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EFFECTS OF SILVICULTURAL MODIFICATIONS OF TEMPERATE RAINFOREST ON BREEDING AND WINTERING BIRD COMMUNITIES, PRINCE OF WALES ISLAND, SOUTHEAST ALASKA[1]

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Abstract. We inventoried breeding and wintering bird communities in four treatments of temperate rainforest on Prince of Wales Island, southeast Alaska during 1991–1992 and 1992–1993. The four forest treatments sampled included: (1) young growth (20 years) originating from clearcut logging with no silvicultural modification (non-modified), (2) young growth (20 years) precommercially thinned along uniformly-spaced thinning grids (thinned), (3) young growth (20 years) with gaps in the overstory canopy created by felling trees in 0.05-ha openings (gapped), and (4) virgin old growth (≥150 years). Of 16 common breeding bird species observed, six showed significant responses to young-growth modifications. One species was more abundant and two species were less abundant in thinned sites, while one species was more abundant and two species were less abundant in gapped sites than at least one of the other treatments. None of the three common wintering species of birds observed was influenced by young-growth modification. Breeding bird communities, in general, were less similar between young- and old-growth treatments than among young-growth treatments. Three of the 16 common breeding bird species were more abundant in old growth than each of the young-growth treatments and one uncommon species was detected almost exclusively in old growth during both the breeding and wintering seasons. Four other breeding bird species were more abundant in young-growth treatments than in old growth. Higher use of old growth by wintering birds was related to winter severity. To enhance habitat for wintering and breeding birds we recommend: (1) thinning young growth along variable-spaced grids to create additional canopy layers and improve snow-intercept properties of young growth for canopy-foraging birds, (2) retention of old-growth clumps in clearcuts for bird species associated with old-growth structure, and (3) long-term conservation of old-growth temperate rainforest for breeding and wintering birds positively associated with old growth.

Key words: breeding birds; canopy gaps; old growth; precommercial thinning; southeast Alaska; temperate rainforest; wintering birds; young growth.

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INTRODUCTION

The Tongass National Forest ("Forest") in southeast Alaska supports approximately ¼ of the world's remaining temperate rainforest (Alaback 1988, 1991, Samson et al. 1989, Beebe 1991). The Forest is characterized primarily by Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla,* Alaback 1991) that is distributed along the Alexander Archipelago extending from the Dixon Entrance (54° N) to the Yakutat forelands (59° N). Temperate rainforests in this region occupy a distinct climatic zone, consisting of high annual precipitation ($>$ 1,400 mm), cool (midsummer isotherm <16°C) and frequently overcast summers, dormant seasonal periods, and relatively infrequent fires (Alaback 1988, 1991).

Approximately 90% of 4 million ha of commercially productive temperate rainforest in the Forest is old growth (USDA Forest Service 1991). In general, old-growth temperate rainforest is characterized by multi-layered tree canopies, a preponderance of large trees, snags, and downed woody material. Abundant and diverse forb and shrub layers are usually present when the dominant and codominant trees are $\geq$ 150 years old (Alaback and Juday 1989, Capp et al. 1992). About 7% of the commercially productive old growth in the Forest has been harvested since the 1950s, with another 23% of the old-growth area to be harvested by the year 2150 (USDA Forest Service 1991). Most commercial logging has taken place in low-elevation forests ($<$ 245 m), because such areas are relatively accessible and contain the most productive timber (with the highest volume) in the Forest (Schoen et al. 1988, Alaback and Juday 1989). Logging in low-elevation forests has reduced habitat for breeding bird species (Kessler and Kogut 1985). Wintering birds also may have been affected because such forests accumulate less snowfall and are thermally more suitable to some bird species than high-elevation forests (Schoen et al. 1988, Suring et al. 1988).

Temperate rainforest that is managed intensively for timber production in southeast Alaska seldom develops the structural attributes important to bird species associated with old growth, such as large-diameter trees and snags within the limits of commercial forest cutting rotations ($\leq$ 100 years; Alaback 1982b, Alaback and Tappeiner 1991). Most managed forests in this region are characterized by relatively little structural complexity in both the understory and overstory vegetation as compared to old-growth forests (Alaback 1982a, 1982b). In some young forests, large trees, logs, and snags remain after logging, thus retaining structural complexity in these otherwise homogeneous forests. Young forests also have been modified silviculturally by precommercial thinning and by creation of small (0.05-ha) openings (gapping) within the overstory canopy to enhance tree growth and/or maintain understory vegetation for Sitka black-tailed deer (*Odocoileus hemionus sitkensis,* see DellaSala et al. 1994 for discussion of silvicultural modifications). Light thinning (trees thinned to 2.4 × 2.4 m spacing) to moderate thinning (3.7 × 3.7 m spacing) has been most effective in retaining understory layers, but the peak vegetation response is reached within 3–5 years following thinning (Alaback and Tappeiner 1984, Alaback and Herman 1988). Because both thinning and gapping involve structural changes in the forest canopy, they may alter forest microclimates and snow intercept properties of young forests and render them less suitable as habitat for wintering birds.

Approximately 29,000 ha of young (15 to 20 years old) naturally regenerating, temperate rainforest in the Forest have been gapped or thinned by the USDA Forest Service. Our main objective was to evaluate the effectiveness of gapping and thinning of young-growth forest for enhancing and/or maintaining habitat for breeding and wintering bird communities in an area intensively managed for timber production. We compared species composition and abundance of breeding and wintering birds among thinned, gapped, and non-modified young-growth treatments and between young growth and old growth, and identified structural attributes of treatments that explained patterns of occurrence and abundance of bird species. Because winter conditions in southeast Alaska vary substantially among years, we also examined whether annual variation in snowfall during two winters influenced abundance and distribution of wintering birds in each of the treatments.

STUDY AREA

The study area (Fig. 1) was located on the northern portion of Prince of Wales Island ("the Island;" 5,778 km^2) approximately 35 km northwest of Ketchikan, Alaska (56° 01′ N, 132° 51′ W). The Island is separated from the Alaskan

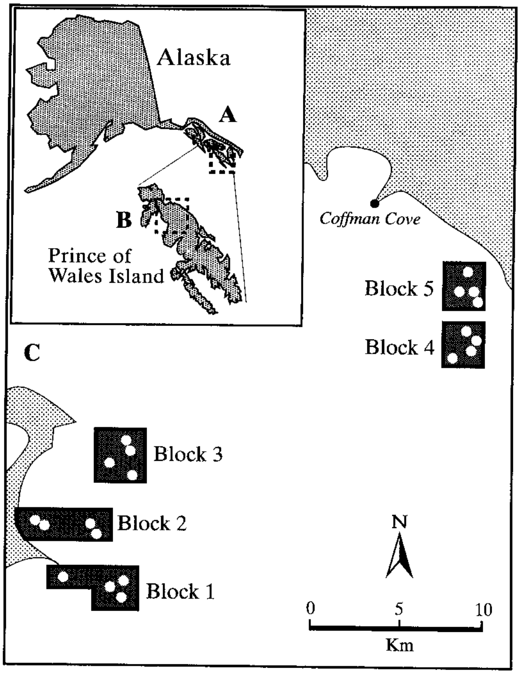

FIGURE 1. Location of study area in southeast Alaska (A), Prince of Wales Island (B), and geographic blocks (C) containing forest treatments (dots).

mainland by other mountainous islands and salt water channels at least 9 km in width. Vegetation on the Island was comprised primarily of western hemlock/blueberry (*Vaccinium* spp.) associations. Dominant tree species included western hemlock, Sitka spruce, western redcedar (*Thuja plicata*), and Alaska cedar (*Chamaecyparis nootkatensis*). Red alder (*Alnus rubra*) was associated with scarified soils and streambeds, and shore pine (*Pinus contorta*) was common in some small patches of muskeg. Dominant shrub species included devil's club (*Oplopanax horridum*), currants (*Ribes* spp.), salmonberry (*R. spectabilis*), blueberries, and rusty menziesia (*Menziesia ferruginea*). Common forbs included goldthreads (*Coptis* spp.), bunchberry (*Cornus canadensis*), deer cabbage (*Fauria cristagalli*), skunk cabbage (*Lysichitum americanum*), and five-leaf bramble (*Rubus pedatus*). Elevation on the Island ranged from 0–1,092 m above sea level.

METHODS

We divided the study area into five geographic blocks within which four sample sites were selected (n = 20 sample sites; Fig. 1). Geographic blocks were separated by 1–16 km and were selected because of ease of access and presence of sites meeting our sampling design criteria. All sites within a block were within 1 km of each other and were grouped according to similarities in physiographic factors (slope, elevation, aspect) reflective of the block. In general, sites within blocks 1 and 2 had the lowest elevations (0–122 m) and most gradual slopes (10–20%), those in blocks 3 and 4 had intermediate (61–229 m) elevations and moderate (15–30%) slopes, and those in block 5 had the highest (61–305 m) elevations and steepest (25–40%) slopes. Grouping sites by physiographic factors, rather than using a completely randomized approached, allowed us to partition some of the variability associated with site conditions from treatment effects and to expand the scope of inference to include a variety of forest conditions represented on the Island. Each block included the following experimental treatments: (1) young growth (20 years) originating from clearcut harvesting with no silvicultural modification (non-modified), (2) young growth (20 years) precommercially thinned along uniformly-spaced thinning grids (thinned), (3) young growth (20 years) with gaps in the overstory canopy created by felling trees in 0.05-ha openings (gapped), and (4) virgin old growth (≥ 150 years). All sites were within 1 km of logging roads and imbedded in a highly fragmented matrix consisting of recent clearcuts, regenerating- (20–40 years) and old-growth forests, salt water marshes, lakes, and streams. The Island's recent logging history and naturally low incidence of wildfires (Alaback 1988, 1991) have resulted in a lack of intermediate (50–149 years) forest age classes.

Each young-growth treatment had reseeded naturally and primarily to hemlock and spruce. Non-modified sites received no silvicultural modification post-harvest and averaged 70 ha (range = 50–95 ha). Thinned sites averaged 63 ha (range = 35–106 ha), were treated in 1987–1988 by thinning trees along uniformly-spaced (3.7 × 3.7 m or 4.3 × 4.3 m) thinning grids, and were sampled for vegetation and bird use 3–5 years post-thinning. Thinning produced piles of slash that were scattered throughout the site. Gapped sites averaged 59 ha (range = 36–83 ha), individual canopy gaps averaged 0.05 ha and gap density ranged from 0.60 to 0.86 gaps/ha. Gaps were created in 1988–1989 by felling trees along the perimeters of existing natural gaps, or creating new openings by tree removal, and were sampled 2–4 years post-gapping. Gap sizes most closely resembled natural gaps caused by blowdown of large trees, which is a common disturbance throughout the region. Slash produced by the creation of canopy gaps was left within each gap. Old-growth sites averaged 75 ha (range = 39–106 ha) and met the regional criteria for old-growth characteristics (Capp et al. 1992).

Vegetation, snow depths, and avian communities were sampled at 5 count point stations at each site. Count points were at least 50 m from the nearest edge and were spaced at random distances of 150 to 300 m along a 1,500-m transect established as part of a related study (DellaSala et al. 1994). A minimum distance between count stations of 150 m was chosen to minimize the probability of counting the same bird at multiple stations (Reynolds et al. 1980).

VEGETATION SAMPLING

One nested, circular vegetation plot was positioned in each of four cardinal directions, at random distances of 10 to 40 m from the center of each of the five count stations in each site (n = 20 plots/site). Plots in old-growth had a 10-m, 5-m, and two 2-m radius; in young growth there was a 5-m and two 1-m radius plots. Smaller plots were used in young growth because of the denser tree spacing and higher conifer stem densities relative to old growth. At each plot, we recorded 15 variables: stem densities (stems/ha) of conifers and snags (> 2 m tall) in three size classes, small (6–35 cm dbh), medium (36–55 cm dbh), and large (> 55 cm dbh); stem densities of hardwoods (small size class only); numbers of tree species; tree and shrub height (m); percent conifer cover; and percent cover of shrubs, forbs, and slash in two depth categories, < 50 cm and ≥ 50 cm. Ten-m radius plots in old growth and 5-m radius plots in young growth were used to record tree and snag densities, dbh in size classes, tree height, and percent tree-canopy cover. Tree-canopy cover was estimated by sighting through an ocular tube (James 1971) for the presence of vegetation from five sample points (plot center and four cardinal directions) located within each vegetation plot. Average tree height was estimated by measuring the heights of two dominant/codominant trees nearest plot center using a clinometer. Five-m radius plots (in both old-growth and young-growth sites) were used to estimate percent shrub cover and shrub height. Vegetation recorded in the small (1- or 2-m radius) plots included percent forb and slash cover.

We also mapped canopy gaps and patches of residual old-growth trees in young-growth sites from current (1991) aerial photos. Residual trees were identified on aerial photos as isolated clumps of unharvested trees taller (> 15 m) than the surrounding canopy of young-growth sites. Residual tree clumps were mapped as polygons; area occupied by clumps was calculated using the ARC/INFO GIS software. Canopy gaps were mapped from aerial photos at a minimum scale of 0.05 ha; no distinction was made between natural and artificial gaps. Mapped locations of gaps and residual tree clumps were verified opportunistically while walking between count stations. Once verified, the GIS was used to calculate distances from each count station to the nearest gap.

AVIAN SAMPLING

Avian communities were surveyed four times at each site during one-week intervals in the breeding (1 June to 23 June) and wintering (7 December to 29 February) seasons of 1991–1992 and 1992–1993. Surveys were conducted at sunrise during the breeding (03:30 and 04:00) and wintering (07:30–08:30) seasons and continued for 3–4 hours and 5–6 hours after sunrise in each season, respectively. No surveys were conducted during heavy precipitation or high winds. Sites within a block were surveyed on the same day and the order in which count stations were visited within sites was rotated systematically to help reduce biases associated with diurnal variations in bird activity (Robbins 1981).

We estimated bird abundance by counting all birds detected at each count point during an 8- and 10-min count period in the breeding and wintering seasons, respectively. We assumed that 8-to 10-min count periods were sufficient to detect the majority of bird species at the count stations because the number of bird species detected began to level-off within the count period (Scott and Ramsey 1981, Verner 1988). Bird detections were limited to a 100-m radius plot centered on each count station (Verner 1985, 1988) because this was the maximum range over which the majority of species in this study were detectable. In addition, we estimated the horizontal distance from observer to each individual bird detection (i.e., detection distance).

MEAN MONTHLY TEMPERATURES AND SNOW DEPTHS

We described winter weather conditions by (1) obtaining mean monthly temperatures for an 81-year period (1909–1990) from the Ketchikan, Alaska, weather station located approximately

30 km southeast of the study area at 23 m elevation and (2) measuring snow depths at count points within each site. Mean monthly temperatures for each year of the study were compared to the 81-year monthly averages. A meter stick was used to measure snow depths at three sampling points spaced at random distances along a 50 m transect bisecting each count station. A total of 15 snow-depth measurements (3 measurements per count point × 5 count stations/site) was taken in each site.

STATISTICAL ANALYSES

Individual sites served as the experimental units for statistical analyses. Vegetation variables were averaged over the 20 vegetation plots and snow depths were averaged over the 15 snow-depth plots representing each site. Vegetation and snow depths were compared among the four treatments using an Analysis of Variance (ANOVA), blocking on the five geographic areas (i.e., blocks). The Randomized Block design was used to take advantage of the increased statistical power achieved by grouping treatments within the same geographic area (Neter and Wasserman 1983). Tukey's HSD test (Wilkinson 1990) was used to locate differences between specific treatment means for significant ANOVAs.

An abundance index for each common (≥ 30 total detections/year) breeding and wintering bird species was calculated by averaging detections over the four site visits for each treatment type in each season. Common species were used in comparisons of abundance among treatments to meet assumptions of statistical models (i.e., stable variances). No abundance estimate was calculated for uncommon species (< 30 total detections/year); however, total detections of uncommon species were examined separately for general patterns across treatments. To determine whether bird species were equally detectable among treatments, we compared the mean detection distance and the effective detection distance (i.e., distance from count points at which the number of birds observed begins to decline, Reynolds et al. 1980) for each breeding bird species among treatments using ANOVA. Low numbers of winter bird detections precluded determination of their detection distances. Winter bird detections were therefore truncated at plot sizes of 40 m, 75 m, and 100 m and abundance of each species was examined for consistency in response to treatments.

Species richness (total number of species), total abundance (number of detections of all species combined), and proportional similarity (Brower et al. 1984) were used as avian community indices and were compared among treatments. The proportional similarity index reflects the proportion of species occurring within a given treatment that also occurred in another treatment. This index ranges from 0 (no overlap in species composition) to 100% (complete overlap). Only those species with ≥ 2 detections in the study area were used in comparisons of species richness and proportional similarity. Proportional similarity indices were not determined for winter birds because of low species richness. Avian community indices and abundance of each bird species were compared among treatments and between years using the Split-plot ANOVA procedure. Year served as the whole plot, treatment as the subplot, and geographic area as the blocking variable. The treatment-by-geographic block error term was used to test both the treatment effect and the treatment-by-year interaction. Because breeding bird abundance was similar across breeding seasons and there were no significant interaction terms for all but one bird species, abundance estimates were combined between years and Tukey's HSD was used to identify differences among treatment means if a treatment effect was indicated. For the one breeding bird species with a significant treatment-by-year interaction, the treatment effects were evaluated using a separate ANOVA for each year. Because abundance of winter birds varied greatly between years and among treatments, the Least Squares Means test (SAS Institute 1985) was used to identify differences among specific treatment means within a year for species with significant treatment effects.

Variables not meeting assumptions of normality (Kolmogorov-Smirnov one sample test, Wilkinson 1990) or homogeneity of group variances (Bartlett's F-test, residual scatter plots, Wilkinson 1990) were transformed using either arcsine or square-root transformations (Zar 1984). A non-parametric Friedman's test was used if transformations did not adequately improve normality or variance homogeneity based on reexamination of assumptions. The power of statistical tests (Zar 1984) was calculated using PASS software (Hintze 1991) for nonsignificant results at $\alpha > 0.05$.

To explore habitat attributes important to breeding birds, we related the abundance of each common bird species to vegetation variables using stepwise regression (forward selection). We restricted this analysis to the young-growth treatments due to the larger sample sizes ($n = 15$) relative to old growth ($n = 5$), and to breeding birds because of low abundance of wintering birds. Vegetation variables having tolerance factors > 0.70 were excluded from the model to reduce multicollinearity (Wilkinson 1990). These analyses were performed using SYSTAT (Wilkinson 1990).

RESULTS

VEGETATION CHARACTERISTICS

Young growth. Eight of the 15 site characteristics measured differed among the three young-growth treatments (Table 1); six of these were associated with thinning and two were associated with gapping. Of these characteristics, thinned sites had 4 × as many snags ($P = 0.04$), 2 × as much forb ($P = 0.04$) and slash ≥ 50 cm-deep cover (Ps < 0.02), and ⅓ as many small conifers (Ps < 0.001) as other young-growth treatments. Thinned sites also had marginally less ($P = 0.07$) canopy cover and marginally greater (Ps < 0.06) shrub cover than at least one of the other young-growth treatments. As expected, gapped sites had substantially (18 ×) greater gap densities (Ps < 0.001) and much lower (⅕) distance to nearest gaps ($P = 0.01$) than other young-growth treatments. All young-growth treatments were characterized by few residual old-growth tree clumps. Sixteen residual tree clumps ranging in size from 0.05–1.3 ha were located in two thinned, one gapped, and one non-modified site.

Young growth vs. old growth. Ten of 15 site characteristics measured differed between young- and old-growth treatments; four of these characteristics, medium (Ps < 0.001) and large conifer (none were recorded in young growth) densities, tree heights (Ps < 0.001), and snag densities (Ps < 0.004) were 4–46 × greater in old growth (Table 1). A total of 245 snags was counted in old-growth sites, approximately 43% were > 35 cm dbh and 20% were ≥15 m tall. Only 32 snags were counted in the young-growth sites, 6% of which were > 35 cm dbh and 6% of which were ≥ 15 m tall. Old growth also was characterized by lower densities of small conifers (Ps < 0.001), lower shrub ($P = 0.04$) and slash ≥ 50 cm-deep cover ($P = 0.005$), lower gap density ($P < 0.001$), and greater forb cover ($P = 0.04$) than at least one of the young-growth treatments.

BREEDING BIRD ABUNDANCE

We identified 16 relatively common (Table 2) and 12 uncommon (Appendix A) breeding forest bird species during 40 survey days (720-person hr) in both years. Eight species accounted for > 75% of the total detections ($n = 6{,}072$): Winter Wrens (18%), Orange-crowned Warblers (14%), and Swainson's Thrushes (13%) were the three most abundant species, followed by Dark-eyed Juncos (8%) and Townsend's Warblers (8%), Pacific-slope Flycatchers (5%), Varied Thrushes (5%), and Hermit Thrushes (5%). Uncommon species collectively accounted for approximately 5% of the total detections in both years (Appendix A).

Mean detection distances for each of the 16 common breeding bird species did not differ (Ps > 0.10) among treatments. In addition, the effective detection distance varied by ≤ 10 m among treatments for nine of 16 common breeding bird species (Chestnut-backed Chickadee, Dark-eyed Junco, Fox Sparrow, Golden-crowned Kinglet, Orange-crowned Warbler, Pacific-slope Flycatcher, Swainson's Thrush, Townsend's Warbler, and Winter Wren) and by 20–30 m for two species (American Robin and Wilson's Warbler). No effective detection distance was identified for the five remaining common species, whose detections varied unpredictably with distance from count points.

Young growth. Percent similarity ($\bar{x} \pm$ SE) of breeding bird communities was consistent among all pairs of young-growth treatments: non-modified vs. gapped (76.3 ± 2.5%), gapped vs. thinned (75.5 ± 1.5%), and non-modified vs. thinned (74.9 ± 1.6%) sites. Total abundance and species richness did not differ (Ps > 0.10) among young-growth treatments (Table 2).

Abundance of five of the 16 common breeding bird species differed among young-growth treatments (Table 2). American Robins were 5 × more ($P = 0.08$) abundant in gapped than in non-modified sites, while Fox Sparrows (Ps ≤ 0.03) and Wilson's Warblers ($P = 0.03$) were ⅓–⅐ × as abundant in gapped than in other young-growth treatments, respectively. In addition, Dark-eyed Juncos were 3 × more ($P = 0.008$) abundant in thinned sites than in non-modified sites, while Hermit Thrushes were ½ as abundant ($P = 0.03$) in thinned than in gapped sites.

TABLE 1. Mean (± SE) site characteristics of non-modified, canopy gapped, and precommercially thinned young-growth (20 years) and old-growth (≥ 150 years) treatments (n = 5 sites/treatment) on Prince of Wales Island, southeast Alaska, 1991 and 1992.

Site characteristic	Treatment[a]			
	Non-modified	Gapped	Thinned	Old growth
Small conifers (6–35 cm dbh)/ha	1,117.9 ± 75.2A	1,117.9 ± 233.0A	435.4 ± 30.0B	411.6 ± 36.9B
Medium conifers (36–55 cm dhb)/ha	1.3 ± 1.3B	2.5 ± 2.5B	0[b]	60.2 ± 4.5A
Large conifers (> 55 cm dbh)/ha[b]	0	0	0	52.8 ± 9.4
Hardwoods (6–35 cm dbh)/ha	45.8 ± 34.5A	85.3 ± 70.5A	17.8 ± 12.0A	2.9 ± 2.9A
No. tree species	3.2 ± 0.4A	3.2 ± 0.4A	2.8 ± 0.6A	3.8 ± 0.5A
Canopy cover (%)	62.4 ± 4.9B	58.2 ± 9.0BC	38.4 ± 5.2C	86.2 ± 8.2A
Tree height (m)	7.1 ± 0.2B	7.3 ± 0.5B	8.0 ± 0.3B	29.1 ± 1.9A
Snags/ha	6.4 ± 2.8C	8.9 ± 2.5BC	25.5 ± 7.8B	78.6 ± 10.4A
Slash cover < 50-cm deep (%)	7.9 ± 1.4A	11.1 ± 2.2A	12.4 ± 1.6A	8.4 ± 3.7A
Slash cover ≥ 50-cm deep (%)	7.7 ± 1.1B	8.5 ± 1.0B	17.4 ± 3.2A	7.0 ± 1.2B
Shrub cover (%)	47.5 ± 5.3B	43.3 ± 3.0B	66.2 ± 6.1A	45.2 ± 4.7B
Shrub height (m)	1.3 ± 0.1A	1.2 ± 0.1A	1.1 ± 0.1A	1.3 ± 0.1A
Forb cover (%)	11.2 ± 2.2B	16.4 ± 2.4AB	22.9 ± 5.0A	21.9 ± 3.9A
No. canopy gaps[c]/ha	0.1 ± 0.1B	0.7 ± 0.1A	0.1 ± 0.1B	0.1 ± 0.1B
Distance to gap[c] (m)	288.4 ± 56.7A	54.6 ± 10.7B	191.0 ± 40.8AB	162.6 ± 55.8AB

[a] Means sharing the same letters do not differ (ANOVA and Tukey's HSD, $P > 0.10$).
[b] No statistical tests were run because means have no variance.
[c] Canopy gaps included in the analysis were at least 0.05 ha.

TABLE 2. Mean[a] (± SE) numbers of detections (abundance) of common (≥ 30 total detections/year) breeding birds, total abundance (all species combined), and species richness in non-modified, canopy gapped, and pre-commercially thinned young-growth (20 years) and old-growth (≥ 150 years) treatments (n = 5 sites/treatment) on Prince of Wales Island, southeast Alaska, 1991 and 1992.

Species	Treatment[b]			
	Non-modified	Gapped	Thinned	Old growth
Red-breasted Sapsucker (*Sphyrapicus ruber*)	0.1 ± 0.1B	0.4 ± 0.1B	0.1 ± 0.1B	1.3 ± 0.3A
Pacific-slope Flycatcher (*Empidonax difficilis*)	0.4 ± 0.1B	0.9 ± 0.3B	0.8 ± 0.2B	5.6 ± 0.6A
Steller's Jay (*Cyanocitta stelleri*)	0.6 ± 0.3A	0.4 ± 0.1A	0.8 ± 0.2A	0.2 ± 0.1A
Chestnut-backed Chickadee (*Parus rufescens*)	1.0 ± 0.3A	1.0 ± 0.2A	0.9 ± 0.2A	1.7 ± 0.4A
American Robin[c] (*Turdus migratorius*)	0.2 ± 0.1B	1.0 ± 0.3A	0.7 ± 0.3AB	0.1 ± 0.1B
Varied Thrush (*Ixoreus naevius*)	2.3 ± 0.5A	1.9 ± 0.6A	1.3 ± 0.3A	2.2 ± 0.5A
Hermit Thrush (*Catharus guttatus*)	1.8 ± 0.4AB	2.7 ± 0.4A	1.2 ± 0.3B	2.0 ± 0.3AB
Swainson's Thrush (*Catharus ustulatus*)	6.4 ± 0.3A	6.1 ± 0.6A	5.2 ± 0.6A	1.5 ± 0.3B
Golden-crowned Kinglet (*Regulus satrapa*)	0.5 ± 0.2B	0.5 ± 0.3B	0.4 ± 0.1B	2.3 ± 0.6A
Orange-crowned Warbler (*Vermivora celata*)	6.4 ± 0.6A	7.3 ± 0.5A	7.2 ± 0.5A	0.6 ± 0.2B
Townsend's Warbler (*Dendroica townsendi*)	3.0 ± 0.4AB	2.8 ± 0.2AB	1.8 ± 0.3B	4.2 ± 0.9A
Wilson's Warbler (*Wilsonia pusilla*)	1.5 ± 0.5A	0.2 ± 0.1B	0.7 ± 0.2AB	0.1 ± 0.1B
Dark-eyed Junco (*Junco hyemalis*)	2.0 ± 0.5BC	3.5 ± 0.7AB	5.7 ± 1.1A	1.1 ± 0.3C
Fox Sparrow (*Passerella iliaca*)	2.8 ± 0.6A	0.9 ± 0.4B	3.3 ± 0.5A	0[d]
Song Sparrow (*Melospiza melodia*)	0.2 ± 0.1A	0.8 ± 0.4A	0.5 ± 0.2A	0.1 ± 0.1A
Total abundance	39.4 ± 0.4A	39.7 ± 1.6A	40.6 ± 2.0A	31.9 ± 2.1B
Species richness	14.4 ± 0.5A	15.8 ± 0.6A	16.4 ± 1.0A	15.4 ± 0.7A

[a] No differences (*P*s > 0.10) were detected in abundance of each species between years. Thus, abundance was pooled between years by averaging total counts (including only observations within 100-m of observers) for each species at each site across four visits in each breeding season. Winter Wrens (*Troglodytes troglodytes*) were not included due to the interaction of year and treatment effects.

[b] Means sharing the same letters do not differ (ANOVA, Tukey's HSD-test, $P > 0.10$).

[c] Friedman's test, Tukey's HSD-test, $P \leq 0.10$.

[d] No statistical tests were run because means have no variance.

Abundance of Steller's Jays, Chestnut-backed Chickadees, Varied Thrushes, and Song Sparrows did not differ (*P*s > 0.10) among young-growth treatments. Statistical power may have been too low to detect differences among treatments for Song Sparrows (0.10), Varied Thrushes (0.16), Steller's Jays (0.24), and Chestnut-backed Chickadees (0.38).

Young growth vs. old growth. Percent similarity of breeding bird communities was substantially lower between old growth and each of the young-growth treatments than among young-growth treatments. Percent similarity ($\bar{x}$ ± SE) was lowest for old growth vs. thinned (45.1 ± 2.2%), followed by old growth vs. non-modified (50.4 ± 2.9%) and gapped (52.2 ± 2.2%) sites. During both years, total abundance differed (*P*s < 0.001) between young- and old-growth treatments; however, species richness did not differ (*P*s > 0.10) among treatments (Table 2). Although total abundance was lowest (*P*s < 0.01) in old growth, the difference was considered small (0.8 × fewer detections).

Six of 16 common breeding bird species differed in abundance between old growth and each of the young-growth treatments (Table 2). Abundance of Golden-crowned Kinglets (*P*s < 0.005), Pacific-slope Flycatchers (*P*s < 0.001), and Red-breasted Sapsuckers ($Ps < 0.004$) were 6–14 × greater in old growth than in each of the young-growth treatments. In contrast, abundance of Orange-crowned Warblers, Swainson's Thrushes, and Fox Sparrows was 3–4 × greater in each of the young-growth treatments than in old growth ($Ps < 0.001$). Four other common species differed between old growth and one of the young-growth treatments: Dark-eyed Juncos, American Robins, and Wilson's Warblers were 6–15 × more abundant in thinned ($P = 0.001$), gapped ($P = 0.03$), and non-modified ($P = 0.004$) sites compared to old growth, respectively, whereas Townsend's Warblers were 2 × more ($P = 0.02$) abundant in old growth than in thinned sites.

Uncommon species. Brown Creepers occurred exclusively (11 total detections each year) in old growth; however, because creeper detections were low and confined to only one treatment (old growth) no statistical comparisons were made among treatments. In addition, both Red Crossbills and Pine Siskins occurred in higher numbers in old growth; however, numbers of crossbills (68 in 1991 vs. 20 in 1992) and siskins (78 in 1991 vs. 2 in 1992) varied substantially between years also precluding statistical comparisons among treatments.

Treatment × year interactions. Differences in Winter Wren abundance among treatments differed ($P = 0.004$) between years. In 1991, Winter Wrens ($\bar{x}$ ± SE) were more ($P = 0.03$) abundant in thinned (5.4 ± 0.6) than in gapped (3.0 ± 0.6) sites; however, in 1992, wrens were more ($Ps < 0.01$) abundant in non-modified (9.4 ± 0.7), gapped (9.7 ± 0.5), and thinned (10.4 ± 0.6) sites than in old growth (6.0 ± 0.6) sites.

BREEDING BIRD ABUNDANCE AND VEGETATION CHARACTERISTICS

Only three of 15 vegetation variables measured in young-growth treatments were associated with differences in the abundance of breeding bird species: percent forb cover, total conifer densities (all size classes combined), and number of gaps. Abundance of Dark-eyed Juncos and Hermit Thrushes was related positively to percent forb cover ($R^2 = 0.44$, df = 1,13, $P = 0.008$) and total conifer densities ($R^2 = 0.36$, df = 1,13, $P = 0.02$), respectively, while abundance of Fox Sparrows was related inversely to the number of gaps ($R^2 = 0.33$, df = 1,13, $P = 0.02$).

MEAN MONTHLY TEMPERATURES AND SNOW DEPTHS

Mean monthly temperatures recorded at the Ketchikan weather station over an 81-year period (1909–1990) were 2.1°C for December, 0.5°C for January, and 2.8°C for February. Monthly temperatures for December through February of 1991–1992 and 1992–1993 were only 1–4°C above and 1°C below the 81-year averages, respectively. However, mean snow depths differed between study years and among treatments ($P < 0.001$). In 1991–1992, snow depths ($\bar{x}$ ± SE, cm) did not differ ($Ps > 0.10$) among non-modified (2.5 ± 1.2), gapped (3.6 ± 1.9), thinned (1.8 ± 1.0), and old-growth (1.3 ± 0.7) treatments. In addition, snow depths during this winter ranged from 0–25 cm throughout the study area with snow present only during a six-day period in February. In contrast, in 1992–1993, snow depths in old growth (12.0 ± 2.1) were nearly ½ those in non-modified (21.2 ± 2.1, $P = 0.10$), gapped (23.3 ± 3.5, $P = 0.04$), and thinned (25.2 ± 2.5, $P = 0.01$) sites. Snow depths ranged from 12–89 cm throughout the study area and snow was present from January through mid-February.

WINTER BIRD ABUNDANCE

We recorded a total of 1,037 winter bird detections during 40 survey days (720-person hours) from December to February 1991–1993; 598 in 1991–1992 and 439 in 1992–1993. In general, three species accounted for most (81%) of the total detections during both winters: Golden-crowned Kinglets (52%), Winter Wrens (19%), and Chestnut-backed Chickadees (10%). Ten uncommon species accounted for 17% to 19% of the total detections each year (Appendix A).

Truncating avian detections at plot sizes of 40 m, 75 m, and 100 m had no discernible influence on our findings. Therefore, winter bird abundance was calculated using the 100-m radius plot size.

Young growth. Total abundance, species richness, and abundance of the three common bird species did not differ ($Ps > 0.10$) among young-growth treatments in either year (Table 3).

Young growth vs. old growth. Patterns of total abundance among treatments differed ($P < 0.001$) between winters (Table 3). In 1991–1992, total abundance did not differ ($Ps > 0.10$) between young- and old-growth treatments, but was 3 × greater ($Ps < 0.001$) in old- than in young-growth

TABLE 3. Mean[a] (± SE) numbers of detections (abundance) of common (≥ 30 detections/year) winter bird species, total abundance (all species combined), and species richness in non-modified, canopy gapped, and precommercially thinned young-growth (20 years) and old-growth (≥ 150 years) treatments ($n = 5$ sites/treatment) on Prince of Wales Island, southeast Alaska, during the winters of 1991–1992 and 1992–1993. Unless otherwise indicated, means across top rows are for 1991–1992; those across bottom rows are for 1992–1993.

	Treatment[b]			
Species	Non-modified	Gapped	Thinned	Old growth
Golden-crowned Kinglet	2.5 ± 0.2B	2.9 ± 0.2B	2.6 ± 0.7B	4.2 ± 0.7A
(*Regulus satrapa*)	1.8 ± 0.3B	2.0 ± 0.4B	2.9 ± 0.3B	7.9 ± 0.6A
Winter Wren	2.4 ± 0.2A	2.4 ± 0.4A	2.3 ± 0.2A	0.7 ± 0.2B
(*Troglodytes troglodytes*)	0.4 ± 0.1A	0.4 ± 0.1A	0.6 ± 0.2A	0.4 ± 0.2A
Chestnut-backed Chickadee	0.6 ± 0.2A	0.4 ± 0.2A	1.1 ± 0.5A	1.4 ± 0.4A
(*Parus rufescens*)	0.3 ± 0.1A	0.4 ± 0.2A	0.4 ± 0.2A	0.6 ± 0.2A
Total abundance	7.2 ± 0.9A	7.0 ± 0.4A	7.4 ± 1.0A	8.2 ± 0.7A
	3.0 ± 0.6B	3.5 ± 0.2B	4.5 ± 0.6B	10.8 ± 1.1A
Species richness[c]	4.1 ± 0.5B	4.8 ± 0.2B	4.5 ± 0.5B	6.5 ± 0.4A

[a] Abundance for each species was averaged across four site visits in each treatment.

[b] Means sharing the same letters do not differ (ANOVA and Least Squares Means Test, $P > 0.10$).

[c] Species richness was pooled between years due to lack of significant annual differences.

treatments in 1992–1993. Species richness was greater (Ps < 0.03) in old- than in young-growth treatments and this pattern was consistent ($P = 0.92$) between years. Old growth averaged at least two more species of birds than any of the young-growth treatments in each year. This difference was primarily attributed to greater use of old growth by some uncommon species (e.g., Brown Creeper, Appendix A). Brown Creepers occurred nearly exclusively (38 of 39 detections in both years) in old growth and the one creeper detected in young growth was within 100 m of an old growth site.

Differences in abundance of Golden-crowned Kinglets among treatments differed ($P = 0.001$) between winters. In 1991–1992, kinglet abundance was nearly 2 × greater in old growth than in young-growth treatments (Ps ≤ 0.07). In contrast, in 1992–1993, kinglet abundance was 4 × greater in old growth than in each of the young-growth treatments (Ps < 0.001).

Differences in abundance of Winter Wrens among treatments differed ($P = 0.003$) between winters. In 1991–1992, Winter Wrens were approximately 3 × as abundant in young- than in old-growth treatments (Ps < 0.001); however, in 1992–1993, wren abundance did not differ (Ps > 0.10) between young- and old-growth treatments.

Although abundance ($\bar{x}$ ± SE) of Chestnut-backed Chickadees was similar (Ps > 0.10) between old- and young-growth treatments during both winters, chickadees were twice as abundant ($P = 0.05$) in 1991–1992 (3.5 ± 0.7) than in 1992–1993 (1.8 ± 0.5).

DISCUSSION

We assumed that overall differences in vegetation characteristics, including old growth vs. young growth and silviculturally modified vs. non-modified young growth, did not influence our ability to detect birds and thus that differences in avian abundance among treatments were unrelated to differences in detectability. This assumption was supported by the similarities in mean detection distances and effective detection distances among treatments and the consistency in interpretation of treatment effects during the winter regardless of plot size selected for count point stations.

BREEDING BIRDS

Young growth. Most breeding bird species utilizing young-growth treatments in this study were habitat generalists that are widespread in coniferous forests of southeast Alaska (Kessler and Kogut 1985, Armstrong 1995) and the Pacific Northwest (Brown 1985). However, six of the 16 common breeding bird species were associated with at least one of the silvicultural modifications of young growth. Dark-eyed Juncos were positively associated with thinning, while Hermit Thrushes and Townsend's Warblers were negatively associated with thinning. American Robins were positively associated with gapping, while Fox Sparrows and Wilson's Warblers were negatively associated with gapping.

Our finding for juncos is consistent with that of Mannan and Meslow (1984) who reported higher numbers of this ground-nesting bird in thinned than in unthinned sites in northeast Oregon. Higher junco abundance in the thinned sites we studied was attributed to increased forb cover that was associated with reduced conifer densities and canopy cover caused by thinning. In contrast, Hermit Thrushes tend to nest in areas with dense conifers and understory vegetation (Mannan and Meslow 1984). Higher abundance of thrushes in gapped sites we studied was related to greater conifer densities relative to thinned sites. However, this pattern was not consistent for non-modified sites that had similar conifer densities as gapped sites. Therefore, thrushes may have been responding to the combination of dense conifers juxtaposed with canopy gaps that was unique to gapped sites. The reductions in canopy cover caused by thinning also may have limited nesting habitat for Townsend's Warblers, which typically nest in areas with dense canopy volume (Tobalske et al. 1991). Although we did not measure canopy volume in this study, thinned sites had the lowest canopy cover of any of the treatments and this difference was most pronounced between thinned and old-growth sites where differences in warbler numbers were greatest.

None of the vegetation variables we measured was correlated with the relatively high abundance of American Robins in gapped sites; however, our results were consistent with the high foraging use by robins of fire-created gaps in coniferous forests of the Sierra Nevada (Bock and Lynch 1970). The reasons for the apparent negative response of Fox Sparrows and Wilson's Warblers to gapping remain unclear. Both species nest and forage in deciduous shrubs and conifer saplings in young regenerating forests in southeast Alaska (Kessler and Kogut 1985) and are associated with forest edges and shrubby clearcuts (Tobalske et al. 1991). The effects of gapping or thinning on Winter Wren abundance could not be determined because responses were inconsistent between years. It is likely that this species was responding to factors unrelated to vegetation characteristics we measured. Low statistical power associated with tests among treatments for Song Sparrows, Varied Thrushes, Steller's Jays, and Chestnut-backed Chickadees also limited our ability to detect treatment effects.

Young growth vs. old growth. Although we did not measure abundance across a successional gradient following logging, and abundance is not always a reliable indicator of habitat quality (Van Horne 1983), three common and one uncommon species were positively associated with old growth: Golden-crowned Kinglets, Red-breasted Sapsuckers, Pacific-slope Flycatchers, and Brown Creepers. The Brown Creeper was included as an old-growth associate because of its exclusive use of old growth during both breeding seasons. Creepers also are uncommon elsewhere in southeast Alaska (Armstrong 1995) and nest primarily in old growth in southeast Alaska (Kessler and Kogut 1985) and the Pacific Northwest (Sakai and Noon 1991).

Each of the old-growth associated species in our study area is known to decline in abundance following clearcut logging (Franzreb and Ohmart 1978, Mannan and Meslow 1984, Kessler and Kogut 1985, Rosenberg and Raphael 1986, Manuwal and Huff 1987, Raphael et al. 1988, Sakai and Noon 1991) and is less abundant in intermediate age classes (75 years) than old-growth forests of southeast Alaska (Kessler and Kogut 1985). These species also tend to use specific structural attributes rarely present in managed young-growth forests in southeast Alaska, including large-diameter trees (Pacific-slope Flycatcher, Sakai and Noon 1991; Brown Creeper, Adams and Morrison 1993), snags (Red-breasted Sapsucker, Raphael and White 1984), and multilayered tree canopies (Golden-crowned Kinglet, Mannan and Meslow 1984). Such characteristics are unlikely to develop within the commercial forest rotation (Alaback 1982a, 1982b, Tappenier and Alaback 1989, McComb et al. 1993).

In contrast, four species, Orange-crowned Warblers, Swainson's Thrushes, Fox Sparrows, and Wilson's Warblers were negatively associated with old growth and may therefore benefit initially from clearcut logging and no silvicultural modification of young regenerating forest. Each of these species was abundant in non-modified young growth, nests or forages in dense understory vegetation, and is common in early forest seral stages in southeast Alaska (Kessler and Kogut 1985). Habitat for these species in southeast Alaska is temporarily increasing due to replacement of old-growth forests by young growth.

Our results may underestimate the influence of silvicultural modifications on overall composition of breeding bird communities because our data describe site use by species of birds with relatively small home ranges that breed in the coastal temperate rainforest of southeast Alaska. We did not collect information on site use by Northern Goshawk (*Accipiter gentilis*) and Marbled Murrelet (*Brachyramphus marmoratus*) that occupy relatively large home ranges and nest almost exclusively in old-growth forests (Crocker-Bedford 1990, Quinlan and Hughes 1990), nor for nocturnal species such as owls, or species associated with old-growth/saltwater edges (e.g., Vancouver Canada Goose *Branta canadensis fulva*, Lebeda and Ratti 1983). These species were only observed flying over our study area. Both Red Crossbills (Benkman 1987) and Pine Siskins (Bent 1968) typically occur in mixed species flocks that undergo periodic population irruptions in response to conifer-cone production. Such factors likely contributed to high interannual variation in abundance of these species and our limited ability to detect treatment effects.

WINTERING BIRDS

The wintering bird community we studied was characterized by few species having low abundances. In general, three species accounted for the majority of winter bird detections, with 10 other species occurring in low numbers. The northern location of our study area may have limited species richness and abundance of wintering birds particularly since the Island lies outside the most northern extent of the distribution of many forest bird species (Armstrong 1995).

Thinning and gapping of young growth had no detectable effect on site use by wintering birds regardless of winter conditions. This was attributed to similarities in snow depths among young-growth treatments. Numbers of winter bird detections, however, varied substantially between years and these differences appeared to be related to winter weather conditions that influenced use of young- and old-growth treatments by wintering birds. Rotenberry (1978) indicated that the number of frost-free days and days with snowpack indirectly influenced population levels of wintering birds. Others (Helms 1968, Grubb 1977, 1979) have attributed differences in habitat use by northern forest birds to climatic factors.

Because winter conditions at low elevation in southeast Alaska typically hover at or above freezing (based on 81-year Ketchikan weather station records), relatively small differences in mean monthly temperatures between years contribute to large differences in snowfall accumulation. The winter of 1991–1992 was characterized by mean monthly temperatures that were 1–4°C above the 81-year regional average and sparse snowfall. These conditions likely contributed to the relatively high numbers of wintering birds throughout the study area and high use of young growth by Winter Wrens. As was the case for all other species, Winter Wren abundance was relatively low during the second winter when snow levels were especially high in young-growth treatments. Greater snow depths during relatively harsh winters may force ground-foraging species like Winter Wrens to winter further south or in other habitats where snowpack is low. Schoen et al. (1988) also reported low Winter Wren abundance in young growth during periods of heavy snow accumulations in southeast Alaska. Notably, Winter Wren abundance in this study was highest in young growth during the winter of 1991–1992 and the breeding season of 1992. Thus, the milder winter of 1991–1992 may have contributed to greater overwintering survival of wrens in young growth and thus greater use of these treatments during the breeding season.

The winter of 1992–1993 was characterized by mean monthly temperatures that were 1°C below the 81-year regional average and greater snowfall than in 1991–1992. Harsher winter conditions in 1992–1993 than in 1991–1992 likely contributed to greater abundance of wintering birds in old growth relative to young growth and substantially higher use of old growth than young growth by Golden-crowned Kinglets. Manuwal and Huff (1987) attributed greater use by overwintering birds of Douglas-fir (*Pseudotsuga menziesii*) old-growth forests in the southern Washington Cascades to more favorable microclimate and better foraging conditions relative to young forests. Similarly, Morrison et al. (1986) reported overwintering birds in old growth, mixed-conifer forests of the western Sierra Nevada used areas characterized by high, heavy canopy cover that provided protection from wind and precipitation.

The snow intercept properties of old-growth forest canopies (Kirchhoff and Schoen 1987) may provide foraging sites free of snow for canopy-foraging species such as Golden-crowned Kinglets, especially during harsh winters. In particular, we observed low numbers of kinglets in young growth following storms that coated tree branches with ice and snow. Kinglets foraged in small flocks primarily in multi-layered tree canopies of old growth that appeared to have less snow covering branches than the uniform tree canopy of young growth. Moreover, because kinglets also nested in old growth in this study they may be particularly vulnerable to combined reductions in wintering and nesting habitat caused by timber harvest.

Old growth also provided wintering habitat for uncommon species like Brown Creepers regardless of winter weather conditions. Creepers roost in large snags during the winter (Walsberg 1986) and forage along the crevices of large tree boles and branches (Jackson 1979, Morrison et al. 1985, Adams and Morrison 1993). These structural features are lacking in managed young growth-forests, which may explain the creepers apparent affinity for old growth during both the wintering and breeding seasons.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

We suggest that land managers replace uniform thinning with variable-spaced thinning to create additional canopy layers for young-growth bird communities. Variable-spaced thinning would eventually produce two-storied tree canopies within even-aged sites, allowing for rapid growth by some trees (thinned areas) and reduced growth or death by others (unthinned areas) (McComb et al. 1993). Thinned areas in these sites would provide forb cover for Dark-eyed Juncos; unthinned areas would provide canopy cover for Townsend's Warblers. A two-storied tree canopy also may distribute snowfall unevenly across tree canopies and provide more snow-free tree branches than uniform tree canopies for canopy-foraging species like Golden-crowned Kinglets. However, thinned areas may initially accumulate snow in the understory until regenerating trees are tall enough to fill openings in the tree canopy created by thinning. Ground-foraging species, such as Winter Wrens, may still experience relatively deep snows during harsh winters at least until a secondary tree canopy develops.

The USDA Forest Service has temporarily abandoned its gapping program in the Forest because this treatment has had limited effects on availability of deer forage (DellaSala et al. 1994). Although we found only one species, American Robins, that was positively associated with gapping, our study reflected conditions in gapped sites only two to four years post-gapping. Thus, we recommend this sampling be replicated over a longer period to evaluate fully the effectiveness of the gapping program. Because variable-spaced thinning produces greater spacings between thinned and unthinned areas relative to uniform thinning, thinned areas may effectively function as gaps for gap-associated species like American Robins. Variable-spaced thinning also may provide a more suitable distribution of dense conifers and openings for Hermit Thrushes than uniform thinning. Costs of variable-spaced thinning are comparable to those for uniform-spaced thinning (A. Anderson, District Manager, Craig, AK, pers. comm.). However, because understory response to thinning (whether variable or uniform spacing) is limited to ≤ 10 years as tree canopies close (Alaback and Herman 1988), thinning would need to be repeated on 10-year intervals increasing the costs associated with extending such benefits through longer periods of the commercial rotation.

Combining variable-spaced thinning with retention of residual clumps of old growth may further reduce negative effects of thinning for bird species that are associated with forest canopies (e.g., Townsend's Warbler), increase the use of otherwise homogenous young growth by species associated with old growth (Wetmore et al. 1985, Raphael et al. 1988), and increase snow intercept properties of young forests to provide more snow-free habitat for wintering birds. The USDA Forest Service retains some residual old-growth trees following commercial logging activities as part of ecosystem management in the Forest (USDA Forest Service 1991). However, because of the relatively small size (0.05–1.3 ha) of residual clumps in this study, such clumps lack interior forest conditions and thus should not be viewed as mitigation for large-scale removal of contiguous forests. Furthermore, because residual clumps are subject to high-velocity winds that are a frequent disturbance in this region (Alaback 1991), they should be relatively large and positioned within topographically protected areas (away from ridge tops). Clumps also could be positioned along clearcut/old-growth forest edges to minimize abruptness and microclimatic effects associated with edges (e.g., increase wind velocities; Chen et al. 1992).

Our results are significant to regional conservation and management of old-growth associated species. Notably, there is only one published study of breeding bird communities (Kessler and Kogut 1985) and no published studies of wintering bird communities in young- and old-growth forests in southeast Alaska. Kessler and Kogut (1985) conducted their study during only one breeding season and without the benefit of replicated sites. In addition, both the Brown Creeper and Red-breasted Sapsucker are "management indicator species" in the Forest (USDA Forest Service 1991) and the Pacific-slope Flycatcher has been proposed for similar designation (DellaSala et al. 1994). The USDA Forest Service uses management indicator species to assess the effects of timber harvest on wildlife habitat. This study supports the use of these species as management indicators and suggests the addition of the Pacific-slope Flycatcher and Golden-crowned Kinglet.

Our findings also suggest that old growth provides important refugia for some breeding and wintering bird species, particularly during harsh winters. Although none of the species we studied is threatened or endangered in southeast Alaska and they were observed in young growth in reduced numbers, up to 70% of 286,000 ha of old growth on the Island and elsewhere in the region will be harvested by the year 2150 (USDA Forest Service 1991). We encourage managers to begin the development of monitoring and conservation planning early on to avoid the future need for more reactionary approaches such as those that have characterized the policy debate in Pacific Northwest where old growth has declined substantially and the economic and social costs of protecting what remains has escalated.

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APPENDIX A. Total detections of uncommon (< 30 total detections in either year) breeding and wintering bird species in non-modified, canopy gapped, and precommercially thinned young-growth (20 years) and old growth (≥ 150 years) treatments ($n = 5$ sites/treatment) on Prince of Wales Island, southeast Alaska. Breeding bird detections were summed counts over the 1991 and 1992 breeding seasons. Wintering bird detections across top rows are for 1991–1992; those across bottom rows are for 1992–1993.

	Treatment			
Species	Non-modified	Gapped	Thinned	Old growth
Uncommon Breeding Birds				
Red Crossbill (*Loxia curvirostra*)	23	12	7	46
Pine Siskin (*Carduelis pinus*)	22	10	5	43
Rufous Hummingbird (*Selasphorus rufus*)	9	7	1	4
Ruby-crowned Kinglet (*Regulus calendula*)	12	10	14	2
Brown Creeper (*Certhia americana*)	0	0	0	22
Tree Swallow (*Tachycineta bicolor*)	2	6	2	0
Lincoln's Sparrow (*Melospiza lincolnii*)	2	2	1	3
Hairy Woodpecker (*Picoides villosus*)	0	0	2	4
Common Raven (*Corvus corax*)	0	3	0	1
Purple Finch (*Carpodacus purpureus*)	0	1	1	2
Northern Flicker (*Colaptes auratus*)	1	1	2	0
Olive-side Flycatcher (*Contopus borealis*)	1	0	1	0
Totals	72	52	36	127
Uncommon Wintering Birds				
Red Crossbill (*Loxia curvirostra*)	18	4	11	1
	1	2	2	0
Brown Creeper (*Certhia americana*)	0	1	0	21
	0	0	0	17
Pine Grosbeak (*Pinecola enucleator*)	9	2	4	0
	7	7	6	2
Common Raven (*Corvus corax*)	0	2	1	5
	0	0	3	9
Steller's Jay (*Cyanocitta stelleri*)	1	7	1	2
	4	3	2	1
Red-breasted Sapsucker (*Sphyrapicus ruber*)	0	0	0	1
	0	0	0	7
Hairy Woodpecker (*Picoides villosus*)	0	2	0	1
	0	1	0	4
Song Sparrow (*Melospiza melodia*)	0	1	1	0
	0	1	2	0
Bald Eagle (*Haliaeetus leucocephalus*)	0	0	0	2
	1	1	0	0
Evening Grosbeak (*Coccothraustes vespertinus*)	0	0	0	2
	0	0	0	0
Totals	28	19	18	35
	13	15	40	40