associated with forests west of the crest of the Oregon Cascades Mountains. Migratory status: R=resident, S=short-distance migrant, L=long-distance migrant; Breeding Geographic Range = breeding geographic distribution in North America; Year-Around Geographic Range = summer and winter resident distribution in North America; Total Geographic Range = Breeding Geographic Range + Year-Around Geographic Range; Habitat Types Used: A=agricultural (includes fields, orchards), F=forested, S=suburban, U=urban; Special Features Used: dead wood used as primary habitat for breeding (L=logs and down material, S=snags); Forest Rating (adapted from Brown 1985, Appendix 16) = number of seral stages used as primary or secondary habitat for breeding or feeding in temperate coniferous forests (i.e., dark-eyed junco breeds in 5 seral stages and feeds in 5 seral stages so Forest Rating = 10). RC=reproductive capacity and is the median number of clutches per year x median number of eggs per clutch.

Bird Species[1]	Migratory Status	Breeding Geographic Range (1000 km^2)	Year-Around Geographic Range (1000 km^2)	Total Geographic Range (1000 km^2)	Habitat Types Used	Special Features Used	Versatility Rating (Brown 1985)	Number Clutches/ year	Number Young/ clutch	RC
mountain quail	R		583	583	AF		32	1	5-15	10.0
band-tailed pigeon	S	972	374	1346	AF		32	1-3	1-2	3.0
mourning dove	S	3002	6077	9079	AFSU		28	2-4	2 (2-4)	9.0
Vaux's swift	L	943		943	AFS	S	34	1	3-7	5.0
Anna's hummingbird	R		482	482	AFS		25	1-3	1-3	4.0
calliope hummingbird	L	1941		1941	F		22	1-2	2	3.0
rufous hummingbird	L	2023		2023	F		37	1-2	2	3.0
Allen's hummingbird	L	113		113	F		28	2	2	4.0
belted kingfisher	R	7928	4439	12367	AFS		16	1	5-8	6.5
northern flicker	R	8207	6870	15077	AFS	LS	33	1	3-14	8.5
acorn woodpecker	R		772	772	AFS	S	16	1	5-6	5.5
Lewis' woodpecker	R	1948	985	2933	AF	S	17	1	5-9	7.0
red-breasted sapsucker	R	833	532	1365	AFS	S	26	1	5 (3-6)	4.5
downy woodpecker	R		11532	11532	AFS	S	21	1	3-7	5.0

Table 2.2, continued.

Bird Species	Migratory Status	Breeding Geographic Range (1000 km^2)	Year-Around Geographic Range (1000 km^2)	Total Geographic Range (1000 km^2)	Habitat Types Used	Special Features Used	Versatility Rating (Brown 1985)	Number Clutches/ year	Number Young/ clutch	RC
hairy woodpecker	R		12137	12137	FS	LS	22	1	4 (3-6)	4.5
pileated woodpecker	R		7080	7080	F	LS	27	1	3-4 (3-8)	5.5
western kingbird	L	5204		5204	AF		15	1	3-4	3.5
olive-sided flycatcher	L	8198		8198	F	S	24	1	3 (2-4)	3.0
western wood-pewee	L	5468		5468	AFSU		29	1	3 (2-4)	3.0
Hammond's flycatcher	L	2840		2840	F		26	1	2-5	3.5
willow flycatcher	L	5094		5094	AF		20	1	2-5	3.5
Pacific-slope flycatcher	L	2534		2534	F		24	1-2	3-4 (3-9)	9.0
tree swallow	L	11757	105	11862	AFS	S	29	1	3-7	5.0
violet-green swallow	L	5132	112	5244	AFSU	S	33	1	4-7	5.5
northern rough-winged swallow	L	8840	108	8548	AFS		9	1	3-9	6.0
barn swallow	L	11483		11483	AFS		17	2	1-8	9.0
scrub jay	R		2056	2056	AFS		24	1	2-7	4.5
Steller's jay	R		3532	3532	FS		32	1	4 (2-6)	4.0
gray jay	R		9347	9347	F		23	1	3-4 (2-5)	3.5
wrentit	R		249	249	F		10	1	3-5	4.0
black-capped chickadee	R		8393	8393	AFS	S	18	1	4-10	7.0
mountain chickadee	R		3084	3084	F	S	20	1-2	5-12	12.8
chestnut-backed chickadee	R		938	938	F	S	28	1	6-7 (5-9)	7.0
bushtit	R		1751	1751	AFS		22	1-2	5-7 (4-15)	14.3

Table 2.2, continued.

Bird Species	Migratory Status	Breeding Geographic Range ($1000\ km^2$)	Year-Around Geographic Range ($1000\ km^2$)	Total Geographic Range ($1000\ km^2$)	Habitat Types Used	Special Features Used	Versatility Rating (Brown 1985)	Number Clutches/ year	Number Young/ clutch	RC
brown creeper	R	3227	3190	6417	F	LS	29	1	5-6 (4-8)	6.0
white-breasted nuthatch	R		7412	7412	FS	S	17	1	5-10	7.5
red-breasted nuthatch	R		6907	6907	FS	LS	24	1	5-6 (4-7)	5.5
house wren	S	7772	250	8022	AFS	LS	18	2	6-7 (5-8)	13.0
winter wren	R	3326	872	4198	F	LS	27	1	5-6 (4-7)	5.5
Bewick's wren	R	418	2491	2909	AFS	LS	22	1-2	5-7 (4-11)	11.3
golden-crowned kinglet	R	2312	4029	6341	F		27	2	8-9 (5-11)	16.0
ruby-crowned kinglet	R	8990	151	9141	FS		26	1	5-11	8.0
western bluebird	R	1099	1098	2197	AF	S	20	1	3-8	5.5
Townsend's solitaire	R	1736	2484	4247	F	L	25	1	3-5	4.0
Swainson's thrush	L	8464		8464	F		26	1-2	3-5	6.0
hermit thrush	S	8710	755	9465	F		30	1	4 (3-5)	4.0
varied thrush	R	2970	491	3461	F		28	1	2-5	3.5
American robin	S	11561	4811	16372	AFSU		37	2-3	3-4 (2-7)	11.3
cedar waxwing	R	3870	35	3905	AFS		27	2	4-5 (2-6)	8.0
European starling	R		12338	12338	AFSU	S	27	2-3	3-6	11.3
Hutton's vireo	R		694	694	F		28	1-2	4 (2-5)	5.3
solitary vireo	L	6665		6665	F		28	1	3-5	4.0
warbling vireo	L	9892		9892	F		26	1	3-5	4.0
orange-crowned warbler	L	7296	91	7387	AF		31	1	4-5 (3-6)	4.5
Nashville warbler	L	3034		3034	F		30	2	3-5	8.0
yellow-rumped warbler	S	9463	437	9900	F		31	2	3-5	8.0

Table 2.2, continued.

Bird Species	Migratory Status	Breeding Geographic Range (1000 km²)	Year-Around Geographic Range (1000 km²)	Total Geographic Range (1000 km²)	Habitat Types Used	Special Features Used	Versatility Rating (Brown 1985)	Number Clutches/ year	Number Young/ clutch	RC
black-throated gray warbler	L	1788	17	1805	F		28	1	4 (3-5)	4.0
Townsend's warbler	L	2132		2132	F		22	1	3-5	4.0
hermit warbler	L	236		236	F		25	1	3-5	4.0
MacGillivray's warbler	L	3133		3133	F		27	1	4 (3-5)	4.0
Wilson's warbler	L	6889		6889	F		33	1	4-5 (3-6)	4.5
common yellowthroat	L	10775	1494	12269	AF		8	1-2	2-6	6.0
black-headed grosbeak	L	3816		3816	AFS		28	1	3-4 (2-5)	3.5
lazuli bunting	L	3531		3531	AF		18	1	3-5	4.0
rufous-sided towhee	R	2840	4091	6931	AFSU		31	2	3-4	7.0
song sparrow	R	5274	5148	10422	AFSU	L	24	2-3	2-6	10.0
chipping sparrow	S	10667	1095	11762	AFS		36	2	3-5	8.0
dark-eyed junco	R	5810	5446	11256	AFSU	L	39	2	4 (3-6)	9.0
white-crowned sparrow	R	6952	1339	8291	AFS		34	1-2	4-5 (3-6)	6.8
fox sparrow	S	6992		6992	F		34	1-2	3-5	6.0
brown-headed cowbird	S	7352	4101	11453	AFS		34	3-4	6-7	22.8
western tanager	L	3771		3771	FS		30	1	3-5	4.0
pine siskin	R	2382	4795	7177	FS		32	1-2	3 (1-6)	5.3
American goldfinch	R	3476	4193	7669	AFS		23	1	5 (4-6)	5.0
lesser goldfinch	R	821	965	1786	AFS		20	1	3-6	4.5
red crossbill	S		6808	6808	F		23	1	4 (2-5)	3.5
purple finch	R	2367	2027	4394	FS		29	1-2	4 (3-6)	6.8

Table 2.2, continued.

Bird Species	Migratory Status	Breeding Geographic Range (1000 km^2)	Year-Around Geographic Range (1000 km^2)	Total Geographic Range (1000 km^2)	Habitat Types Used	Special Features Used	Versatility Rating (Brown 1985)	Number Clutches/ year	Number Young/ clutch	RC
Cassin's finch	R	1046	1117	2163	F		23	1	3-6	4.5
house finch	R		4686	4686	AFS		28	2-3	2-6	10.0
evening grosbeak	R		4156	4156	FS		33	1	4 (2-5)	3.5

[1] Scientific names are: mountain quail (*Oreortyx pictus*), band-tailed pigeon (*Columba fasciata*), mourning dove (*Zenaida macroura*), Vaux's swift (*Chaetura vauxi*), Anna's hummingbird (*Calypte anna*), calliope hummingbird (*Stellula calliope*), rufous hummingbird (*Selasphorus rufus*), Allen's hummingbird (*Selasphorus sasin*), belted kingfisher (*Ceryle alcyon*), northern flicker (*Colaptes auratus*), acorn woodpecker (*Melanerpes formiciorus*), Lewis' woodpecker (*Melanerpes lewis*), red-breasted sapsucker (*Sphyrapicus ruber*), downy woodpecker (*Picoides pubescens*), hairy woodpecker (*Picoides villosus*), pileated woodpecker (*Dryocopus pileatus*), western kingbird (*Tyrannus verticalis*), olive-sided flycatcher (*Contopus borealis*), western wood-pewee (*Contopus sordidulus*), Hammond's flycatcher (*Empidonax hammondii*), willow flycatcher (*Empidonax trailii*), Pacific-slope flycatcher (*Empidonax difficilis*), tree swallow (*Tachycineta bicolor*), violet-green swallow (*Tachycineta thalassina*), northern rough-winged swallow (*Stelgidopteryx serripennis*), barn swallow (*Hirundo rustica*), scrub jay (*Aphelocoma coerulescens*), Steller's jay (*Cyanocitta stelleri*), gray jay (*Perisoreus canadensis*), wrentit (*Chamaea fasciata*), black-capped chickadee (*Parus atricapillus*), mountain chickadee (*Parus gambeli*), chestnut-backed chickadee (*Parus rufescens*), bushtit (*Psaltriparus minimus*), brown creeper (*Certhia americana*), white-breasted nuthatch (*Sitta carolinensis*), red-breasted nuthatch (*Sitta canadensis*), house wren (*Troglodytes aedon*), winter wren (*Troglodytes troglodytes*), Bewick's wren (*Thryomanes bewickii*), golden-crowned kinglet (*Regulus satrapa*), ruby-crowned kinglet (*Regulus calendula*), western bluebird (*Sialia mexicana*), Townsend's solitaire (*Myadestes townsendi*), Swainson's thrush (*Catharus ustulatus*), hermit thrush (*Catharus guttatus*), varied thrush (*Ixoreus naevius*), American robin (*Turdus migratorius*), cedar waxwing (*Bombycilla cedrorum*), European starling (*Sturnus vulgaris*), Hutton's vireo (*Vireo huttoni*), solitary vireo (*Vireo solitarius*), warbling vireo (*Vireo gilvus*), orange-crowned warbler (*Vermivora celata*), Nashville warbler (*Vermivora ruficapilla*), yellow-rumped warbler (*Dendroica coronata*), black-throated gray warbler (*Dendroica nigrescens*), Townsend's warbler (*Dendroica townsendi*), hermit warbler (*Dendroica occidentalis*), MacGillivray's warbler (*Oporornis tolmiei*), Wilson's warbler (*Wilsonia pusilla*), common yellowthroat (*Geothlypis trichas*), black-headed grosbeak (*Pheucticus melanocephalus*), lazuli bunting (*Passerina amoena*), rufous-sided towhee (*Pipilo erythrophthalmus*), song sparrow (*Melospiza melodia*), chipping sparrow (*Spizella passerina*), dark-eyed junco (*Junco hyemalis*), white-crowned sparrow (*Zonotrichia leucophrys*), fox sparrow (*Passerella iliaca*), brown-headed cowbird (*Molothrus ater*), western tanager (*Piranga ludoviciana*), pine siskin (*Carduelis pinus*), American goldfinch (*Carduelis tristis*), lesser goldfinch (*Carduelis psaltria*), red crossbill (*Loxia curvirostra*), purple finch (*Carpodacus purpureus*), Cassin's finch (*Carpodacus cassinii*), house finch (*Carpodacus mexicanus*), evening grosbeak (*Coccothraustes vespertinus*).

Table 2.3. Definition of variables used to calculate versatility indices for each bird species. Each category is weighted to sum to 1.00, with the exception of Special Features which is rated -1 or 0, depending on species' use of dead wood. Forest rating is a subdivision of Habitat type and has 3 ratings. Migratory status, habitat use, and geographic range (breeding and winter) in North America were used to calculate versatility indices for species west of the Oregon Cascades Mountains. Total geographic range is the sum of breeding geographic range and year-around geographic range. See text for detail. Values for the versatility index can range from 0.42 to 3.23.

Versatility Index = MI + TGR + (HAA + HAS + HAU + HAF) + RR + (SF + 1)

Variable	Assigned Point Value	Standardized Value
Migratory Status (MI)		
L = long-distance migrant	1	0.17
S = short-distance migrant	2	0.33
R = resident	3	0.50
Total Geographic Range (1000 km^2) (TGR)		
0 - 5000	1	0.10
5001 - 10,000	2	0.20
10,001 - 15,000	3	0.30
15,001 - 20,000	4	0.40
Habitat Types Used (HA)		
A = agricultural (HAA)	1	0.25
S = suburban (HAS)	1	0.25
U = urban (HAU)	1	0.25
F = forest (HAF)		
Versatility Index (Brown 1985)		
1-15	1	0.08
16-30	2	0.13
>30	3	0.25
Special Features Used (SF)		
Snags or logs used as primary habitat	-1	-1
Snags or logs not used	0	0
Reproductive Rating (RR)		
0 to 5	1	0.07
6 to 10	2	0.13
11 to 15	3	0.20
16 to 20	4	0.27
20 to 25	5	0.33

Table 2.4. Versatility indices for diurnal bird species associated with forests west of the crest of the Oregon Cascades Mountains. Versatility index (VI) is calculated by summing ratings for geographic range (TGR), migratory status (MI), use of forest (HA-F), agricultural (HA-A), suburban (HA-S), and urban (HA-U) habitats, use of special features (primarily dead wood) (SF), reproductive rating (RR), and 1 point (FREE). Values for VI can range from a maximum of 3.23 to a minimum of 0.42. See text for definition of ratings variables.

SPECIES	TGR	MI	HA-F	HA-A	HA-S	HA-U	RR	SF	FREE	VI	ACRONYM	SCIENTIFIC NAME
VI > 2.5 (Highly versatile)												
dark-eyed junco	0.3	0.5	0.25	0.25	0.25	0.25	0.13	0	1	2.93	DEJU	Junco hyemalis
American robin	0.4	0.33	0.25	0.25	0.25	0.25	0.2	0	1	2.93	AMRO	Turdus migratorius
song sparrow	0.3	0.5	0.13	0.25	0.25	0.25	0.13	0	1	2.81	SOSP	Melaspiza melodia
brown-headed cowbird	0.3	0.33	0.25	0.25	0.25	0	0.33	0	1	2.71	BHCO	Molothrus ater
white-crowned sparrow	0.2	0.5	0.25	0.25	0.25	0	0.13	0	1	2.58	WCSP	Zonotrichia leucophrys
belted kingfisher	0.3	0.5	0.13	0.25	0.25	0	0.13	0	1	2.56	BEKI	Ceryle alcyon
mourning dove	0.2	0.33	0.13	0.25	0.25	0.25	0.13	0	1	2.54	MODO	Zenaida macroura
chipping sparrow	0.3	0.33	0.25	0.25	0.25	0	0.13	0	1	2.51	CHSP	Spizella passerina
VI = 2.0 - 2.49 (Very versatile)												
bushtit	0.1	0.5	0.13	0.25	0.25	0	0.2	0	1	2.43	BUSH	Psaltriparus minimus
American goldfinch	0.2	0.5	0.13	0.25	0.25	0	0.07	0	1	2.40	AMGO	Carduelis tristis
cedar waxwing	0.1	0.5	0.13	0.25	0.25	0	0.13	0	1	2.36	CEWA	Bombycilla cedrorum
house finch	0.1	0.5	0.13	0.25	0.25	0	0.13	0	1	2.36	HOFI	Carpodacus mexicanus
western wood-pewee	0.2	0.17	0.13	0.25	0.25	0.25	0.07	0	1	2.32	WWPE	Contopus sordidulus
Anna's hummingbird	0.1	0.5	0.13	0.25	0.25	0	0.07	0	1	2.30	ANHU	Calypte anna
lesser goldfinch	0.1	0.5	0.13	0.25	0.25	0	0.07	0	1	2.30	LEGO	Carduelis psaltria
scrub jay	0.1	0.5	0.13	0.25	0.25	0	0.07	0	1	2.30	SCJA	Aphelocoma coerulescens
barn swallow	0.3	0.17	0.13	0.25	0.25	0	0.13	0	1	2.23	BASW	Hirundo rustica
ruby-crowned kinglet	0.2	0.5	0.13	0	0.25	0	0.13	0	1	2.21	RCKI	Regulus calendula
pine siskin	0.2	0.5	0.25	0	0.25	0	0.07	0	1	2.27	PISI	Carduelis pinus
mountain quail	0.1	0.5	0.13	0.25	0	0	0.13	0	1	2.11	MOQU	Oreortyx pictus
golden-crowned kinglet	0.2	0.5	0.13	0	0	0	0.27	0	1	2.10	GCKI	Regulus satrapa
Steller's jay	0.1	0.5	0.25	0	0.25	0	0.07	0	1	2.17	STJA	Cyanocitta stelleri
northern rough-winged swallow	0.2	0.17	0.08	0.25	0.25	0	0.13	0	1	2.08	NRSW	Stelgidopteryx serripennis
band-tailed pigeon	0.1	0.33	0.25	0.25	0	0	0.07	0	1	2.00	BTPI	Columba fasciata

Table 2.4, continued.

SPECIES	TGR	MI	HA-F	HA-A	HA-S	HA-U	RR	SF	FREE	VI	ACRONYM	SCIENTIFIC NAME
VI = 1.5 - 1.99 (Versatile)												
black-headed grosbeak	0.1	0.17	0.13	0.25	0.25	0	0.07	0	1	1.97	BHGR	Pheucticus melanocephalus
orange-crowned warbler	0.2	0.17	0.25	0.25	0	0	0.07	0	1	1.94	OCWA	Vermivora celata
common yellowthroat	0.3	0.17	0.08	0.25	0	0	0.13	0	1	1.93	COYE	Geothlypis trichas
evening grosbeak	0.1	0.5	0.25	0	0	0	0.07	0	1	1.92	EVGR	Coccothraustes vespertinus
fox sparrow	0.2	0.33	0.25	0	0	0	0.13	0	1	1.91	FOSP	Passerella iliaca
yellow-rumped warbler	0.2	0.33	0.25	0	0	0	0.13	0	1	1.91	YRWA	Dendroica coronata
gray jay	0.2	0.5	0.13	0	0	0	0.07	0	1	1.90	GRJA	Perisoreus canadensis
European starling	0.3	0.5	0.13	0.25	0.25	0.25	0.2	-1	1	1.88	EUST	Sturnus vulgaris
purple finch	0.1	0.5	0.13	0	0	0	0.13	0	1	1.86	PUFI	Carpodacus purpureus
rufous-sided towhee	0.2	0.5	0.25	0.25	0.25	0.25	0.13	-1	1	1.83	RSTO	Pipilo erythrophthalmus
willow flycatcher	0.2	0.17	0.13	0.25	0	0	0.07	0	1	1.82	WIFL	Empidonax trailii
Cassin's finch	0.1	0.5	0.13	0	0	0	0.07	0	1	1.80	CAFI	Carpodacus cassinii
Hutton's vireo	0.1	0.5	0.13	0	0	0	0.07	0	1	1.80	HUVI	Vireo huttoni
varied thrush	0.1	0.5	0.13	0	0	0	0.07	0	1	1.80	VATH	Ixoreus naevius
northern flicker	0.4	0.5	0.25	0.25	0.25	0	0.13	-1	1	1.78	NOFL	Colaptes auratus
western kingbird	0.2	0.17	0.08	0.25	0	0	0.07	0	1	1.77	WEKI	Tyrannus verticalis
wrentit	0.1	0.5	0.08	0	0	0	0.07	0	1	1.75	WREN	Chamaea fasciata
hermit thrush	0.2	0.33	0.13	0	0	0	0.07	0	1	1.73	HETH	Catharus guttatus
red crossbill	0.2	0.33	0.13	0	0	0	0.07	0	1	1.73	RECR	Loxia curvirostra
lazuli bunting	0.1	0.17	0.13	0.25	0	0	0.07	0	1	1.72	LABU	Passerina amoena
western tanager	0.1	0.17	0.13	0	0.25	0	0.07	0	1	1.72	WETA	Piranga ludoviciana
Wilson's warbler	0.2	0.17	0.25	0	0	0	0.07	0	1	1.69	WIWA	Wilsonia pusilla
Swainson's thrush	0.2	0.17	0.13	0	0	0	0.13	0	1	1.63	SWTH	Catharus ustulatus
rufous hummingbird	0.1	0.17	0.25	0	0	0	0.07	0	1	1.59	RUHU	Selasphorus rufus
olive-sided flycatcher	0.2	0.17	0.13	0	0	0	0.07	0	1	1.57	OSFL	Contopus borealis
solitary vireo	0.2	0.17	0.13	0	0	0	0.07	0	1	1.57	SOVI	Vireo solitarius
warbling vireo	0.2	0.17	0.13	0	0	0	0.07	0	1	1.57	WAVI	Vireo gilvus
Nashville warbler	0.1	0.17	0.13	0	0	0	0.13	0	1	1.53	NAWA	Vermivora ruficapilla
Pacific-slope flycatcher	0.1	0.17	0.13	0	0	0	0.13	0	1	1.53	PSFL	Empidonax difficilis
downy woodpecker	0.3	0.5	0.13	0.25	0.25	0	0.07	-1	1	1.50	DOWO	Picoides pubescens
violet-green swallow	0.2	0.17	0.25	0.25	0.25	0.25	0.13	-1	1	1.50	VGSW	Tachycineta thalassina

Table 2.4, continued.

SPECIES	TGR	MI	HA-F	HA-A	HA-S	HA-U	RR	SF	FREE	VI	ACRONYM	SCIENTIFIC NAME
VI = 1.0 - 1.49 (Low versatility)												
Allen's hummingbird	0.1	0.17	0.13	0	0	0	0.07	0	1	1.47	ALHU	Selasphorus sasin
black-throated gray warbler	0.1	0.17	0.13	0	0	0	0.07	0	1	1.47	BTWA	Dendroica virens
calliope hummingbird	0.1	0.17	0.13	0	0	0	0.07	0	1	1.47	CAHU	Stellula calliope
Hammond's flycatcher	0.1	0.17	0.13	0	0	0	0.07	0	1	1.47	HAFL	Empidonax hammondii
hermit warbler	0.1	0.17	0.13	0	0	0	0.07	0	1	1.47	HEWA	Dendroica occidentalis
MacGillivray's warbler	0.1	0.17	0.13	0	0	0	0.07	0	1	1.47	MAWA	Oporornis tolmiei
Townsend's warbler	0.1	0.17	0.13	0	0	0	0.07	0	1	1.47	TOWA	Dendroica townsendi
black-capped chickadee	0.2	0.5	0.13	0.25	0.25	0	0.13	-1	1	1.46	BCCH	Parus atricapillus
Bewick's wren	0.1	0.5	0.13	0.25	0.25	0	0.2	-1	1	1.43	BEWR	Thryomanes bewickii
acorn woodpecker	0.1	0.5	0.13	0.25	0.25	0	0.13	-1	1	1.36	ACWO	Melanerpes formicivorus
house wren	0.2	0.33	0.13	0.25	0.25	0	0.2	-1	1	1.36	HOWR	Troglodytes aedon
red-breasted sapsucker	0.1	0.5	0.13	0.25	0.25	0	0.07	-1	1	1.30	RBSA	Sphyrapicus ruber
hairy woodpecker	0.3	0.5	0.13	0	0.25	0	0.07	-1	1	1.25	HAWO	Picoides villosus
red-breasted nuthatch	0.2	0.5	0.13	0	0.25	0	0.13	-1	1	1.21	RBNU	Sitta canadensis
white-breasted nuthatch	0.2	0.5	0.13	0	0.25	0	0.13	-1	1	1.21	WBNU	Sitta carolinensis
tree swallow	0.3	0.17	0.13	0.25	0.25	0	0.07	-1	1	1.17	TRSW	Tachycineta bicolor
Lewis' woodpecker	0.1	0.5	0.13	0.25	0	0	0.13	-1	1	1.11	LEWO	Melanerpes lewis
western bluebird	0.1	0.5	0.13	0.25	0	0	0.13	-1	1	1.11	WEBL	Sialia mexicana
Vaux's swift	0.1	0.17	0.25	0.25	0.25	0	0.07	-1	1	1.09	VASW	Chaetura vauxi
VI = 0.5 - 0.99 (Very low versatility)												
brown creeper	0.2	0.5	0.13	0	0	0	0.13	-1	1	0.96	BRCR	Certhia americana
pileated woodpecker	0.2	0.5	0.13	0	0	0	0.13	-1	1	0.96	PIWO	Dryocopus pileatus
mountain bluebird	0.1	0.5	0.13	0	0	0	0.2	-1	1	0.93	MOBL	Sialia currucoides
mountain chickadee	0.1	0.5	0.13	0	0	0	0.2	-1	1	0.93	MOCH	Parus gambeli
chestnut-backed chickadee	0.1	0.5	0.13	0	0	0	0.13	-1	1	0.86	CBCH	Parus rufescens
winter wren	0.1	0.5	0.13	0	0	0	0.13	-1	1	0.86	WIWR	Troglodytes troglodytes
Townsend's solitaire	0.1	0.5	0.13	0	0	0	0.07	-1	1	0.80	TOSO	Myadestes townsendi

Migratory status (MI):

Following the example of Lehmkuhl and Ruggiero (1991), and using Harrison (1979), Brown (1985b), Ehrlich et al. (1988), and Terborgh (1989) for information regarding migratory status, I categorized species as (1) long-distance migrants (L): migrating to Central or South America; (2) short-distance migrants (S): migrating altitudinally or short distances within North America; or (3) resident birds (R): present year-around. Birds were assigned a point value of 1 for long-distance migrants, 2 for short-distance migrants, or 3 for residents. I converted point values to proportions of 1 with resident birds receiving the highest value for migratory status (MI = 0.50). Presumably they experience less stress annually since they do not expend energy migrating. Long-distance migrants, traveling farthest, were given the lowest value (MI = 0.17) since I considered them least versatile of the MI group. Short-distance migrants were given an intermediate score (MI = 0.33). Values of the 3 categories for MI sum to 1.

Total geographic range (TGR):

Geographic distribution was measured for breeding range and/or year-around use for each bird species. Distribution was measured digitally, using range maps from Field Guide to the Birds of North America (National Geographic Society 1988). Both breeding range and year-round range for North America (excluding Mexico) were measured. Breeding range was added to year-around range to calculate total geographic distribution (TGR) in North America. For long-distance migratory species, breeding range usually represented the only North American distribution for the bird. For resident and short-distance migrants both breeding and year-around range were included in total geographic distribution. Birds with the largest geographic ranges received the highest (most versatile) rating. I subdivided ranges into 4 categories: (1) 0 - 5000, (2) 5001 - 10,000, (3) 10,001 - 15,000, and (4) 15,001 - 20,000 x1000 km^2. Categories 1, 2, 3, and 4 were given point values of 1, 2, 3, and 4, and standardized to 0.1, 0.2, 0.3, and 0.4, respectively. Values for TGR categories sum to 1.

Habitat type (HA):

Habitat used by bird species included agricultural (HAA), suburban (HAS), urban (HAU), and forest types (HAF). I assigned a point value of 1 if a bird occurred in agricultural, suburban, or urban habitats and 0 if it did not. To standardize categories so that collectively they could sum to 1.00, I converted each point awarded for occurrence in agricultural, suburban, or urban habitats to a score of 0.25 (e.g., if a bird occurred in agricultural and suburban but not urban settings, it was given a score of 0.25 for HAA, 0.25 for HAS, and 0 for HAU). HAF was calculated differently, as described below.

All birds included in my versatility rating were associated with forest habitats (HAF). I adapted the versatility rating developed by Brown (1985b), which rates each species by adding the number of plant communities and stand conditions used as primary or secondary breeding or feeding sites. For birds, these versatility ratings ranged from 2 to 39. Species with ratings of 1 to 15 were considered to have low versatility, and were scored 1 point. Species with ratings of 16 to 30 were considered to have medium versatility, and were scored 2 points. Versatile species with ratings of > 30 were scored 3 points. For low ratings, HAF = 0.08; for medium ratings, HAF = 0.13; and for high ratings, HAF = 0.25.

The more habitat types used by a species, the higher the score for habitat used was given (e.g., dark-eyed juncos occurred in agricultural (HAA = 0.25), suburban (HAS = 0.25), urban (HAU = 0.25) settings, and fed and bred in 39 forest plant communities and stand conditions (Brown 1985b) (HAF = 0.25) so received a high score of 1.00 for total habitat types used. Red-breasted nuthatches (*Sitta canadensis*) occurred in forest habitat, using 24 plant communities and stand conditions (HAF = 0.13), and in suburban habitat (HAS = 0.25). They received a lower score of 0.38 for total habitat types used.

Reproductive Rating (RR):

Reproductive capacity for each species was calculated as a function of number of clutches per year and number of eggs produced per clutch using information from the

Oregon Species Information System (Olsen-Edge and O'Neil 1992), Harrison (1979), Brown (1985b), and Ehrlich et al. (1988). For each species, I used median number of clutches/year multiplied by median number of eggs/clutch as reproductive potential. I standardized reproductive potential to reproductive rating (RR) so that birds laying few eggs and only 1 clutch per year scored lowest. For lowest reproductive potential (median number of clutches/year x median number of eggs/year = 0 - 5), RR = 0.07. For highest reproductive potential (median number of clutches/year x median number if eggs/clutch = 21 - 25), RR = 0.33. Birds able to produce more eggs per year and therefore potentially more offspring were given higher scores for this rating. (e.g., brown-headed cowbirds [*Molothrus ater*] lay 6 to 7 eggs per clutch, 3 to 4 clutches per year. This gives them a high reproductive potential of 6.5 x 3.5, or 22.8. RR = 0.33 for this reproductive potential. Western tanagers (*Piranga ludoviciana*) lay 3 to 5 eggs/clutch, 1 clutch/year; reproductive potential = 1 x 4, or 4. RR=0.07 for this reproductive potential.)

Special Features (SF):

Species using dead wood (snags or down wood) as primary breeding habitat (Brown 1985b) were given a Special Features rating. These birds required dead wood either for breeding behavior (e.g., logs for drumming by ruffed grouse [*Bonasa umbellus*]) or nesting sites (e.g., snags for woodpeckers, logs for Bewick's wrens [*Thryomanes bewickii*] and Townsend's solitaires [*Myadestes townsendi*]). Because these bird species were considered less versatile (unable to successfully nest without the presence of dead wood), they were given a score of -1. Species not using dead wood were scored 0. To maintain the overall versatility index (VI) as a positive number, I added 1 to the SF rating. Birds requiring dead wood earned a 0 score, while birds not requiring dead wood actually added a point to their rating, giving them a higher versatility index.

I assigned point values to categories within each variable starting with 1 as lowest score and assigning it to the category that represented least degree of versatility based on literature or expert opinion (e.g., for migratory status, long-distance migrants received an assigned point value of 1 which when converted to percentage value equaled 0.17, short-distance migrants received a point value of 2 which converted to 0.33, and resident birds received a point value of 3 which converted to 0.50). I standardized assigned point values so that number of points represented a proportional fraction of 100% for standardized values (Table 2.3). Values for the index range from a potential low of 0.42 (low versatility, potentially at high risk of extirpation from disturbance) to a maximum of 3.23 (high versatility, at low risk of extirpation from disturbance) (Table 2.4).

I wanted to characterize each treatment using the versatility indices for the dominant (most abundant) bird species. To determine number of bird species to include in calculating a versatility index average, I averaged versatility indices by treatment for years following harvest for the 10 most abundant bird species (Figure 2.2), and calculated standard deviation for each treatment mean (Figure 2.3). Five to 7 bird species represented 40 to 70% of individuals post-harvest. I chose to use the 6 most abundant bird species in each treatment to generate an average versatility index (VI6) since this represented about 50% the bird community, and variation in average versatility indices and standard deviations had stabilized (Figures 2.2 and 2.3). I combined data for both post-treatment years in characterizing the treatments.

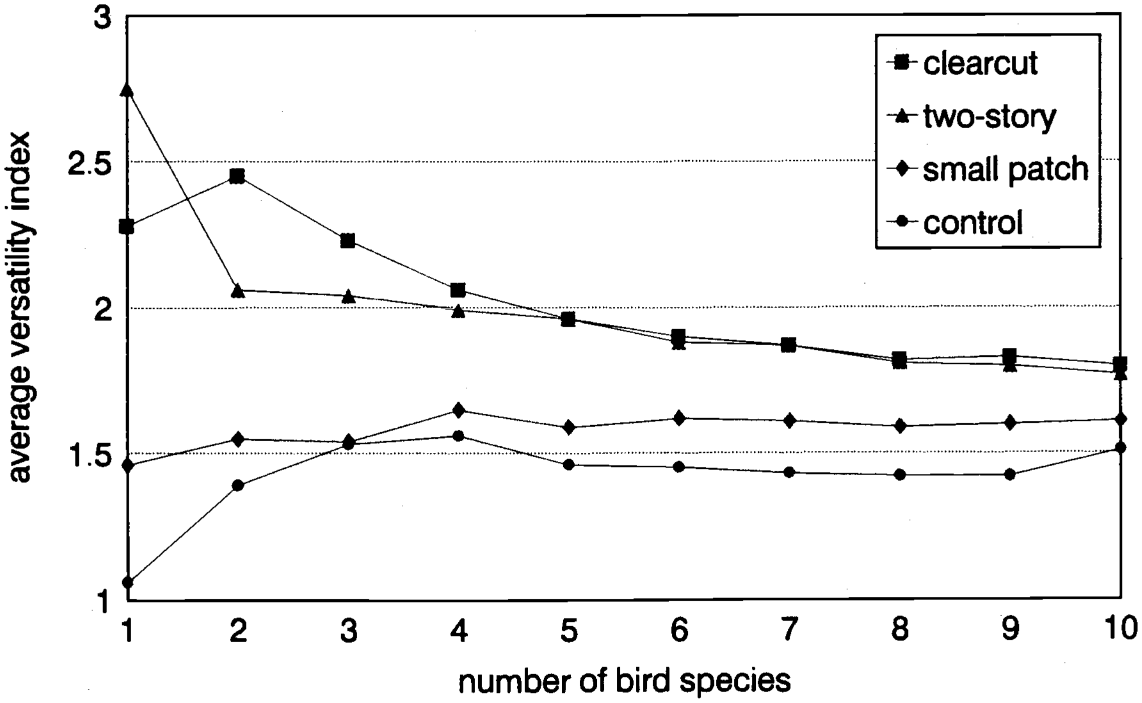


Figure 2.2. Versatility Indices averaged for most abundant bird species in 3 silvicultural treatments (small patch group selection: n = 14, two-story: n = 6, clearcut: n = 6) and control (n = 3). Bird abundances were summed for 2 post-treatment years. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

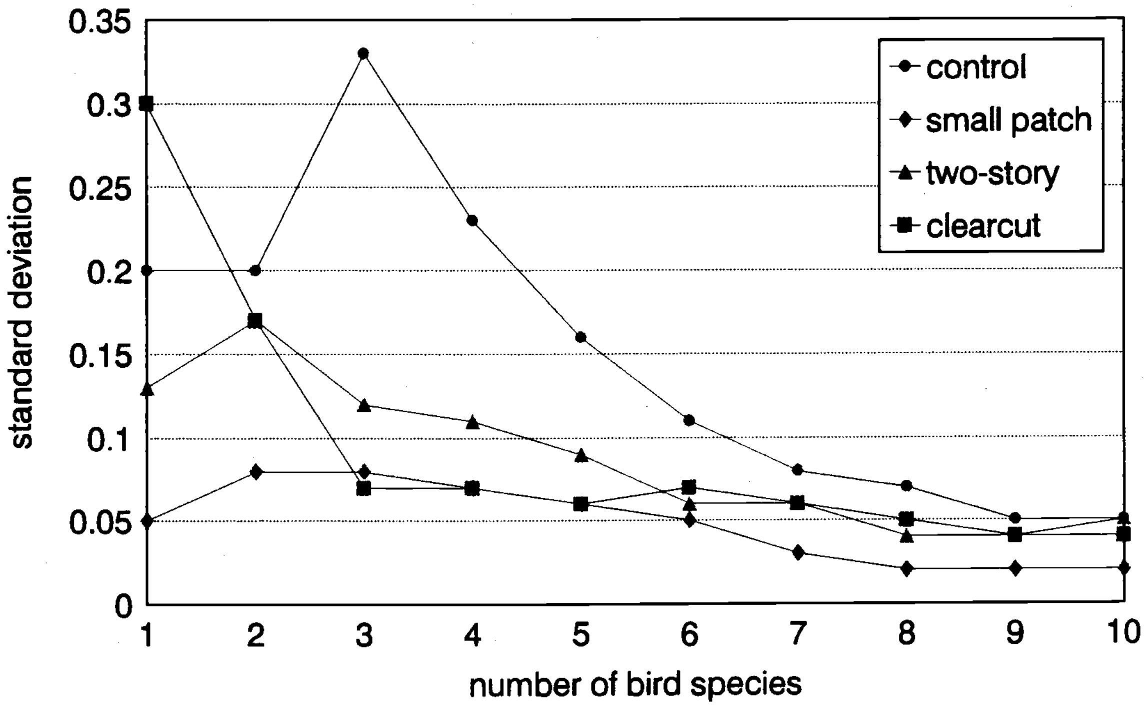


Figure 2.3. Standard deviation for Versatility Index calculated using the most abundant bird species in 3 silvicultural treatments (small patch group selection: n = 14, two-story: n = 6, clearcut: n = 6) and control (n = 3). Versatility indices were calculated from bird abundances summed for 2 post-treatment years. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

RESULTS

Detection Distance Differences

Detection distances differed among treatments or there were significant year*treatment interactions for 11 bird species (Pacific-slope flycatcher [*Empidonax difficilis*], Steller's jay [*Cyanocitta stelleri*], gray jay [*Perisoreus canadensis*], chestnut-backed chickadee [*Parus 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*], purple finch [*Carpodacus purpureus*]) and 3 mammal species (Douglas' squirrel, Townsend's chipmunk, and black-tailed deer) (Table 2.5). Upper 95% confidence intervals were within 75 m for all species with and without detection distance differences. Based on these data, I concluded that a 75 m maximum distance criterion included all individuals likely to be encountered in each stand type.

Differences in detection distances among years and treatments were likely caused by changes in type of habitat. Some species were infrequently observed in two-story and clearcut stands following harvest (e.g., gray jay, Swainson's thrush). The lower number of observations and/or greater variability in average detection distance may account for detection distance differences among treatments. Some species (e.g., chestnut-backed chickadees, golden-crowned kinglets, and Townsend's chipmunks) were observed at closer distances in control and small patch stands than in two-story and clearcut treatments. Chickadees and kinglets usually foraged or moved among trees in all treatments. Trees remaining in two-story and clearcut treatments were more widely scattered than in control and small patch stands which may account for differences in detection distances among treatments.

Table 2.5. Average detection distance (m) and standard error (SE) from bird count point (VCP) for bird species ($n \geq 30$; individuals detected ≤ 75 m from VCP). Analysis of variance was used to detect differences among treatments. Data represent detections for pretreatment, 1-year post-treatment, and 2-years post-treatment. P is the probability associated with differences in average detection distance for (1) year by treatment interaction effect (YR*TRT), (2) treatment effect (TRT), and (3) year effect (YR). Treatments were (1) control (no harvest treatment), (2) small patch (1/3 volume harvested removing 0.2-ha patches), (3) two-story (3/4 volume removed uniformly, and (4) clearcut (1.2 green trees/ha retained). Scientific names for birds and mammals are listed in the text.

	SILVICULTURAL TREATMENT								YR*TRT	TRT	YR
SPECIES	Control (SE)		Small Patch (SE)		Two-Story (SE)		Clearcut (SE)		P	P	P
BIRDS											
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
MAMMALS											
Black-tailed deer	26	(10)	30	(4)	31	(6)	32	(9)	0.003	NA	NA
Douglas' squirrel	33	(3)	42	(2)	38	(9)	37	(12)	0.1	0.3	0.003
Townsend's chipmunk	17	(3)	25	(3)	30	(5)	31	(5)	0.008	NA	NA

Community Responses

Bird Community Measures

Sixty-nine breeding bird species representing 20,629 observations were recorded within 75 m of VCP stations during 3 years of observation. Eighty-four percent (17,391/20,629) were new detections (Table 2.6).

Bird abundance declined following harvest in two-story and clearcut stands the first year following harvest ($\underline{P} \leq 0.04$) (two-story: 230 to 167 bird observations/5 ha; clearcut: 211 to 140 observations/5 ha). Bird abundance in small patch stands decreased betweeen 1-year post-treatment and 2-years post-treatment ($\underline{P} = 0.05$), although the decrease was slight (202 to 199 bird observations/5 ha) (Table 2.7 and Table 2.8).

Bird diversity and equitability decreased in clearcut stands the first year following harvest (diversity: $\underline{P} = 0.06$; equitability: $\underline{P} = 0.05$). I did not detect differences among treatments the second year after harvest for either of these measures (Table 2.7 and Table 2.8).

I was unable to detect differences in species richness among treatments (Table 2.8), although richness appeared higher in two-story stands (n = 25.9 species), lower in control (n = 21.2) and clearcut stands (n = 21.9) and intermediate in small patch stands (n = 23.3 species).

All measures of community similarity (percent similarity, Jaccard coefficient, and Morisita's Index) were affected by treatment ($\underline{P} \leq 0.0002$). In general, bird communities in small patch stands were most similar in composition to control stands in comparisons both 1-year and 2-years post-treatment. Two-story and clearcut stands were more similar to each other in bird species composition than to the control or small patch treatment, and differed significantly in community composition compared to pretreatment conditions.

Table 2.6. Breeding bird and mammal species observed representing 17,667 observations during 3 years of observation. Observations were for birds or mammals $\leq$ 75 m from variable circular plot center (VCP). McDonald-Dunn Research Forest, Benton County, 1989 - 1993.

BIRDS

Common Name	Abundance
hermit warbler	1641
dark-eyed junco	1354
chestnut-backed chickadee	1325
Wilson's warbler	1287
winter wren	1146
Pacific-slope flycatcher	852
Swainson's thrush	747
red-breasted nuthatch	740
golden-crowned kinglet	716
western tanager	687
brown creeper	665
white-crowned sparrow	645
rufous-sided towhee	575
orange-crowned warbler	550
American robin	549
Steller's jay	543
house wren	462
evening grosbeak	363
MacGillivray's warbler	357
purple finch	280
black-throated gray warbler	251
black-headed grosbeak	199
red-breasted sapsucker	194
American goldfinch	179
red crossbill	166
hairy woodpecker	124
gray jay	94
northern flicker	83
olive-sided flycatcher	75
brown-headed cowbird	56
rufous hummingbird	38

Table 2.6, continued.

BIRDS

Common Name	Abundance
bushtit	34
willow flycatcher	30
pileated woodpecker	27
Hammond's flycatcher	26
Townsend's warbler	25
Bewick's wren	24
cedar waxwing	22
violet-green swallow	19
Hutton's vireo	18
western wood-pewee	17
lazuli bunting	17
hermit thrush	16
solitary vireo	16
ruffed grouse	15
mourning dove	15
downy woodpecker	14
red-tailed hawk	13
band-tailed pigeon	12
pine siskin	12
western bluebird	10
song sparrow	10
American crow	9
varied thrush	9
blue grouse	6
warbling vireo	6
common raven	4
great-horned owl	3
black-capped chickadee	3
European starling	3
chipping sparrow	3
mountain quail	2
wild turkey	2
turkey vulture	1
sharp-shinned hawk	1

Table 2.6, continued.

BIRDS

Common Name	Abundance
northern pygmy-owl	1
tree swallow	1
barn swallow	1
commmon yellowthroat	1
TOTAL BIRD OBSERVATIONS	17,391

MAMMALS

Common Name	Abundance
Douglas' squirrel*	187
Townsend's chipmunk*	54
black-tailed deer**	35
TOTAL MAMMAL OBSERVATIONS	276

* Vocalizations or sightings
** Sightings

Table 2.7. Averages and standard errors (in parentheses) for bird abundance, Simpson diversity and equitability, species richness, and community similarity measures by treatment and year (YR1=pretreatment year, YR2=1-year post-harvest, YR3=2-years post-harvest) using birds ($n \geq 30$) observed ≤ 75 m from VCP. Community similarity measures are comparisons between pretreatment and post-treatment years. For community similarity measures, YR2=pretreatment v. 1-year post-treatment comparison; YR3=pretreatment v. 2-years post-treatment.

BIRD COMMUNITY MEASURE	CONTROL			SMALL PATCH			TWO-STORY			CLEARCUT		
	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3
abundance	192 (12)	192 (3)	198 (32)	212 (7)	202 (6)	199 (9)	230 (11)	167 (19)	180 (13)	211 (11)	140 (19)	157 (14)
diversity	0.90 (0.006)	0.90 (0.007)	0.89 (0.01)	0.92 (0.004)	0.92 (0.004)	0.92 (0.003)	0.92 (0.003)	0.92 (0.008)	0.92 (0.003)	0.92 (0.005)	0.87 (0.02)	0.87 (0.02)
equitability	0.95 (0.003)	0.94 (0.009)	0.94 (0.006)	0.96 (0.003)	0.96 (0.004)	0.97 (0.007)	0.96 (0.003)	0.95 (0.007)	0.96 (0.003)	0.96 (0.003)	0.92 (0.02)	0.91 (0.02)
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)	23.5 (0.6)	27.2 (1.8)	27.0 (1.3)	22.8 (1.5)	22.2 (2.0)	20.8 (1.7)
community similarity												
percent similarity		74 (1)	75 (4)		73 (1)	67 (2)		42 (4)	32 (3)		29 (3)	23 (5)
Jaccard coefficient		0.62 (0.05)	0.65 (0.06)		0.64 (0.02)	0.65 (0.03)		0.53 (0.05)	0.47 (0.03)		0.43 (0.04)	0.35 (0.06)
Morista's index		0.93 (0.02)	0.94 (0.02)		0.91 (0.01)	0.83 (0.03)		0.49 (0.05)	0.36 (0.06)		0.30 (0.06)	0.23 (0.06)

Table 2.8. Repeated measures analysis of variance tests of hypothesis for measures of bird community structure (birds ≤ 75 m from VCP center; for birds with $n \geq 30$ observations). YEAR1 is pretreatment, YEAR2 is 1-year post-treatment, YEAR3 is 2-years post-treatment. Treatments are CN=control, SP=small patch, TS=two-story, and CC=clearcut. P is the probability associated with differences among treatment (TRT), year (YEAR), or treatment by year interaction (YEAR*TRT) effects.

							YEAR 1 - YEAR 2 CONTRAST[1]					YEAR 2 - YEAR 3 CONTRAST[1]				
									Contrast of CN with					Contrast of CN with		
BIRD COMMUNITY MEASURE	YEAR*TRT		YEAR		TRT		CTRST	C*TRT	SP	TS	CC	CTRST	C*TRT	SP	TS	CC
	df	P	df	P	df	P	P	P	P	P	P	P	P	P	P	P
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
diversity	6, 16	0.04		NA		NA	0.09	0.04	0.6	0.9	0.06	0.7	0.7	0.6	0.4	1.0
equitability	6, 10	0.1	2, 5	0.1	3, 6	0.05	0.06	0.03	0.6	0.8	0.05	0.8	0.6	0.8	0.5	0.7
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

[1] For abundance, degrees of freedom (df) for contrasts are 1, 5 for CTRST (contrast), 3, 5 for C*TRT (contrast*treatment interaction) and 1, 5 for contrast of CN with SP, TS, CC. For diversity, equitability, and richness degrees of freedom for contrasts are 1, 6 for CTRST (contrast), 3, 6 for C*TRT (contrast*treatment interaction) and 1, 6 for contrast of CN with SP, TS, CC.

Percent similarity differed among treatments for pretreatment v. 1-year post-treatment ($\underline{P} = 0.0001$) (Figure 2.4A) and for pretreatment v. 2-years post-treatment comparisons ($\underline{P} = 0.0001$) (Figure 2.4B). Control and small patch stands were more similar in community composition, but two-story and clearcut treatment communities were significantly altered; community structure was less than 50% similar with pretreatment levels. The second year after harvest, percent similarity for small patch stands appeared to decline ($\underline{P} = 0.07$), which may indicate that even small patch stand communities are significantly altered by harvesting.

Morisita's index differed among treatments ($\underline{P} = 0.0001$). The first year after harvest, small patch and control stands remained similar in community composition, but two-story and clearcut stands differed from control and small patch stands ($\underline{P} = 0.0001$) (Figure 2.5A). Bird communities in clearcut stands were least similar with pretreatment communities (Figure 2.5A). The second year after harvest, I detected differences among all treatments using Morisita's index ($P \leq 0.04$) (Figure 2.5B). This index may be the most sensitive to community change. Since it represents the probability of encounter of individuals of the same species, it may be the best measure of community similarity to apply to these types of data.

The Jaccard coefficient differed among treatments ($\underline{P} \leq 0.0002$). Although bird communities in small patch stands differed from clearcut and two-story stands the first year after harvest, I did not detect a difference between control and two-story stands until the second year after harvest (Figures 2.6A and B). It is likely that two-story stands continue to have a number of forest associated species (found predominantly in control and small patch stands) present, although not in as high abundance, so remain somewhat similar to control and patch cut stands using the Jaccard coefficient as an index of community similarity.

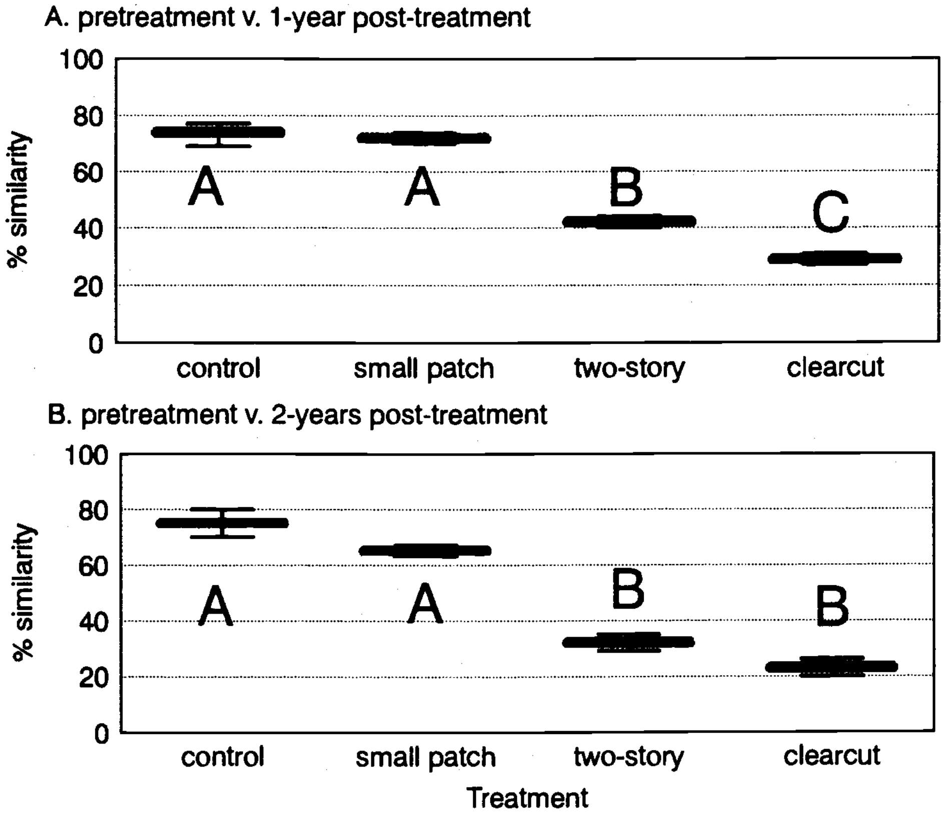


Figure 2.4. Average percent similarity (Brower et al. 1990) and standard error for comparisons of A. 1-year post-treatment and B. 2-years post-treatment with pretreatment bird community. Treatments were control, small patch, two-story, and clearcut. Treatment differences ($P \leq 0.05$) are indicated by different letters. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

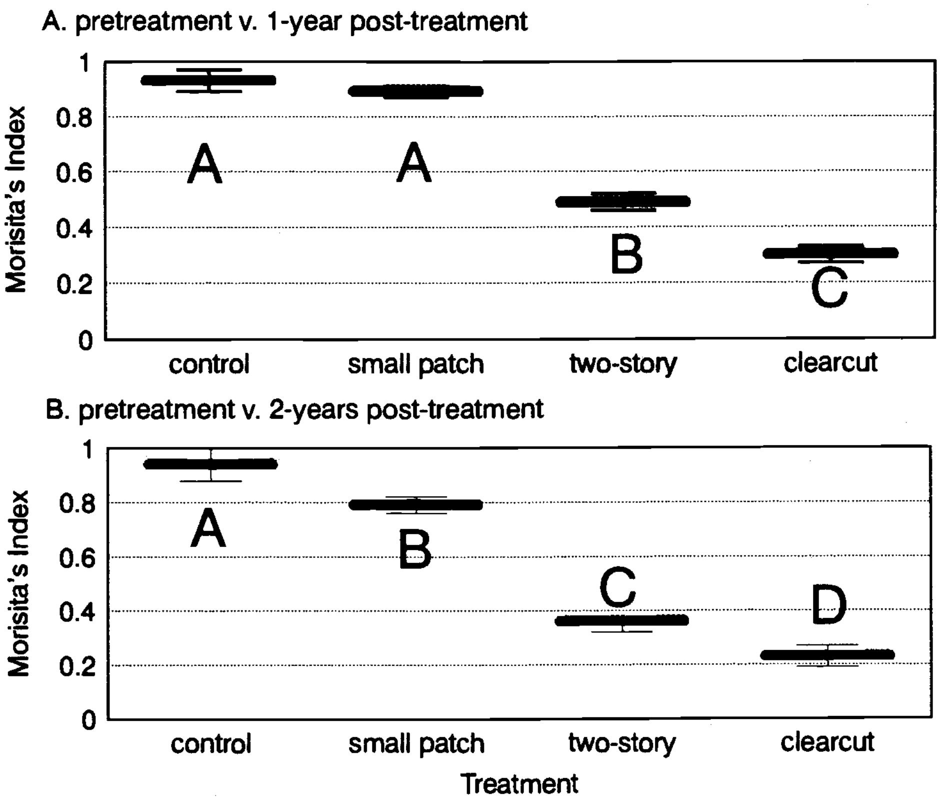


Figure 2.5. Average Morisita's index (Brower et al. 1990) and standard error for comparisons of A. 1-year post-treatment and B. 2-years post-treatment with pretreatment bird community. Treatments were control, small patch, two-story, and clearcut. Treatment differences ($\underline{P} \leq 0.05$) are indicated by different letters. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

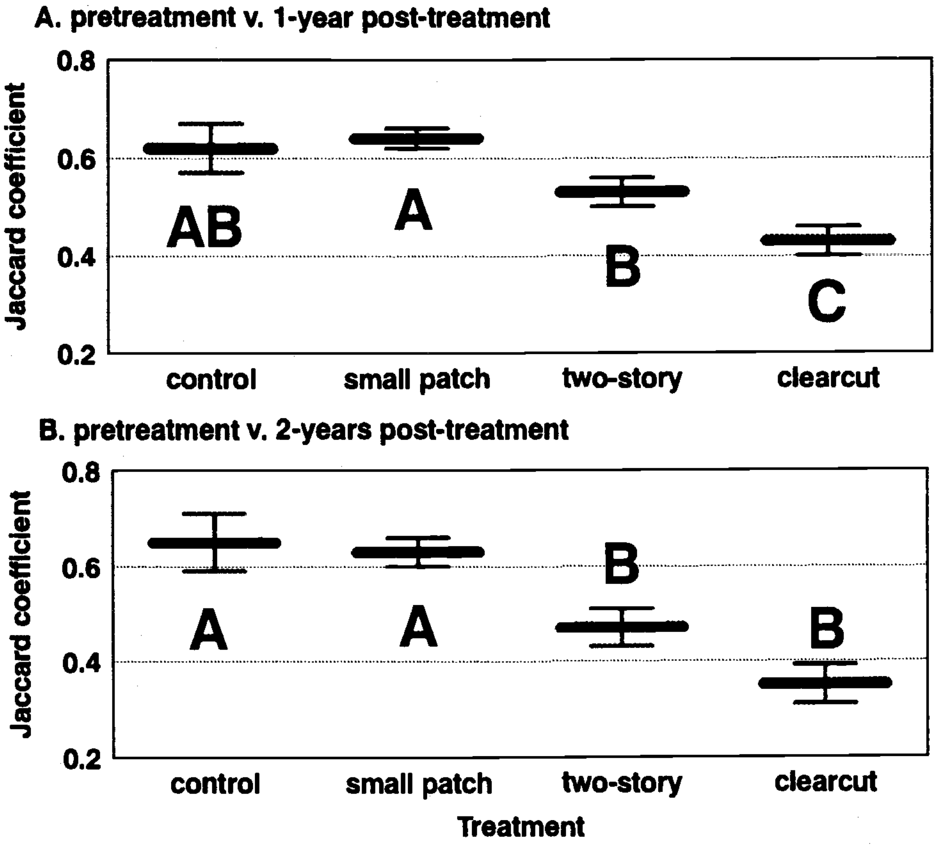


Figure 2.6. Average Jaccard coefficient (Brower et al. 1990) and standard error for comparisons of A. 1-year post-treatment and B. 2-years post-treatment with pretreatment bird community. Treatments were control, small patch, two-story, and clearcut. Treatment differences ($\underline{P} \leq 0.05$) are indicated by different letters. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

Bird Versatility Index

Species with highest versatility index (VI ≥ 2.50) included dark-eyed junco, American robin (*Turdus migratorius*), song sparrow (*Melaspiza melodia*), brown-headed cowbird, white-crowned sparrow (*Zonotrichia leucophrys*), and mourning dove (*Zenaida macroura*). These birds are widespread throughout North America, habitat generalists, have high reproductive ratings, and are either residents or short-distance migrants (Table 2.3).

Species with versatility indices ranging from 2.00 to 2.49 included bushtit (*Psaltriparus minimus*), American goldfinch (*Carduelis tristis*), cedar waxwing (*Bombycilla cedrorum*), western wood-pewee (*Contopus sordidulus*), pine siskin (*Carduelis pinus*), mountain quail (*Oreortyx pictus*), golden-crowned kinglet, and Steller's jay. Most are residents, widespread in distribution, and tend to use agricultural and suburban habitat as well as forest (Table 2.3).

Less versatile bird species (VI = 1.00 to 1.49) are migratory species with lower reproductive rates using forest habitat, or are resident woodpeckers or other cavity nesting and bark foraging species requiring dead wood for nest sites. The heavy weighting placed on SF category causes the versatility index to be low for these birds. Migratory species include black-throated gray warbler (*Dendroica virens*), hermit warbler (*Dendroica occidentalis*), MacGillivray's warbler (*Oporornis tolmiei*), Townsend's warbler (*Dendroica townsendi*), and Bewick's wren (Table 2.3). Woodpeckers and other cavity nesters include red-breasted sapsucker (*Sphyrapicus ruber*), hairy woodpecker (*Picoides villosus*), red-breasted nuthatch, and western bluebird (*Sialia mexicana*) (Table 2.3).

Birds with lowest versatility indices (≤ 1.00) were primarily species requiring dead wood for nesting and limited in their use of forest habitat (e.g., using few stand conditions or plant community types [Brown 1985b]). They include pileated woodpecker (*Dryocopus pileatus*), brown creeper (*Certhia americana*), chestnut-backed chickadee, and winter wren (*Troglodytes troglodytes*) (Table 2.3).

The 6 most abundant bird species in each treatment accounted for $\geq$ 40% of observations recorded. In control stands, winter wrens, Pacific-slope flycatchers, hermit warblers, chestnut-backed chickadees, Wilson's warblers (*Wilsonia pusilla*), and Swainson's thrushes comprised 60% of the bird community (Figure 2.7A). In small patch stands, hermit warblers were most abundant and with Wilson's warblers, chestnut-backed chickadees, dark-eyed juncos, winter wrens, and Pacific-slope flycatchers represented 50% of observations (Figure 2.7B). Dark-eyed juncos, chestnut-backed chickadees, white-crowned sparrows, Wilson's warblers, house wrens (*Troglodytes aedon*), and rufous-sided towhees (*Pipilo erythrophthalmus*) comprised 40% of the bird community in two-story stands (Figure 2.7C), and white-crowned sparrows, dark-eyed juncos, house wrens, chestnut-backed chickadees, hermit warblers, and rufous-sided towhees were 47% of observations in clearcut stands (Figure 2.7D).

Using the 6 dominant bird species in each treatment, the average Versatility $\text{Index}_{6\ \text{dominant species}}$ (VI6) was 1.45 (standard error [se] = 0.11) for control stands and 1.62 (se = 0.05) for small patch stands. For two-story stands, VI6 = 1.88 (se = 0.06), and was similar to clearcut stands with a VI6 of 1.90 (se = 0.07). The VI6 differed among treatments ($\underline{P} = 0.001$). I did not detect a difference between control and small patch treatment VI6s, nor between clearcut and two-story treatment VI6s ($\underline{P} > 0.05$). Control and small patch treatment VI6s were significantly different from two-story and clearcut treatment VI6s however ($\underline{P} \leq 0.05$).

Birds most abundant in control and small patch stands included species that were forest associates with restricted geographic distribution (e.g., Pacific-slope flycatchers), had higher proportions of Neotropical migrants, and lower potential productivity (e.g., 1 clutch per year). Species most common in two-story and clearcut stands tended to be year-around residents, raising 2 to 3 clutches per year. They had wide geographic distribution and most could use habitats other than forests (e.g., rural, agricultural, and urban settings) (Table 2.2). Using my versatility index (VI6) as an

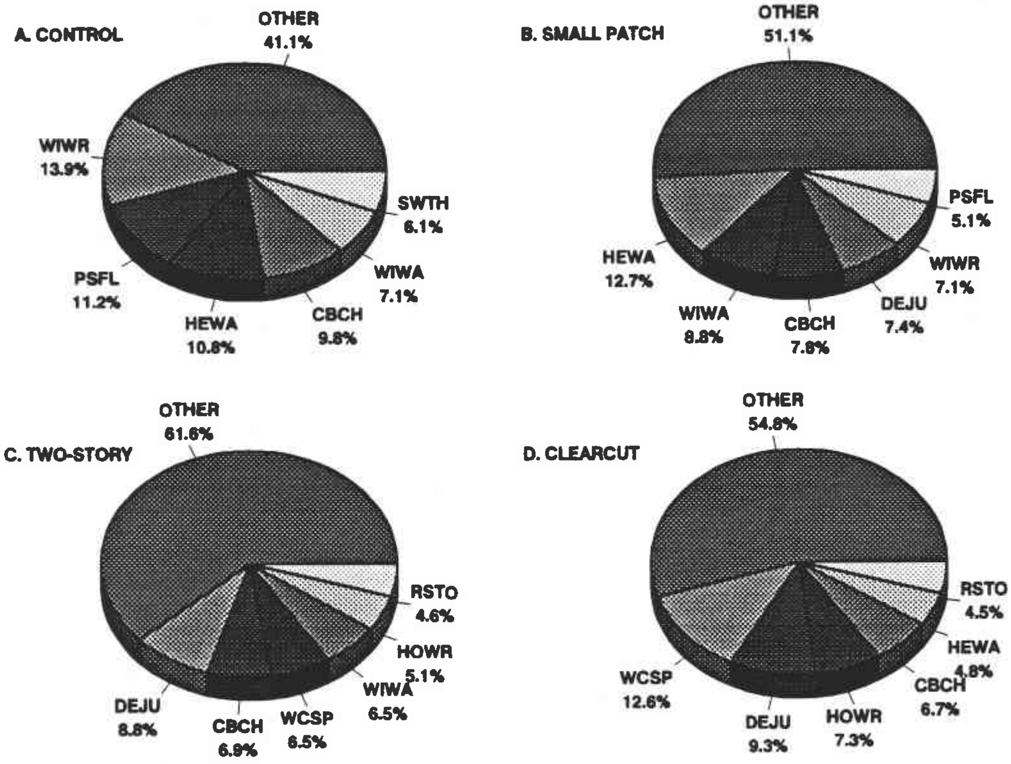


Figure 2.7. Proportional representation (% of total) of the 6 most abundant bird species for A. control, B. small patch, C. two-story, and D. clearcut treatments. Data were collected on McDonald-Dunn Research Forest 1990 - 1992, and represent post-treatment observations only. Species are designated by acronyms (CBCH = chestnut-backed chickadee, DEJU = dark-eyed junco, HEWA = hermit warbler, PSFL = Pacific-slope flycatcher, SWTH = Swainson's thrush, WIWA = Wilson's warbler, WIWR = winter wren, HOWR = house wren, RSTO = rufous-sided towhee, WCSP = white-crowned sparrow, OTHER = all other species).

indicator of effects of harvest on bird communities, clearcut and two-story stands appear to provide habitat for species that are better able to tolerate disturbance. Species that characterize bird communities in control stands are probably at greater risk of extirpation if disturbances are large or frequent.

Mammal Community Measures

I captured 1536 small mammals during 8676 TN (Table 2.9). Seventy-seven percent (1176/1536) were new individuals. Five of 14 species represented 97% of new captures. Most abundant species were deer mouse (43% of new captures), Trowbridge's shrew (28% of new captures), Oregon vole (15% of new captures), Townsend's chipmunk (5% of new captures), and Pacific shrew (4% of new captures).

I did not detect differences in abundance, Simpson diversity, or Simpson equitability among silvicultural treatments and control (Table 2.10). Variability in datamay have prevented detecting differences. Species richness increased from 1.2 to 1.6 species per stand in small patch stands the first year following harvest. There were no significant differences in comparisons for other treatments in year 1 or for any comparisons in year 2 (Table 2.10).

I did not detect differences in community similarity among treatments using any of the percent similarity, Morisita's index, or the Jaccard coefficient the first year after harvest ($P \geq 0.5$) (Figures 2.8A, 2.9A, and 2.10A). The second year after harvest, I detected differences among treatments using percent similarity (Figure 2.8B) and Morisita's index (Figure 2.9B). I did not detect differences among treatments using the Jaccard coefficient ($\underline{P} = 0.2$) (Figure 2.10B). The Jaccard coefficient only compares number of species common to 2 communities and does not include relative abundances of species. Many mammal species occurred in both treated and untreated stands, although in different abundances, and may have prevented detection of differences using this measure.

Table 2.9. Mammal species captured during 8676 trap nights (TN) representing 1176 individuals. Observations were first-time captures for mammals in pitfall and Sherman traps for pretreatment and 1-year post-treatment live-trapping in 3 replications (Lewisburg Saddle, Peavy, Dunn), and 2-year post-treatment live-trapping in 2 replications (Lewisburg Saddle and Peavy). McDonald-Dunn Research Forest, Benton County, 1989 - 1992.

MAMMALS

Common Name	Abundance
deer mouse	504
Trowbridge's shrew	334
Oregon vole	180
Townsend's chipmunk	59
Pacific shrew	51
vagrant shrew	17
shrew-mole	10
western red-backed vole	9
coast mole	6
Townsend's mole	2
northern flying squirrel	1
dusky-footed woodrat	1
red tree vole	1
Pacific water shrew	1
TOTAL MAMMAL OBSERVATIONS	1176

Table 2.10. Repeated measures analysis of variance and orthogonal contrasts for measures of mammal community structure. Treatments are CN=control, SP=small patch, TS=two story, and CC=clearcut. P is the probability associated with differences among treatment (TRT), year (YEAR), or treatment by year interaction (YEAR*TRT) effects.

MAMMAL COMMUNITY MEASURE	YEAR*TRT		YEAR		TRT		YEAR 1 - YEAR 2 CONTRAST[1]					YEAR 2 - YEAR 3 CONTRAST[1]				
									Contrast of CN with					Contrast of CN with		
							CTRST	C*TRT	SP	TS	CC	CTRST	C*TRT	SP	TS	CC
	df	P	df	P	df	P	P	P	P	P	P	P	P	P	P	P
abundance	6, 12	0.8	2, 12	0.2	3, 6	0.2										
Simpson diversity	6, 18	0.8	2, 18	0.2	3, 18	0.6										
Simpson equitability	6, 12	0.9	2, 12	0.5	3, 6	0.7										
richness	6, 6	0.03		NA		NA	0.02	0.06	0.04	0.6	0.1	0.8	0.1	0.08	0.05	0.03

[1] For species richness, degrees of freedom (df) for contrasts are 1, 3 for CTRST (contrast), 3, 3 for C*TRT (contrast*treatment interaction) and 1,3 for contrast of CN with SP, TS, CC.

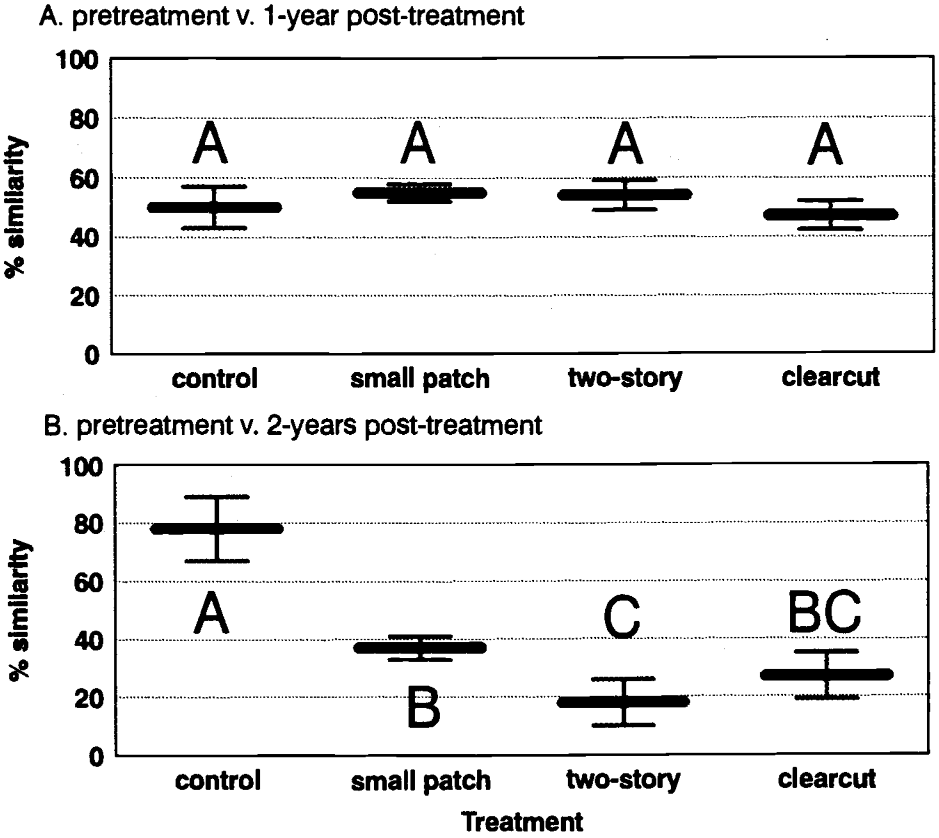


Figure 2.8. Average percent similarity (Brower et al. 1990) and standard error for comparisons of A. 1-year post-treatment and B. 2-years post-treatment with pretreatment mammal community. Treatments were control, small patch, two-story, and clearcut. Treatment differences ($\underline{P} \leq 0.05$) are indicated by different letters. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

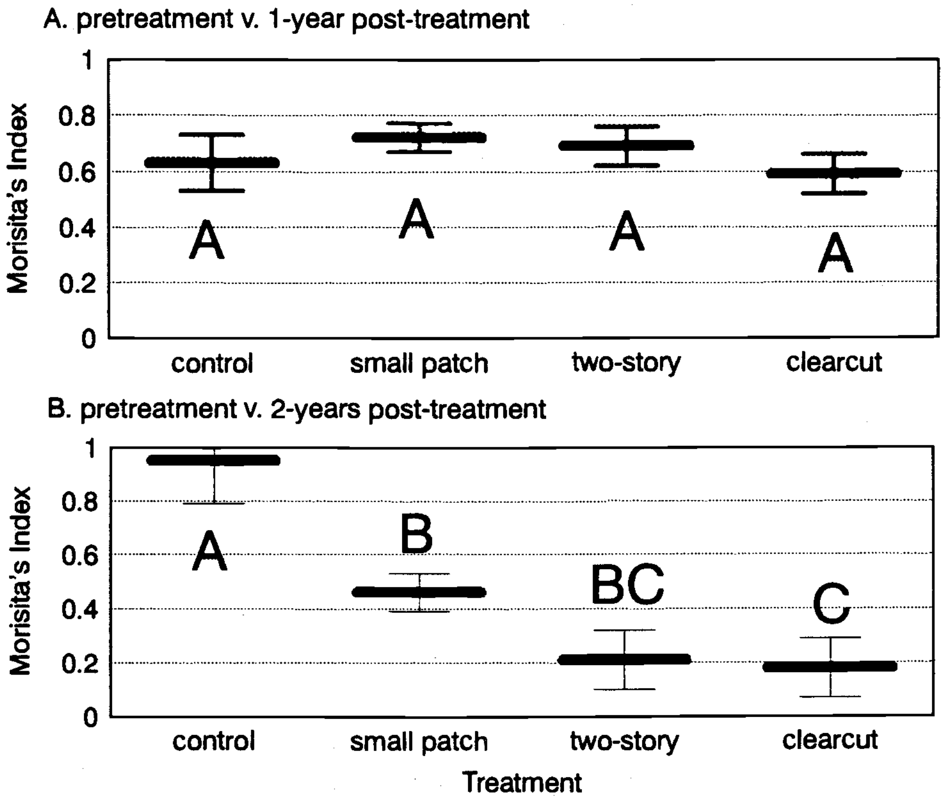


Figure 2.9. Average Morisita's index (Brower et al. 1990) and standard error for comparisons of A. 1-year post-treatment and B. 2-years post-treatment with pretreatment mammal community. Treatments were control, small patch, two-story, and clearcut. Treatment differences ($\underline{P} \leq 0.05$) are indicated by different letters. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

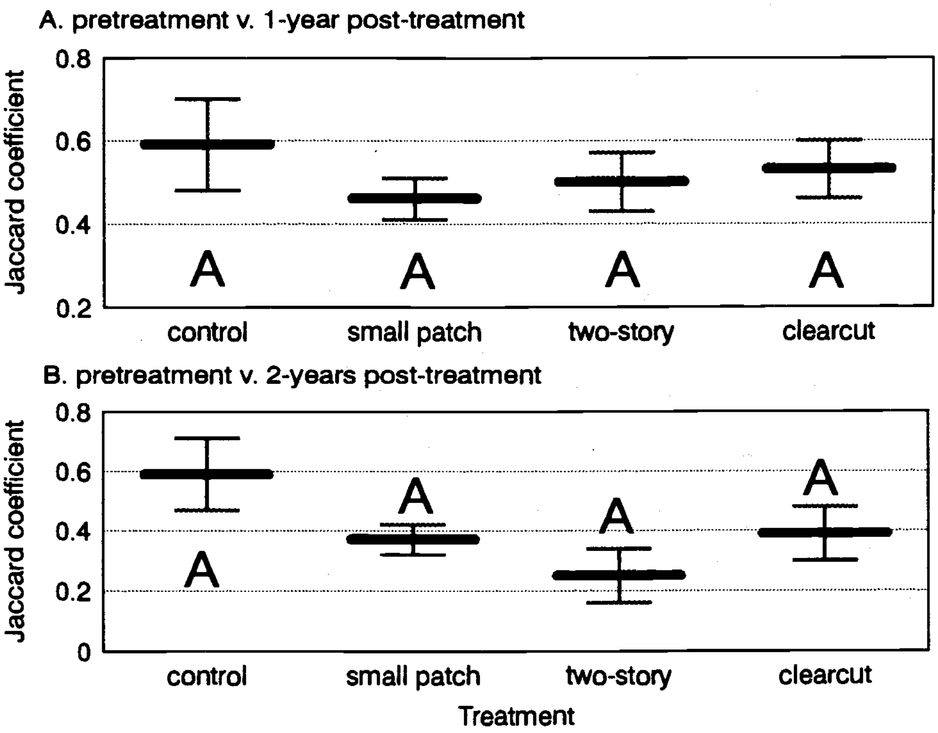


Figure 2.10. Average Jaccard coefficient (Brower et al. 1990) and standard error for comparisons of A. 1-year post-treatment and B. 2-years post-treatment with pretreatment mammal community. Treatments were control, small patch, two-story, and clearcut. Treatment differences (P ≤ 0.05) are indicated by different letters. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

Mammal communities in control stands appeared to maintain the highest degree of similarity among years, and similarity appeared to decline in other treatments. These data indicate a trend for control stands to retain a higher percentage of the same species, with harvested stands experiencing a shift in species composition.

Mammal community composition in small patch stands seemed most similar in diversity, evenness, and richness to mammal communities in control stands. Mammal communities in two-story stands seemed more similar to communities in clearcuts. Although sample sizes were small, there appeared to be trends in mammal response to harvest treatment. Many species in forested control stands also were present in harvested treatments but relative abundance changed. Deer mice and Oregon voles increased after harvest and dominated animal communities in clearcuts and two-story stands (Table 2.11 and Table 2.12). To adequately test these changes, however, larger sample sizes are needed (e.g., increasing trapping effort to 1 8-day trapping session in summer [July - August] and 1 in fall [October - November]).

Individual Species Responses

Birds

Thirty-three bird species ($n \geq 30$ observations each species) were analyzed for response to treatment. Sixteen species responded to treatment; 7 species did not show a response to harvest treatment using RMA, but 3 of these differed among treatments using ranked data; 10 species showed no detectable response to treatment. For statistical analyses, log transformations of abundance were used and are reported as results for all analyses (Table 2.13). Untransformed bird abundances are reported in this text and can be found in Table 2.14, but because of treatment differences in variance for means, transformed means and their standard errors should be used for statistical comparisons.

Table 2.11. Mammal capture rate (number of individuals/1000 trap nights [TN]) for Sherman and pitfall traps by treatment and year (YR1=pretreatment year, YR2=first year post-harvest, YR3=second year post-harvest) for all first time captures, McDonald-Dunn Research Forest, 1989 - 1992. No trapping was conducted for Dunn replication for YR3. For Lewisburg Saddle, only pitfall traps were used in YR1. Number of trap nights for year 1: CONTROL=276 TN, SMALL PATCH=1176 TN, TWO-STORY=552 TN, CLEARCUT=552 TN; for year 2: CONTROL=360 TN, SMALL PATCH =1680 TN, TWO-STORY=720 TN, CLEARCUT=720 TN; for year 3: CONTROL=240 TN, SMALL PATCH=1440 TN, TWO-STORY=480 TN, CLEARCUT=480 TN; n is actual number of first time captures for each species.

		CONTROL			SMALL PATCH			TWO-STORY			CLEARCUT		
SPECIES	n	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3
shrew-mole	10	7	0	0	1	1	0	4	1	2	0	0	2
coast mole	6	14	0	4	0	0	1	0	0	0	0	0	0
Townsend's mole	2	0	0	0	0	0	0	0	0	0	0	3	0
Pacific water shrew	1	0	0	0	0	1	0	0	0	0	0	0	0
Pacific shrew	51	11	22	8	7	7	8	0	3	2	2	4	0
Trowbridge's shrew	334	228	61	29	47	45	9	38	40	0	38	36	2
vagrant shrew	17	4	3	0	0	5	4	0	0	0	0	1	0
northern flying squirrel	1	0	0	0	0	0	1	0	0	0	0	0	0
Townsend's chipmunk	59	25	6	0	8	2	11	11	4	2	2	10	6
western red-backed vole	9	7	0	4	1	1	0	2	1	0	0	1	0
Oregon vole	180	11	6	25	2	11	26	2	13	73	2	11	119
red tree vole	1	0	0	0	0	1	0	0	0	0	0	0	0
dusky-footed woodrat	1	0	0	0	0	0	0	2	0	0	0	0	0
deer mouse	504	47	75	54	33	63	38	43	82	73	53	104	60

Table 2.12. Mammal capture rate (number of individuals/1000 trap nights [TN]) for pitfall traps by treatment and year (YR1=pretreatment year, YR2=first year post-harvest, YR3=second year post-harvest) for all first time captures, McDonald-Dunn Research Forest, 1989 - 1992. No trapping was conducted for Dunn replication for YR3. For Lewisburg Saddle, only pitfall traps were used in YR1. Treatments are control (CN), small patch (SP), two-story (TS), and clearcut (CC). Number of trap nights for year 1: CN=156 TN, SP=936 TN, TS=312 TN, CC=312 TN; for year 2: CN=180 TN, SP=840 TN, TS=360 TN, CC=360 TN; for year 3: CN=120 TN, SP=720 TN, TS=240 TN, CC=240 TN; n is the total number of animals captured. See text for scientific names.

		CONTROL			SMALL PATCH			TWO-STORY			CLEARCUT		
SPECIES	n	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3
shrew-mole	8	13	0	0	1	1	0	3	3	4	0	0	4
coast mole	6	26	0	8	0	0	1	0	0	0	0	0	0
Townsend's mole	2	0	0	0	0	0	0	0	0	0	0	6	0
Pacific water shrew	1	0	0	0	0	1	0	0	0	0	0	0	0
Pacific shrew	40	19	44	8	7	12	7	0	3	4	3	8	0
Trowbridge's shrew	325	391	122	50	56	88	18	64	81	0	67	72	4
vagrant shrew	16	6	6	0	0	10	8	0	0	0	0	0	0
western red-backed vole	6	13	0	0	1	2	0	0	0	0	0	3	0
Oregon vole	106	13	0	25	0	12	25	3	25	83	0	17	154
deer mouse	12	26	0	0	0	0	3	10	0	4	0	6	0

Table 2.13. Repeated measures analysis of variance and orthogonal contrasts for pretreatment v. 1-year post-treatment (YEAR 1 - YEAR 2 CONTRAST) and 1-year post-treatment v. 2-years post-treatment (YEAR 2 - YEAR 3 CONTRAST) for bird species abundances (birds ≤ 75 m from VCP center; $n \geq 30$ observations) and sightings and vocalizations for 3 mammal species. Abundances were log-transformed ($\log_{10}$[abundance+1]) for analyses. Treatments are CN=control, SP=small patch, TS=two-story, and CC=clearcut. P is the probability associated with differences among treatment (TRT), year (YEAR), or treatment by year interaction (YEAR*TRT) effects.

							YEAR 1 - YEAR 2 CONTRAST[1]					YEAR 2 - YEAR 3 CONTRAST[1]				
									Contrast of CN with					Contrast of CN with		
	YEAR*TRT		YEAR		TRT		CTRST	C*TRT	SP	TS	CC	CTRST	C*TRT	SP	TS	CC
SPECIES	df	P	df	P	df	P	P	P	P	P	P	P	P	P	P	P
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										
Olive-sided flycatcher	6, 16	0.2	2, 16	0.1	3, 8	0.02										
Willow flycatcher	6, 16	0.02		NA		NA	0.2	0.6	1.0	0.6	0.4	0.02	0.03	0.9	0.03	0.3
Pacific slope flycatcher	6, 10	0.3	2, 5	0.02	3, 6	0.0001	0.005	0.1	0.8	0.1	0.1	0.03	0.3	0.3	0.07	0.2
Steller's jay	6, 10	0.03		NA		NA	0.005	0.002	0.2	0.006	0.001	0.7	0.9	1.0	0.8	0.8
Gray jay	6, 22	0.3	2, 22	0.2	3, 22	0.5										
Chestnut-backed chickadee	6, 10	0.0008		NA		NA	0.0001	0.0001	0.03	0.04	0.0004	0.005	0.4	0.5	0.8	0.6
Bushtit	6, 16	0.2	2, 16	0.7	3, 6	0.7										
Brown creeper	6, 16	0.0		NA		NA	0.0008	0.001	0.4	0.02	0.001	0.1	0.2	0.8	0.1	0.3
Red-breasted nuthatch	6, 16	0.0002		NA		NA	0.0003	0.002	0.9	0.02	0.004	0.1	0.8	0.5	0.9	0.8
House wren	6, 22	0.001		NA		NA	0.002	0.02	0.6	0.02	0.03	0.3	0.7	0.3	0.3	0.3

Table 2.13, continued.

							YEAR 1 - YEAR 2 CONTRAST[1]					YEAR 2 - YEAR 3 CONTRAST[1]				
									Contrast of CN with					Contrast of CN with		
	YEAR*TRT		YEAR		TRT		CTRST	C*TRT	SP	TS	CC	CTRST	C*TRT	SP	TS	CC
SPECIES	df	P	df	P	df	P	P	P	P	P	P	P	P	P	P	P
Winter wren	6, 16	0.0003		NA		NA	0.0004	0.008	0.6	0.1	0.02	0.3	0.2	0.2	0.04	0.2
Golden-crowned kinglet	6, 22	0.01		NA		NA	0.002	0.07	0.9	0.1	0.09	0.4	0.6	0.2	0.3	0.3
Swainson's thrush	6, 16	0.0001		NA		NA	0.0001	0.0003	0.6	0.002	0.004	0.8	0.01	0.03	0.6	0.1
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	0.4	0.3	0.1	0.1	0.5	0.04	0.8	0.5	0.8	0.9
Black-throated grey warbler	6, 16	0.8	2, 16	0.0007	3, 8	0.6	0.0001	0.02	0.9	0.02	0.05	0.2	0.4	0.9	0.5	0.3
Hermit warbler	6, 16	0.0004		NA		NA	0.0008	0.003	0.4	0.01	0.003	0.04	0.8	0.7	0.6	0.9
MacGillivray's warbler	6, 22	0.02		NA		NA	0.09	0.2	0.08	0.1	0.4	0.03	0.5	0.9	0.3	0.4
Wilson's warbler	6, 16	0.0002		NA		NA	0.0007	0.002	0.2	0.009	0.002	0.8	0.8	0.4	0.4	0.5
Western tanager	6, 16	0.0005		NA		NA	0.09	0.01	0.5	0.04	0.009	0.5	0.1	0.05	0.3	0.1
Black-headed grosbeak	6, 24	0.9	2, 24	0.4	3, 24	0.3										
Rufous-sided towhee	6, 22	0.005		NA		NA	0.006	0.04	0.4	0.02	0.06	0.09	0.7	0.3	0.4	0.3
Dark-eyed junco	6, 16	0.2	2, 16	0.003	3, 6	0.2	0.02	0.5	0.2	0.1	0.3	0.7	0.2	0.08	0.06	0.08
White-crowned sparrow	6, 16	0.0		NA		NA	0.0001	0.0001	0.2	0.0001	0.0001	0.004	0.08	0.3	0.02	0.2
Brown-headed cowbird	6, 16	0.3	2, 16	0.003	3, 6	0.05	0.03	0.2	0.5	0.07	0.5	0.3	1.0	0.7	0.7	0.9

Table 2.13, continued.

							YEAR 1 - YEAR 2 CONTRAST[1]					YEAR 2 - YEAR 3 CONTRAST[1]				
									Contrast of CN with					Contrast of CN with		
	YEAR*TRT		YEAR		TRT		CTRST	C*TRT	SP	TS	CC	CTRST	C*TRT	SP	TS	CC
SPECIES	df	P	df	P	df	P	P	P	P	P	P	P	P	P	P	P
Purple finch	6, 16	0.07	2, 16	0.0	3, 6	0.05	0.0002	0.05	1.0	0.05	0.9	0.3	0.3	0.3	0.9	0.8
Red crossbill	6, 22	0.6	2, 22	0.3	3, 22	0.9										
American goldfinch	6, 16	0.01		NA		NA	0.009	0.02	0.6	0.06	0.01	0.5	0.6	0.8	0.4	0.8
Evening grosbeak	6, 22	0.9	2, 22	0.06	3, 22	0.4	0.09	0.2	0.5	0.2	0.1	0.08	0.9	0.8	0.9	0.8
Douglas' squirrel	6, 16	0.09	2, 16	0.003	3, 6	0.01	0.02	0.2	0.2	0.7	0.8	0.9	0.3	0.4	0.1	0.4
Townsend's chipmunk	6, 22	0.2	2, 22	0.6	3, 22	0.01										
Black-tailed deer	6, 16	0.4	2, 16	0.2	3, 6	0.1										

[1] Degrees of freedom (df) for contrasts are 1,6 for CTRST (contrast), 3,6 for C*TRT (contrast*treatment interaction) and 1,6 for contrast of CN with SP, TS, CC.

Table 2.14. Average bird abundance (number of observations/5 ha) or average number of sightings and/or vocalizations for 3 mammal species and standard error (in parentheses) by treatment and year (YR1=pretreatment year, YR2=first year post-harvest, YR3=second year post-harvest) for bird (n ≥ 30 observations) observed ≤ 75 m from VCP center. Abundances are untransformed data. Species are arranged taxonomically; n is total number observed. See text for scientific names.

		CONTROL			SMALL PATCH			TWO-STORY			CLEARCUT		
SPECIES	n	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3
Rufous hummingbird	38	0 (0)	0.3 (0.3)	0.3 (0.3)	0.3 (0.1)	0.5 (0.3)	0.1 (0.1)	0 (0)	1.2 (0.5)	0.8 (0.8)	0.5 (0.2)	0.7 (0.2)	0.8 (0.5)
Northern flicker	83	0 (0)	0.3 (0.3)	0.3 (0.3)	0.9 (0.3)	0.5 (0.3)	0.6 (0.3)	2.0 (0.6)	2.0 (0.9)	0.8 (0.3)	0.8 (0.3)	1.3 (0.5)	1.7 (0.6)
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)	2.8 (1.4)	2.3 (1.6)	2.3 (1.2)	0.8 (0.5)	1.7 (1.1)	0.7 (0.3)
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)	2.7 (0.9)	2.8 (1.3)	1.7 (0.4)	0.7 (0.3)	2.2 (0.8)	1.8 (0.3)
Olive-sided flycatcher	75	0.3 (0.3)	0.3 (0.3)	0 (0)	0.2 (0.2)	0.1 (0.1)	0.1 (0.1)	0.3 (0.3)	2.2 (1.1)	3.0 (0.5)	1.3 (1.1)	2.2 (0.9)	2.0 (1.1)
Willow flycatcher	30	0 (0)	0 (0)	0 (0)	0.2 (0.2)	0.2 (0.2)	0.1 (0.1)	0.2 (0.2)	0.3 (0.2)	2.0 (0.6)	0 (0)	0.3 (0.3)	1.0 (0.6)
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)	13.7 (2.9)	2.0 (0.7)	1.3 (0.8)	14.0 (5.2)	1.0 (0.4)	0.8 (0.5)
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)	11.8 (7.5)	2.5 (0.9)	6.0 (2.6)	11.3 (3.6)	2.5 (1.0)	4.3 (3.6)
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)	1.7 (1.2)	0.5 (0.3)	0.2 (0.2)	1.5 (0.6)	0 (0)	0.2 (0.2)
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)	17.5 (1.7)	13.5 (1.9)	9.8 (2.6)	18.3 (2.4)	9.7 (2.3)	6.7 (2.6)
Bushtit	34	2.0 (2.0)	0 (0)	0 (0)	0.1 (0.1)	0.2 (0.2)	0.1 (0.1)	0 (0)	0.3 (0.3)	2.7 (1.9)	0.3 (0.3)	0.2 (0.2)	0 (0)
Brown creeper	665	8.3 (2.7)	9.0 (0)	10.7 (1.5)	10.0 (1.4)	8.3 (0.8)	8.9 (1.2)	13.8 (1.6)	6.8 (2.2)	2.7 (1.0)	8.7 (1.7)	1.0 (0.5)	0.2 (0.2)
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)	15.2 (3.6)	2.2 (0.9)	1.8 (0.8)	13.8 (2.7)	0.3 (0.2)	0 (0)

Table 2.14, continued.

		CONTROL			SMALL PATCH			TWO-STORY			CLEARCUT		
SPECIES	n	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3
House wren	462	0.7 (0.7)	0.7 (0.7)	0 (0)	0.1 (0.1)	0.3 (0.2)	3.1 (1.3)	0 (0)	12.5 (4.4)	18.2 (1.8)	0.5 (0.3)	15.5 (6.9)	21.5 (5.6)
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)	19.0 (2.2)	5.0 (1.8)	0.7 (0.3)	17.5 (2.3)	1.2 (0.6)	0.3 (0.2)
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)	15.8 (4.3)	1.8 (0.8)	1.2 (0.8)	10.7 (2.7)	0.5 (0.3)	0 (0)
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)	16.2 (1.4)	0.8 (0.4)	2.3 (0.8)	14.5 (2.5)	1.3 (0.6)	0.8 (0.5)
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)	6.7 (1.3)	9.7 (4.2)	6.7 (2.0)	7.5 (1.6)	3.7 (2.0)	3.8 (1.6)
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)	2.3 (0.8)	5.2 (1.4)	8.5 (1.8)	7.0 (3.5)	5.2 (1.6)	9.0 (2.4)
Black-throated grey 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)	7.3 (1.9)	1.3 (0.7)	1.0 (0.4)	3.5 (1.1)	0.5 (0.5)	0.5 (0.3)
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)	22.5 (5.0)	3.2 (1.6)	1.0 (0.6)	24.2 (3.9)	0.5 (0.2)	0.2 (0.2)
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)	1.7 (0.9)	4.5 (1.9)	13.2 (2.5)	2.7 (1.5)	3.0 (1.4)	9.0 (2.8)
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)	24.5 (2.1)	7.5 (2.3)	6.5 (0.8)	18.3 (1.7)	2.5 (1.3)	2.5 (1.3)
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)	10.2 (3.8)	5.2 (1.8)	5.5 (2.0)	10.7 (4.0)	1.8 (0.7)	1.3 (0.6)
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)	3.2 (1.1)	2.3 (0.9)	2.2 (1.0)	3.2 (1.7)	1.0 (0.4)	0.7 (0.4)
Rufous-sided 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)	1.8 (1.1)	10.0 (2.3)	15.5 (2.5)	2.2 (1.0)	8.2 (2.5)	13.0 (1.4)
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)	10.1 (1.9)	26.3 (2.5)	16.3 (1.3)	9.8 (1.6)	22.2 (3.8)	16.0 (2.8)
White-crowned sparrow	645	0 (0)	0 (0)	0 (0)	0 (0)	0.3 (0.2)	1.4 (0.9)	0 (0)	13.5 (3.2)	25.3 (3.9)	0 (0)	27.3 (5.5)	37.5 (6.4)

Table 2.14, continued.

		CONTROL			SMALL PATCH			TWO-STORY			CLEARCUT		
SPECIES	n	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3
Brown-headed cowbird	56	0 (0)	0 (0)	0.3 (0.3)	0 (0)	0.5 (0.4)	0.4 (0.1)	0.2 (0.2)	2.7 (1.2)	2.7 (1.0)	0 (0)	0.8 (0.8)	0.8 (0.4)
Purple finch	280	0 (0)	0.7 (0.3)	0.3 (0.3)	2.0 (0.9)	3.4 (1.0)	4.0 (0.8)	1.7 (0.8)	6.3 (1.7)	6.3 (2.1)	2.7 (1.2)	4.7 (1.7)	2.7 (1.2)
Red crossbill	166	3.7 (3.7)	0 (0)	0 (0)	2.8 (1.7)	4.4 (2.6)	0.1 (0.1)	6.0 (6.0)	0.7 (0.5)	0.2 (0.2)	0.2 (0.2)	0.2 (0.2)	1.8 (1.8)
American goldfinch	179	0.3 (0.3)	0 (0)	0 (0)	0 (0)	0 (0)	0.1 (0.1)	0 (0)	3.7 (1.6)	6.3 (2.3)	0.2 (0.2)	9.2 (4.5)	10.0 (4.4)
Evening grosbeak	363	3.7 (2.7)	8.0 (7.0)	2.3 (1.9)	9.1 (2.7)	4.7 (0.7)	1.5 (0.4)	8.7 (3.3)	2.8 (1.1)	0.7 (0.4)	4.8 (2.3)	0.8 (0.8)	0 (0)
Douglas' squirrel	187	2.7 (0.7)	1.3 (0.9)	1.0 (1.0)	3.6 (1.0)	3.0 (0.4)	3.2 (0.6)	2.5 (0.9)	0.5 (0.3)	1.3 (0.8)	1.0 (0.5)	0.2 (0.2)	0.2 (0.2)
Townsend's chipmunk	54	0 (0)	0 (0)	0.3 (0.3)	0.6 (0.2)	0.7 (0.2)	0.4 (0.2)	1.2 (0.2)	0.5 (0.3)	0.7 (0.3)	0.8 (0.3)	1.0 (0.5)	0.5 (0.3)
Black-tailed deer	35	0 (0)	0 (0)	0 (0)	0.4 (0.2)	0.4 (0.2)	0.6 (0.2)	0.3 (0.3)	0.2 (0.2)	0.2 (0.2)	0.2 (0.2)	0.7 (0.5)	1.3 (0.6)

Significant Responses to Treatment

Sixteen bird species had significant treatment by year interactions. There appeared to be 3 trends in response of bird abundance to treatment: (1) decreasing linear (2 bird species), (2) decreasing threshold (8 bird species), and (3) increasing linear (6 bird species). I was unable to differentiate "early" or "late-threshold" responses because my silvicultural treatments represented only a few levels of canopy removal (e.g., 100%, 75%, and 33% overstory removal for clearcut, two-story, and group selection treatments, respectively).

In general, response followed a pattern of control and small patch stands ("forested" stands) similar in bird species composition and abundance, and two-story and clearcut stands ("open" stands) similar in bird composition and abundance. "Forested" stands differed greatly from "open" stands in bird species composition and abundance. Most bird species showed no difference in abundance following harvest in small patch stands, but were lower in abundance in two-story and clearcut stands (Table 2.13).

Decreasing linear response: Birds described by the "decreasing linear" response showed the following generalized trends: little or no change through time in abundance in control or small patch stands, a reduction in abundance in two-story and clearcut stands 1-year post-harvest, a greater reduction in abundance in two- story and clearcut stands 2-years post-harvest (Figure 2.11). Brown creepers and chestnut-backed chickadee abundance demonstrated this pattern, although chestnut-backed chickadees appeared to increase in abundance in small patch stands (Figure 2.12).

Brown creeper abundance remained relatively constant in controls (8 to 11 observations/5 ha over the 3-year study) and small patch stands (10 observations/5 ha prior to harvest, 8 to 9 observations/5 ha post-harvest) (Tables 2.13 and 2.14). Abundance in two-story stands 1-year post-harvest was only half that prior to harvest (14 observations/5 ha pre-harvest v. 7 observations/5 ha post-harvest) and declined to

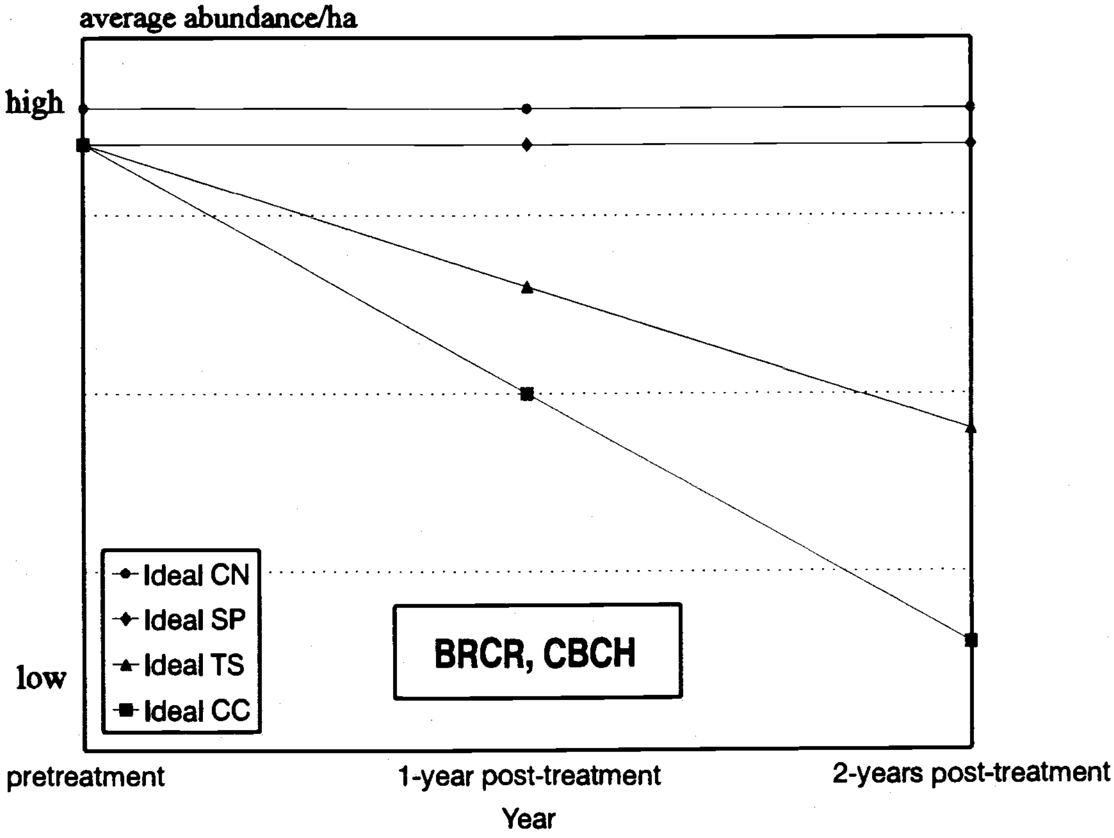


Figure 2.11. Model of decreasing linear bird response to harvest treatment. Generalized treatment responses (average abundance/5 ha) are depicted for control (Ideal CN), small patch (Ideal SP), two-story (Ideal TS), and clearcut (Ideal CC) stands over 3 years (pretreatment, 1-year post-treatment, and 2-years post-treatment). Brown creeper (BRCR) and chestnut-backed chickadee (CBCH) abundance followed this response pattern. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

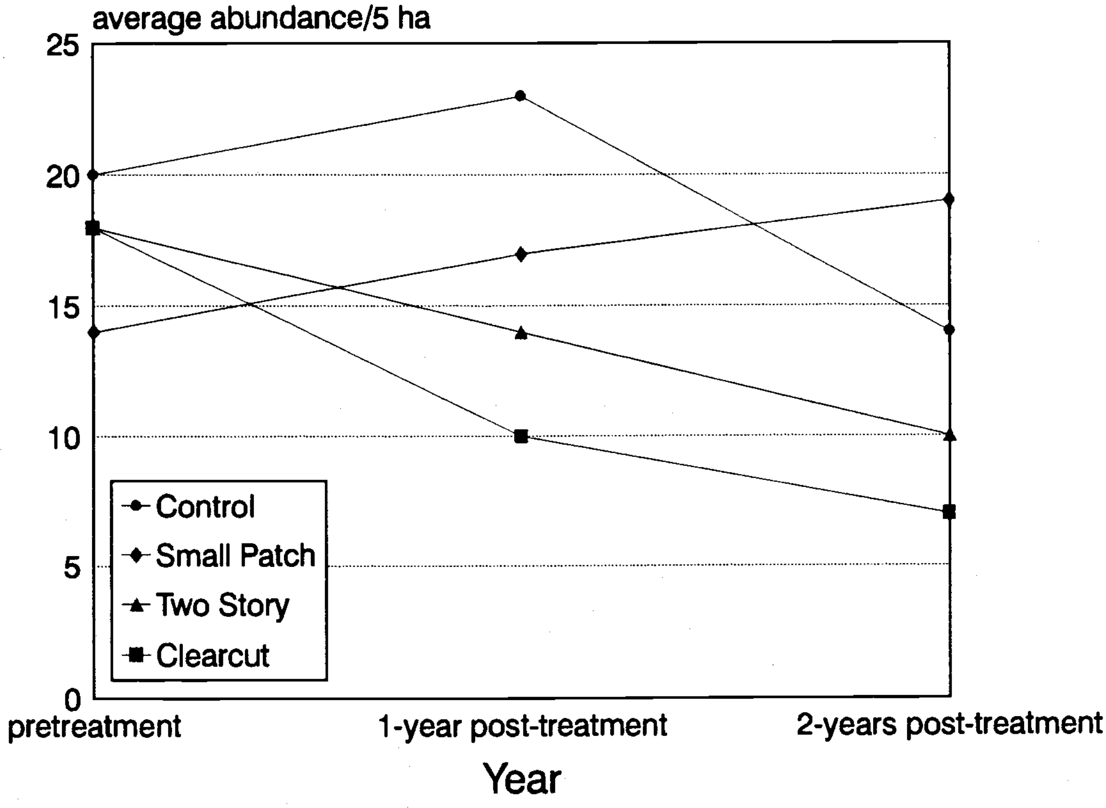


Figure 2.12. Example of decreasing linear bird response to harvest treatment depicting chestnut-backed chickadee. Average bird abundance (number of chestnut-backed chickadee observations/5 ha) is shown for control, small patch, two-story, and clearcut treatments for 3 years (pretreatment, 1-year post-treatment, 2-years post-treatment). Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

only 3 observations/5 ha in the second year after harvest. The pattern in clearcuts was similar to two-story stands, although abundance decreased from 9 to 0 observations/5 ha after harvest (Tables 2.13 and 2.14).

The first year after harvest, chestnut-backed chickadees increased in abundance in small patch stands from an average of 14 to 17 observations/5 ha (Tables 2.13 and 2.14). Abundance declined in two-story stands from 18 to 14 observations/5 ha and in clearcut stands from 18 to 10 observations/5 ha. Chickadee abundance also was affected the second year after harvest ($\underline{P} = 0.005$). Bird observations continued to increase in small patch stands and decrease in two-story and clearcut stands during the second year after harvest (Tables 2.13 and 2.14).

Creeper and chickadee abundance decreased in two-story and clearcut stands but birds continued to use these stands. Creepers probably foraged on retained trees and snags but were not observed nesting in these stands. Chestnut-backed chickadees, however, appeared to better tolerate disturbance, increasing in small patch stands and continuing to nest in small patch, two-story, and clearcut stands (pers. obs.).

Decreasing threshold response: Birds following a "decreasing threshold" response to treatments tended to retain high abundance in control and small patch cut stands but immediately after harvest were absent or extremely low in abundance in two-story and clearcut stands (Figure 2.13). Eight bird species followed this pattern of response: Steller's jay, red-breasted nuthatch, winter wren, golden-crowned kinglet, Swainson's thrush, hermit warbler, Wilson's warbler, and western tanager. An example depicting hermit warbler response is shown in Figure 2.14.

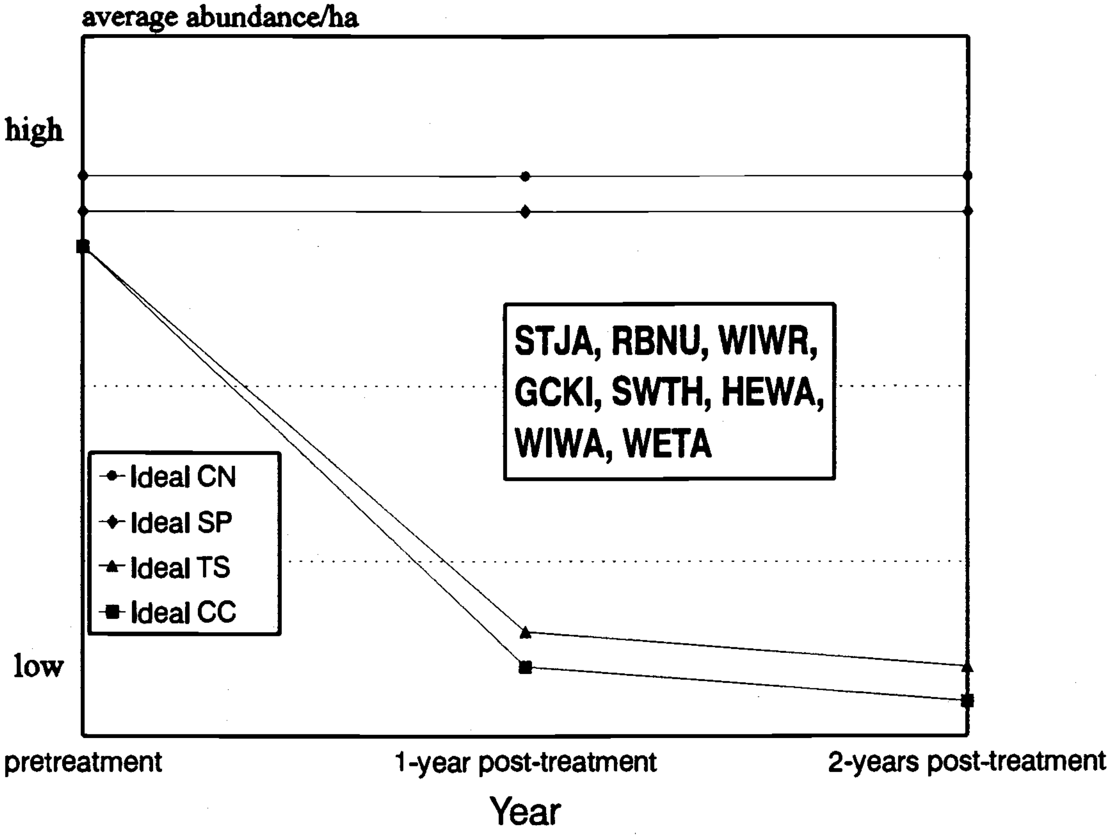


Figure 2.13. Model of decreasing threshold bird response to harvest treatment. Generalized treatment responses (average abundance/5 ha) are depicted for control (Ideal CN), small patch (Ideal SP), two-story (Ideal TS), and clearcut (Ideal CC) stands over 3 years (pretreatment, 1-year post-treatment, and 2-years post-treatment). Steller's jay (STJA), red-breasted nuthatch (RBNU), winter wren (WIWR), golden-crowned kinglet (GCKI), Swainson's thrush (SWTH), hermit warbler (HEWA), Wilson's warbler (WIWA), and western tanager (WETA) abundance followed this response pattern. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

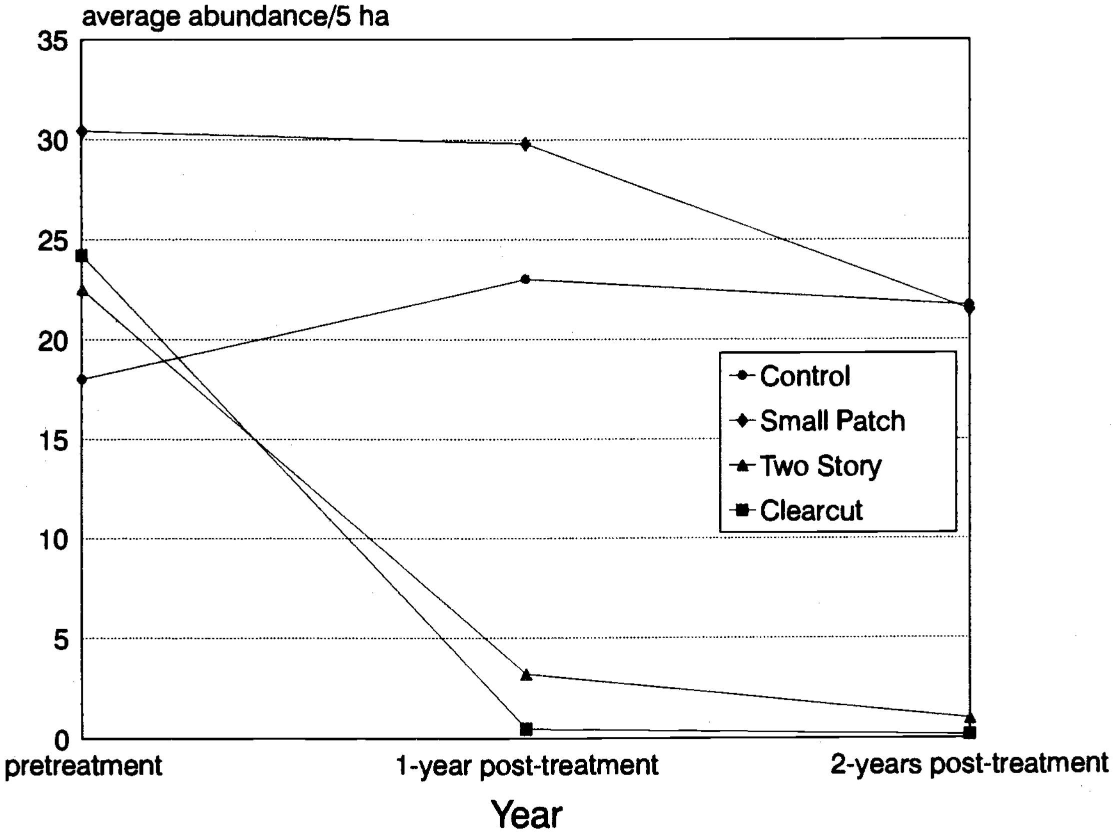


Figure 2.14. Example of decreasing threshold bird response to harvest treatment depicting hermit warbler. Average bird abundance (number of hermit warbler observations/5 ha) is shown for control, small patch, two-story, and clearcut treatments for the 3-year study period (pretreatment, 1-year post-treatment, 2-years post-treatment). Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

Steller's jays decreased in abundance in two-story and clearcut stands the first year following harvest (Table 2.13). Abundance dropped from 12 to 3 observations/5 ha in two-story treatments and from 11 to 3 observations/5 ha in clearcuts. No change was detected between post-treatment years. I did not detect a change in Steller's jay abundance in control or small patch stands (Tables 2.13 and 2.14).

Red-breasted nuthatch abundance declined the first year after harvest in two-story and clearcut stands (Table 2.13). Abundance declined from 15 to 2 observations/5 ha in two-story stands, and from 13 to 0 observations/5 ha in clearcuts. Abundance in these stands remained low the second year following harvest with no significant decrease from the previous year ($\underline{P} = 0.1$). Both control (14 to 8 observations/5 ha) and small patch (15 to 9 observations/5 ha) stands experienced similar declines in abundance between pretreatment and post-treatment years. Changes in abundance following treatment in small patch stands may mirror natural population fluctuations (Table 2.14).

Winter wren abundance seemed to decline in small patch stands from 19 observations/5 ha preharvest to 15 (1-year post-harvest) to 12 (2-years post-harvest) but these declines were not statistically significantly ($\underline{P} \geq 0.2$) (Table 2.13). This may indicate that birds experience detrimental effects from 0.2-ha openings which may lead to a decline in abundance in these stands that could only be detected over a period longer than 2 years. In two-story and clearcut stands, abundance was less than 25% of the preharvest level. Declines were significant in clearcuts ($\underline{P} = 0.02$) and may be significant for two-story stands ($\underline{P} = 0.1$) (Tables 2.13 and 2.14).

Golden-crowned kinglet abundance in two-story and clearcut stands was less than 10% of original numbers, decreasing from 16 to 2 observations/5 ha in two-story stands and from 11 to 1 bird(s)/5 ha in clearcuts (Table 2.13). Kinglet abundance appeared to decline in small patch stands (from 15 observations/5 ha preharvest to 8 observations/5 ha post-harvest), although this decline was not statistically significant (P = 0.9). Abundance in control stands decreased in the second year of the study, then increased in the final year. Although golden-crowned kinglets in control stands averaged 15 to 9 observations/5 ha, they did not follow a pattern of decline over the 3-year period (Table 2.14). Winter wrens and golden-crowned kinglets may be sensitive to removal of 0.2-ha openings in the small patch stands, resulting in decreased abundance, but additional data would need to be collected to confirm this observation.

Swainson's thrushes were less abundant in clearcuts following harvest, declining from an average of 15 to 1 bird/5 ha (Table 2.13). Thrushes declined in two-story stands as well (two-story stands: 16 observations/5 ha preharvest v. 2 observations/5 ha 2-years post-harvest). In small patch stands, abundance decreased from 12 observations/5 ha (preharvest) to 11 observations/5 ha (1-year post-harvest) to 7 observations/5 ha (2-years post-harvest) (Table 2.13). Swainson's thrushes experienced detrimental effects from 0.2-ha openings that were evident only after 2 years, perhaps due to changes in breeding habitat (e.g., vegetation composition and structure) or other factors (e.g., increased predation) (Tables 2.13 and 2.14).

Hermit warblers did not seem negatively affected by small patch harvesting the first year after harvest, but abundance in two-story and clearcut stands was reduced from 23 to 3 observations/5 ha in two-story stands and from 24 to 1 observation(s)/5 ha in clearcuts (Tables 2.13 and 2.14). Hermit warblers seemed to tolerate overstory removal in 0.2-ha patches where a larger proportion of the stand remained forest matrix. They did not tolerate the high degree of overstory removal in two-story and clearcut stands.

Wilson's warblers were less abundant in two-story and clearcut stands the first year after harvest, declining in two-story stands from 25 observations/5 ha pretreatment to 8 observations/5 ha after harvest ($\underline{P} = 0.009$) and in clearcuts from an average of 18 to 3 observations/5 ha ($\underline{P} = 0.002$). Abundance remained constant in control and small patch stands, averaging 12 to 16 observations/5 ha in controls and 17 to 20 observations/5 ha in small patch stands (Tables 2.13 and 2.14).

Western tanagers responded negatively to two-story and clearcut harvest treatments the first year after harvest, decreasing in two-story stands from 10 to 6 observations/5 ha ($\underline{P} = 0.04$), and in clearcuts from 11 to 1 observation(s)/5 ha ($\underline{P} = 0.009$). Birds increased in control stands (from 3 to 10 observations/5 ha) while remaining constant in abundance in small patch stands (10 observations/5 ha during the 3-year study period) (Tables 2.13 and 2.14). I noticed male tanagers singing and tanager pairs moving among remaining trees in two-story stands. Presumably tanagers continued to use two-story stands for nesting, although this is not confirmed and nest success is unknown.

Increasing linear response: The "increasing linear" response, generalized in Figure 2.15, shows bird abundance increasing in two-story and clearcut stands 1-year post-harvest and continuing to increase 2-years post-harvest. There may be little or no change in abundance; indeed the birds may be absent, in control and small patch stands. Birds showing these large increases are apparently adapted to early seral stages or highly disturbed habitat, since most reached highest abundance among these treatments in clearcut stands. Six bird species followed this pattern of increase: willow flycatcher (*Empidonax trailii*), house wren, MacGillivray's warbler, rufous-sided towhee, white-crowned sparrow, and American goldfinch. An example depicting white-crowned sparrow is shown in Figure 2.16.

Willow flycatchers were present only in low numbers throughout the study period (0 to 2 observations/5 ha). Willow flycatchers reached highest abundance in two-story stands. They were not observed or were extremely low in abundance in control stands (0 observations/5 ha), small patch stands (0.1 to 0.2 observations/5 ha), and clearcut stands (0 to 1 observation/5 ha). There was no significant change in

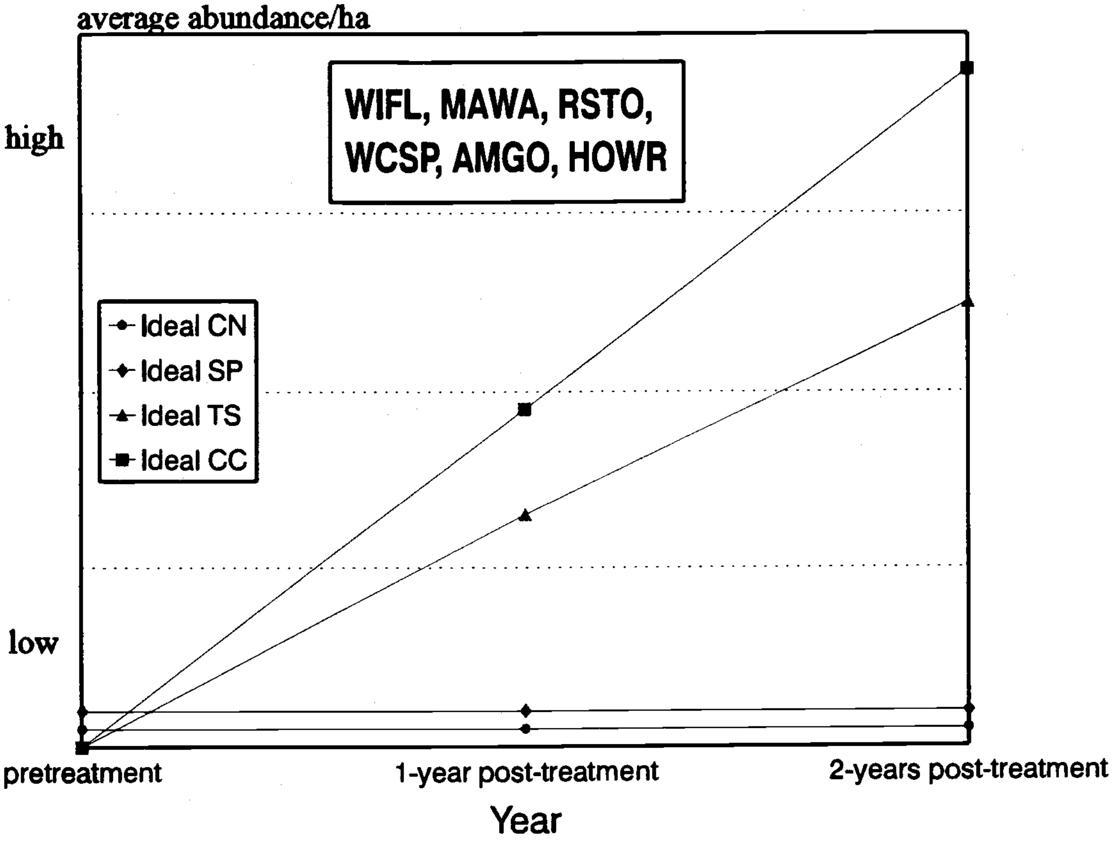


Figure 2.15. Model of increasing linear bird response to harvest treatment. Generalized treatment responses (average abundance/5 ha) are depicted for control (Ideal CN), small patch (Ideal SP), two-story (Ideal TS), and clearcut (Ideal CC) stands over the 3-year study period (pretreatment, 1-year post-treatment, and 2-years post-treatment). Willow flycatcher (WIFL) MacGillivray's warbler (MAWA), rufous-sided towhee (RSTO), white-crowned sparrow (WCSP), American goldfinch (AMGO), and house wren (HOWR) abundance followed this response pattern. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

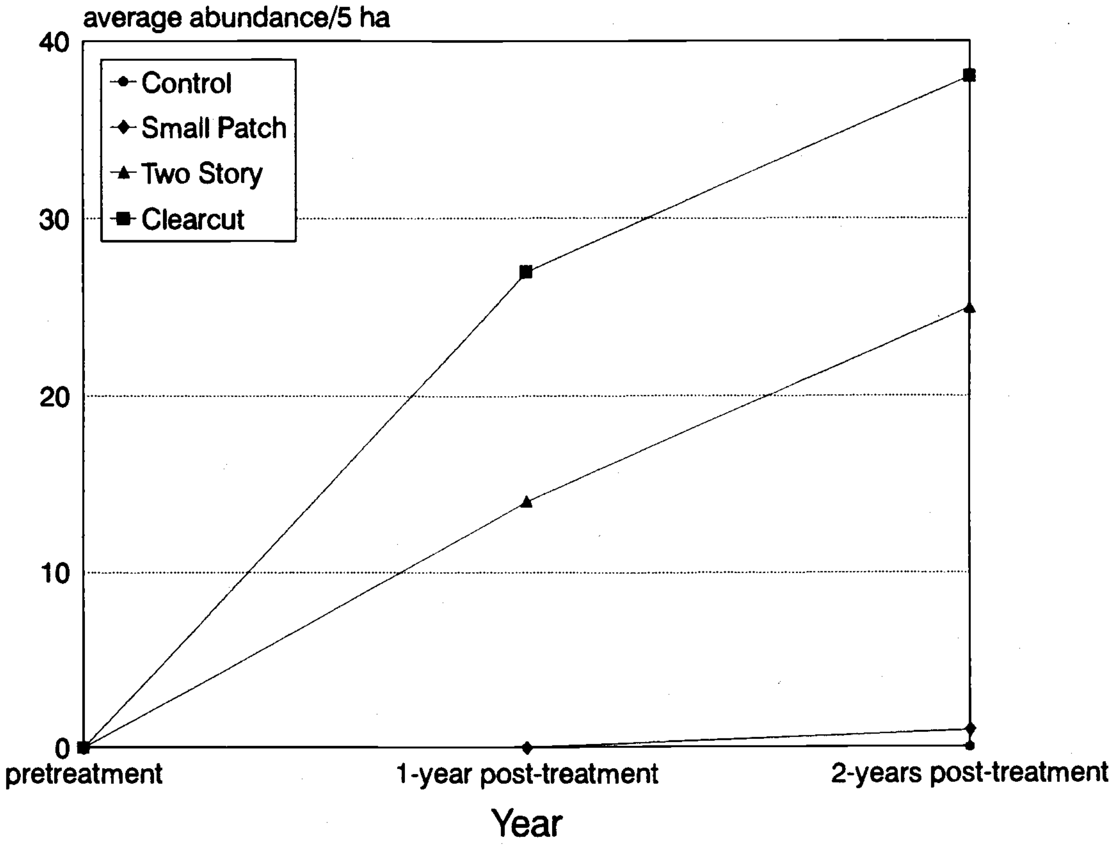


Figure 2.16. Example of increasing linear bird response to harvest treatment depicting white-crowned sparrow. Average bird abundance (number of white-crowned sparrows/5 ha) is shown for control, small patch, two-story, and clearcut treatments for the 3-year study period (pretreatment, 1-year post-treatment, 2-years post-treatment). Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.

abundance until the second year after harvest, when abundance increased in two-story stands from 0.2 to 2 observations/5 ha (P = 0.03) (Tables 2.13 and 2.14).

House wren abundance remained low in control stands (0 to 0.7 observations/5 ha). They appeared to increase in abundance the second year after harvest in small patch stands, although this increase was not significant (Tables 2.13 and 2.14). Birds reached highest abundance in two-story and clearcut stands, with significant increases occurring the first year after harvest (TS: P = 0.02; CC: P = 0.03).

MacGillivray's warblers remained low in abundance in control stands (1 observation/5 ha during the 3-year study period) but increased in small patch, two-story, and clearcut treatments during the second year after harvest (P = 0.03) (SP: from 3 to 6 observations/5 ha; TS: from 5 to 13 observations/5 ha; CC: from 3 to 9 observations/5 ha) (Tables 2.13 and 2.14). These birds may have responded to an increase in shrub density in harvested stands because they use shrubs for nesting and foraging. Small patch stands may provide some benefit to these birds if 0.2-ha openings alter breeding habitat (e.g., vegetation composition and structure).

Rufous-sided towhee abundance increased in two-story (P = 0.02) and clearcut stands (P = 0.06) the first year after harvest (two-story: from 2 to 10 observations/5 ha; clearcut: from 2 to 8 observations/5 ha). They also appeared to respond to openings in small patch stands, showing a tendency to increase in abundance in these stands (3 observations/5 ha pretreatment, 11 observations/5 ha 2-years post-treatment) but these increases were not significant. Their abundance in controls remained low (1 observation/5 ha) throughout the 3-year study (Table 2.14).

White-crowned sparrows were only infrequently observed in small patch stands, and those observations were primarily of feeding or perching, not of singing males. They were never observed in control stands or in any stands prior to harvest. White-crowned sparrows increased significantly in two-story (P = 0.0001) and clearcut stands (P = 0.0001) 1 year after harvest and continued to increase in two-story stands (P = 0.02) the second year post-harvest. Sparrows reached highest abundance in clearcut stands 2-years post-harvest (37.5 observations/5 ha), but also were abundant in two-story stands (25.3 observations/5 ha 2-years post-harvest) (Table 2.14).

American goldfinches were rarely observed in controls or pretreatment stands. The first year following harvest, they increased in abundance from 0 to 3.7 observations/5 ha in two-story stands ($\underline{P} = 0.06$) and from 0.2 to 9.2 observations/5 ha in clearcuts ($\underline{P} = 0.01$). They were higher in abundance in clearcuts (Tables 2.13 and 2.14).

White-crowned sparrows and American goldfinches appeared to respond to two-story and clearcut treatments, but not to small patch stands. They may respond to dense shrub development that occurs in two-story and clearcut stands without a high percentage of overstory cover. House wren, MacGillivray's warbler, and rufous-sided towhee detections appeared to increase in all treatments (small patch, two-story, and clearcut stands). Willow flycatcher abundance increased in two-story stands perhaps because of an increase in shrub cover in combination with some overstory retention.

Possible Responses to Treatment

Responses to silvicultural treatment were indicated by a statistically significant treatment by year interaction. For 7 of 33 bird species, there appeared to be a response to stand management (treatment effects: $\underline{P} \leq 0.10$); however, I did not detect a year by treatment interaction (Table 2.13). This could have been caused by low power of the statistical test, because transformed data did not meet assumptions of RMA, or because some bird species were consistently more abundant in some stands.

Six species (northern flicker [*Colaptes auratus*], hairy woodpecker, olive-sided flycatcher [*Contopus borealis*], American robin, brown-headed cowbird, purple finch) appeared to increase over the study period; Pacific-slope flycatcher appeared to decrease. Species that appeared to increase included 3 residents (northern flicker, hairy woodpecker, purple finch), 2 short-distance migrants (American robin, brown-headed cowbird), and 1 long-distance migrant (olive-sided flycatcher). One long-distance migrant (Pacific-slope flycatcher) appeared to decrease over time.

Using nonparametric statistical tests, I ranked data for these species. Olive-sided flycatcher ($\underline{P} = 0.04$), purple finch ($\underline{P} = 0.0007$), and brown-headed cowbird ($\underline{P} = 0.004$) abundances increased following harvest. Hairy woodpecker ($\underline{P} = 0.08$), Pacific-slope flycatcher ($\underline{P} = 0.16$), northern flicker ($\underline{P} = 0.38$), and American robin ($\underline{P} = 0.70$) abundances did not differ among treatments.

Olive-sided flycatcher abundance increased in two-story stands compared with control stands ($\underline{P} = 0.05$). I could not detect differences between two-story and clearcut or between two-story and small patch stands ($\underline{P} \geq 0.05$), nor did I detect differences between control and small patch or control and clearcut stands ($\underline{P} \geq 0.05$).

Brown-headed cowbirds increased in abundance in two-story stands following harvest ($\underline{P} = 0.05$). Cowbird abundance remained low in control stands. I did not detect a difference between control and small patch, control and clearcut, two-story and small patch, or two-story and clearcut stands ($\underline{P} \geq 0.05$).

Purple finches responded to treatment. They increased in abundance following harvest in two-story stands, with abundances significantly higher than those in control or clearcut stands ($\underline{P} = 0.05$). I could not detect a difference between two-story and small patch stands ($\underline{P} > 0.05$).

Although I did not detect a difference in Pacific-slope flycatcher abundance following stand management, I suspect this was due to low power of my statistical tests. Over the 3-year study period, observations decreased from an average of 14 to 2 bird observations/5 ha in two-story stands, and from 14 to 1 bird observations/5 ha in clearcuts, while remaining constant in control (from 24 to 20 bird observations/5 ha) and small patch stands (from 13 to 10 bird observations/5 ha) (Table 2.14). Pacific-slope flycatchers appeared to tolerate small scale disturbances such as those created by harvest of 0.2-ha circular patches, but were intolerant of larger scale disturbances.

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, northern flicker, hairy woodpecker, and American robin. Based on bird observations (Table 2.14), hairy woodpeckers and northern flickers appeared to increase in two-story stands. American robins appeared to increase in small patch and two-story stands but decreased following clearcutting. American robins might tolerate moderate to high levels of disturbance, remaining more abundant in stands with some overstory. Additional study sites with more control stands might clarify responses of these birds to harvest treatments.

No Response to Treatments

Ten species did not appear to respond to treatments ($\underline{P} > 0.10$). These birds (rufous hummingbird [*Selasphorus rufus*], red-breasted sapsucker, gray jay, bushtit, orange-crowned warbler, black-throated gray warbler, black-headed grosbeak [*Pheucticus melanocehpalus*], dark-eyed junco, red crossbill, and evening grosbeak) showed no noticeable trend, perhaps because habitat upon which they relied or to which they were sensitive (e.g., shrub density) was not strongly impacted by harvest. Some birds used larger territories than my average 6- to 8-ha stand size (e.g., red-breasted sapsucker), or sample size was small (e.g., rufous hummingbird, n = 38; bushtit: n = 34) so they may have been inadequately sampled for detection of changes among treatments. Most of my red crossbill and evening grosbeak observations represent foraging rather than nesting. Douglas-fir seed availability probably influenced their abundance rather than treatment. Some "no trend" species differed in abundance among years, but not in treatment response (e.g., orange-crowned warbler, black-throated gray-warbler, dark-eyed junco). Black-throated gray warbler populations may have been declining in McDonald-Dunn Forest during the 3-year study period, or the stand types I studied may represent marginal habitat and their populations were too variable in control stands to establish comparisons to other treatments. Dark-eyed juncos and orange-crowned warblers may have been responding to population fluctuations and unresponsive to harvest treatment. Dark-eyed junco response is depicted as an example of the "no trend" response in Figure 2.17.

Trends in Bird Abundance in Large Patch, Wedge, and Strip Cut Stands

I counted birds in 3 unreplicated treatments (large patch, strip cut, and wedge cut) in 1 block (Dunn replication). Large patch (LP) stands (n = 2) had 1/3 wood volume removed in 0.6-ha circular patches. The strip cut (ST) stand (n = 1) had 0.8- to 2-ha linear strips removed and the wedge cut (WD) stand (n = 1) had 0.8- to 2-ha triangular-shaped patches removed. All trees and snags were removed from harvested portions of these stands. No harvesting in the stands took place outside the boundaries of the strips or patches. Because stands were not replicated, I did not statistically analyze them for changes in bird or mammal abundance. In this section, I report only general responses observed pretreatment, 1-year and 2-years post-treatment (For detailed information, refer to Appendix 1).

Bird abundance (all birds detected within 75 m of VCPs in the stands, excluding evening grosbeaks and red crossbills) decreased after harvest in large patch, strip cut, and wedge cut stands. Abundance in large patch stands declined from 205 observations/5 ha to 148 observations/5 ha, in strip cut from 213 to 147, and in wedge cut from 201 to 152. Simpson diversity remained the same or increased during the 3-year period (LP: 0.92 to 0.94; ST: 0.91 to 0.93; WD: 0.90 to 0.93). Simpson equitability remained constant over the 3-year period (LP: 0.97; ST: 0.97; WD: 0.95 to 0.96). Species richness appeared to increase in all 3 treatments (LP: 21.5 to 26.5 species; ST: 19 to 24 species; WD: 19 to 25 species).

Community similarity (percent similarity with pretreatment bird community composition) declined for the wedge cut stand (from 70 to 59%), but remained about the same for large patch and strip cut stands (LP: 67 to 60%; ST: 68 to 68%). Most abundant birds found in these stands post-treatment are represented in Figure 2.18.

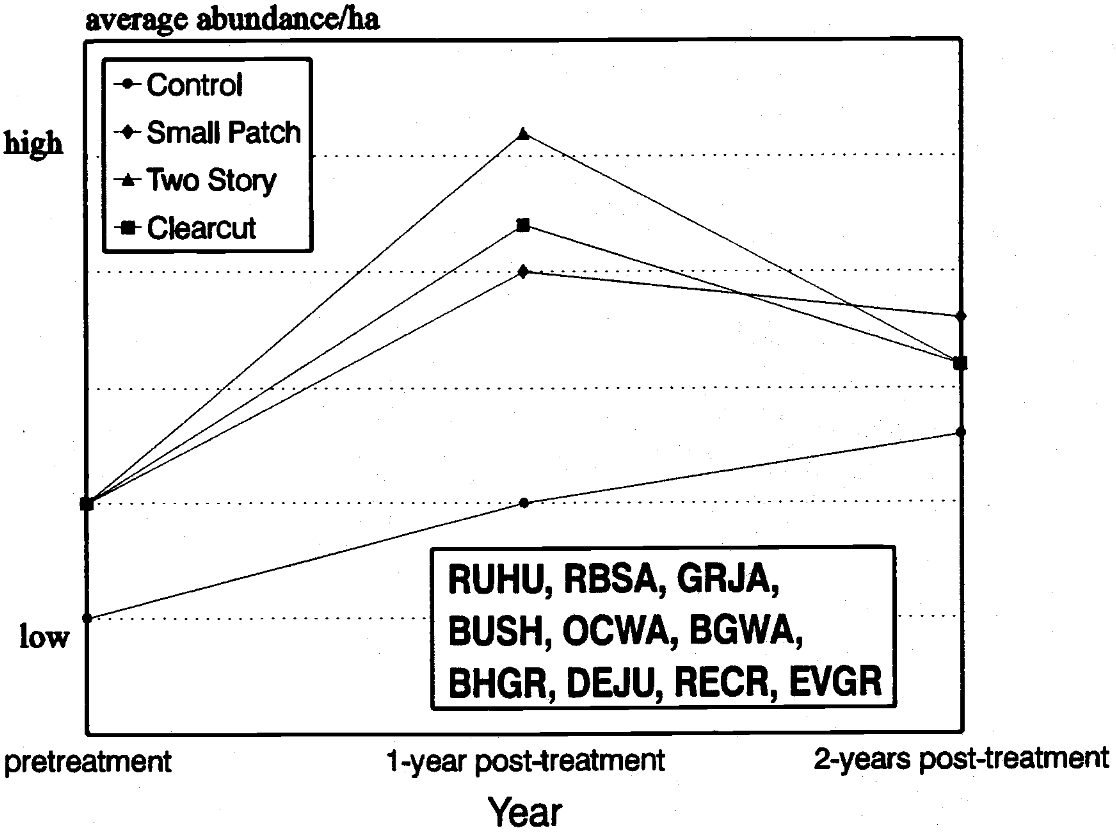
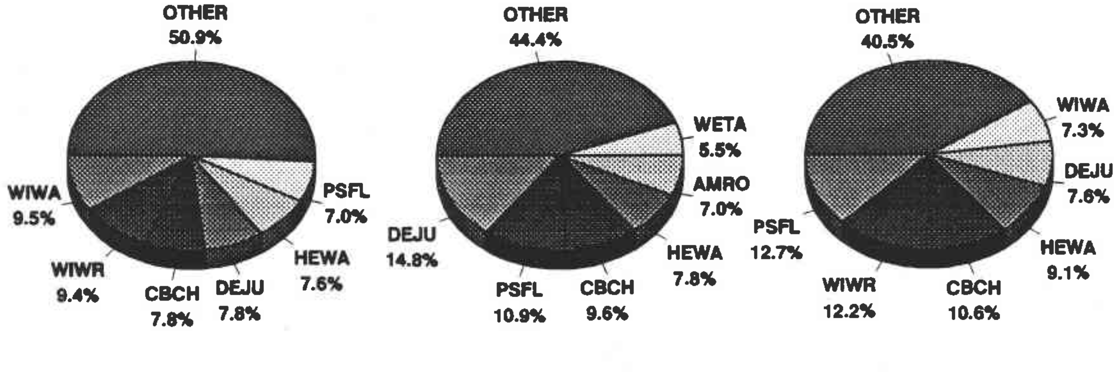


Figure 2.17. Birds showing no detectable response to harvest treatment. Abundance (verage abundance/5 ha) are depicted for control (Ideal CN), small patch (Ideal SP), two-story (Ideal TS), and clearcut (Ideal CC) stands over the 3-year study period (pretreatment, 1-year post-treatment, and 2-years post-treatment). Rufous hummingbird (RUHU), red-breasted sapsucker (RBSA), gray jay (GRJA), bushtit (BUSH), orange-crowned warbler (OCWA), black-throated gray warbler (BGWA), black-headed grosbeak (BHGR), dark-eyed junco (DEJU), red crossbill (RECR), and evening grosbeak (EVGR) were species for which I could not detect treatment differences. Bird data were collected on McDonald-Dunn Research Forest, 1989 - 1992.



A. LARGE PATCH

B. STRIP CUT

C. WEDGE CUT

Figure 2.18. Proportional representation (% of total) of the 6 most abundant bird species for A. large patch, B. strip cut, and C. wedge cut treatments. Data represent post-treatment observations only, and were collected on the Dunn replication, McDonald-Dunn Research Forest 1990 - 1992. Species are designated by acronyms (AMRO = American robin, CBCH = chestnut-backed chickadee, DEJU = dark-eyed junco, HEWA = hermit warbler, PSFL = Pacific-slope flycatcher, WETA = western tanager, WIWA = Wilson's warbler, WIWR = winter wren, OTHER = all other species).

In large patch stands, the 6 most abundant species prior to harvest represented 56% of observations. Species included hermit warbler (12%), Pacific-slope flycatcher (10%), Wilson's warbler (10%), chestnut-backed chickadee (9%), winter wren (8%), and Swainson's thrush (7%). Two years after harvest, most abundant species representing 46% of observations were Wilson's warbler (10%), dark-eyed junco (9%), winter wren (9%), Swainson's thrush (6%), red-breasted sapsucker (2 nest trees with adults and young recorded) (6%), and orange-crowned warbler (6%). The average Versatility Index for these species increased from 1.34 (pretreatment) to 1.73 2-years post-treatment.

Six species comprised 62% of the preharvest bird population in strip cut stands: hermit warbler (14%), dark-eyed junco (14%), Pacific-slope flycatcher (12%), chestnut-backed chickadee (9%), Wilson's warbler (7%), and golden-crowned kinglet (6%). Two years after harvest, most abundant species were dark-eyed junco (15%), chestnut-backed chickadee (10%), Pacific-slope flycatcher (8%), red-breasted nuthatch (8%), house wren (8%), and MacGillivray's warbler (5%). They comprised 54% of the bird population. The average Versatility Index for these species decreased from 1.76 (pretreatment) to 1.56 2-years post-treatment.

In wedge cut stands prior to harvest, 6 species made up 67% of the population: winter wren (20%), Pacific-slope flycatcher (15%), chestnut-backed chickadee (10%), hermit warbler (10%), Wilson's warbler (7%), and brown creeper (5%). Two years after harvest, 5 species comprised 52% of the population: Pacific-slope flycatcher (13%), dark-eyed junco (13%), brown creeper (10%), winter wren (9%), and western tanager (7%). White-crowned sparrows, chestnut-backed chickadees, and red-breasted nuthatches were equally abundant in this stand; each comprised 5% of the post-harvest population. The average Versatility Index for these species increased from 1.23 (pretreatment) to 1.48 2-years post-treatment (I used chestnut-backed chickadee as the sixth most abundant species for post-harvest average Versatility Index. It has the smallest versatility index of the 3 species of equal abundance so was the most conservative measure to include).

Mammals

Vocalizations and Sightings

I could not detect treatment effects for black-tailed deer, Townsend's chipmunk, and Douglas' squirrel using RMA probably because log transformations failed to equalize variances (e.g., there was no treatment*year interaction effect but there was a treatment effect [$\underline{P} \leq 0.10$]) (Table 2.13). I used ranked data to test for treatment differences, and compared pretreatment to 2-years post-treatment data only.

Douglas' squirrel sightings and vocalizations were lower in clearcuts, and higher in small patch stands (Table 2.14). I could not detect a difference among treatments however ($\underline{P} = 0.86$). Townsend's chipmunks were more abundant in two-story and clearcut stands, and lower in abundance in control stands (Table 2.14), although differences were not statistically significant ($\underline{P} = 0.17$). Black-tailed deer observations did differ among treatments ($\underline{P} = 0.03$), with most sightings in clearcuts, although I could not detect a difference among treatments using multiple comparisons based on Friedman rank sums at the $\underline{P} = 0.05$ level. Deer were observed in small patch and two-story stands, but rarely observed in control stands (Table 2.14). Data for these species were collected opportunistically, so may not represent adequate samples.

Live-trapping results

Live-trapping results are reported as number of individuals captured/1000 trap nights (TN) using Sherman and pitfall traps (Table 2.11), or using pitfall traps only (Table 2.12). Probably because of small sample sizes and variability in capture rates for treatments (Table 2.11 and Table 2.12), I was unable to detect any differences in response of Townsend's chipmunk, Oregon vole, deer mouse, and Trowbridge's shrew to treatments (Table 2.15). Two of these species (deer mouse, Oregon vole), however, appeared to increase in response to harvest and Trowbridge's shrew appeared to

Table 2.15. Repeated measures analysis of variance and orthogonal contrasts between pretreatment and 1-year post-treatment for mammal capture rates (number of captures/1000TN/stand) (capture rates were transformed using [$\log_{10}$(capture rate+1)]. For species or species groups with n ≥ 30 observations. Species groups are (1) nest predators (Townsend's chipmunk, deer mouse), (2) rodents (western red-backed vole, northern flying squirrel, Oregon vole, dusky-footed woodrat, deer mouse, red tree vole, and Townsend's chipmunk) (3) insectivores (shrew-mole, coast mole, Townsend's mole, Pacific water shrew, Pacific shrew, Trowbridge's shrew, vagrant shrew); and (4) shrews (Pacific water shrew, Pacific shrew, Trowbridge's shrew, vagrant shrew). For individual species and species groups, analyses are for live-trapping on 2 replications (Peavy and Dunn), pretreatment and 1-year post-treatment. For pitfall-trapped only species (Trowbridge's shrew), analysis is for live-trapping on 3 replications (Lewisburg Saddle, Peavy, and Dunn) for pretreatment and 1-year post-treatment. Treatments are control (CN), small patch group selection (SP), two-story (TS), and clearcut (CC). P is the probablity associated with differences among treatment (TRT), year (YEAR), or treatment by year interaction (YEAR*TRT) effects; df are degrees of freedom for each test.

								YEAR 1 - YEAR 2 CONTRAST									
												Contrast of CN with					
SPECIES OR SPECIES GROUP		YEAR*TRT		YEAR		TRT		CONTRAST		CONTRAST*TRT		SP		TS		CC	
	n	df	P	df	P	df	P	df	P	df	P	df	P	df	P	df	P
Individual Species																	
Townsend's chipmunk	59	3, 3	0.3	1, 3	0.8	3, 3	0.5	1, 3	0.8	3, 3	0.3	1, 3	0.2	1, 3	0.1	1, 3	0.3
Oregon vole	180	3, 3	0.3	1, 3	0.01	3, 3	0.9	1, 3	0.01	3, 3	0.3	1, 3	0.1	1, 3	0.1	1, 3	0.1
Deer mouse	504	3, 3	0.5	1, 3	0.03	3, 3	0.5	1, 3	0.03	3, 3	0.5	1, 3	0.3	1, 3	0.2	1, 3	0.2
Trowbridge's shrew	334	3, 3	0.1	1, 3	0.5	3, 3	0.5	1, 3	0.5	3, 3	0.1	1, 3	0.2	1, 3	0.06	1, 3	0.05
Species Groups																	
Rodents	755	3, 3	0.5	1, 3	0.03	3, 3	0.5	1, 3	0.03	3, 3	0.5	1, 3	0.3	1, 3	0.2	1, 3	0.2
Insectivores	421	3, 3	0.08	1, 3	0.8	3, 3	0.4	1, 3	0.7	3, 3	0.08	1, 3	0.08	1, 3	0.03	1, 3	0.04
Shrews	403	3, 3	0.1	1, 3	0.9	3, 3	0.02	1, 3	0.9	3, 3	0.1	1, 3	0.1	1, 3	0.05	1, 3	0.06
Nest Predators	563	3, 3	0.8	1, 3	0.06	3, 3	0.4	1, 3	0.06	3, 3	0.8	1, 3	0.5	1, 3	0.5	1, 3	0.4

Table 2.15, continued.

SPECIES OR SPECIES GROUP								YEAR 1 - YEAR 2 CONTRAST									
												Contrast of CN with					
		YEAR*TRT		YEAR		TRT		CONTRAST		CONTRAST*TRT		SP		TS		CC	
	n	df	P	df	P	df	P	df	P	df	P	df	P	df	P	df	P
Pitfall traps only																	
Trowbridge's shrew	325	3, 6	0.1	1, 6	0.7	3, 6	0.5	1, 6	0.7	3, 6	0.1	1, 6	0.2	1, 6	0.06	1, 6	0.05

decrease in abundance. Townsend's chipmunk data were too variable and sample size may have been too small to detect any trends in response to treatment.

Capture rates for deer mice indicate a positive response to two-story and clearcut harvesting, since rates increased from 31 to 75 deer mice/1000 TN in two-story stands and from 48 to 92 mice/1000 TN in clearcuts (Table 2.16). They did not appear to change in abundance in control or small patch stands. Oregon voles also appeared to increase in harvested treatments. Capture rates in small patch stands increased from 9 to 18 voles/1000 TN, from 4 to 19 in two-story stands, and from 4 to 17 in clearcuts (Table 2.16).

Trowbridge's shrews appeared to decline in two-story and clearcut stands. Capture rate decreased from 73 to 27 shrews/1000 TN in two-story stands and from 65 to 31 in clearcuts.

When I combined species that were taxonomically related to analyze response of 3 groups (rodents, insectivores, and shrews) to treatments, only shrews responded to treatment ($\underline{P} = 0.02$). Shrews decreased in two-story ($\underline{P} = 0.05$) and clearcut stands ($\underline{P} = 0.06$) after harvest (Table 2.15). Although the shrew group included 4 species (Trowbridge's shrew, vagrant shrew, Pacific water shrew, Pacific shrew), 1 species dominated. Trowbridge's shrews comprised 83% of captures, so probably most influenced treatment response.

I analyzed treatment response of small mammals that are potential nest predators, combining capture rate data for deer mice and Townsend's chipmunks. They showed no significant response to harvest (Table 2.15). They tended to increase in two-story and clearcut stands, but this may be caused by the high proportion of deer mice (90%) weighting the capture rate, since deer mice showed the same trend.

I analyzed captures for Trowbridge's shrews from only pitfall traps, since they are predominantly captured in pitfall traps and rarely in Sherman traps (pitfall trap

Table 2.16. Average mammal capture rate (average number of individuals/1000 trap nights) and standard error (in parentheses) by treatment and year (YR1=pretreatment year, YR2=first year post-harvest) for mammals live-trapped in Sherman and pitfall traps. For species or species groups with n ≥ 30 observations. Species groups are (1) nest predators (Townsend's chipmunk, deer mouse), (2) rodents (western red-backed vole, northern flying squirrel, Oregon vole, dusky-footed woodrat, deer mouse, red tree vole, and Townsend's chipmunk) (3) insectivores (shrew-mole, coast mole, Townsend's mole, Pacific water shrew, Pacific shrew, Trowbridge's shrew, vagrant shrew); and (4) shrews (Pacific water shrew, Pacific shrew, Trowbridge's shrew, vagrant shrew). These data are untransformed capture rates but analyses are on [$\log_{10}$(abundance+1)] transformed data.

		CONTROL		SMALL PATCH		TWO-STORY		CLEARCUT	
SPECIES	n	YR1	YR2	YR1	YR2	YR1	YR2	YR1	YR2
<u>Individual Species:</u>									
Townsend's chipmunk	59	0 (0)	8.5 (8.5)	7.3 (3.3)	2.0 (1.3)	14.8 (5.3)	6.3 (6.3)	18.5 (13.3)	10.5 (4.1)
Oregon vole	180	17 (.)	8.5 (8.5)	8.5 (8.5)	17.8 (4.1)	4.0 (4.0)	18.5 (6.3)	4.0 (4.0)	16.8 (6.7)
Deer mouse	504	83.5 (41.5)	79.5 (12.5)	45.6 (7.1)	56.1 (8.6)	31.3 (9.3)	75.0 (22.3)	48.0 (17.3)	91.8 (26.7)
Trowbridge's shrew	334	16.5 (8.5)	75.0 (58.0)	41.6 (11.8)	35.4 (7.4)	72.8 (37.1)	27.0 (9.2)	64.5 (18.3)	31.3 (14.4)
<u>Species Groups:</u>									
Rodents	755	92.0 (33.0)	96.5 (29.5)	56.0 (7.7)	75.9 (12.1)	52.0 (14.3)	99.8 (26.5)	70.5 (21.2)	119.0 (24.4)
Insectivores	421	20.5 (12.5)	112.0 (79.0)	47.8 (10.8)	50.9 (13.6)	79.0 (38.4)	29.0 (11.0)	66.5 (19.6)	41.8 (12.5)
Shrews	403	20.5 (12.5)	112.0 (79.0)	47.8 (10.8)	49.9 (13.0)	77.0 (36.5)	29.0 (11.0)	66.5 (19.6)	37.5 (14.9)
Nest Predators	563	83.5 (41.5)	88.0 (21.0)	52.9 (8.5)	58.1 (8.9)	46.0 (14.3)	81.3 (26.0)	66.5 (21.9)	102.3 (24.8)
<u>Pitfall traps only:</u>									
Trowbridge's shrew	325	8.5 (8.5)	17.0 (17.0)	10.4 (3.4)	19.8 (4.2)	20.8 (5.4)	24.8 (5.9)	22.5 (14.5)	27.3 (10.5)

captures represented 97% of total captures). This allowed inclusion of all 3 replications (Lewisburg Saddle, Peavy, and Dunn), pretreatment and 1-year post-treatment capture rates. I detected a decline in shrew abundance in two-story ($\underline{P} = 0.06$) and clearcut ($\underline{P} = 0.05$) stands (Table 2.15).

Mammals Captured in Large Patch, Wedge, and Strip Cut Stands

I captured 5 species in large patch stands, 4 species in the strip cut stand, and 3 species in the wedge cut stand. These data represent very small sample sizes and should only be used as an indicator of presence.

In large patch stands prior to harvest, I captured deer mice (38 captures/1000 TN), Trowbridge's shrews (17 captures/1000 TN), Townsend's chipmunks (4 captures/1000 TN), and Pacific shrews (4 captures/1000 TN). After harvest, deer mouse (100 captures/1000 TN) and Townsend's chipmunk (8 captures/1000 TN) captures increased. Trowbridge's shrew capture rate appeared to decline (4 captures/1000 TN). I did not capture Pacific shrews but did catch a flying squirrel (4 captures/1000 TN).

I captured deer mice (8 captures/1000 TN) and Trowbridge's shrews (17 captures/1000 TN) prior to harvest in the strip cut stand. Following harvest, species included deer mouse (67 captures/1000 TN), Trowbridge's shrew (58 captures/1000 TN), Oregon vole (8 captures/1000 TN), and shrew-mole (8 captures/1000 TN).

Prior to harvest in the wedge cut stand I captured Trowbridge's shrew (17 captures/1000 TN), deer mouse (8 captures/1000 TN), and Oregon vole (8 captures/1000 TN). After harvest, I caught only 2 of these species: deer mouse (58 captures/1000 TN), and Trowbridge's shrew (33 captures/1000 TN).

DISCUSSION

Forest management affects vertebrate communities. Clearcutting, the traditional regeneration technique used in Pacific Northwest Douglas-fir forests over the past 50 years, radically alters stand structure (e.g., vertical and horizontal vegetation layering, presence of snags and logs), often to the extent that vertebrate species adapted to mature forest conditions are replaced by those adapted to highly disturbed or early seral stage conditions (Blake 1982, Gashwiler 1970, Hagar 1960, Hooven and Black 1976, Martell 1983). Silvicultural systems such as group selection where patches of trees are removed in small groups may retain much of the original stand structure (depending on the patch size and number of patches removed). Patches may simulate small disturbances such as the development of root rot pockets or windthrown trees. Mature forest wildlife species may be able to incorporate these patches as habitat if patches do not dominate the forest matrix. Two-story (or green tree retention) harvesting retains some characteristics of a mature forest (large trees, snags, logs), but at a much lower density. The retained trees create a more complex vertical layer, which may provide foraging and/or nest sites for some mature forest associated species.

I examined short-term effects of several alternative silvicultural systems on bird and mammal communities associated with mature Douglas-fir forests of the Oregon Coast Range. All treatments (small patch group selection, two-story, and modified clearcut) affected vertebrate communities, although two-story and clearcut treatments had the strongest effect. In general, small patch stands were most similar in community composition to control stands, while two-story stands were most similar to clearcut stands. Two-story and clearcut stand communities differed from control and small patch communities.

Bird species diversity and equitability remained high in all but the clearcut treatment. Diversity and equitability declined in the clearcuts, indicating a reduction in number of species and a less equitable distribution of individuals among species. Two-story stands appeared to maintain populations of some mature forest associates, so maintained high values for these indices. Bird abundance declined in both two-story and clearcut treatments however, so although two-story stands supported some mature forest associates, they were present only in low numbers. The loss of overstory and midstory canopy from both treatments reduced the amount of vertical structure in those treatments and may have caused the reduction in abundance of species associated with these foliage layers.

Although there was no significant change in bird species richness, I observed more species in two-story stands than any other treatment. Many were early seral stage associates, but species associated with mature forests also were present (e.g, brown creepers). 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 mature forest associates. Vega (1993) compared bird communities in clearcut, green tree retention (two-story), and mature conifer stands ($n = 4$ stands each) in the Oregon Cascades Mountains and did not detect a statistically significant difference ($P > 0.05$) in species richness. However, richness in retention stands was highest (16.3 species), compared with lower numbers in clearcuts (11.3) and mature forest (14.0 species) stands.

As plant species composition and structure in two-story stands change with time, habitat may be provided for greater numbers of species. In a comparison of two-story, clearcut, and unharvested stands in the Monongahela National Forest in West Virginia, Nichols and Wood (1993) observed highest species richness in two-story stands. Two-story and clearcut stands had been harvested 12 years prior to study, so additional development of understory plant species and longer period since disturbance may have affected bird species richness. Two-story conifer stands may show a similar pattern in 10 years.

Bird communities in control stands were only 74 to 75% similar (percent similarity index) in structure and composition over the 3-year study period. No harvesting was conducted in these stands, so differences in species composition may be attributed to sampling error or to changes in bird populations caused by factors affecting population changes such as breeding success the previous year or food availability. Changes in landscape pattern (e.g., alteration of surrounding landscape from mature forest to harvested stands) also may have affected control bird communities, although the turnover was detected in 2-year post-treatment comparisons, when little or no additional harvesting had been conducted.

I counted birds in the Lewisburg Saddle replication for 5 years (1 year pretreatment, 4 years post-treatment). I summarized bird observations (number of observations/5 ha) for the 16 bird species that showed statistically significant responses to treatment (Table 2.17). Species such as MacGillivray's warbler, rufous-sided towhee, and white-crowned sparrow continued to remain absent or low in abundance in control stands even 4 years post-harvest. Species that were abundant in control stands the first 2 years after harvest continued to remain at pretreatment levels into the fourth and fifth years post-harvest (e.g., chestnut-backed chickadee, brown creeper, Swainson's thrush, hermit warbler). Some species showed higher degrees of variability in abundance (e.g., winter wren, golden-crowned kinglet, Wilson's warbler). Changes in their abundance or detections of less common species (e.g., those using larger home ranges) may have contributed to the 25% turnover between years that I noted in community similarity measures. Trends noted the first 2 years after harvest remained consistent 4 years after harvest in this replication. However, the variation in abundance for some species (e.g., winter wren) indicate year to year variation that can affect monitoring or experimental design and interpretation. Adequate replication should ensure detection of population trends.

Bird communities in non-control treatments (small patch, two-story, clearcut, large patch, strip cut, and wedge cut) were affected by treatment. There appeared to be greater change in bird community structure with increasing intensity of harvest and in

Table 2.17. Bird abundance (observations/5 ha) for Lewisburg Saddle stands (YR1=pretreatment year, YR2=1-year post-harvest, YR3=2-years post-harvest, YR4=3-years post-harvest, YR5=4-years post-harvest) for bird observed ≤ 75 m from VCP stations and for species with significant treatment effects (P ≤ 0.10). Species are arranged taxonomically. Data represent 1 control stand, 6 small patch stands, 2 two-story stands, and 2 clearcut stands.

	CONTROL					SMALL PATCH					TWO-STORY					CLEARCUT				
SPECIES	YR1	YR2	YR3	YR4	YR5	YR1	YR2	YR3	YR4	YR5	YR1	YR2	YR3	YR4	YR5	YR1	YR2	YR3	YR4	YR5
Willow flycatcher	0	0	0	0	0	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0
Steller's jay	0	1	7	2	8	5	8	9	6	6	3	3	11	7	3	6	2	1	1	0
Chestnut-backed chickadee	19	17	13	29	11	15	17	21	27	10	22	14	13	9	4	23	8	13	5	1
Brown creeper	10	9	8	12	8	11	7	9	8	5	17	9	4	2	0	13	2	1	0	0
Red-breasted nuthatch	18	11	9	9	6	6	10	9	12	8	11	2	1	2	2	13	0	0	0	0
House wren	0	2	0	0	0	0	0	1	1	0	0	3	19	20	18	0	2	17	26	21
Winter wren	9	2	12	5	18	14	13	16	11	15	13	6	2	1	0	18	3	1	0	0
Golden-crowned kinglet	29	13	20	10	12	49	10	14	11	9	24	2	3	1	0	18	0	0	0	0
Swainson's thrush	4	3	3	6	9	13	13	8	11	13	17	1	4	2	1	10	1	1	2	2
Hermit warbler	30	36	45	45	36	57	41	30	41	25	14	1	1	2	0	15	0	1	1	0
MacGillivray's warbler	0	0	0	0	0	0	2	2	7	7	0	1	10	18	26	0	1	10	10	13
Wilson's warbler	10	8	4	9	2	20	17	19	21	16	24	4	5	4	9	15	1	1	4	3
Western tanager	0	0	3	5	5	2	3	2	8	5	3	1	3	4	1	1	0	0	1	1
Rufous-sided towhee	0	1	0	0	0	1	1	2	7	7	1	4	12	16	21	1	2	11	17	17
White-crowned sparrow	0	0	0	0	0	0	0	0	1	1	0	10	22	34	30	0	17	27	30	37
American goldfinch	0	0	0	0	0	0	0	0	0	1	0	4	9	10	3	0	6	1	13	9

the second year after harvest. Bird communities in small patches were more similar to preharvest communities; communities in clearcuts were least similar.

I found Morisita's index most sensitive to detecting change among bird communities, with strongest differences the second year after harvest. Birds may adjust to changes in their breeding territories over a longer period than 1 year, so researchers may consider monitoring bird populations after this adjustment period rather than immediately after harvest.

Versatility Index

The Versatility Index I developed seemed to serve as an index of stand-level disturbance. The Versatility Index (VI6) was lowest for control stands when I averaged scores for the 6 most abundant species. Four of the bird species dominating this community were neotropical migrants (Pacific-slope flycatcher, hermit warbler, Wilson's warbler, and Swainson's thrush); 1 was a resident (winter wren) that has been associated with less fragmented landscapes in the Pacific Northwest (Rosenberg and Raphael 1986, Lehmkuhl and Ruggiero 1991, McGarigal 1993). These are birds that are presumed or demonstrated to be sensitive to disturbance because of life history characteristics (e.g., single brooded, vulnerable to predation) and habitat associations (Terborgh 1989, Robbins et al. 1992). Versatility indices averaged highest for two-story and clearcut stands (indicating presence of versatile birds capable of using a variety of habitat types). Small patch stands were more similar to controls, although the presence of dark-eyed junco (a bird with a high Versatility Index) generated a higher average Versatility Index for small patch stands than controls.

I applied my Versatility Index to data from Hagar's (1993) comparison of thinned and unthinned stands in the Oregon Coast Range. The 6 most abundant birds in unthinned stands were hermit warbler, Pacific-slope flycatcher, winter wren, golden-crowned kinglet, Wilson's warbler, and black-throated gray warbler. The 6 most abundant birds in thinned stands were hermit warbler, winter wren, Wilson's warbler, Pacific-slope flycatcher, golden-crowned kinglet, and dark-eyed junco. Average VI6 for unthinned stands was 1.52; for thinned stands, average VI6=1.76. The increase in VI6 was caused by change in one species: black-throated gray warbler was replaced by dark-eyed junco in thinned stands.

I also calculated average bird Versatility Indices for thinned and unthinned western hemlock stands studied by Artman (1990) in western Washington. Average versatility index for unthinned stands was 1.51, compared with an average VI6 of 1.68 for thinned stands. Again the difference was attributed to the change in 1 of the 6 bird species used in calculating the index. Unthinned stands were dominated by Pacific-slope flycatcher, winter wren, golden-crowned kinglet, Hutton's vireo (*Vireo huttoni*), chestnut-backed chickadee, and evening grosbeak. Evening grosbeaks were replaced by dark-eyed juncos in thinned stands.

The occurrence of dark-eyed juncos heavily influenced the increase in VI6 from untreated stands to treated ones in all 3 studies (mine, Artman's [1990], and Hagar's [1993]). VI6 increased between untreated controls and thinned (Hagar and Artman studies) and small patch stands (this study) because of a change in dominance from 1 species to dark-eyed junco (perhaps juncos can be used as an indicator of disturbance). The Versatility Index may better represent the bird community and be more sensitive to change if each species is weighted by its dominance in the community. This would make the Index more difficult to calculate, and at present it appears to detect stand-level disturbance. Addition of 1 or 2 bird species in calculating the Index might also decrease the ability of 1 species to dominate the change in average index value.

Although I applied the Versatility Index to bird communities at the stand level, it might be useful in making landscape level comparisons. Bird communities associated with higher levels of disturbance (e.g., fragmentation) might generate higher values for VI6 than those communities associated with less disturbed landscapes. The Index could be tested using McGarigal's (1993) data.

Species Decreasing in Response to Harvest

The 11 species (Pacific-slope flycatcher, brown creeper, chestnut-backed chickadee, Steller's jay, red-breasted nuthatch, winter wren, golden-crowned kinglet, Swainson's thrush, hermit warbler, Wilson's warbler, and western tanager) that declined in response to harvest were species associated with mid- to late-successional forests, using large trees for foraging or as nest sites (Brown 1985b). Franzreb (1977) compared birds using logged (10 m^2/ha basal area) and unlogged (51 m^2/ha) sites in a mixed conifer forest in Arizona. She observed lower abundance of brown creepers, Pacific-slope flycatchers, red-breasted nuthatches, and golden-crowned kinglets on the logged 201.6-ha site. Densities of these species on the unlogged area (131.2 ha) were 3 to 40 times greater. Medin and Booth (1989) found only red-breasted nuthatches and western tanagers declined in response to single-tree selection logging (29% reduction in wood volume) in Idaho. They detected no change in golden-crowned kinglet density. Swainson's thrushes and brown creepers increased in abundance. Keller and Anderson (1992) found brown creepers avoided strip 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 Arizona, Wyoming, and Idaho, however they may indicate types of responses to be expected from different intensities of selective logging.

Small patch harvest may have negative effects for some bird populations. The first year after harvest, Swainson's thrushes declined in clearcut and two-story stands by 90% (≤ 2 observations/5 ha). There was no detectable change in abundance in small patch stands. However the second year after harvest, Swainson's thrushes declined to 60% of original population size in small patch stands. 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 permeability of these stands to predators or introduced levels of disturbance that thrushes could not tolerate. To determine whether this effect reflects a long-term trend in population response, Swainson's thrush populations should be monitored in small patch stands over a longer study period. Other ground and shrub nesters (particularly neotropical migratory birds since they generally raise only 1 clutch per year) also may decline over time in group selection stands.

Medin and Booth (1989) identified Swainson's thrushes as species that increased following selection logging (29% reduction in volume) in mixed conifer (Douglas-fir, ponderosa pine, grand fir, logdepole pine) stands in west-central Idaho. However, their study comparing an unlogged control stand to a logged selection cut stand was unreplicated and may not reflect bird response in Douglas-fir forests of the Oregon Coast Range.

Species Increasing in Response to Harvest

Olive-sided flycatchers, white-crowned sparrows, and American goldfinches appeared to use large open areas or early seral stages in forest development for breeding habitat. They were rarely observed in the 0.2-ha patches in small patch stands. Medin and Booth (1989) found flycatcher density higher on a logged than an unlogged site. McGarigal (1993) found olive-sided flycatchers were affected by the arrangement and type of stands in a landscape. Flycatchers were more abundant in fragmented landscapes with high-contrast edges (mature forest with early seral stage). Although I detected higher numbers of this Neotropical migrant in two-story stands, the type of stand adjacent to the two-story stand also may have been critical in determining use.

Northern flickers, house wrens, MacGillivray's warblers, and rufous-sided towhees colonized openings such as the 0.2-ha harvested patches created in group selection harvesting. I found nests of 3 species (northern flicker, house wren, rufous-sided towhee) in or adjacent to patches. For cavity nesters (flickers and house wrens), retention of snags (in most cases hardwoods such as Oregon white oak or bigleaf maple) in these stands in combination with an opening created nesting habitat. I found house wrens using snags in openings, but flickers used snags adjacent to openings.

For MacGillivray's warblers and rufous-sided towhees, shrub cover in the 0.2-ha patches probably provided nest sites. I did not detect a significant increase in shrub cover in these stands (Chambers 1996), but shrub cover did appear to increase in the open patches (pers. obs.). Group selection stands, although perhaps not primary habitat for these birds, may be useful in maintaining populations. These species reached highest abundances in two-story and clearcut stands. Vega (1993) also found higher abundance of MacGillivray's warblers and rufous-sided towhees in clearcut and retention stands, although only MacGillivray's warbler abundance differed between stand types ($\underline{P} \leq 0.10$). Both species were low in abundance or absent from uncut stands.

Willow flycatchers and purple finches were most abundant in two-story stands. Willow flycatchers select habitats that are brushy and moist (Harrison 1979), so might be expected to inhabit both clearcuts and two-story stands. Purple finches nest in coniferous and mixed woodlands (Harrison 1979, Brown 1985b) and may be more common in riparian areas (Brown 1985b). Most of my stands were dry, upland sites. Both willow flycatchers and purple finches were low in abundance in all treatments, perhaps because these sites did not represent primary habitat. Vega (1993) found willow flycatchers significantly more abundant in clearcuts than in two-story stands in the Oregon Cascades. It is possible that clearcuts in my study represented drier sites so had lower numbers of these species.

Brown-headed cowbirds reached highest abundance in two-story stands. Cowbirds parasitize nests of other birds (Harrison 1979, Terborgh 1989), and have contributed to population declines of Kirtland's warbler (*Dendroica kirtlandii*), least Bell's vireo (*Vireo belli pusillus*), and black-capped vireo (*Vireo atricapillus*), and other birds (Harrison 1979, Terborgh 1989, Robinson et al. 1992). Their increase in the

United States over the past 90 years has been attributed to increases in open habitats (Brittingham and Temple 1983), expansion of range (from the Great Plains region to the entire continent north to the boreal forest), and increases in number of host species they parasitize (from 50 to 200 species) (Terborgh 1989).

In the eastern United States, cowbirds or cowbird parasitism were more common along forest edges (Gates and Gysel 1978, Brittingham and Temple 1983, Wilcove 1985). In a recent study of the effects of two-story timber management on songbird density and reproductive success, Nichols and Wood (1993) found cowbirds most common in two-story stands compared with clearcuts and uncut forest.

Cowbird abundance and rates of parasitism are generally higher at forest edges than forest interiors (e.g., > 300 m from edge), although the "cowbird edge effect" varies among regions and probably depends on landscape-level variation in fragmentation and cowbird abundance (Robinson et al. 1992). Increasing the level of fragmentation in a forest landscape might increase permeability to cowbirds. The amount of increase may depend on landscape features such as proximity to agricultural or other large openings.

If cowbirds respond similarly in western forests, they could become a threat to some bird populations. Birds building open cup nests, raising single broods, and those that do not actively defend nests (e.g., Neotropical migrants) might be most vulnerable to cowbird parasitism (Terborgh 1989). From my study, harvesting 0.2-ha patches did not increase cowbird abundance in group selection stands where 1/3 of the basal area was removed. Changing the size or shape of patches or the proportion of basal area removed might increase cowbird use, however. Removing a larger proportion of basal area, as in the two-story treatment increased cowbird use. These stands may benefit many species by, for example, providing dispersal (e.g., spotted owls, flying squirrels) or nesting habitat for some mature forest associates (e.g., flying squirrels, red tree voles), but the potential effects of songbird parasitism should be considered. If cowbird populations and levels of parasitism are monitored and found to pose a threat to some bird populations, use of this harvest treatment should be carefully considered. Robinson et al. (1992) suggested controlling cowbirds at the landscape-level by managing large tracts of land to minimize edge habitat.

Cowbird abundance was low in all treatments in my study (0 to 2.7 observations/5 ha). Although cowbirds were significantly more abundant in two-story stands, their numbers may be inadequate to affect songbird populations. Areas farther from agricultural land (e.g., central Coast Range) also may be less likely to support cowbird populations despite increased fragmentation. Because of the cowbird's potential effect on songbirds, however, nests in two-story stands should be considered as potentially more susceptible to parasitism.

Neotropical Migrants

Concern for Neotropical migrants has increased over the past 15 years as declines in some forest breeding species were 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 my study, 12 of the bird species responding to silvicultural treatment were Neotropical migratory species. Four species (Swainson's thrush, hermit warbler, Wilson's warbler, western tanager) declined following harvest, and a fifth (Pacific-slope flycatcher) appeared to decline although I could not detect a statistically significant difference. Swainson's thrushes and Pacific-slope flycatchers seemed sensitive to all harvest treatments including small patch harvesting. Hermit warblers, Wilson's warblers, and western tanagers decreased in two-story and clearcut treatments but seemed to be unaffected by small patch harvesting.

Those increasing 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 all harvest treatments. Both MacGillivray's warbler and olive-sided flycatcher populations are reported in decline by Breeding Bird Survey (BBS) data (Robbins et al. 1992). Olive-sided flycatchers have been in continuous decline over the past 26 years, while MacGillivray's warblers have been in decline over the past 10 years (Robbins et al. 1992). Olive-sided flycatchers were identified by McGarigal (1993) as associated with high contrast edges. Clearcut and two-story stands on McDonald-Dunn Research Forest often were adjacent to mature (> 100 years) forest so could have created appropriate habitat conditions for these birds. 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.

Although 4 of the species in my study did not show a statistically significant response to treatment, 2 of these (rufous hummingbird and orange-crowned warbler) appeared to increase; and 1 to decrease (black-headed grosbeak). Black-throated gray warblers showed no significant or apparent response to treatment. Perhaps these species did not respond strongly to silvicultural treatment because their habitat selection was not related to removal of overstory cover.

Unreplicated Alternative Treatments - Large Patch, Wedge, and Strip Cut Stands

Some mature forest associates declined following harvest in large patch, wedge, and strip cut stands. Pacific-slope flycatchers, chestnut-backed chickadees, winter wrens, golden-crowned kinglets, Swainson's thrushes, hermit warblers, and Wilson's warblers appeared negatively affected by the treatments, although no species was eliminated from these stands. Red-breasted nuthatches and brown creepers remained at preharvest levels. White-crowned sparrow, American goldfinch, and house wren populations increased, although abundances were not as high as those seen in two-story or clearcut treatment responses.

These treatments appeared to affect the mature forest bird community to a greater extent than small patch treatment, but post-harvest communities were more similar to control or small patch communities than two-story or clearcut communities. These treatments may enable mature forest communities to persist, although at lower levels of abundance.

Mammal Responses

From live-capture results, only shrews (Trowbridge's, vagrant, Pacific water, and Pacific shrews) showed a response to silvicultural treatment. Shrews decreased in the more heavily harvested treatments, but appeared unaffected by small patch harvesting. Trowbridge's shrews, which made up the majority of the shrew population, are associated with forest habitats (Whitaker and Maser 1976, Doyle 1990). They seem sensitive to change in microclimate (particularly moisture). Harvesting may affect log and soil moisture, litter depth and moisture, log availability, and other factors that may be important habitat features for these animals. It also may affect availability of food (insects, larvae) (Terry 1981, Morrison and Anthony 1989). In a comparison of small mammals in logged and unlogged stands, Medin and Booth (1989) captured shrews only in unlogged forest. They speculated that selection logging sufficiently altered the forest habitat so as to make it unsuitable for shrews.

These data represent only short-term results from a limited number of trap-nights. However, in a winter live-trapping study conducted in 1992, insectivores (shrews, moles) were most abundant in control stands (4 captures/100 TN), compared with other treatments (small patch: 2 captures/100 TN; two-story: 2 captures/100 TN; clearcut: 1 capture/100 TN) (Scott Schuster, pers. comm.).

Summary

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

Group selection cutting designed to imitate fine-scale disturbances in Douglas-fir stands may allow mature-forest associates to persist in the face of stand management, and may benefit some wildlife populations. In other forest types, creating small openings, such as that caused by the death of a single tree or small group of trees, increased bird abundance while not affecting species diversity (McComb and Rumsey 1983, Kilgore 1971, 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 appeared to provide habitat for many of the same species that occurred in clearcut stands. Retaining some overstory, however, provided short-term benefits for some forest associated species (e.g., nest sites for western tanager, foraging sites for brown creeper). Structure in these stands will become more complex than in developing clearcut stands and may attain mature forest characteristics well in advance of clearcuts.

Modified clearcut stands provided additional snags and green trees. Although communities inhabiting these stands immediately following harvest did not appear to differ from clearcuts, the retention of snags may provide nesting habitat for cavity nesting birds. The retention of some green trees assures some snag recruitment of appropriate size for largest cavity nesters (pileated woodpecker) in the future.

Vertebrate community responses to alternative silvicultural treatments indicated that if timber harvest was part of management goals, application of a variety of silvicultural treatments across the landscape would help maintain biotic diversity by moderating the effects of clearcutting for mature forest associated species.

SCOPE AND LIMITATIONS

This study was conducted in the Central Oregon Coast Range and is applicable to Douglas-fir dominated forests in this region. It examined short-term (2 years post-harvest) responses to 3 alternative silvicultural treatments. Although response to 3 treatments was considered in this study, there are many other possible silvicultural options (e.g., group selection using larger circular patches, linear strips, irregular openings; two-story harvesting leaving aggregated patches of trees instead of uniform distribution). Documenting wildlife response to other treatments would provide better information for creating landscapes designed to maintain viable populations of terrestrial vertebrates.

Monitoring wildlife responses over longer periods than 2 to 5 years is advisable to determine whether management goals were successful in achieving mature or old-growth characteristics and providing habitat for bird and small mammal species associated with those conditions. I suggest sampling birds in treated stands at least every 5 years until even-aged and two-aged stands reach a mature seral stage classification or uneven-aged stands attain and maintain the desired diameter distribution and target tree size.

Models that predict forest stand development over time (e.g., ORGANON) (Hann et al. 1992) have been developed. However, because data used in predicting development of stand structure is based on tree growth in clearcut stands planted with Douglas-fir or other common tree species, these models may not appropriately estimate planted or residual tree growth in two-story or group selection stands at this time. It is likely, however, that two-story stands will provide habitat for mature and old-growth associated species at an earlier time than clearcut stand, since they retain some features of mature or old-growth forests. Setting a large target tree size and making infrequent entries in uneven-aged stands may help favor old-growth associated species throughout the cutting cycle, assuming the cutting cycle is appropriately long. As models are updated, predicting stand development over time and estimating the point at which desired structure is attained may improve.

I used animal abundance as a treatment response variable rather than using a measure of animal 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 animal survival and reproduction, nest searches and territory mapping in conjunction with VCP counts would be better indicators of bird response. Extending trapping periods for small mammals and including amphibian searches would provide better response data for these taxa.

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CHAPTER 3

HABITAT ASSOCIATIONS OF SHRUB-NESTING DIURNAL BREEDING BIRDS IN THREE SILVICULTURAL TREATMENTS AND CONTROL STANDS, CENTRAL OREGON COAST RANGE

Carol L. Chambers

Department of Forest Resources
Oregon State University
Corvallis, Oregon 97331

INTRODUCTION

The composition of a bird community may be dependent upon many features of the landscape, but perhaps the most important factor in determining suitable habitat is vegetation complexity (MacArthur and MacArthur 1961, Maurer et al. 1981, Rotenberry and Wiens 1980). Other large-scale features (landscape, terrain, and substrate) as well as micro-site features (snags, down wood, moisture gradients) may influence habitat selection (Anderson 1981, Anderson and Shugart 1974).

Modifying habitat may have direct consequences on bird species diversity. A reduction in habitat complexity may decrease species diversity, may alter interspecific competition through a shift in type of habitat used, or may affect intraspecific competition due to reduced availability of preferred habitat (Anderson and Shugart 1974, Smith and Petit 1988). Indirectly, affecting bird species diversity may imbalance other natural systems, such as control of insect pests by avifauna (Torgersen et al. 1990).

Some wildlife populations may be at greater risk from habitat changes than others because they are relatively immobile and cannot move to new habitat (e.g., amphibians) but mobile species (birds, large mammals) also may be sensitive. Neotropical migratory birds have a limited breeding season; most build only 1 nest per year (Brown 1985b). Resident birds often initiate nesting ≥ 1 month(s) in advance of neotropical bird arrival. Reduction in habitat and later arrival may place migratory birds in competition with resident species that already occupy breeding territories (Terborgh 1989).

Douglas-fir forests support the highest total bird abundance of coniferous forests in North America (Raphael et al. 1988). Bird communities occupying these forests have presumably adapted to structural and compositional features unique to the vegetation type. The use of clearcutting as a dominant silvicultural practice for the past 50 years in the Pacific Northwest has resulted in stands that are structurally and compositionally more uniform than naturally regenerated forests (Spies and Franklin 1991, Spies 1991). Many animal species rely on availability of specific structures such as snags and logs (Brown 1985b), or vegetation layers such as shrub or ground plant species (McComb et al. 1993) that have been reduced or eliminated from managed stands. Knowledge of vertebrate habitat associations can be used to improve habitat suitability in managed stands.

Silvicultural alternatives to clearcutting may be developed to increase or retain vertebrate diversity in managed stands by increasing structure and composition of vegetation and retaining or creating dead wood sources such as snags, down logs, and brush piles (McComb et al. 1994). Stands with dense, uniform shrub cover can be underplanted with shade tolerant tree species with the intention of creating an understory layer that is patchy and provides additional vertical structure in the canopy layers.

The shrub layer is an important component of wildlife habitat which provides forage (Hanley and McKendrik 1985), cover, perching, and nest sites (e.g., Knopf and Sedgwick 1992, McComb et al. 1993) for some species. Disturbances create growth opportunities for some shrub species. Salmonberry (*Rubus spectabilis*) and salal (*Gaultheria shallon*) are clonal shrubs that can rapidly expand in respond to an increase in resources (e.g., light, nutrients) following an overstory disturbance (Tappeiner et al. 1991). Vine maple (*Acer circinatum*) can spread by layering. Seeds of many shrub species may persist in forest floor litter for many years and respond to changes in overstory structure. Once established, some species (e.g., salal) can dominate understory layers in a stand, forming dense continuous strata that can persist for years (Tappeiner et al. 1991). In uniform stands with little understory, small- to large-scale disturbances of varying intensity may allow development of additional strata.

I studied the effect of 3 alternative silvicultural systems on bird communities of mature Douglas-fir (*Pseudotsuga menziesii*) in the Oregon Coast Range (Chambers 1996). The alternative silvicultural systems (small patch group selection, two-story, modified clearcut) were designed to simulate different scales and intensities of disturbance and provide documentation of bird community responses. Group selection removed trees in small (0.2-ha) patches, leaving most (e.g., 75%) of the vegetation in the stand intact. The two-story treatment removed 3/4 of the trees in the stand, leaving 20 to 30 trees per ha (> 53 cm dbh) in the overstory layer but decreasing cover in many other layers. The modified clearcut treatment was an even-aged system that removed most of the trees in the stand but retained some components such as green trees (1.2 trees/ha) and snags (3.8 snags/ha). The two-story and clearcut treatments were more intense disturbances than that created by the group selection treatment.

I observed 15 bird species that occurred within 2 or more treatments (including control) that are considered shrub-associates. These birds build nests within 10 m of the ground (Harrison 1979, Brown 1985b, Ehrlich et al. 1988) and included: American goldfinch (*Carduelis tristis*), black-headed grosbeak (*Pheucticus melanocehpalus*), black-throated gray warbler (*Dendroica virens*), dark-eyed junco (*Junco hyemalis*), hermit thrush (*Catharus guttatus*), MacGillivray's warbler (*Oporornis tolmiei*), orange-crowned warbler (*Vermivora celata*), Pacific-slope flycatcher (*Empidonax difficilis*), rufous-sided towhee (*Pipilo erythrophthalmus*), song sparrow (*Melaspiza melodia*), Swainson's thrush (*Catharus ustulatus*), white-crowned sparrow (*Zonotrichia leucophrys*), willow flycatcher (*Empidonax trailii*), Wilson's warbler (*Wilsonia pusilla*), and winter wren (*Troglodytes troglodytes*). Fourteen of these species build open cup nests (winter wrens are cavity nesters) (Harrison 1979), and may be susceptible to nest predation in some stand treatments (Chambers 1996).

My objective was to determine the associations of 5 shrub nesting birds with habitat features resulting from 3 silvicultural systems (modified clearcut, two-story, and group selection harvest systems) in the Oregon Coast Range. I selected 4 neotropical migratory birds (MacGillivray's warbler, orange-crowned warbler, Swainson's thrush, and Wilson's warbler) and 1 resident bird (winter wren) that is sensitive to fragmentation (Rosenberg and Raphael 1986, Lehmkuhl et al. 1991, McGarigal 1993) for habitat analysis. These birds nest within the 0- to 2-m height range I sampled with artificial nests (Chambers 1996) and had sample sizes ≥ 30 bird observations per species for each post-treatment year.

Forest managers and land use planners should be aware of the consequences that forestry practices and land development may have on animal habitat. An understanding of bird habitat associations is needed to allow managers to design practices that provide adequate supplies of critical resources such as food, nesting sites, and cover from predators in spite of alteration of the plant community (Anderson 1981, Smith and Petit 1988). Wildlife habitat studies therefore must identify and attempt to quantify biotic and abiotic variables that can be used to assess habitat suitability for a given species (Anderson 1981, Rexstad et al. 1988).

STUDY AREA

Thirty-three stands were selected for study within Oregon State University's McDonald-Dunn Forest, a 5261-ha experimental forest located on the eastern of edge of the Coast Range, north and northwest of Corvallis. Three blocks of 11 stands each were located near (1) Lewisburg Saddle: Township 11S, Range 5W, Willamette Baseline and Meridian, portions of Sections 4, 8, 9, 16, 17; (2) Peavy: Township 10S, Range 5W, Willamette Baseline and Meridian, portions of Sections 25, 35, 36; and (3) Dunn: Township 10S, Range 5W, Willamette Baseline and Meridian, portions of Sections 14, 22, 23, 27. Stands were 5 to 18 ha in size. Douglas-fir comprised ≥ 64% basal area prior to harvest; in most stands (25 of 33 stands), it represented ≥ 80% total basal area. Species including grand fir (*Abies grandis*), 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*) comprised the remaining basal area.

Treatments applied to both the Lewisburg Saddle and Peavy blocks consisted of 1 control (uncut) stand, 6 small patch group selection stands (1/3 volume removed in 0.2-ha circular patches), 2 two-story stands (3/4 volume removed with remaining trees scattered uniformly throughout the stands), and 2 modified clearcut stands (1.2 green trees/ha retained) stands. Treatments applied to the Dunn block included 1 control, 2 two-story, 2 modified clearcut, 2 small patch group selection, 2 large patch group selection (1/3 volume removed in 0.6-ha circular patches), 1 wedge cut (0.8- to 2-ha wedge cuts removing approximately 1/3 volume), and 1 strip cut (linear strips removing approximately 1/3 volume in 0.8- to 2-ha strips) stand(s).

Herbicides were used in some stands to control vegetation that competed with Douglas-fir seedlings. McDonald-Dunn Research Forest staff decided on timing and type of herbicide application with use based on assessment of their need in individual stands. Vegetation management treatments were not replicated, therefore their effects on wildlife could not be tested. Clearcuts were aerially sprayed, two-story and group selection stands were hand-sprayed. Most remaining hardwood trees were girdled following harvest.

For statistical analyses I used replicated treatments: control: n = 3; small group selection: n = 14, two-story: n = 6, modified clearcut: n = 6. Harvesting began in fall 1989, and was completed by early spring 1991. One block was cut per year: Lewisburg Saddle block: 1989; Peavy block: 1990; Dunn block: 1991.

METHODS

Bird Sampling

Diurnal breeding 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 a minimum of

100-m from the stand edge and the centers of other VCPs. Bird counts began at sunrise and continued through mid-morning (0500 to 1000) on calm mornings. Each VCP was visited 6 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 winds > 15 km/h.

Counts began 2 minutes after arrival at the plot to allow for resumption of normal bird activity. Each count lasted 8 minutes, during which time birds seen or heard singing in or adjacent to the stand were identified to species, their distance (m) from the VCP center estimated, and their approximate location mapped. Distances were recorded to the nearest meter for birds ≤ 10 m from VCP center, nearest 5 m for birds >10 m but ≤ 50 m, nearest 10 m for birds > 50 m. Abundance (number of observations/5 ha) for each bird species was averaged across stands within treatments (control: n = 3; small patch group selection: n = 14; two-story: n = 6; modified clearcut: n = 6) for analyses.

Four observers participated in sampling. Three of these conducted sampling throughout all 4 years of the study, while the fourth sampled in 2 of the 4 years. Each observer sampled all VCPs 1 to 4 times during the breeding season.

Habitat Data Collection

Data for 53 stand features (Table 3.1) were collected at VCPs between July and September each year following bird data collection. I used sample plots of 2 sizes (0.03 ha and 0.28 ha) for characterizing vegetation and habitat features.

Five 0.03-ha plots at each VCP were used for measurement of vegetation and habitat variables. One plot was placed at the center point of the VCP, 4 satellite plots were randomly placed 20- to 40-m from the VCP center in the 4 cardinal directions. Percent cover of vegetation layers, density of live trees, and basal areas for conifers, hardwoods, and snags were measured at all 0.03-ha plots and averaged for each stand

Table 3.1. Habitat characteristics measured in plots centered on bird count points in control, small patch group selection, two-story, and clearcut stands, McDonald Forest, Oregon Coast Range, 1989 - 1992.

Variable	Variable Definition	Acronym
Conifer and Hardwood Tally		
small conifers	conifer stems/ha: 0- to 19-cm dbh	SMCON
small hardwoods	hardwood stems/ha: 0- to 19-cm dbh	SMHWD
medium conifers	conifer stems/ha: 20- to 55-cm dbh	MDCON
medium hardwoods	hardwood stems/ha: 20- to 55-cm dbh	MDHWD
large conifers	conifer stems/ha: > 55 cm dbh	LGCON
large hardwoods	hardwood stems/ha: > 55 cm dbh	LGHWD
Snags		
small, decay class 1	snags/ha, 10 - 29 cm dbh, decay class 1	SS1
small, decay class 2/3	snags/ha, 10 - 29 cm dbh, decay class 2-3	SS23
small, decay class 4/5	snags/ha, 10 - 29 cm dbh, decay class 4-5	SS45
medium, decay class 1	snags/ha, 30 - 55 cm dbh, decay class 1	SM1
medium, decay class 2/3	snags/ha, 30 - 55 cm dbh, decay class 2-3	SM23
medium, decay class 4/5	snags/ha, 30 - 55 cm dbh, decay class 4-5	SM45
large, decay class 1	snags/ha, > 55 cm dbh, decay class 1	SL1
large, decay class 2/3	snags/ha, > 55 cm dbh, decay class 2-3	SL23
large, decay class 4/5	snags/ha, > 55 cm dbh, decay class 4-5	SL45
Basal Area		
conifer basal area	conifer basal area (20 BAF), m^2/ha	CBA
hardwood basal area	hardwood basal area (20 BAF), m^2/ha	HBA
snag basal area	snag basal area (20 BAF), m^2/ha	SBA
Litter Depth		
litter depth	litter depth (mm)	LIT
Down Wood/Logs		
small, decay class 1	m/ha, 10- to 29-cm dbh, decay class 1	SLG1
small, decay class 2/3	m/ha, 10- to 29-cm dbh, decay class 2-3	SLG23
small, decay class 4/5	m/ha, 10- to 29-cm dbh, decay class 4-5	SLG45
medium, decay class 1	m/ha, 30- to 55-cm dbh, decay class 1	ML1
medium, decay class 2/3	m/ha, 30- to 55-cm dbh, decay class 2-3	ML23
medium, decay class 4/5	m/ha, 30- to 55-cm dbh, decay class 4-5	ML45
large, decay class 1	m/ha, > 55-cm dbh, decay class 1	LL1

Table 3.1, continued.

Variable	Variable Definition	Acronym
Down Wood/Logs		
large, decay class 2/3	m/ha, > 55-cm dbh, decay class 2-3	LL23
large, decay class 4/5	m/ha, > 55-cm dbh, decay class 4-5	LL45
Percent Vegetation Cover		
herb cover	herbaceous cover, < 1 m height (%)	HRBCOV
grass cover	grass cover (%)	GRSCOV
fern cover	fern cover (*Polystichum munitum*) (%)	FRNCOV
other vegetation cover	woody vine cover, < 1 m height (%)	OTHCOV
low shrub cover	low shrub cover, 0 - 1.3 m height (%)	LSHCOV
tall shrub cover	tall shrub cover, > 1.3 - 4 m height (%)	TSHCOV
pole layer	pole tree cover, > 4 - 20 m height (%)	POLCOV
saw timber layer	sawtimber tree cover, > 20 m height (%)	SAWCOV
bigleaf maple cover	bigleaf maple (*Acer macrophyllum*) cover, > 20 m height (%)	ACMCOV
Douglas-fir cover	Douglas-fir (*Pseudotsuga menziesii*) cover, > 20 m height (%)	PSMCOV
hazelnut cover	hazelnut (*Corylus cornuta*) cover, > 1.3 - 4 m height (%)	COCCOV
grand fir cover	grand fir (*Abies grandis*) cover, > 20 m height (%)	ABGCOV
Vertical Structure		
0- to 1-m cover	% cover of 0- to 1-m height vegetation strata	COV1
2- to 5-m cover	% cover of 2- to 5-m height vegetation strata	COV2
6- to 10-m cover	% cover of 6- to 10-m height vegetation strata	COV6
11- to 15-m cover	% cover of 11- to 15-m height vegetation strata	COV11
16- to 20-m cover	% cover of 16- to 20-m height vegetation strata	COV16
21- to 25-m cover	% cover of 21- to 25-m height vegetation strata	COV21
26- to 30-m cover	% cover of 26- to 30-m height vegetation strata	COV26
31- to 35-m cover	% cover of 31- to 35-m height vegetation strata	COV31
36- to 40-m cover	% cover of 36- to 40-m height vegetation strata	COV36
41- to 45-m cover	% cover of 41- to 45-m height vegetation strata	COV41
46- to 50-m cover	% cover of 46- to 50-m height vegetation strata	COV46
51- to 55-m cover	% cover of 51- to 55-m height vegetation strata	COV51
56- to 60-m cover	% cover of 56- to 60-m height vegetation strata	COV56

(n = 15 per stand). I measured log density and litter depth data only at the VCP center (n = 3 per stand).

Vegetative cover was measured using 2 methods. One method measured cover in layers used by Brown (1985a) to describe stand conditions that occur during the development of mature and old-growth Douglas-fir forests. Vegetation was classified into 5 height categories (Sawtimber trees: >20.0 m, Pole trees: 4.1 - 20.0 m, Tall shrubs: 1.3 - 4.0 m, Low shrubs: 0 - 1.3 m, Herbaceous: 0 - 1.0 m); percent cover and average height was visually estimated for these layers and for dominant tree and shrub species (trees that occurred in the shrub layer were counted in that layer). Live conifers and hardwoods were tallied by diameter class into 3 size classes: small (0- to 19-cm dbh), medium (20- to 55-cm dbh), and large (>55-cm dbh).

I used a second method of measuring vegetative cover to estimate percent cover by 5-m strata (e.g., percent cover for plants in the 6- to 10-m height range, 11- to 15-m height range, to 56- to 60-m height range). I used this technique in an attempt to better estimate changes within layers (e.g., within the mid-canopy layer) in vegetation complexity for each treatment.

I measured litter depth at 9 sites in the 0.03-ha plot located at the VCP center point. Basal areas of hardwoods, conifers and snags also were measured in these plots using a 20 BAF prism. I measured density of logs (m/ha) by size and decay class (Brown 1985a) using the 0.03 ha plot centered on the VCP. I counted snags by size and decay class (Brown 1985a) using a 0.28-ha plot centered on the VCP. Logs and snags were classified into 3 size categories (10- to 29-cm, 30- to 55-cm, and > 55 cm diameter) and 3 decay class categories (decay class 1, decay classes 2 and 3, decay classes 4 and 5).

Statistical Analyses

Bird-Habitat Relationships

I selected 5 bird species for multiple regression analyses of bird abundance on habitat and vegetation features: winter wren (n = 474 for 1-year post-treatment, n = 396 for 2-years post-treatment), Swainson's thrush (n = 243 for 1-year post-treatment, n = 189 for 2-years post-treatment), Wilson's warbler (n = 443 for 1-year post-treatment, n = 391 for 2-years post-treatment), MacGillivray's warbler (n = 97 for 1-year post-treatment, n = 224 for 2-years post-treatment), and orange-crowned warbler (n = 194 for 1-year post-treatment, n = 247 for 2-years post-treatment).

Bird abundances (observations/5 ha) were summed for each stand (n = 29) and year (1-year post-treatment, 2-years post-treatment). Only birds mapped ≤ 75 m from each VCP center were used in data analyses. Repeat observations and birds observed flying over stands were eliminated from data analyses. I used log transformations of bird abundance ($\log_{10}$[abundance+1]) to meet assumptions of equal variance (Sabin and Stafford 1990).

I analyzed data for post-treatment years separately. Bird species abundances were correlated to habitat and vegetation features using Pearson correlations (SAS Institute Inc. 1985).

To identify differences in bird response to habitat variables caused by treatment, I plotted bird abundance against each habitat and vegetation variable by treatment and year. I used an analysis of covariance to determine whether the slope of the variable differed among treatments. If there was a significant variable by treatment interaction ($\underline{P} \leq 0.05$), I developed separate models for that variable for each treatment to use in multiple regression analyses.

I used stepwise multiple regression (SAS Institute Inc. 1985) to describe bird-habitat relationships for 1-year post-treatment and 2-years post-treatment. I used subsets of habitat variables to ensure a sufficient number of degrees of freedom and selected variables that best explained variance in bird abundance to develop an overall model. The significance level for entry of a variable into the model was set at 0.15. I selected the best model based on Mallow's C(p) value (Younger 1979:493-495).

Habitat and Vegetation Characteristics

Habitat data were transformed using a log transformation [$\log_{10}$(variable+1)] to meet assumptions of equal variance (Sabin and Stafford 1990). Habitat variables were compared among treatments for 3 years (pretreatment, 1-year post- and 2-years post-treatment) using SAS repeated measures analysis (RMA) (SAS Institute Inc. 1989). I used Mauchly's criterion to test the appropriateness of a univariate analysis for time effects. If Mauchly's criterion was significant ($\underline{P} \leq 0.10$), I interpreted results for RMA using the Wilks' Lambda statistic for MANOVA tests of hypotheses of: (1) no treatment by year interaction, (2) no treatment effects, and (3) no year effects.

If I detected significant treatment by year interaction ($\underline{P} \leq 0.05$) I did not report results of Wilks' Lambda tests for treatment or for year tests but included results of RMA orthogonal contrasts of treatments v. control using profile contrasts which compare successive years (e.g., compare year 1 to year 2 and year 2 to year 3) (SAS Institute Inc. 1989). These values indicate if the habitat variable responded to treatment.

If Mauchly's Criterion was significant and there were no detectable interaction effects ($\underline{P} > 0.05$), I reported results for Wilks' Lambda tests for year and treatment effects, as well as profile orthogonal contrasts of treatments v. control for successive years. If Mauchly's Criterion was not significant ($\underline{P} > 0.10$), I used results from the univariate repeated measures analysis of variance using the procedure PROC MIXED (SAS Institute 1992). If Mauchly's Criterion was not significant ($\underline{P}> 0.10$) and the univariate analysis resulted in signficant year by treatment interactions ($\underline{P} \leq 0.05$), I included results of RMA orthogonal contrasts of treatments v. control for successive years (e.g., compare year 2 to year 1 and year 3 to year 2) (SAS Institute Inc. 1989).

These values can be used as indicators of trends in habitat variable response to treatment.

I used non-parametric analyses to detect differences in treatments when the assumptions for RMA were not met. I averaged habitat variables for pretreatment and 2-years post-treatment data by treatment and year within each block (control: n = 3, small patch: n = 3, two-story: n = 3, clearcut: n = 3). I compared only 2 years: pretreatment v. 2-years post-treatment. I calculated differences between pretreatment and 2-years post-treatment, ranked these data using PROC RANK (SAS Institute 1990) and used an 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).

Although I compared habitat and vegetation characteristics for all 53 variables, I only reported in this chapter results of analyses for those variables important in predicting bird-habitat associations. Results for analyses of variables not used in bird-habitat associations are reported in Appendices C and D. Analyses were performed as described above.

RESULTS

Bird-Habitat Relationships

The multiple regression models I selected for each bird species included some variables with partial R^2 values $\leq$ 0.10. Variables with high partial R^2 values ($>$ 0.10) are probably most valuable in explaining bird abundance. Variables with partial R^2 values $\leq$ 0.10 may not always be biologically meaningful, but I retained them in the models based on Mallow's C(p) statistic. Models are reported by species and year.

Winter wren

1-Year Post-Harvest -- Winter wren abundance was postively correlated with 25 variables the first year after harvest ($\underline{P} \leq 0.05$) and negatively correlated with 1 variable ($P = 0.02$) (Table 3.2). Sawtimber cover and fern (*Polystichum munitum*) cover were the best predictors of winter wren abundance (Table 3.3). Separate models for sawtimber cover in control, small patch, and two-story treatments contributed most to explaining variability in winter wren abundance. The multiple regression model R^2 was 0.82; with sawtimber cover in the control treatment accounting for most variability (partial $R^2 = 0.54$).

2-Years Post-Harvest -- The second year after harvest, winter wren abundance was positively correlated with 33 habitat variables ($\underline{P} \leq 0.04$) and negatively correlated with 1 variable ($P = 0.0001$) (Table 3.2). Pole cover, fern cover, and density of small conifers were best predictors of winter wren abundance. The model R^2 was 0.85 (Table 3.3). Pole cover accounted for most of the variability in winter wren abundance in the model (partial $R^2 = 0.80$). Fern cover (partial $R^2 = 0.02$) and density of small conifers (partial $R^2 = 0.03$) also explained some of the variability in winter wren abundance among stands.

Swainson's thrush

1-Year Post-Harvest -- Swainson's thrushes were positively correlated with 26 habitat variables ($\underline{P} \leq 0.05$) and negatively correlated with 2 variables ($\underline{P} \leq 0.05$) (Table 3.2). Swainson's thrush abundance was best predicted by Douglas-fir overstory cover, bigleaf maple cover in two-story, clearcut, and control treatments, and percent cover invertical strata 2- to 5-m and 26- to 30-m above ground. The model R^2 was 0.75 (Table 3.3). Douglas-fir overstory cover explained the most variance in Swainson's thrush abundance among stands (partial $R^2 = 0.44$).

2-Years Post-Harvest -- Swainson's thrush abundance was positively correlated with 30 habitat variables ($\underline{P} \leq 0.04$) and negatively correlated with 2 variables ($\underline{P} \leq 0.02$) (Table 3.2). Density of small hardwoods in small patch and two-story treatments,

Table 3.2. Relationships between habitat variables and bird abundance based on Pearson correlations. A + indicates a positive Pearson correlation coefficient ($\underline{P} \leq 0.05$), -- indicates a negative Pearson correlation coefficient ($\underline{P} \leq 0.05$). A +++ indicates a positive Pearson correlation coefficient ($\underline{P} \leq 0.01$), ---- indicates a negative Pearson correlation coefficient ($\underline{P} \leq 0.01$). A blank indicates the relationship between the habitat variable and bird abundance was not statistically significant ($\underline{P} > 0.05$). Data are for 1-year post-treatment (YR1) or 2-years post-treatment (YR2), McDonald-Dunn Research Forest, 1990 - 1992. All variables (bird and habitat) were transformed for statistical analyses using $\log_{10}$(variable+1). Boldface type indicates variables that were included in the linear regression model.

VARIABLE	Winter Wren		Swainson's Thrush		Wilson's Warbler		MacGillivray's Warbler		Orange-crowned Warbler	
	YR1	YR2	YR1	YR2	YR1	YR2	YR1	YR2	YR1	YR2
Conifer and Hardwood Tally										
SMCON		+++	+	+	+++	+		----		
SMHWD	+++	+++	+++	+++	+++	+++				
MDCON	+++	+++	+++	+++	+++	+++		----		
MDHWD	+++	+++	+++	+++	+++	+++		--		
LGCON	+++	+++	+++	+++	+++	+++				
LGHWD		+++						----		
Snags										
SS1	+	+++				+				
SS23		+++						----		
SS45		+	+				--			
SM1						+				+++
SM23		+++			+	+		----		
SM45		+++	+							
SL1	--			--		--				

Table 3.2, continued.

VARIABLE	Winter Wren		Swainson's Thrush		Wilson's Warbler		MacGillivray's Warbler		Orange-crowned Warbler	
	YR1	YR2	YR1	YR2	YR1	YR2	YR1	YR2	YR1	YR2
Snags										
SL23							+++	--		
SL45										
Basal Area										
CBA	+++	+++	+++	+++	+++	+++				
HBA	+++	+++	+++	+++	+++	+++				
SBA						--				
Litter Depth										
LIT				+++		+				
Down Wood/Logs										
SLG1		----	----	----		----		+++		
SLG23		+++			+			----		
SLG45		+++		+		+		----		
ML1			--					+		
ML23				+						
ML45				+		+	+			
LL1						----				

Table 3.2, continued.

VARIABLE	Winter Wren		Swainson's Thrush		Wilson's Warbler		MacGillivray's Warbler		Orange-crowned Warbler	
	YR1	YR2	YR1	YR2	YR1	YR2	YR1	YR2	YR1	YR2
Down Wood/Logs										
LL23										
LL45										
Percent Vegetation Cover										
HRBCOV										
GRSCOV								--		
FRNCOV	+++	+++	+	+++	+++	+++				
OTHCOV										
LSHCOV							+	+++		
TSHCOV	+++	+++	+++	+++	+++	+++				
POLCOV	+++	+++	+++	+++	+++	+++		----		
SAWCOV	+++	+++	+++	+++	+++	+++		--		
ACMCOV	+++	+++	+++	+++	+++	+++				
PSMCOV	+++	+++	+++	+++	+++	+++		--		
COCCOV	+++	+++	+++	+++	+++	+++				
ABGCOV	+++	+++	+	+++	+				--	

Table 3.2, continued.

VARIABLE	Winter Wren		Swainson's Thrush		Wilson's Warbler		MacGillivray's Warbler		Orange-crowned Warbler	
	YR1	YR2	YR1	YR2	YR1	YR2	YR1	YR2	YR1	YR2
Vertical Structure										
COV1								+++		
COV2	+++	+++	+++	+++	+++	+++				
COV6	+++	+++	+++	+++	+++	+++				
COV11	+++	+++	+++	+++	+++	+++				
COV16	+++	+++	+++	+++	+++	+++		--		
COV21	+++	+++	+++	+++	+++	+++		--		
COV26	+++	+++	+++	+++	+++	+++				
COV31	+++	+++	+++	+++	+++	+++				
COV36	+++	+++	+++	+++	+++	+++				
COV41	+++	+++	+++	+++	+++	+++				
COV46	+	+++		+++	+++	+++				
COV51				+						--
COV56										

Table 3.3. Regression models for bird and habitat characteristics of 4 stand treatments (control, small patch group selection, two-story, and clearcut), Oregon Coast Range. Separate multiple regression models were created for 1-year post-treatment (YR1) and 2-years post-treatment (YR2). Mallow's C(p) was used as a criterion for selection the final multiple regression model. Regression models for winter wren (YR1), Swainson's thrush (YR1 and YR2), and Wilson's warbler (YR2) include parameter estimates based on a single silvicultural treatment for some habitat variables. These habitat variables are designated with treatment name abbreviation (cn: control, sp: small patch group selection, ts: two-story, cc: clearcut) after the variable name (e.g., SAWCOVcn = parameter estimate based on control treatment sawtimber cover; SAWCOV = parameter estimate based on all treatment saw timber cover). Variables with Partial R^2 values > 0.10 are presumed to be biologically significant in predicting bird abundance and are printed in boldface type.

Bird Species	Year	Habitat Variable	Partial R^2	P	Model R^2	C(p)
Winter wren	YR1	**SAWCOVcn**	**0.54**	**0.0001**		
		FRNCOV	**0.20**	**0.0002**		
		SAWCOVsp	0.04	0.06		
		SAWCOVts	0.04	0.04	0.82	4
	YR2	**POLCOV**	**0.80**	**0.0001**		
		FRNCOV	0.02	0.12		
		SMCON	0.03	0.05	0.85	4
Swainson's thrush	YR1	**PSMCOV**	**0.44**	**0.0001**		
		ACMCOVts	0.07	0.07		
		COV2	0.06	0.07		
		COV26	0.06	0.05		
		ACMCOVcn	0.04	0.08		
		ACMCOVcc	0.03	0.10	0.70	6
	YR2	**SAWCOVcn**	**0.49**	**0.0001**		
		SMHWDts	**0.12**	**0.009**		
		PSMCOVcn	0.06	0.05		
		COV2cl	0.05	0.05		
		LIT	0.03	0.10		
		POLCOVsp	0.02	0.14		
		COV2sp	0.05	0.02		
		SMHWDsp	0.05	0.01	0.87	10

Table 3.3, continued.

Bird Species	Year	Habitat Variable	Partial R^2	P	Model R^2	C(p)
Wilson's warbler	YR1	**PSMCOV**	**0.62**	**0.0001**		
		MDHWD	0.08	0.01	0.70	3
	YR2	**PSMCOV**	**0.51**	**0.0001**		
		HBAsp	**0.13**	**0.005**		
		FRNCOV	0.07	0.03		
		HBAcl	0.09	0.004		
		ML45	0.03	0.05	0.83	6
MacGillivray's warbler	YR1	**LSHCOV**	**0.20**	**0.02**		
		SL23	**0.14**	**0.03**		
		GRSCOV	0.08	0.08	0.42	4
	YR2	**MDCON**	**0.52**	**0.0001**		
		TSHCOV	**0.13**	**0.005**		
		SLG1	0.06	0.04		
		LSHCOV	0.04	0.05		
		ABGCOV	0.04	0.05		
		SLG23	0.04	0.03	0.83	7
Orange-crowned warbler	YR1	**ABGCOV**	**0.19**	**0.02**		
		SLG45	**0.17**	**0.02**		
		SM1	0.06	0.12		
		ML1	0.06	0.12	0.48	5
	YR2	**ML23**	**0.11**	**0.08**		
		OTHCOV	**0.13**	**0.05**	0.23	14

litter depth, percent pole cover in small patch stands, vegetation cover 2- to 5-m above ground in clearcut and small patch stands, percent sawtimber cover in control stands, and percent Douglas-fir cover were best predictors of Swainson's thrush abundance (model $R^2 = 0.87$) (Table 3.3).

Wilson's warbler

1-Year Post-Harvest -- Wilson's warbler abundance was positively correlated with 27 habitat variables ($\underline{P} \leq 0.03$) (Table 3.2). Douglas-fir cover and density of medium hardwoods were best predictors of bird abundance ($R^2 = 0.70$). Douglas-fir cover explained the most variation in bird abundance among the stands (partial $R^2 = 0.62$) (Table 3.3).

2-Years Post-Harvest -- The second year after harvest, Wilson's warbler abundance was positively correlated with 30 habitat variables ($\underline{P} \leq 0.04$) and negatively correlated with 4 variables ($\underline{P} \leq 0.04$) (Table 3.2). Douglas-fir cover, hardwood basal area, fern cover, and medium, decay class 4 and 5 logs were predictors of Wilson's warblers in multiple regression analysis ($R^2 = 0.83$). Douglas-fir cover explained the most variation in bird abundance among the stands (partial $R^2 = 0.51$) (Table 3.3).

MacGillivray's warbler

1-Year Post-Harvest -- MacGillivray's warbler abundance was positively correlated with 3 habitat variables ($\underline{P} \leq 0.05$) and negatively correlated with 1 variable ($\underline{P} = 0.03$) the first year after harvest (Table 3.2). There also was a weak negative correlation of bird abundance with grass cover ($R = -0.30$, $\underline{P} = 0.12$). Variables selected in the multiple regression model included low shrub cover, large-sized decay class 2 and 3 snags, and grass cover. The model R^2 was 0.42. Low shrub cover explained the most variation in bird abundance among the stands (partial $R^2 = 0.20$) (Table 3.3).

2-Years Post-Harvest -- The second year after harvest, MacGillivray's warbler abundance was positively correlated with 4 variables ($\underline{P} \leq 0.02$), and negatively correlated with 15 variables ($\underline{P} \leq 0.05$) (Table 3.2). Two variables included in the multiple regression model were not significantly correlated with bird abundance: tall shrub cover ($R = 0.08$, $\underline{P} = 0.7$) and grand fir cover ($R = -0.22$, $\underline{P} = 0.3$). The multiple regression model included density of medium-sized conifers, low and tall shrub cover, and small logs in decay classes 1, 2, and 3 as predictors of bird abundance ($R^2 = 0.83$) (Table 3.3).

Orange-crowned warbler

1-Year Post-Harvest -- Orange-crowned warbler abundance was negatively correlated with grand fir cover ($\underline{P} = 0.02$) (Table 3.2). Non-significant ($\underline{P} \geq 0.1$) positive correlations with orange-crowned warbler abundance were noted for medium decay class 1 snags ($R = 0.30$), and 2 log classes (small, decay class 4 and 5 logs: $R = 0.31$; medium, decay class 1 logs: $R = 0.18$). Four variables were selected as predictors of bird abundance in the model ($R^2 = 0.48$). Grand fir cover accounted for the most variability in orange-crowned warbler abundance (partial $R^2 = 0.19$) (Table 3.3).

2-Years Post-Harvest -- Orange-crowned warbler abundance was negatively correlated with 51- to 55-m height percent vegetation cover ($\underline{P} = 0.05$), and positively correlated with medium-sized decay class 1 snags ($\underline{P} = 0.005$). Two variables (medium-sized decay class 2 and 3 logs and percent cover of 0- to 1-m height woody vines) were the best predictors of orange-crowned warbler abundance but the model R^2 was only 0.23, and Mallow's C(p) was 14 (Table 3.3). This model does not appear to adequately explain variability in orange-crowned warbler abundance.

Habitat and Vegetation Characteristics

Twenty-four of 53 habitat and vegetation characteristics were selected during stepwise habitat analyses as predictors of bird abundance (Table 3.3). I detected treatment differences for 17 of these variables, with most effects occurring the first year after harvest. Fifteen variables declined as a result of timber harvest. Four habitat features were negatively affected by all treatment types (small patch, two-story, clearcut); 7 variables declined in two-story and clearcut stands; 3 declined in clearcuts only (Table 3.4), and 1 variable (small logs, decay class 2 and 3) declined in two-story stands; based on nonparametric tests. I detected increases in 2 variables in all treatments: small and medium-sized decay class 1 log density (Table 3.4 and Table 3.5). Increases in decay class 1 logs were a result of logging debris remaining after timber harvest. In all treatments, I recorded at least a 16-fold increase in log density ($\underline{P} \leq 0.03$). Variables not used in bird-habitat multiple regression models are reported as treatment averages in Appendix C. Results of repeated measures analyses for these variables are listed in Appendix D.

Sawtimber overstory cover, Douglas-fir cover, grand fir cover, and density of medium hardwoods declined in all treatments (Table 3.4). Decreases in sawtimber and Douglas-fir cover were greatest in two-story and clearcut treatments, with cover reduced more than 80%. Sawtimber cover in small patch stands decreased only 20%; Douglas-fir cover declined 37% in this treatment (Table 3.5). Density of medium hardwoods declined to 4% of original density in clearcuts, to 17% in two-story stands, and to 77% in small patch stands (Table 3.5). Grand fir did not represent a large proportion of cover in any treatment, but cover was eliminated by harvesting in all treatments (Table 3.5).

Seven habitat variables declined following harvest in two-story and clearcut stands, but not in small patch stands: hardwood basal area ($\underline{P} \leq 0.006$), fern cover ($\underline{P} \leq 0.07$), tall shrub cover ($\underline{P} \leq 0.03$), pole tree cover ($\underline{P} \leq 0.09$), density of small ($\underline{P} \leq$

Table 3.4. Repeated measures analysis of variance and orthogonal contrasts for pretreatment v. 1-year post-treatment (YEAR 1 - YEAR 2 CONTRAST) and 1-year post-treatment v. 2-years post-treatment (YEAR 2 - YEAR 3 CONTRAST) for habitat characteristics. Treatments are CN=control, SP=small patch, TS=two-story, and CC=clearcut. P is the probability associated with differences among treatment (TRT), year (YEAR), or treatment by year interaction (YEAR*TRT) effects.

							YEAR 1 - YEAR 2 CONTRAST[1]					YEAR 2 - YEAR 3 CONTRAST[1]				
									Contrast of CN with					Contrast of CN with		
HABITAT	YEAR*TRT		YEAR		TRT		MEAN	TRT	SP	TS	CC	MEAN	TRT	SP	TS	CC
VARIABLE	df	P	df	P	df	P	P	P	P	P	P	P	P	P	P	P
Litter depth	6, 12	0.05		NA		NA	0.008	0.9				0.0003	0.08	0.1	0.4	0.02
Hardwood basal area	6, 12	0.001		NA		NA	0.001	0.005	0.1	0.003	0.006	1.0	0.2			
Grass cover	6, 12	0.4	2, 12	0.002	3, 6	0.7	0.02	0.4				0.3	0.1			
Fern cover	6, 12	0.06	2, 12	0.0001	3, 6	0.3	0.003	0.08	0.3	0.07	0.03	0.1	0.8			
Low shrub cover	6, 12	0.3	2, 12	0.2	3, 6	0.09	0.2	0.4				0.5	0.4			
Tall shrub cover	6, 12	0.0005		NA		NA	0.0007	0.02	0.6	0.03	0.03	0.01	0.04	0.5	0.1	0.3
Pole cover	6, 10	0.003		NA		NA	0.002	0.04	0.8	0.09	0.04	0.003	0.05	0.1	0.01	0.04
Saw cover	6, 12	0.0001		NA		NA	0.0001	0.0002	0.07	0.0009	0.0001	0.08	0.4			
Douglas-fir cover	6, 12	0.0001		NA		NA	0.0001	0.0004	0.05	0.003	0.0002	0.8	0.2			
Bigleaf maple cover	6, 10	0.7	2, 5	0.001	3, 6	0.05	0.004	0.5				0.4	0.2			
Grand fir cover	6, 10	0.03		NA		NA	1.0	0.7				0.02	0.005	0.002	0.001	
0.002																
Small conifers	6, 10	0.008		NA		NA	0.5	0.02	0.1	0.01	0.009	0.2	0.3			
Small hardwoods	6, 12	0.0001		NA		NA	0.007	0.003	0.5	0.009	0.004	0.1	0.3			
Medium conifers	6, 12	0.004		NA		NA	0.007	0.04	0.5	0.06	0.02	0.5	0.6			
Medium hardwoods	6, 12	0.0006		NA		NA	0.0008	0.003	0.04	0.002	0.001	0.4	1.0			
Medium snags - decay1	6, 12	0.4	2, 12	0.5	3, 6	0.4										
Large snags - decay 2/3	6, 12	0.1	2, 12	0.2	3, 6	0.4										
Small logs - decay 1	6, 12	0.004		NA		NA	0.003	0.01	0.03	0.004	0.007	0.02	0.1	0.2	0.05	0.7
Small logs - decay 2/3	6, 12	0.2	2, 12	0.3	3, 6	0.1	0.2	0.2				0.2	0.4			

Table 3.4, continued.

HABITAT	YEAR*TRT		YEAR		TRT		YEAR 1 - YEAR 2 CONTRAST[1]					YEAR 2 - YEAR 3 CONTRAST[1]				
									Contrast of CN with					Contrast of CN with		
							MEAN	TRT	SP	TS	CC	MEAN	TRT	SP	TS	CC
VARIABLE	df	P	df	P	df	P	P	P	P	P	P	P	P	P	P	P
Small logs - decay 4/5	6, 12	0.3	2, 12	0.005	3, 6	0.2	0.003	0.5				0.1	0.4			
Medium logs - decay 1	6, 12	0.004		NA		NA	0.003	0.01	0.03	0.004	0.007	0.02	0.1	0.2	0.05	0.7
Medium logs - decay 4/5	6, 10	0.4	2, 5	0.02	3, 6	0.7	0.005	0.6				0.8	0.2			
2 - 5 m cover	6, 6	0.002		NA		NA	0.004	0.03	0.6	0.1	0.02	0.1	0.07	0.6	0.5	0.06
26 - 30 m cover	6, 6	0.07	2, 6	0.2	3, 3	0.02	0.3	0.1	0.3	0.1	0.05	0.3	0.3			

[1] Degrees of freedom (df) for contrasts are 1,6 for CTRST (contrast), 3,6 for C*TRT (contrast*treatment interaction) and 1,6 for contrast of CN with SP, TS, and CC.

Table 3.5. Mean and standard error (in parentheses) by treatment and year (YR1 = pretreatment year, YR2 = first year post-harvest, YR3 = second year post-harvest) for habitat variables.

	CONTROL			SMALL PATCH			TWO STORY			CLEARCUT		
HABITAT VARIABLE[1]	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3
Litter depth (mm)	38 (7)	44 (3)	36 (6)	35 (4)	43 (1)	33 (3)	32 (4)	38 (6)	28 (6)	35 (5)	48 (11)	22 (5)
Hardwood Basal Area (m^2/ha)	19 (7)	24 (11)	23 (9)	12 (3)	10 (1)	8 (1)	13 (4)	1 (0.5)	4 (1)	11 (3)	1 (0.5)	0.2 (0.2)
Grass Cover (%)	13 (11)	21 (19)	20 (17)	9 (4)	14 (4)	16 (3)	2 (1)	7 (2)	7 (2)	4 (2)	10 (2)	11 (3)
Fern Cover (%)	28 (8)	29 (12)	26 (9)	21 (3)	14 (2)	15 (2)	16 (2)	8 (2)	8 (2)	24 (4)	9 (2)	8 (2)
Low Shrub Cover (%)	25 (2)	22 (6)	26 (7)	27 (3)	33 (4)	39 (4)	46 (7)	51 (8)	44 (6)	36 (6)	42 (7)	53 (10)
Tall Shrub Cover (%)	26 (8)	23 (4)	27 (10)	34 (5)	18 (2)	23 (3)	42 (8)	7 (1)	16 (2)	37 (8)	6 (2)	6 (2)
Pole Cover (%)	42 (4)	33 (14)	33 (11)	38 (5)	24 (3)	24 (2)	28 (4)	4 (1)	2 (0)	36 (10)	2 (1)	2 (0)
Saw Cover (%)	57 (2)	62 (5)	65 (5)	56 (5)	45 (4)	38 (3)	62 (3)	10 (1)	10 (2)	58 (5)	6 (3)	0 (0)
Douglas-fir Cover (%)	49 (5)	47 (5)	54 (8)	49 (3)	31 (4)	31 (2)	52 (3)	8 (1)	10 (2)	53 (4)	3 (1)	0 (0)
Big-leaf maple Cover (%)	13 (3)	13 (5)	10 (5)	19 (3)	6 (2)	6 (2)	15 (3)	1 (0)	0 (0)	10 (4)	0 (0)	0 (0)
Grand fir Cover (%)	2 (1)	2 (1)	4 (1)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Small Conifers (#/ha)	274(102)	691(239)	583 (239)	242 (73)	280 (57)	328 (83)	267(150)	83 (35)	48 (13)	360(188)	83 (38)	54 (22)
Small Hardwoods (#/ha)	1299(949)	1818(1038)	882 (583)	1098(337)	1073(267)	958(121)	1213(465)	22 (10)	10 (3)	2063(949)	41 (38)	6 (6)
Medium Conifers (#/ha)	188 (60)	245(131)	321 (185)	213 (73)	213 (48)	220 (57)	201(118)	32 (16)	25 (10)	188(115)	16 (16)	3 (3)
Medium Hardwoods (#/ha)	105 (70)	172 (29)	146 (45)	172 (57)	131 (32)	118 (16)	150 (38)	25 (16)	13 (6)	153 (73)	6 (3)	3 (3)
Medium Snags - Decay 1 (#/ha)	0 (0)	1 (1)	1 (1)	1 (0)	1 (0)	2 (0)	1 (0)	0 (0)	2 (1)	1 (1)	0 (0)	0 (0)
Large Snags - Decay 2-3 (#/ha)	1 (1)	2 (1)	3 (1)	1 (0)	2 (1)	5 (1)	2 (1)	2 (2)	0 (0)	1 (1)	1 (0)	4 (2)
Small Logs - Decay 1 (m/ha)	64 (25)	38 (19)	108 (67)	16 (10)	322 (45)	150 (29)	41 (19)	697(111)	373 (67)	32 (32)	519 (83)	417 (64)
Small Logs - Decay 2-3 (m/ha)	121 (64)	245 (80)	210 (70)	271 (48)	220 (41)	433 (89)	328 (92)	153 (38)	115 (22)	201 (48)	67 (29)	86 (19)
Small Logs - Decay 4-5 (m/ha)	89 (32)	92 (54)	159 (73)	143 (29)	29 (10)	127 (29)	143 (41)	25 (13)	29 (16)	118 (29)	6 (6)	19 (6)
Medium Logs - Decay 1 (m/ha)	127 (67)	25 (25)	32 (32)	6 (6)	105 (32)	48 (16)	10 (10)	197 (41)	111 (32)	0 (0)	162 (51)	108 (25)
Medium Logs - Decay 4-5 (m/ha)	191 (73)	131 (80)	121 (76)	80 (19)	25 (10)	48 (13)	134 (38)	64 (32)	22 (13)	134 (35)	13 (6)	29 (16)
2 - 5 m Cover (%)	35 (3)	21 (8)	28 (8)	31 (4)	16 (2)	20 (2)	31 (6)	6 (2)	11 (2)	41 (10)	3 (1)	3 (1)
26 - 30 m Cover (%)	22 (10)	42 (1)	42 (10)	30 (7)	27 (3)	25 (2)	32 (7)	6 (2)	9 (2)	24 (14)	1 (1)	0 (0)

[1] Small conifers and hardwoods included trees 0- to 19-cm dbh; medium conifers and hardwoods were 20- to 55-cm dbh. Small logs included all dead wood 10- to 19-cm diameter; medium logs were 20- to 53-cm diameter. Medium snags were 30- to 53-cm diameter; large snags were > 53-cm diameter.

0.01) and medium ($\underline{P} \leq 0.06$) sized conifers, and density of small diameter hardwoods ($\underline{P} \leq 0.009$). Hardwood basal area was almost eliminated in two-story and clearcut stands 1-year post-harvest. Hardwoods that were not removed during logging were subsequently girdled and treated with herbicide in these stands. Aerial herbicideapplication in clearcuts may have resulted in the continued absence of hardwoods in those stands 2-years post-harvest. I noted an increase in hardwood basal area in two-story stands the second year after harvest that could have been due to resprouting of hardwoods such as bigleaf maple (pers. obs.), although this increase was not statistically significant. Two-story stands were sprayed by hand, with herbicides targeting only competing vegetation around planted Douglas-fir seedlings, so this treatment may have allowed retention of more hardwood stems.

Fern cover decreased to $\leq 50\%$ in two-story and clearcut stands. Tall shrubs were reduced to 16% of former cover in these stands. Pole tree cover was reduced to less than 15% in two-story stands and 5% in clearcuts. Small conifers were reduced to $\leq 30\%$, small hardwoods to 2%, and medium conifers to $\leq 16\%$ former densities in two-story and clearcut stands (Table 3.5).

Three other habitat variables declined in response to clearcutting but not in other treatments. These were litter depth ($\underline{P} \leq 0.06$), percent cover 2- to 5-m above ground ($\underline{P} \leq 0.06$), and percent cover 26- to 30-m above ground ($\underline{P} \leq 0.06$). Litter depth may not have changed in two-story stands because of foliage inputs from plants ≤ 1 m above ground (low shrub, herbaceous, or woody vine layers). In small patch stands, changes in vegetation in the 0.2-ha patches did not significantly alter litter depth and vegetation appeared to be unaffected in unharvested portions of the stands.

I used nonparametric tests to detect treatment differences in small, decay class 2 and 3 logs. There were differences among treatments ($\underline{P} = 0.003$), but I could only detect differences between control and two-story treatments using an alpha level of 0.05. Log density declined 65% in two-story stands, 57% in clearcuts (Table 3.5).

Although I was unable to detect differences between control and clearcut treatments, I expect log density declined in these clearcuts.

I could not detect treatment effects ($\underline{P} > 0.09$) on 7 vegetation and habitat characteristics: grass cover, low shrub cover, bigleaf maple cover, decay class 1 medium snags, decay class 2 and 3 large snags, decay class 4 and 5 small logs, and decay class 4 and 5 medium logs (Table 3.4). I did detect year effects for grass cover ($\underline{P} = 0.002$), decay class 4 and 5 small logs ($\underline{P} = 0.005$), and decay class 4 and 5 medium logs ($\underline{P} = 0.02$). Grass cover increased in all treatments the first year after harvest ($\underline{P} = 0.02$) (Table 3.5). Log density declined during that period (decay class 4 and 5 small logs: $\underline{P} = 0.003$; decay class 4 and 5 medium logs: $\underline{P} = 0.005$) (Table 3.5). Variability among control stands or observer error may have contributed to inability to detect treatment differences. These features also may have been present in such low density that my sampling design was inadequate to detect differences among treatments.

I used estimates of percent vegetation cover by 5-m layers to compare changes in vertical structure. Figure 3.1 is a visual representation of the vertical strata in each treatment from the forest floor (0 m) to height of original overstory trees (60 m). Variability in ≥ 50-m layers was too high to detect differences among treatments, possibly caused by differences in tree heights among blocks (trees in the Dunn block were 45- to 50-m tall, while trees in the other blocks were 50- to 60-m tall). However, I did detect decreases in most vertical layers in clearcut stands (Figure 3.1D), and in understory (2- to 5-m height) and midstory (25- to 40-m height) layers in two-story stands (Figure 3.1C). Vertical structure in small patch stands were least affected by harvest (Figure 3.1B). All vertical layers (sawtimber trees, pole trees, shrubs) of the canopy were affected to some degree by harvesting, although the small patch group selection cutting had less effect than did the two-story and clearcut treatments on habitat features.

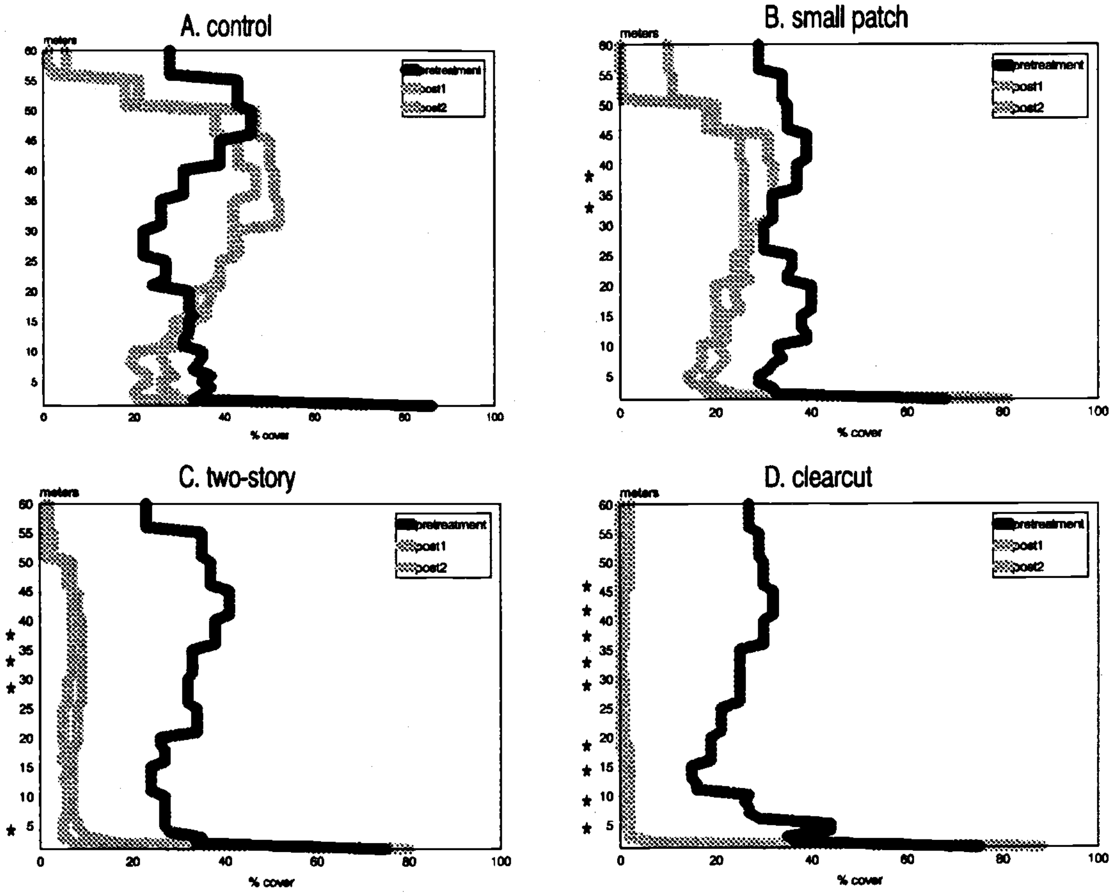

Figure 3.1. Percent vegetation cover averaged for A. control, B. small patch group selection, C. two-story, and D. clearcut treatments. Pretreatment averages for vertical strata were compared with post-treatment averages and significant differences between years (P < 0.10) marked with an asterisk on the y-axis. Post1 and Post2 represent 1- and 2-years post-treatment, respectively. I did not differentiate between them for the purpose of this graph.

DISCUSSION

Group selection, two-story, and/or clearcut regeneration systems affected over half of the habitat or vegetation features that were identified as predictors of winter wren, Swainson's thrush, Wilson's warbler, MacGillivray's warbler, or orange-crowned warbler abundance. In most cases, harvesting decreased vegetation complexity, with vegetation complexity declining with increasing intensity of forest management. Overstory cover and hardwoods were affected in all treatments. Hardwoods were associated with abundance of several bird species in this and other studies (Hagar 1993, John Hayes pers. comm.), so their removal may affect some species. Shrub and midstory layers were affected in two-story and clearcut stands. I detected increases in densities of small and medium decay class 1 logs in all treatments, a result of logging debris not removed from the stands (pers. obs.).

I detected fewer effects on habitat features by group selection harvesting than by two-story or clearcut systems (e.g., 6 variables were affected in small patch stands; 14 in two-story stands; 16 in clearcuts). Vegetation and habitat characteristics were more similar between control and group selection stands and between the two-story and clearcut stands.

Clearcutting most dramatically altered plant and bird species composition (Chambers 1996). Since clearcut stands only begin to attain mature forest status 60 to 90 years following harvest (Brown 1985a), there is little potential for development of bird communities associated with mature forests in the years immediately following logging. Two-story stands retain some old forest structures that may provide at least foraging habitat for some mature forest species. Two-story stands also may retain greater understory diversity since control of competing vegetation using aerial application of herbicides may be more restricted due to the presence of residual trees (Rick Schaefer, pers. comm.). The greater complexity of vegetation may provide habitat for more bird species than clearcuts are capable of providing. Group selection cutting may have the least impact on mature forest species, although one study found selective cutting lowered breeding potential of mature forest species (Maurer et al. 1981).

Breeding birds must find nest sites and procure food for both themselves and offspring. Feeding and nesting habits were considered when addressing habitat associations.

Winter wren

Winter wrens nest 0- to 2-m above ground in concealed natural cavities of root wads, stumps, mossy hummocks, and occasionally in woodpecker holes. They feed on insects, spiders, and occasionally fruits and seeds, foraging on the ground and in shrubs (Martin et al. 1951, Harrison 1979, Ehrlich et al. 1988). Winter wrens have been associated with large sawtimber and old-growth stands in coastal Oregon forests (Brown 1985b, Hagar 1993, McGarigal 1993). Winter wrens also were positively associated with shrub cover (McGarigal and McComb 1992, Hagar 1993), and hardwoods (> 30 cm dbh) (Hagar 1993).

I found similar habitat associations for winter wrens. I found sawtimber cover to be an important predictor of winter wren abundance the first year after harvest. The second year after harvest, winter wren abundance was better predicted by pole cover and small conifer density. Birds were positively associated with fern cover both years.

Sawtimber and pole cover were important predictors of winter wren abundance. Two-story and clearcut harvesting negatively affected both sawtimber and pole cover, small patch harvesting affected sawtimber cover. Although any of these regeneration systems may have a detrimental effect on winter wrens, two-story and clearcut stands may be particularly damaging to winter wren habitat since sawtimber cover, pole cover, fern cover and small conifers were removed.

Winter wren abundance did not appear to change over time in control stands. Retaining unmanaged mature and old-growth stands or using silvicultural treatments that minimize impact on overstory, pole, and fern cover such as small patch group selection system may maintain breeding habitat for these birds.

Swainson's thrush

Swainson's thrushes nest in shrubs or low in conifer trees, usually 1.2- to 2.4-m above ground (Harrison 1979, Ehrlich et al. 1988). They feed on invertebrates and berries by gleaning from vegetation and the ground, or may hawk for insects (Ehrlich et al. 1988). In western Oregon and Washington forests, Brown (1985b) listed primary habitat as including open sapling-pole, closed sapling pole, large sawtimber, and old-growth stand conditions in coniferous wetlands, hardwood and shrubby wetlands, red alder (*Alnus rubra*), and temperate coniferous forest communities. In the Oregon Coast Range, Carey et al. (1991) found Swainson's thrush abundance did not differ between young (40- to 72-year-old), mature (80- to 120-year-old), and old-growth (200- to 525-year-old) temperate coniferous forest.

I found similar habitat associations for Swainson's thrushes. Birds were associated with a combination of overstory conifer cover, hardwoods, and understory cover. The first year after harvest, Douglas-fir cover explained most variation in bird abundance; bigleaf maple cover and shrub cover in the 2- to 5-m height range also were important. The second year after harvest, sawtimber cover (consisting of primarily Douglas-fir and grand fir) were important predictors of Swainson's thrush abundance. Small hardwood density, shrub cover, pole cover, and litter depth also were included as predictor variables. Small hardwoods, shrubs, and litter depth may represent feeding sites. Shrub cover may indicate availability of nest sites. Overstory and pole cover may be indicators of stand conditions suitable for Swainson's thrush use. I found these birds more abundant in control and small patch stands than in two-story and clearcut stands after harvest (Chambers 1996). The removal of mid- and overstory in two-story and clearcut treatments appeared to eliminate suitable habitat.

Swainson's thrushes may be least negatively affected by small patch group selection harvesting, since overstory and understory components (conifers, hardwoods, shrubs) are not affected in many parts of the stand. I did, however, detect a decline in Swainson's thrush abundance in small patch stands the second year after harvest (Chambers 1996). Two-story and clearcut systems removed much of the understory in the 2- to 5-m height range, as well as in the overstory. These treatments negatively affected habitat quality for Swainson's thrushes.

Wilson's warbler

Wilson's warblers are insectivorous. They feed by hawking, hovering, or gleaning insects and larvae from vegetation. They nest on the ground or in dense vegetation within 1 m of the ground, often in heavy undergrowth (Martin et al. 1951, Bent 1963b, Harrison 1979, Ehrlich et al. 1988). They are often associated with brushy areas in or near moist or riparian zones (Brown 1985b, Ehrlich et al. 1988). Primary habitat in western Oregon and Washington includes mature and old-growth stand conditions in conifer-hardwood forests and shrub, open sapling-pole, mature, and old-growth in hardwood and coniferous wetlands (Brown 1985b).

I found Wilson's warblers associated with Douglas-fir overstory cover and hardwood density the first year after harvest, and Douglas-fir cover, fern cover, hardwoods, and well decayed logs the second year after harvest. Wilson's warblers may be selecting areas with high fern cover for nest sites (I observed Wilson's warblers nesting in the base of ferns). Hardwoods may represent foraging sites or perhaps be an indication of moister sites. Wilson's warblers in my study were associated with mature forest with higher percentages of overstory rather than early seral stages with little overstory cover.

Wilson's warbler abundance declined significantly in two-story and clearcut stands after harvest, but I did not detect a decline in abundance in small patch stands (Chambers 1996). Douglas-fir cover and fern cover decreased significantly in all harvested stands, but declines were much greater in two-story and clearcut treatments (e.g., fern cover decreased by at least 50% in two-story and clearcut stands). Wilson's warblers appeared to find suitable habitat in control and small patch stands, but changes in habitat characteristics in two-story and clearcut stands negatively affected abundance.

MacGillivray's warbler

MacGillivray's warblers are primarily insectivorous. They nest in small, dense shrubs (e.g., salal) 0.3- to 1.5-m above ground (Bent 1963b, Harrison 1979, Ehrlich et al. 1988). Primary habitat in western Oregon and Washington is in shrub or open sapling-pole stand conditions in temperate coniferous forest or in hardwood or conifer wetlands (Brown 1985b). These birds have been observed in areas of new growth with abundant down wood, in blackberry (*Rubus* spp.) patches and salal thickets (Bent 1963b).

I found similar habitat use in my study. The first year after harvest, I found MacGillivray's warblers more abundant in areas with dense low shrub cover; large, decay class 2 to 3 snags; and little or no grass cover (probably excluded by competition from shrubs). The second year post-harvest, MacGillivray's warblers were associated with abundant shrub cover and higher densities of small, decay class 1 logs. Decay class 1 logs increased in all treatments (small patch, two-story, and clearcut) as a result of logging. MacGillivray's warblers were negatively associated with grand fir cover. Grand fir was present only in control stands the second year after harvest, so grand fir and conifer density probably serve as indicators of a lack of overstory or midstory cover.

MacGillivray's warblers were predicted by Brown (1985b) as unlikely to occur in areas with high overstory or midstory cover.

MacGillivray's warblers increased in abundance in all harvest treatments (Chambers 1996). Although abundance remained at 1 bird observation/5 ha in control stands, detections increased 6 fold in small patch stands and two-story stands, and 3-fold in clearcuts (Chambers 1996). Creating early seral stage conditions and providing down wood appeared to improve habitat for these birds.

Orange-crowned warbler

Orange-crowned warblers are primarily insectivorous, sometimes feeding on floral nectar or tree sap. They are foliage gleaners, usually occurring in areas with dense shrub or midstory foliage cover. They nest on the ground under ferns, grasses, or in briars or above ground up to 0.9-m in shrubs or vines (Bent 1963a, Harrison 1979, Ehrlich et al. 1988). Primary habitat in western Oregon and Washington includes shrub and open sapling-pole stand conditions in temperate coniferous forest, hardwood or coniferous wetlands (Brown 1985b). Carey et al. (1991) found orange-crowned warblers more abundant in young (40 to 72 year old) forests than mature (80 to 120 years old) or old-growth (200 to 525 years old) in the Oregon Coast Range.

The models I developed poorly explained variability in orange-crowned warbler abundance, particularly the second year post-harest. I found birds negatively associated with grand fir cover, and more abundant in areas with small logs of decay class 4 to 5 and medium-sized, decay class 1 logs and snags the first year after harvest. The second year post-harvest, the model I selected consisted of 2 variables that were negatively associated with orange-crowned warbler abundance: woody vine cover and medium-sized decay class 2 to 3 logs. Since I expect that orange-crowned warblers might occur in the presence of these features, I do not recommend using results of this model to develop management plans for this species.

Orange-crowned warbler abundance appeared to increase in all treatments (small patch, two-story, and clearcut) after harvest, although this increase was not statistically significant (Chambers 1996). Orange-crowned warblers did not appear to be negatively affected by any harvest treatment, probably because they are more dependent on understory features than overstory retention. The variables I used to create multiple regression models may not have been measured at an appropriate scale to detect differences in habitat use, or birds responded equally to all levels of disturbance caused by treatment.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Use of habitat features by 4 of 5 bird species I selected for study was similar to that predicted by Brown (1985b) or found in other studies (e.g., Carey et al. 1991). However I was able to describe additional habitat features associated with abundance of these species (e.g., fern cover for winter wrens). I was unable to develop an adequate model for 1 species, orange-crowned warbler.

Most of my models were better predictors of bird abundance the second year after harvest (e.g., R^2 increased), probably because immediate effects of logging were more notable the first year after harvest. Changes in vegetation and bird responses to those changes may have been more detectable 2 years after harvest than 1 year after harvest. I recommend that monitoring bird and habitat responses to silvicultural treatments be delayed to the second post-treatment year.

Based on habitat associations, 4 bird species (winter wren, Swainson's thrush, Wilson's warbler, and MacGillivray's warbler) may be impacted by timber harvest. I could not explain variation in abundance for orange-crowned warblers based on my data and did not detect differences among treatments after harvest (Chambers 1996). This species appeared unaffected by harvest. Of the three regeneration systems, the group selection system had less effect on mature forest associated species (e.g., winter wren) than either the two-story or clearcut systems and should be considered as an alternative when managing for mature forest biotic diversity. Species such as MacGillivray's warbler selected habitat that was more likely to be produced by the clearcut or two-story treatment. However they also colonized the small patches (0.2-ha) in the group selection treatment.

Based on data from a companion study (Chambers 1996), 2 species associated with early forest seral stages (MacGillivray's warbler and orange-crowned warbler) may be at greater risk from nest predation in two-story and clearcut stands. Artificial nests placed in shrubs were used to monitor nest predation rates. Nest predation rates were higher in open-canopy treatments (two-story and clearcut) compared with control and small patch group selection treatments. Group selection as a regeneration method may provide better habitat for winter wren, Swainson's thrush, Wilson's warbler, and MacGillivray's warbler, since it had the least impact on important habitat features so provides more cover that conceals eggs and nestlings from predation. However, some of these bird species reach much higher abundance in two-story and clearcut stands. My nest predation results were based on artificial nest predation rates rather than active nests. Birds actively occupying a nest may serve as a deterrent to nest predators, may attract predators, or their populations may be large enough that predation rates are negligable. Nest predation rates may be different from those I found using artificial nests.

Gender differences in functional use of habitat are not reflected in my study. I used breeding bird counts to define habitat use. In most cases, my counts detected singing males rather than females, so do not reflect nest site selection. Sedgwick and Knopf (1992) found differences in male versus female habitat use greater than male versus non-used sites. I did find nests for Wilson's warbler and Swainson's thrush, but habitat features important at fine-scale resolution were not the focus of my study. My results are more applicable at the stand- or territory-scale rather than at a level needed for predicting nest habitat. To fully describe bird habitat relationships, descriptions of nest site characteristics and reproductive performance would be instructive.

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CHAPTER 4

ARTIFICIAL NEST PREDATION RATES AMONG THREE SILVICULTURAL SYSTEMS AND CONTROL STANDS, CENTRAL OREGON COAST RANGE

Carol L. Chambers

Department of Forest Resources
Oregon State University
Corvallis, Oregon 97331

INTRODUCTION

Clearcutting has been the primary method for regenerating stands of Douglas-fir (*Pseudotsuga menziesii*) in the Pacific Northwest for the past 50 years (Swanson and Franklin 1992). Although an economical method of stand regeneration, this system eliminates habitat for many mature forest wildlife species (Hagar 1960, Medin 1985, Chambers 1996) until similar mature forest stand structure is reestablished. Structures that are important to species associated with late-successional forests include large trees with multilayered canopies, several tree species, large snags and logs, and deep forest floor litter (Ruggiero et al. 1991). These structures reestablish slowly after harvest; often a minimum of 80 years in Douglas-fir forests is required (Brown 1985).

Alternatives to clearcutting are being adopted because of concerns over effects of forest management on ecological, economic, and social values. Long-term management to maintain or restore habitat for species associated with old-growth forests has become a priority on federal lands in the Pacific Northwest (Forest Ecosystem Management Assessment Team 1993). It also is gaining importance on state and private lands (e.g., Oregon Forest Practices Act, Oregon Department of Forestry 1991). Silvicultural alternatives are being suggested that create or restore late-successional forest attributes based on the assumption that these systems lead to development of forest structures to which mature forest biota are adapted (Forest Ecosystem Management Assessment Team 1993).

Among regeneration alternatives being used are (1) modified clearcuts with green trees and snags retained, (2) two-story (or green tree retention) systems, and (3) group selection uneven-aged systems. Modified clearcuts and two-story stands that retain standing live and dead trees are intended to simulate stand structure following moderate to large-scale disturbances such as wildfire or wind. While these large scale disturbances are the most dramatic, they are infrequent in coniferous forests west of the Cascades Mountains (e.g., stand replacing fires may occur only every 300 to 700 years)

(Spies et al. 1990). A group selection system removing only a single tree or small group of trees simulates finer scale disturbances such as those created by insects, pathogens, or wind throw. These small scale events can be more frequent (e.g., forest area representing new gaps created annually in Cascades Mountains mature and old-growth stands was 0.7% and 0.2%, respectively), and over time may affect large areas of forest (Spies et al. 1990).

Of the systems described, green-tree retention may become the predominant alternative to clearcutting in the Pacific Northwest. On state and private lands it allows removal of a large volume of wood but retains some features thought to be important to mature forest associated species and may be more positively viewed by the public than clearcutting (Brunson and Shelby 1992). On federal lands, clearcutting has been replaced with green-tree retention, with a minimum of 15% of trees left on site (Forest Ecosystem Management Assessment Team 1993).

Alternative silvicultural systems could potentially create stands that become sink rather than source habitat for songbirds. Monitoring reproductive effort and success following implementation could help determine beneficial or detrimental effects of these practices. For example, alternative silvicultural systems may create or retain stand structures (e.g., snags, logs, large live trees) that serve as breeding, foraging, or dispersal habitat for mature forest species. However some of these structures may increase availability of perch or hiding sites for predators (Nichols and Wood 1993).

A number of bird populations are in decline in Oregon (Marshall et al. 1992, Sharp 1992). Causes include loss of habitat (e.g., decline in old-growth and mature forest habitat), loss of nest structures (e.g., snags), competition from exotic species (e.g., European starling [*Sturnus vulgaris*] competition with western bluebird [*Sialia mexicana*] for nest cavities), and silvicultural practices (e.g., salvage leading to snag loss, conversion to young forest managed on short-term rotations) that altered the forest environment (Marshall et al. 1992). Using Breeding Bird Survey (BBS) data from 1968 to 1989, Sharp (1992) documented state-wide declines for rufous hummingbird (*Selasphorus rufus*), Swainson's thrush (*Catharus ustulatus*), orange-crowned warbler (*Vermivora celata*), MacGillivray's warbler (*Oporornis tolmiei*), white-crowned sparrow (*Zonotrichia leucophrys*), American goldfinch (*Carduelis tristis*), and others. His report concentrated on Neotropical migrants so other species that were not considered also may be in decline.

I found many of these species present in the group selection, two-story, and modified clearcut stands that I studied. Rufous hummingbirds, orange-crowned warblers, MacGillivray's warblers, white-crowned sparrows, and American goldfinches were all present or abundant in two-story and clearcut stands; Swainson's thrushes were abundant in group selection stands (Chambers 1996). Identifying density or abundance, however, is not necessarily a measure of habitat quality. Analysis of reproductive efforts and success may better distinguish effects of habitat alteration on bird populations (Van Horne 1983).

Reproductive success in birds can be partly measured through analysis of nesting mortality. Predation has been identified as a primary cause of nesting mortality (Loiselle and Hoppes 1983). The susceptibility of avian nests to predation may depend on location and habitat type. Nests that are conspicuous may be more at risk than those located in dense or complex vegetation types (Wray and Whitmore 1979, Yahner and Cypher 1987, Crabtree et al. 1989, Moller 1989, Terborgh 1989). Presumably greater vegetation density near avian nests may reduce foraging efficiency of predators and result in lower rates of depredation (Yahner and Cypher 1987, Yahner and Morrell 1991).

Other factors affecting nest predation rates include degree of forest fragmentation, proximity to suburban or agricultural areas, and types of predators (Yahner and Scott 1988, Yahner et al. 1989, Loiselle and Hoppes 1989). Fragmentation increased nest predation and brown-headed cowbird (*Molothrus ater*) parasitism in forests of the eastern United States, Idaho, and Denmark (Whitcomb et al. 1981, Wilcove 1985, Ratti and Reese 1988, Small and Hunter 1988, Yahner and Scott

1988, Moller 1989, Yahner et al. 1989). Proximity to agricultural, suburban, or urban areas also appeared to affect densities of mammalian and avian predators and impact nesting success for some bird species (Terborgh 1989, Andren 1992).

Although artificial nest predation studies are not a direct measure of nestling survival and results should be used with caution (Yahner and Voytko 1989), they may provide an index to nest success. If some alternative silvicultural systems are more likely to result in songbird nest predation, managers should consider their effects and the trade-offs involved in using these systems.

I know of only 1 study documenting the effects of artificial nest predation in Pacific Northwest forests. Vega (1993) conducted a study in the Oregon Cascades and found predation rates higher on artificial shrub nests in green-tree retention stands than in clearcut and mature stands.

My objectives were to: (1) compare artificial nest predation rates among 3 alternative silvicultural treatments and a control, and (2) determine whether the relative abundance of common avian nest predators differed among treatments.

STUDY AREA

Twenty-nine stands were selected for study within Oregon State University's McDonald-Dunn Forest, a 5261-ha experimental forest located on the eastern of edge of the Coast Range, north and northwest of Corvallis. Three blocks of 7 to 11 stands each were located near Lewisburg Saddle (Township 11S, Range 5W, Willamette Baseline and Meridian, portions of Sections 4, 8, 9, 16, 17), Peavy (Township 10S, Range 5W, Willamette Baseline and Meridian, portions of Sections 25, 35, 36), and Dunn (Township 10S, Range 5W, Willamette Baseline and Meridian, portions of Sections 14, 22, 23, 27). Stands were 5 to 18 ha in size. Douglas-fir comprised $\geq$ 64% basal area prior to harvest; in most stands (25 of 33 stands), it represented $\geq$ 80% total basal area. Species including grand fir (*Abies grandis*), 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*) comprised the remaining basal area.

Both the Lewisburg Saddle and Peavy blocks consisted of 1 control (uncut) stand, 6 small patch group selection stands (1/3 volume removed in 0.2-ha circular patches), 2 two-story stands (3/4 volume removed uniformly), and 2 modified clearcut stands (1.2 green trees/ha retained). The Dunn block included 1 control stand, 2 two-story stands, 2 modified clearcut stands, and 2 small patch group selection stands. Clearcuts were modified to leave 1.2 green trees >53 cm dbh/ha remaining. Twenty to 30 green trees >53 cm dbh/ha were retained in two-story stands. Snags (average dbh = 91 cm, 3.7/ha) were created by topping green trees at 15 to 18 m in all stands except controls. Harvesting and snag topping occurred between 1990 and 1992. Following harvest, vegetation cover was reduced by 50 to 70% in group selection stands in midstory (11 - 25 m) and overstory (31 - 60 m) layers ($\underline{P} \leq 0.10$) (Chambers 1996). Cover was reduced by $\geq$ 75% in all vertical strata > 1 m in clearcut stands and in all strata in two-story stands except $\leq$ 1 m and 41 - 45 m layers ($\underline{P} \leq 0.10$) (Chambers 1996). Vegetation cover in control stands did not change over the course of this study (Chambers 1996).

I used all available stands with the exception of the small patch treatment for the artificial nest predation study. I selected a subset of small patch stands (2 stands per replication) because of time constraints and limited personnel. Data for nest searches were based on 3 control, 6 small patch, 6 two-story, and 6 modified clearcut stands.

METHODS

Artificial Nest Trials

Artificial Nests

Nests (6 cm diameter, 10 cm deep) were constructed from 2.5-cm mesh chicken wire and sprayed with flat black paint. I waited 1 week before using nests so they could lose human and paint scent.

Predation Trials

Artificial nests were placed in stands during 2 periods (trials): June 2 - 8 and June 25 - July 1, 1992. Chicken wire nests were lined with leaf litter or other vegetation at the site and attached with florist wire 0.1 to 1.5 m above ground in shrub interiors (at least 0.4 m from the outer edge of the shrub). I created a shallow depression in the soil for ground nests, and concealed these under vegetation, slash, or logs. Two quail (*Coturnix chinensis*) eggs were placed in each nest. I used rubber gloves when handling nests and eggs to minimize human scent and used no markings or flagging that might identify nests to predators.

Three ground and 3 shrub nests were placed in each stand (6 nests/stand). Nests were paired (1 ground + 1 shrub) within a 10-m diameter circle 15 m from each variable circular plot (VCP) station. Nest pairs were placed $\geq$ 100 m from stand edges and $\geq$ 100 m from other nest pairs. I replicated the study among 6 stands of each silvicultural treatment and 3 control stands.

Nests were checked after 6 days and outcome (disturbed v. undisturbed) noted. A nest was considered disturbed if $\geq$ 1 egg was missing or broken. Egg fragments or eggs with holes were used as indicators of mammal consumption. Missing eggs were considered taken by avian predators. Eggs and nests were removed at the end of each trial.

Bird Sampling

To allow comparisons of relative abundance of potential avian nest predators among treatments, diurnal breeding birds were surveyed using Reynolds et al.'s (1980) variable circular plot (VCP) method in each stand. Three VCP stations were located ≥ 100 m apart and ≥ 100 m from stand edge in each stand. Stations were visited 4 to 6 times from May 15 to July 15 during the breeding season between sunrise and 4 hr after sunrise. After a 2-minute wait period, counts were conducted for 8 minutes. All visual and aural detections of birds were recorded and distance from the station was estimated. Distances were recorded to the nearest meter for birds ≤ 10 m from VCP, nearest 5 m for birds >10 m but ≤ 50 m, nearest 10 m for birds > 50 m. Order of visitation was alternated among stands to account for seasonal variation in breeding phenology and hourly variation in animal activity. Counts were halted by rain or winds > 15 km/h. Abundance for each species was averaged among stands for each treatment (control: n=3; group selection: n=14; two-story: n=6; modified clearcut: n=6).

Small Mammal Sampling

I compared relative abundance of potential mammalian nest predators by conducting live trapping in each stand. Three stations (VCPs) within each stand were used to sample relative abundance of small mammals. Ten live traps were placed at each VCP, with 1 Sherman live trap and pitfall trap (double-deep number 10 tin cans) each at the center point and at each of the 4 cardinal directions 10- to 15-m from the center point. Pitfall traps were buried flush with the ground along logs, snags, or other natural drift fences when available. Sherman traps were placed along natural drift fences.

I used polyester bedding to help prevent hypothermia and baited traps with rolled oats and peanut butter-covered hamster chow. To keep pitfall traps free of water accumulation, I punched 4 drain holes in the cans and placed a metal cover approximately 10-15 cm above each pitfall. Sherman traps were covered with a milk carton sleeve (half-gallon unformed milk carton) for insulation and protection from rain.

Traps were opened and checked for a 4-day period in each stand prior to harvest and 1 year post-harvest with the exception of the Lewisburg Saddle block. During the first year for this block, 9 pitfall traps per stand only were used to sample small mammals (3 traps per VCP station, 3 VCPs per stand) so these data were excluded from analysis. Trapping took place in July 1991 and between July and September, 1992. Animals were identified to species, sexed, weighed, marked and released. Capture rate for each species was standardized by calculating number of individuals per 1000 trap nights (TN) for each stand and year.

During breeding bird counts, I noted activity (calling) or sightings of Douglas' squirrels (*Tamisciurus douglasii*) and Townsend's chipmunks (*Tamias townsendii*). Squirrels and chipmunks are potential nest predators (Martin et al. 1951, Ratti and Reese 1988, Terborgh 1989) so number of squirrel and chipmunk sightings were compared among treatments to estimate their response to treatment and possible effect on nesting birds.

Statistical Analysis

Nest Predation

Stands were considered independent observations for analysis of each nest type (ground or shrub) (control: n = 3, group selection: n = 6, two-story: n = 6, clearcut: n = 6). Data from both trials were combined. Nest predation rates were analyzed using an ANOVA with ranked data (PROC RANK) (SAS Institute Inc. 1990) because of small sample sizes. Multiple comparisons tests based on Friedman rank sums were used to detect differences among treatments (Hollander and Wolfe 1973:151).

Small Mammal and Bird Abundance

For birds, repeat observations and those > 75 m from the VCP were excluded from analyses. Only initial captures were used in mammal analyses. Average bird (number of observations/5 ha) and small mammal abundances (number of captures per 1000 trap nights [TN]) were used as indices of abundance and were compared among treatments for pretreatment and 1-year post-treatment using SAS repeated measures analysis (RMA) (SAS Institute Inc. 1989). The control was contrasted with each treatment using profile orthogonal contrasts (SAS Institute Inc. 1989). If Mauchly's criterion was significant ($\underline{P} \leq 0.10$) I interpreted results from RMA using the Wilks' Lambda statistic for MANOVA tests of hypotheses. If Mauchly's Criterion not significant ($\underline{P} > 0.10$), I used results from the univariate repeated measures analysis of variance using the procedure PROC MIXED (SAS Institute Inc. 1992). Animal abundance data were transformed using a log transformation [$\log_{10}$(variable+1)] to meet assumptions of equal variance (Sabin and Stafford 1990).

I used nonparametric analyses to detect differences in treatments when the asumptions for RMA were not met. I compared pretreatment v. 2-year post-treatment data only, averaging over treatment. I used an ANOVA with ranked data (PROC RANK) (SAS Institute Inc. 1990) and multiple comparisons tests based on Friedman rank sums to detect differences among treatments (Hollander and Wolfe 1973:151).

RESULTS

Ground Nests

Nine ground nests (7%) were found disturbed. Ground nests were disturbed in all treatments in the first trial, and in clearcut and two-story stands in the second trial. Eggs had holes or were fragmented in 5 nests, eggs were absent in 4 nests. Predation averaged 6% for clearcut stands, 8% for two-story stands, 8% for group selection stands, and 6% for control stands (Figure 4.1). There was no detectable difference in predation rate when both trials were combined for analysis ($\underline{P} = 0.99$).

Shrub Nests

Eight shrub nests (6%) were disturbed. Shrub nests were disturbed in two-story and group selection stands in the first trial, and in clearcut and two-story stands in the second trial. Eggs were missing in 5 nests and were fragmented or had holes in 3 nests. With data combined, predation rates differed among treatments ($\underline{P} = 0.10$), averaging 8% for clearcuts, 11% for two-story stands, 3% for group selection and 0% for controls (Figure 4.1). Clearcuts and two-story stands seemed to experience slightly higher predation rates than group selection and control stands, although these differences could not be detected with treatment multiple comparisons based on Friedman rank sums.

Avian Nest Predators

Steller's jay (*Cyanocitta stelleri*) abundance decreased in two-story and clearcut stands the first year after harvest compared with control stands. Average abundance declined from 11 to 3 bird observations/5 ha in clearcuts ($\underline{P} = 0.001$), from 12 to 3 bird observations/5 ha in two-story stands ($\underline{P} = 0.006$). There was no significant change in Steller's jay abundance in control stands or in group selection stands. Gray jays (*Perisoreus canadensis*) were present in low numbers (0 to 2 bird observations/5 ha) in all treatments. There was no detectable change in their abundance following harvest ($\underline{P} = 0.5$). American crow (*Corvus brachyrhynchos*) and common raven (*Corvus corax*) detections were too few for analysis (Chambers 1996).

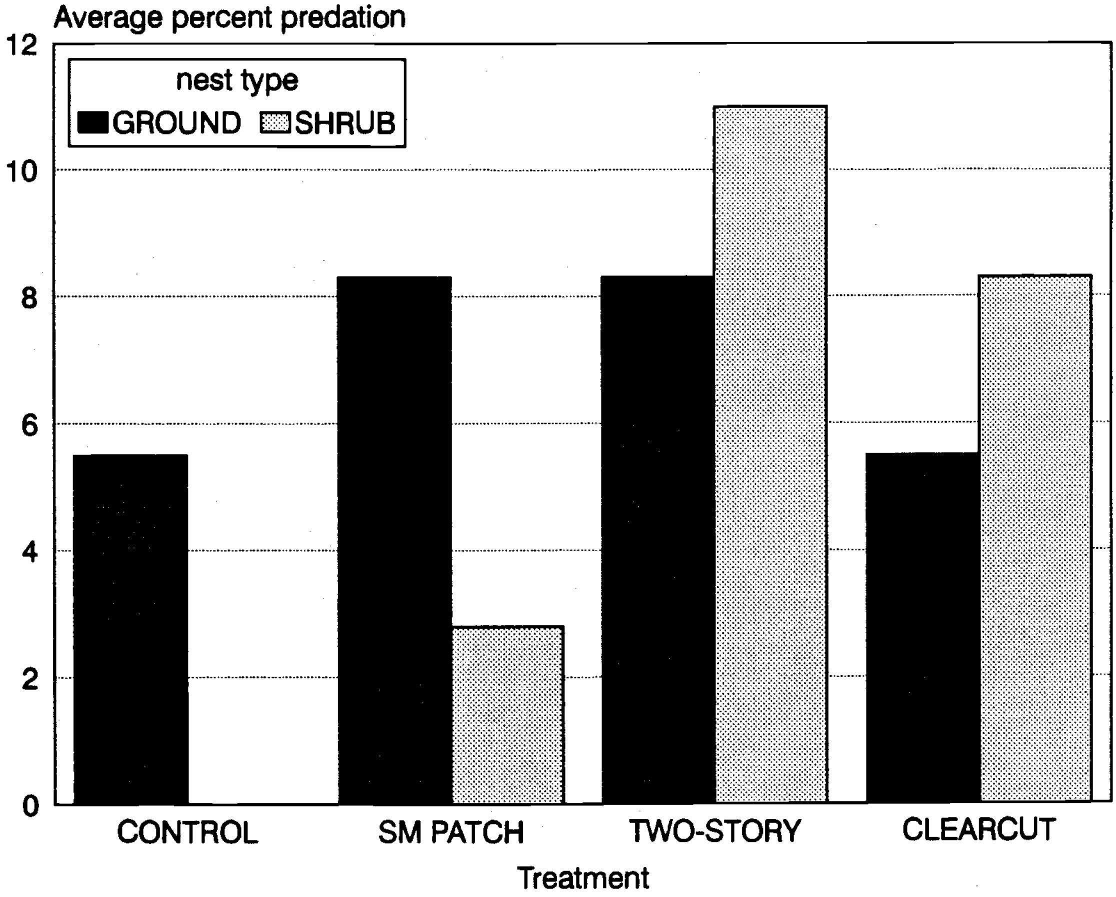

Figure 4.1. Average predation rates (%) on artificial ground and shrub nests in control stands (n=3) and stands harvested using even-aged or uneven-aged silvicultural systems (SM PATCH=group selection uneven-aged management with 1/3 of wood volume removed in 0.2-ha circular patches, n=6; TWO-STORY=two-story even-aged stands with 20 to 30 green trees > 53 cm dbh/ha remaining uniformly scattered through the stand, n=6; CLEARCUT=modified even-aged clearcut with 1.2 green trees > 53 cm dbh/ha remaining, n=6). Data from 2 nest predation trials were combined for analysis. P is the probability associated with differences in nest predation among treatments. For ground nests, P = 0.99; for shrub nests, P = 0.10. McDonald-Dunn Research Forest, June 2 - July 1, 1992.

Mammalian Nest Predators

Ground nest predation rates in clearcut, two-story, and small patch stands were similar to rates in control stands. About half of the disturbed nests had egg fragments or eggs with holes, indicating consumption by mammals rather than birds. Data from small mammal trapping indicated no detectable difference ($\underline{P} = 0.4$) in small rodent nest predators (deer mouse [*Peromyscus maniculatus*] and Townsend's chipmunk). I did not detect a difference among treatments for Townsend's chipmunks or Douglas' squirrel observations recorded during bird counts ($\underline{P} > 0.17$) after harvest, although chipmunks appeared to be more abundant in open stands (two-story and clearcuts) while Douglas' squirrel appeared more abundant in group selection stands (Chambers 1996). The abundance of rodent egg predators in all silvicultural treatments may account for the lack of difference in predation rates of ground nests among treatments.

DISCUSSION

Alternative silvicultural systems such as group selection and two-story treatments may soon dominate stand management in the Pacific Northwest because of wildlife and aesthetic concerns and new management guidelines (Forest Ecosystem Management Assessment Team 1993). Preliminary data from the eastern Central Oregon Coast Range suggest that two-story stands resemble clearcuts in their bird community structure and composition, while group selection stands that remove 1/3 of the stand's timber volume in small (0.2-ha) openings may continue to support populations of many mature forest bird species following timber extraction (Chambers 1996).

Ground nests were equally vulnerable in all stand types, presumably due to abundance of mammalian predators. Species that build open cup nests on the ground (e.g., dark-eyed junco [*Junco hyemalis*], rufous-sided towhee [*Pipilo erythrophthalmus*], white-crowned sparrow, song sparrow [*Melaspiza melodia*]) would therefore be susceptible to predation in all treatments.

I found no evidence to suggest that ground or shrub nest predation rates in group selection stands might be higher than control stands. Shrub nest predation rates may be somewhat higher in two-story and clearcut stands however. Over 60% of the shrub nests disturbed were probably caused by avian predation since eggs were missing rather than fragmented. Green trees (1.2 to 30/ha) remaining in two-story and clearcut stands may serve as perch sites for avian predators. These stand types also have fewer vertical canopy layers, so search time by avian predators for active nests may be less than in uncut or group selection stands. Nichols and Wood (1993) also reported higher predation rates in two-story stands in a West Virginia study and speculated that overstory trees served as potential perch sites for avian predators such as crows and blue jays (*Cyanocitta cristata*).

I suggest that predation rates on artificial nests may be somewhat higher for shrub nests in clearcut and two-story stands, probably due to the effect of avian predators. Vega's (1993) shrub nests were disturbed in all treatments (clearcut, green tree retention, and mature forest control), but greatest in green-tree retention stands (47%) and clearcuts (24%) compared with control stands (6%). Vega (1993) also detected highest abundance of Steller's jays in green tree retention stands ($\underline{P} = 0.03$). Although Steller's jay abundance was lower in two story and clearcut stands in my study, these birds may have been more effective in detecting shrub nests due to the simplified structure of remaining vegetation (Chambers 1996).

My results are applicable to those birds nesting on or close to the ground in open cup nests since I placed nests only in the lower strata (≤ 3 m tall) of the stand. Rufous hummingbirds, dark-eyed juncos, white-crowned sparrows, rufous-sided towhees, Wilson's warblers (*Wilsonia pusilla*), orange-crowned warblers, MacGillivray's warblers, and American goldfinches used two-story stands as nesting habitat. In clearcuts, white-crowned sparrows, dark-eyed juncos, American goldfinches, rufous-sided towhees, orange-crowned warblers, and MacGillivray's warblers were commonly observed. Because of the higher predation rates experienced by shrub nesters in clearcut and two-story stands, these species may be particularly susceptible to predation. Common ground- and shrub-nesting birds in controls (dark-eyed junco, Wilson's warbler, Swainson's thrush) and group selection stands (dark-eyed junco, Wilson's warbler, Swainson's thrush, rufous-sided towhee, and orange-crowned warbler) seem at less risk from predation.

I assumed that my artificial nests simulated real nests, although there were no parent birds moving around the artificial nests in my stands. The presence of parent birds may act as an additional attractant for predators, since predators can reduce food search time by keying in on active nests. The artificial nest predation rates I found may actually be lower than is experienced by birds nesting in these stands.

Species such as Virginia opossums (*Didelphis virginiana*), raccoons (*Procyon lotor*), weasels (*Mustela* spp.), spotted skunks (*Spilogale gracile*), and striped skunks (*Mephitis mephitis*) also eat eggs or nestlings (Martin et al. 1951, Ratti and Reese 1988, Terborgh 1989) and could occur in Douglas-fir stands, but were not sampled in this study.

Hermit warblers (*Dendroica occidentalis*), western tanagers (*Piranga ludoviciana*), and other species that may nest higher in the canopy were not represented by this study. They may experience greater predation rates from avian predators in all silvicultural treatments since canopy volume and therefore nest search time is reduced. These data reflect predation rates in a small number of stands and are restricted to the eastern side of the Oregon Coast Range, although Vega's (1993) data reflect similar results for the western Cascade Mountains in Oregon.

Predation rates in my study were very low (7%) compared with other studies where rates averaged 30 to 80% (Yahner and Voytko 1989, Gibbs 1991, Yahner and Morrell 1991). This may indicate the difficulty nest predators may have in finding nests in the dense understory typical of the Oregon Coast Range. Alternative silvicultural systems such as group selection that affect only a portion (< 33%) of the stand probably provide better cover for shrub nesting birds in mature forests than do systems that remove greater amounts of timber and disturb vegetation cover to a greater extent.

CONCLUSIONS

A number of bird species are declining in Oregon (Sharp 1992, Marshall et al. 1992). These declines may be a result of habitat loss, pressure from exotic species, or increased susceptibility to predation. Alternative silvicultural systems may provide habitat for some of these species, although it appears shrub-nesting songbirds may be at higher risk of nest predation in two-story (green-tree retention) and modified clearcut stands. These stands apparently provide nesting habitat, but the trees retained in these stands may act as predator perch sites.

Overall predation rates were low ($\leq 27\%$) for this and Vega's (1993) study compared with eastern Unites States studies where rates were commonly > 40% (Yahner and Voytko 1989, Gibbs 1991, Yahner and Morrell 1991). Perhaps the complexity of vegetation typical in Pacific Northwest Douglas-fir forests prevents easy depredation, especially by avian predators. Predation rates may be lower since landscapes in this region remain largely forested rather than forest islands in agricultural or suburban settings.

The risk of nest predation appears to be relatively low in western Oregon Douglas-fir forests, although this conclusion is based on artificial nest predation rates and not active bird nests. Since two-story and modified clearcuts may offer long-term benefits to mature forest-associated species (e.g., dispersal habitat for northern spotted owl [*Strix occidentalis caurina*] or northern flying squirrel [*Glaucomys sabrinus*], feeding habitat for brown creepers [*Certhia americana*] and other bark foragers), treatments retaining trees and snags should not be excluded from forest management, although their placement on the landscape and juxtaposition with other stand types should be considered when assessing landscapes for viability of populations of shrub nesting birds. However, uneven-aged silvicultural systems such as small patch group selection harvesting should be considered since they appear to provide habitat for mature forest species without added risks of shrub nest predation.

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CONCLUSIONS

In Douglas-fir forests of the Oregon Coast Range, silvicultural treatments that represented alternatives to clearcutting created or retained features (e.g., vertical structure, snags) associated with late-successional forests. The 3 treatments we used (modified clearcut, two-story, and small patch group selection) represented different intensities of natural disturbances (heavy, heavy/moderate, and light, respectively). Vertebrate responses to these treatments indicated that a diversity of silvicultural treatments provided habitat for more species than any single treatment. Ten species tolerated light disturbances created by the small patch group selection treatment but not heavy to moderate disturbances of clearcuts and two-story stands. These species included a number of migratory species and species with restricted geographic ranges and habitat associations (e.g., hermit warbler). Nine species were more abundant in two-story and clearcut stands than in unharvested or small patch stands. These species included a larger proportion of resident birds that were habitat generalists (e.g., found in urban, suburban, or agricultural settings) (e.g., white-crowned sparrows). To provide habitat for the range of diurnal breeding birds and small mammals of the Oregon Coast Range, a variety of stand conditions should be maintained.

Two-story stands may provide shrub nesting habitat for a variety of bird species. However, because rates of artificial shrub nest predation were higher in these stands, reproductive success rate should be monitored to insure habitat is adequate to maintain bird populations.

The silvicultural treatments we used represented stand management techniques for multiple resource values (timber and wildlife habitat); however, they represent only 3 alternatives. Different levels of green tree retention and aggregation of remaining trees could affect the type of wildlife habitat created in a stand. Placement of stands on the landscape should be considered with respect to their effects on population viability and dispersal habitat. Silvicultural treatments designed to produce wildlife habitat should be monitored and treatments adapted, as needed, to insure management goals are met.

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APPENDICES

Appendix A. Community measures, bird abundance (number of observations/5 ha) and average number of sightings and/or vocalizations for 3 mammal species by treatment and year (YR1=pretreatment year, YR2=first year post-harvest, YR3=second year post-harvest) for animals (n ≥ 30 observations) observed ≤ 75 m from VCP, McDonald-Dunn Forest, Oregon Coast Range, 1990 - 1992. Community similarity measures are comparisons between pretreatment and post-treatment years. For community similarity measures, YR2=pretreatment v. 1-year post-treatment comparison; YR3=pretreatment v. 2-years post-treatment comparison. Treatments were large patch group selection (2 stands), strip cut (1 stand), and wedge cut (1 stand). Standard error (in parentheses) is given for large patch treatment. Species are arranged taxonomically. See text for scientific names.

	LARGE PATCH						STRIP CUT			WEDGE CUT		
COMMUNITY MEASURE	YR1		YR2		YR3		YR1	YR2	YR3	YR1	YR2	YR3
Community Measures												
Total abundance	205	(14)	180	(10)	148	(8)	213	179	147	201	205	152
Simpson diversity	0.92	(0)	0.92	(0)	0.94	(0.02)	0.91	0.92	0.93	0.90	0.90	0.93
Simpson equitability	0.97	(0.01)	0.97	(0.01)	0.97	(0.01)	0.97	0.95	0.97	0.95	0.95	0.96
Species richness	22	(3)	22	(2)	27	(2)	19	26	24	19	19	25
Community Similarity												
Percent similarity			67	(8)	60	(6)		68	68		70	59
Jaccard coefficient			0.63	(0.07)	0.64	(0.11)		0.61	0.65		0.65	0.52
Morisita's index			0.86	(0.09)	0.77	(0.09)		0.87	0.86		0.85	0.76

Appendix A, continued.

	LARGE PATCH						STRIP CUT			WEDGE CUT		
SPECIES	YR1		YR2		YR3		YR1	YR2	YR3	YR1	YR2	YR3
Bird Species												
Rufous hummingbird	0	(0)	1	(1)	0	(0)	0	0	0	0	0	0
Northern flicker	1	(1)	1	(1)	3	(3)	0	0	0	0	0	0
Red-breasted sapsucker	3	(3)	4	(4)	9	(2)	0	0	0	0	1	1
Hairy woodpecker	1	(1)	0	(0)	1	(1)	2	0	2	3	0	1
Pacific slope flycatcher	22	(5)	11	(3)	6	(3)	26	21	12	30	24	20
Steller's jay	4	(1)	11	(4)	4	(3)	4	4	6	8	3	5
Gray jay	0	(0)	0	(0)	0	(0)	0	0	0	1	0	0
Chestnut-backed chickadee	19	(6)	18	(3)	6	(1)	20	18	14	21	34	8
Bushtit	1	(1)	0	(0)	1	(1)	0	0	0	0	0	0
Brown creeper	6	(4)	6	(6)	7	(2)	9	13	4	10	9	15
Red-breasted nuthatch	9	(1)	4	(1)	6	(1)	9	2	12	6	9	8
House wren	0	(0)	4	(4)	5	(5)	0	5	12	0	0	6
Winter wren	17	(1)	21	(0)	13	(12)	8	5	2	41	15	14

Appendix A, continued.

	LARGE PATCH						STRIP CUT			WEDGE CUT		
SPECIES	YR1		YR2		YR3		YR1	YR2	YR3	YR1	YR2	YR3
Bird Species												
Golden-crowned kinglet	7	(1)	1	(1)	4	(2)	12	2	5	8	9	2
Swainson's thrush	14	(2)	13	(3)	10	(6)	10	6	1	4	4	7
American robin	10	(5)	12	(7)	5	(4)	11	21	6	8	4	3
Orange-crowned warbler	13	(6)	3	(3)	9	(4)	12	4	4	8	0	4
Black-throated grey warbler	8	(2)	4	(0)	2	(1)	3	7	2	7	2	0
Hermit warbler	25	(3)	10	(9)	6	(4)	30	6	6	21	28	3
MacGillivray's warbler	3	(3)	5	(5)	8	(1)	0	1	8	0	0	2
Wilson's warbler	22	(7)	15	(8)	15	(1)	14	2	6	14	20	7
Western tanager	10	(2)	5	(1)	4	(1)	9	14	7	7	1	10
Black-headed grosbeak	3	(3)	2	(0)	2	(1)	2	0	2	0	0	2
Rufous-sided towhee	2	(2)	7	(3)	4	(2)	0	7	0	0	1	2

Appendix A, continued.

	LARGE PATCH						STRIP CUT			WEDGE CUT		
SPECIES	YR1		YR2		YR3		YR1	YR2	YR3	YR1	YR2	YR3
Bird Species												
Dark-eyed junco	9	(2)	20	(4)	14	(4)	29	29	22	2	22	20
White-crowned sparrow	0	(0)	2	(2)	4	(3)	0	2	5	0	4	8
Brown-headed cowbird	0	(0)	0	(0)	1	(1)	0	1	3	0	0	0
Purple finch	2	(0)	1	(0)	1	(1)	2	1	0	1	3	0
Red crossbill	0	(0)	0	(0)	1	(1)	0	0	0	0	0	0
American goldfinch	0	(0)	0	(0)	1	(1)	0	0	2	0	1	1
Evening grosbeak	1	(1)	0	(0)	3	(3)	3	0	0	9	0	2
Mammal Species												
Douglas' squirrel	2	(2)	3	(3)	3	(3)	1	0	0	2	1	0
Townsend's chipmunk	0	(0)	1	(1)	1	(1)	0	0	0	0	1	0
Black-tailed deer	1	(1)	0	(0)	1	(1)	0	0	0	0	0	0

Appendix B. Results of winter bird counts in 3 silvicultural treatments and control stands.

INTRODUCTION

The availability of winter habitat may influence successful breeding and population persistence of resident bird species (Huff et al. 1991). Winter may be a more critical period for survival because of limitations or changes in seasonal food and cover resources. In fact, some species exhibit morphological adaptations or behavioral characteristics that seem better adapted to survival in winter than breeding habitat (e.g., some finch species are insectivores during the breeding season but granivores during the winter and have beaks better adapted for handling seeds) (Salomonson and Balda 1977, Cody 1985).

Because birds may vary habitat use seasonally (Cody 1985, Manuwal and Huff 1987, Hagar 1993), it is important for land managers to understand their habitat needs both during spring breeding and winter seasons to assure adequate habitat is available (Morrison et al. 1985). Cover and food resources provided by late-successional forests may provide better winter habitat than early or mid-seral stages. Diurnal bird species richness and/or total abundance was higher during winter in old-growth forest stands (250- to 600-year-old) than young (42- to 75-year-old), mid-seral (65- to 140-year-old), or mature (105- to 165-year-old) stands in the Pacific Northwest (Manuwal and Huff 1987, Huff et al. 1991). In mixed conifer forests of the Sierra Nevada, overwintering birds used areas with heavier upper and mid-canopy cover as compared to summer habitat use (Morrison et al. 1986).

This task of identifying appropriate winter and breeding habitat is complicated by changes in forest composition and structure caused by human-induced disturbances. A variety of forest management techniques (e.g., controlled burning, thinning, even-aged and uneven-aged regeneration systems) may produce very different effects on vertical and horizontal vegetation layers. Since this may have an important influence on bird communities (MacArthur and MacArthur 1961, Roth 1976), it is necessary to examine effects of disturbances.

Changes in forest management policies in the Pacific Northwest have resulted in acceptance of a broader array of management alternatives to clearcutting on state and federal forest lands (Oregon Forest Practices Act, Forest Ecosystem Management Assessment Team 1993). Even-aged, two-aged, and uneven-aged silvicultural treatments that retain some features of old-growth forests (e.g., snags, logs, large diameter trees) but still allow some timber extraction may create stand structures that maintain habitat for birds. In a comparison of breeding bird response to 3 alternative silvicultural treatments: uneven-aged small patch group selection, two-story, and modified clearcut and controls; some bird species reached highest abundance in clearcut and two-story stands (e.g., white-crowned sparrow [*Zonotrichia leucophrys*], rufous-sided towhee [*Pipilo erythrophthalmus*]) while others reached highest abundance in uncut control or small patch group selection stands (e.g., winter wren [*Troglodytes troglodytes*]) (Chambers 1996). Use of these treated stands may shift during the winter, however. If birds favor areas with greater structural and compositional complexity, they might be expected to be most abundant in control or small patch group selection stands, which retain all (controls) or most (small patch group selection) of the trees and shrubs originally present in the stand. Based on this hypothesis, the objective of this study was to determine whether there were differences among resident bird use of 3 silviculturally-treated stands and control stands during winter.

STUDY AREA

Twelve stands were selected for study within Oregon State University's McDonald-Dunn Forest, a 5261-ha experimental forest located on the eastern of edge of the Coast Range, north and northwest of Corvallis. Three blocks of 4 stands each were located near (1) Lewisburg Saddle: Township 11S, Range 5W, Willamette Baseline and Meridian, portions of Sections 4, 8, 9, 16, 17; (2) Peavy: Township 10S, Range 5W, Willamette Baseline and Meridian, portions of Sections 25, 35, 36; and (3) Dunn: Township 10S, Range 5W, Willamette Baseline and Meridian, portions of Sections 14, 22, 23, 27. Stands were 5 to 18 ha in size. Douglas-fir comprised $\geq$ 64% basal area prior to harvest; in most stands (25 of 33 stands), it represented $\geq$ 80% total basal area. Species including grand fir (*Abies grandis*), 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*) comprised the remaining basal area.

Treatments applied to the Lewisburg Saddle, Peavy, and Dunn blocks consisted of 1 control (uncut) stand, 2 to 6 small patch group selection stands (1/3 volume removed in 0.2-ha circular patches), 2 two-story stands (3/4 volume removed with remaining green trees [20 to 30/ha] scattered uniformly throughout the stand), and 6 modified clearcut stands (1.2 green trees/ha retained). Harvesting began in fall 1989, and was completed by early spring 1991. One block was cut per year: Lewisburg Saddle block: 1989; Peavy block: 1990; Dunn block: 1991. One stand of each treatment was selected from each block for winter bird study, so for statistical analyses, sample sizes for each treatment were: control: n = 3; small group selection: n = 3, two-story: n = 3, modified clearcut: n = 3.

METHODS

Bird Data Collection

Winter birds were sampled from December, 1994 through March, 1995, using the modified variable circular plot (VCP) method described by Reynolds et al. (1980). Three VCPs were established in each stand with VCP centers a minimum of 100 m from the stand edge and other VCP centers. Each VCP was visited 3 times between 0900 and 1600. Order of visitation was alternated among stands to account for daily variation in bird activity. Counts were halted by rain or winds > 15 km/h.

Counts began 2 minutes after arrival at the VCP station to allow for resumption of normal bird activity. Each count lasted 8 minutes, during which time birds observed in or adjacent to the stand were identified to species, their distance (m) from the VCP center estimated, and their approximate location mapped. Distances were recorded to the nearest meter for birds $\leq$ 10 m from VCP station, nearest 5 m for birds >10 m but $\leq$ 50 m, nearest 10 m for birds > 50 m. One observer conducted all sampling.

Statistical Analyses

All individuals observed within each stand were included in analyses. Repeat observations and records of birds observed flying over stands were recorded but not used in analyses. Bird data were transformed using a log transformation [$\log_{10}$(bird abundance + 1)] to meet assumptions of normal distribution and equal variance (Sabin and Stafford 1990).

Analysis of variance (SAS Institute Inc. 1989) was used to determine if there were differences among treatments in total bird abundance (average number of observations/VCP/day) and individual species abundances (average number of observations/VCP/day) for species with $\geq$ 20 total observations. If treatment differences were significant ($P < 0.10$), multiple means comparisons were made using Scheffe's test with alpha at 0.10 (SAS Institute Inc. 1989).

RESULTS

A total of 303 birds representing 30 species were observed during the 1994-1995 winter bird counts (Table 1). Most abundant species were winter wren (25%), golden-crowned kinglet (*Regulus satrapa*) (13%), song sparrow (*Melaspiza melodia*) (10%), Steller's jay (*Cyanocitta stelleri*) (8%), rufous-sided towhee (8%), and dark-eyed junco (*Junco hyemalis*) (7%).

Bird abundance differed among treatments and was highest in control stands and lowest in clearcut stands ($\underline{P} = 0.02$). Scheffe's means separation test indicated control and small patch stands were more similar in bird abundance and two-story and clearcut stands were more similar (Table 2). Species richness appeared to be higher in small patch stands, although richness was not statistically tested to detect treatment differences (Table 2).

Six species were observed frequently ($n > 20$ observations) enough for analysis. Of these, 4 species responded to treatment ($P < 0.05$): golden-crowned kinglet, Steller's jay, rufous-sided towhee, and dark-eyed junco. We were unable to detect differences among treatments for winter wrens and song sparrows ($\underline{P} > 0.2$).

Golden-crowned kinglet observations were higher in control and small patch stands compared with two-story and clearcut stands ($\underline{P} = 0.0001$). Steller's jays were most abundant in control stands and small patch stands, lower in two-story stands and almost absent in clearcut stands ($\underline{P} = 0.04$). Dark-eyed junco observations were higher in harvested treatments compared with control stands ($\underline{P} = 0.0009$). Rufous-sided towhees were more abundant in harvested stands ($\underline{P} = 0.003$).

Table 1. Birds observed during winter counts (December 1994 - March 1995) representing 303 observations, McDonald-Dunn Research Forest, Benton County. Silvicultural treatments are control (CN), small patch (SP), two-story (TS), and modified clearcut (CC).

	Treatment				
Common Name[1]	CN	SP	TS	CC	Total
winter wren	25	24	15	11	75
golden-crowned kinglet	22	16	1	0	39
song sparrow	2	5	12	11	30
Steller's jay	7	7	8	2	24
rufous-sided towhee	0	4	14	6	24
dark-eyed junco	0	9	9	4	22
American robin *Turdus migratorius*	1	4	3	5	13
northern flicker *Colaptes auratus*	2	2	6	2	12
black-capped chickadee *Parus atricapillus*	4	2	1	1	8
red-breasted nuthatch *Sitta canadensis*	4	3	1	0	8
red-breasted sapsucker *Sphyrapicus ruber*	0	2	1	3	6
red-tailed hawk *Buteo jamaicensis*	1	1	0	4	6
Hutton's vireo *Vireo huttoni*	1	3	1	1	6
varied thrush *Ixoreus naevius*	2	2	0	1	5
chestnut-backed chickadee *Parus rufescens*	2	1	0	0	3
pileated woodpecker *Dryocopus pileatus*	2	0	0	0	2
hairy woodpecker *Picoides villosus*	0	1	1	0	2
house wren *Troglodytes aedon*	0	0	1	1	2
American crow *Corvus brachyrhynchos*	0	1	1	0	2
gray jay *Perisoreus canadensis*	1	1	0	0	2

Table 1, Continued.

Common Name	CN	SP	TS	CC	Treatment Total
brown creeper *Certhia americana*	2	0	0	0	2
pine siskin *Carduelis pinus*	0	1	0	1	2
northern pygmy-owl *Glaucidium gnoma*	1	0	0	0	1
great-horned owl *Bubo virginianus*	0	0	0	1	1
sharp-shinned hawk *Accipiter striatus*	0	0	1	0	1
bushtit *Psaltriparus minimus*	0	1	0	0	1
downy woodpecker *Picoides pubescens*	0	0	0	1	1
European starling *Sturnus vulgaris*	0	0	0	1	1
white-crowned sparrow	0	1	0	0	1
evening grosbeak *Coccothraustes vespertinus*	0	0	1	0	1

[1] Scientific names are listed after common name in the table or can be found in the text.

Table 2. Abundance (observations/VCP/day) of winter birds in 3 silvicultural treatments (small patch group selection, two-story, modified clearcut) and control stands averaged over 3 counts conducted between December 1994 and March 1995, McDonald-Dunn Research Forest, Central Coast Range, Oregon. Untransformed means and standard errors (SE) are reported for each treatment for total bird abundance, species richness, and bird species with > 20 observations. P is the probability associated with the rejection of the null hypothesis that there is no difference among transformed ($\log_{10}$[abundance+1]) means. Means that differed significantly ($P < 0.1$) using Scheffe means separation tests are designated with different letters.

	CONTROL		SMALL PATCH		TWO-STORY		CLEARCUT		
SPECIES[1]	Mean	SE	Mean	SE	Mean	SE	Mean	SE	P
Bird abundance	6.6^{A}		7.4^{AB}		4.5^{BC}		3.6^{C}		0.02
Species richness	16		22		17		17		
Steller's jay	4^{A}	1	3^{AB}	1	1^{AB}	1	0.3^{B}	0.3	0.04
Winter wren	9	1	8	2	5	1	4	3	0.3
Golden-crowned kinglet	29^{A}	3	20^{A}	3	1^{B}	1	0^{B}	0	0.0001
Rufous-sided towhee	0^{A}	0	1^{AB}	0.3	4^{AB}	1	3^{B}	1	0.003
Song sparrow	1	1	2	1	6	2	5	3	0.2
Dark-eyed junco	0^{A}	0	6^{B}	1	11^{B}	4	9^{B}	3	0.0009

[1] Scientific names for species are Steller's jay: *Cyanocitta stelleri*; winter wren: *Troglodytes troglodytes*; golden-crowned kinglet: *Regulus satrapa*; rufous-sided towhee: *Pipilo erythrophthalmus*; song sparrow: *Melaspiza melodia*; and dark-eyed junco: *Junco hyemalis*.

DISCUSSION

Many bird species vary their use of habitat between seasons because of changes in habitat structural features that affect availability of cover and roost sites (Morrison et al. 1986, Huff et al. 1991). Quantity and quality of food resources also may vary seasonally, and birds may alter foraging locations or patterns to obtain food (Martin et al. 1951, Conner 1980, Hutto 1981, Lewke 1982, Morrison et al. 1985).

Following harvest, I found breeding bird abundance higher in control (uncut) and small patch group selection stands than in two-story and clearcut stands (Chambers 1996). Bird communities in control and small patch stands were dominated by migratory bird species while resident bird species were more abundant in two-story and clearcut stands (Chambers 1996). During the winter season, resident bird abundance was higher in control and small patch stands, lower in two-story and clearcut stands.

Two forest-associated species (golden-crowned kinglet and Steller's jay) were lowest in abundance in clearcut stands. Golden-crowned kinglets were most abundant in control and small patch stands. This pattern was similar to that found during the breeding season (Chambers 1996). Morrison et al. (1986) also found no difference between golden-crowned kinglet winter and summer habitat use in a mixed conifer forest in Sierra Nevada, California. Marcot (1985) and Huff et al. (1991), however, did find a seasonal shift in habitat use by golden-crowned kinglets in Douglas-fir forests in the Pacific northwest. Marcot (1985) found golden-crowned kinglets were more abundant in sawtimber stands during breeding season, but during rest of year their density was highest in shrub-sapling stages. Huff et al. (1991) found kinglets more abundant in mid- than late-seral stands during the winter. The two-story and clearcut stands I studied were recently harvested (1- to 2-years prior) and were structurally simpler than control and small patch stands (Chambers 1996). Probably conditions in two-story or clearcut stands did not provide adequate cover or food for kinglets.

Steller's jays were more abundant in control and small patch stands, lower in two-story stands and almost absent in clearcut stands; these patterns were also detected during the breeding season (Chambers 1996) so it appeared Steller's jays did not alter habitat use seasonally.

No treatment response was detected for winter wren, a forest associate that has been shown to be sensitive to forest fragmentation (Rosenberg and Raphael 1986, Lehmkuhl and Ruggiero 1991, McGarigal 1993). However, winter wrens were more abundant in control and small patch stands during the breeding season (Chambers 1996), indicating a seasonal shift in habitat use. In a California study, Barrows (1986) found winter wrens almost exclusively in old-growth habitat during the breeding season, but more randomly distributed among stands of different seral stages in winter. Winter wrens appeared to be more selective of breeding sites.

Two species (rufous-sided towhee and dark-eyed junco) associated with early seral stages or disturbed areas differed in response to silvicultural treatment during the winter season. Rufous-sided towhees were observed most frequently in clearcuts, but also may have been more abundant in other treatments (two-story and group selection). During the breeding season, rufous-sided towhees were most abundant in two-story and clearcut stands (Chambers 1996). Trends in the winter data indicate this species may be more of a habitat generalist during the winter season. Perhaps shrub cover for nesting is more available in open stands (e.g., clearcut and two-story stands) but winter needs for food and cover can be met in small patch stands as well.

During the winter, dark-eyed juncos were more abundant in clearcut, two-story, and small patch stands than in control stands. I found dark-eyed juncos abundant in all stand types (including control stands) during the breeding season, however (Chambers 1996). They seemed more selective of winter habitat, using areas with more disturbance.

No difference in song sparrow abundance was detected among treatments during the winter season. I did not have an adequate sample size during the breeding season to test for treatment differences (Chambers 1996).

Cody (1985) suggested that wintering species may shift to niches vacated by migratory or summer visitors that winter elsewhere. I did detect seasonal shifts for some species. During the winter, some species became more selective (e.g., dark-eyed junco), some maintained the same degree of selectiveness (e.g., golden-crowned kinglet), others became less selective (e.g., winter wren). Some species were more abundant in harvested stands, others selected control stands.

Manuwal and Huff (1987), Morrison et al. (1986), and Huff et al. (1991) have suggested that late-successional forests or those with heavy upper and mid-story canopies provide structural features that may offer better winter habitat to resident birds. Although I did not find greater selection for late-successional forest, total bird abundance was higher in control and small patch stands. These data indicate a need for a variety of seral stages on a landscape to provide habitat for all winter resident bird species, but stands that are more similar to mature forest may provide habitat for higher numbers of individuals.

MANAGEMENT RECOMMENDATIONS

In the Pacific northwest, birds were more abundant in late-successional stands than in younger forest seral stages (Manuwal and Huff 1987, Huff et al. 1991). Huff et al. (1991) found total winter bird abundance in late-seral stands at least twice that of mid-seral stands. I found total winter bird abundance 1.5 to 2 times higher in control and small patch stands than in two-story or clearcut stands. Retaining late-successional forest stands may be particularly important in areas being managed under short (40 to 80 year) rotations and planted with a single tree species since structure and composition may be much simpler than late-successional forests. Habitat selected by some birds may never develop under these management conditions (Morrison et al. 1986). However, some bird species were more abundant in clearcuts and two-story stands. Maintaining a variety of seral stages may benefit species such as rufous-sided towhees and dark-eyed juncos.

Although stand conditions in two-story and clearcut treatments in my study did not currently provide mature forest structure, they retained elements (snags, logs, large trees) of old-growth forests and added to stand-level structural complexity. These features may help provide habitat for winter birds that use late-successional forest earlier than traditional clearcuts. Treatments that develop late-successional characteristics more quickly or retain structural and compositional complexity may be used by more bird species. They should be considered when developing stand prescriptions.

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Appendix C. Mean and standard error (in parentheses) by treatment and year (YR1=pretreatment year, YR2=first year post-harvest, YR3=second year post-harvest) for habitat variables.

HABITAT VARIABLE	CONTROL			SMALL PATCH			TWO-STORY			CLEARCUT		
	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3	YR1	YR2	YR3
Conifer Basal Area (m^2/ha)	41 (1)	39 (6)	42 (6)	38 (3)	29 (3)	28 (4)	38 (3)	12 (2)	11 (2)	40 (3)	2 (1)	0.5 (0.5)
Snag Basal Area (m^2/ha)	3 (1)	4 (1)	3 (1)	3 (1)	2 (1)	2 (1)	3 (1)	2 (1)	2 (1)	3 (1)	3 (2)	4 (1)
Herbaceous Cover (%)	60 (3)	64 (4)	59 (3)	53 (4)	50 (3)	51 (3)	44 (4)	39 (8)	43 (8)	54 (8)	52 (4)	46 (11)
Wood Vine Cover (%)	19 (5)	16 (6)	16 (6)	24 (4)	23 (3)	20 (3)	26 (4)	24 (5)	28 (8)	27 (5)	33 (4)	28 (3)
Hazelnut Cover (%)	10 (5)	10 (3)	14 (6)	11 (3)	8 (1)	11 (1)	14 (5)	4 (1)	8 (1)	9 (4)	2 (1)	2 (0)
Large Conifers (#/ha)	226 (70)	286 (10)	337 (38)	258 (45)	242 (32)	207 (25)	341 (83)	99 (19)	102 (19)	414 (83)	13 (6)	3 (3)
Large Hardwoods (#/ha)	3 (3)	22 (16)	10 (6)	10 (3)	10 (3)	13 (6)	13 (6)	0 (0)	0 (0)	19 (13)	0 (0)	3 (3)
Small Snags - Decay 1 (#/ha)	4 (3)	4 (1)	7 (5)	5 (3)	5 (1)	8 (1)	3 (1)	1 (0)	2 (1)	6 (2)	1 (1)	2 (2)
Small Snags - Decay 2-3 (#/ha)	6 (4)	7 (1)	18 (9)	10 (5)	10 (2)	16 (3)	18 (9)	5 (2)	4 (1)	13 (8)	5 (3)	5 (3)
Small Snags - Decay 4-5 (#/ha)	1 (1)	2 (1)	1 (0)	1 (0)	3 (1)	1 (0)	3 (1)	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)
Medium Snags - Decay 2-3 (#/ha)	4 (2)	8 (2)	10 (4)	6 (3)	5 (1)	8 (2)	8 (4)	4 (2)	3 (1)	6 (4)	2 (1)	2 (1)
Medium Snags - Decay 4-5 (#/ha)	2 (1)	3 (1)	2 (1)	1 (0)	1 (0)	1 (0)	2 (1)	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)
Large Snags - Decay 1 (#/ha)	1 (1)	1 (0)	1 (1)	0 (0)	1 (0)	0 (0)	0 (0)	2 (1)	2 (1)	1 (0)	2 (1)	2 (1)
Large Snags - Decay 4-5 (#/ha)	2 (1)	3 (1)	0 (0)	1 (0)	0 (0)	0 (0)	1 (0)	1 (0)	0 (0)	1 (0)	0 (0)	0 (0)
Medium Logs - Decay 2-3 (m/ha)	274(105)	162 (96)	197 (92)	134 (22)	140 (29)	73 (19)	140 (41)	108 (35)	73 (35)	239 (76)	118 (35)	99 (35)
Large Logs - Decay 1 (m/ha)	35 (25)	29 (22)	19 (13)	10 (6)	29 (13)	10 (6)	0 (0)	35 (16)	45 (19)	0 (0)	3 (3)	38 (19)
Large Logs - Decay 2-3 (m/ha)	10 (10)	38 (22)	0 (0)	35 (22)	45 (22)	16 (10)	35 (19)	13 (10)	19 (10)	51 (29)	41 (19)	10 (10)
Large Logs - Decay 4-5 (m/ha)	108 (51)	54 (22)	22 (16)	19 (10)	10 (6)	16 (10)	45 (25)	6 (6)	0 (0)	51 (22)	10 (6)	6 (6)
1 m Cover (%)	86 (6)	81 (3)	78 (3)	68 (5)	76 (4)	81 (3)	75 (4)	78 (10)	80 (5)	75 (3)	82 (5)	88 (2)
6 - 10 m Cover (%)	35 (1)	21 (7)	27 (7)	33 (4)	17 (2)	21 (1)	27 (5)	6 (2)	7 (1)	28 (9)	2 (1)	1 (0)
11 - 15 m Cover (%)	32 (2)	32 (3)	29 (4)	39 (5)	20 (3)	22 (1)	24 (5)	6 (2)	7 (1)	16 (5)	2 (1)	1 (0)
16 - 20 m Cover (%)	32 (4)	36 (4)	34 (6)	40 (4)	20 (3)	25 (2)	27 (6)	5 (2)	7 (1)	19 (9)	2 (1)	0 (0)
21 - 25 m Cover (%)	26 (9)	39 (3)	39 (9)	35 (5)	24 (3)	26 (2)	34 (6)	5 (2)	8 (1)	21 (11)	1 (1)	0 (0)
31 - 35 m Cover (%)	26 (13)	52 (9)	41 (6)	32 (7)	32 (4)	26 (3)	34 (7)	7 (2)	9 (2)	25 (11)	0 (0)	0 (0)
36 - 40 m Cover (%)	31 (9)	51 (6)	46 (2)	37 (7)	32 (5)	26 (3)	38 (3)	7 (2)	9 (2)	30 (10)	1 (1)	0 (0)
41 - 45 m Cover (%)	39 (0)	50 (6)	42 (5)	39 (5)	30 (4)	25 (3)	42 (4)	7 (2)	8 (2)	32 (9)	1 (1)	0 (0)
46 - 50 m Cover (%)	46 (7)	47 (3)	38 (10)	35 (8)	20 (5)	18 (3)	38 (10)	7 (1)	6 (2)	30 (14)	2 (1)	0 (0)
51 - 55 m Cover (%)	43 (11)	21 (9)	18 (10)	34 (8)	11 (4)	0 (0)	35 (12)	3 (1)	1 (1)	29 (15)	2 (1)	0 (0)
56 - 60 m Cover (%)	28 (26)	5 (5)	2 (2)	29 (8)	10 (4)	0 (0)	23 (14)	2 (1)	1 (1)	27 (16)	2 (1)	0 (0)

Appendix D. Repeated measures analysis of variance and orthogonal contrasts for pretreatment v. 1-year post-treatment (YEAR 1 - YEAR 2 CONTRAST) and 1-year post-treatment v. 2-years post-treatment (YEAR 2 - YEAR 3 CONTRAST) for habitat characteristics. Treatments are CN=control, SP=small patch, TS=two-story, and CC=clearcut. P is the probability associated with differences among treatment (TRT), year (YEAR), or treatment by year interaction (YEAR*TRT) effects.

							YEAR 1 CONTRAST[1]					YEAR 2 CONTRAST[1]				
									Contrast of CN with					Contrast of CN with		
HABITAT	YEAR*TRT		YEAR		TRT		MEAN	TRT	SP	TS	CC	MEAN	TRT	SP	TS	CC
VARIABLE	df	P	df	P	df	P	P	P	P	P	P	P	P	P	P	P
Conifer basal area	6, 12	0.0001		NA		NA	0.0002	0.0008	0.4	0.1	0.006	0.4	0.5			
Snag basal area	6, 12	0.6	2, 12	0.3	3, 6	0.2										
Herbaceous cover	6, 12	0.9	2, 12	0.9	3, 6	0.01										
Other herbaceous plant cover	6, 12	0.8	2, 12	0.7	3, 6	0.2										
Hazelnut cover	6, 12	0.009		NA		NA	0.02	0.05	0.3	0.03	0.02	0.002	0.07	0.1	0.04	0.9
Large conifers	6, 12	0.0001		NA		NA	0.0001	0.0001	0.08	0.008	0.001	0.4	0.1	0.05	0.3	0.05
Large hardwoods	6, 12	0.1	2, 12	0.5	3, 6	0.5										
Small snags - decay 1	6, 12	0.7	2, 12	0.3	3, 6	0.03	0.5	0.5				0.1	0.8			
Small snags - decay 2/3	6, 12	0.0003		NA		NA	0.02	0.005	0.4	0.003	0.1	0.05	0.2			
Small snags - decay 4/5	6, 12	0.06	2, 12	0.1	3, 6	0.2	0.1	0.08	0.5	0.05	0.09	0.3	0.5			
Medium snags - decay 2/3	6, 12	0.1	2, 12	0.7	3, 6	0.2										
Medium snags - decay 4/5	6, 12	0.03		NA		NA	0.06	0.07	0.9	0.09	0.1	0.9	0.8			
Large snags - decay 1	6, 10	0.8	2, 5	0.3	3, 6	0.8										
Large snags - decay 4/5	6, 12	0.7	2, 12	0.3	3, 6	0.09	0.4	1.0				0.1	0.2			
Medium logs - decay 2/3	6, 12	0.2	2, 12	0.002	3, 6	0.9	0.03	0.4				0.2	0.06	0.01	0.03	0.05
Large logs - decay 1	6, 12	0.5	2, 12	0.2	3, 6	0.8										
Large logs - decay 2/3	6, 10	0.4	2, 5	0.05	3, 6	1.0	0.5	0.6				0.1	0.5			
Large logs - decay 4/5	6, 10	0.3	2, 5	0.2	3, 6	0.5										

Appendix D, continued.

							YEAR 1 - YEAR 2 CONTRAST[1]					YEAR 2 - YEAR 3 CONTRAST[1]				
									Contrast of CN with					Contrast of CN with		
HABITAT	YEAR*TRT		YEAR		TRT		MEAN	TRT	SP	TS	CC	MEAN	TRT	SP	TS	CC
VARIABLE	df	P	df	P	df	P	P	P	P	P	P	P	P	P	P	P
0 - 1 m cover	6, 6	0.7	2, 6	0.3	3, 3	0.1	0.2	0.3				0.3	0.9			
6 - 10 m cover	6, 4	0.03		NA		NA	0.01	0.09	0.7	0.2	0.05	0.4	0.2			
11 - 15 m cover	6, 6	0.04		NA		NA	0.04	0.1	0.2	0.2	0.05	0.5	0.3			
16 - 20 m cover	6, 6	0.08	2, 6	0.02	3, 3	0.01	0.07	0.1	0.2	0.2	0.05	0.3	0.5			
21 - 25 m cover	6, 6	0.1	2, 6	0.05	3, 3	0.01	0.1	0.2				0.4	0.5			
31 - 35 m cover	6, 4	0.02		NA		NA	0.3	0.04	0.1	0.08	0.01	0.08	0.03	0.4	0.04	0.2
36 - 40 m cover	6, 4	0.02		NA		NA	0.03	0.03	0.1	0.05	0.01	0.5	0.3			
41 - 45 m cover	6, 4	0.1	2, 2	0.05	3, 3	0.05	0.03	0.1	0.3	0.2	0.05	0.8	0.7			
46 - 50 m cover	6, 6	0.4	2, 6	0.02	3, 3	0.07	0.07	0.5				0.9	0.7			
51 - 55 m cover	6, 4	0.1	2, 2	0.009	3, 3	0.007	0.02	1.0				0.5	0.5			
56 - 60 m cover	6, 6	0.3	2, 6	0.0001	3, 3	0.3	0.001	0.3				0.3	0.5			

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[1] Degrees of freedom (df) for contrasts are 1,6 for CTRST (contrast), 3,6 for C*TRT (contrast*treatment interaction) and 1,6 for contrast of CN with SP, TS, and CC.