Research Report

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Forest bird response to partial cutting in lodgepole pine forests on caribou winter range in west-central British Columbia

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Abstract

Breeding birds were surveyed 1 year pre-harvest (1995) and 4 years post-harvest (1996–2001) to measure the response to partial cutting in old lodgepole pine (*Pinus contorta* Dougl.) forests on the Chilcotin Plateau of British Columbia. The irregular group shelterwood and group selection systems recommended to manage northern caribou (*Rangifer tarandus caribou* Gmelin) habitat did not negatively affect the breeding bird community. In some years within the post-harvest period, dark-eyed juncos (*Junco hyemalis* L.), red crossbills (*Loxia curvirostra* L.), yellow-rumped warblers (*Dendroica coronata* L.), and gray jays (*Perisoreus canadensis* L.) showed significant ($\alpha = 0.05$) increases in use of the partial-cutting treatments compared with the no-harvest treatment. No species decreased significantly in any of the partial-cutting treatments. The increased observations of mostly common species resulted in significantly ($\alpha = 0.05$) higher species richness, and increased frequency of observations for the bird community in some years in the partial cuts. Partial cutting of caribou habitat will maintain bird communities typical of mature to older lodgepole pine forests.

KEYWORDS: *birds, group selection silvicultural system, lodgepole pine, partial cutting, shelterwood silvicultural system.*

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Introduction

Forest breeding birds are affected by structural changes to their habitat through natural disturbance processes and, more recently, by forest management (Imbeau *et al.* 2001). In the west-central interior of British Columbia, extensive lodgepole pine (*Pinus contorta* Dougl.) forests burned frequently leaving a mosaic of large and small even-aged patches across the landscape (Steen and Coupé 1997). About every 40 years, mature and older forests have also sustained episodic attacks by mountain pine beetle (*Dendroctonus ponderosae* Hopkins) especially in the lower elevations, sometimes resulting in uneven-aged stand structure (Hawkes *et al.* 2004). These forests are typically clearcut and then regenerated with lodgepole pine through natural or planted stock about every 80 years (Daintith *et al.* 2005).

Breeding bird communities associated with the extensive lodgepole pine forests in west-central and other parts of British Columbia have been poorly documented. Based on studies in mature pine forests in the United States (Austin and Perry 1979; Hein 1980; Taylor and Barmore 1980), richness and density are expected to be low. Similarly, in southern British Columbia, Herbers *et al.* (2004) found the lowest diversity and abundance of wintering birds in mature forests dominated by lodgepole pine compared with forest types with higher tree species diversity and less pine. In the boreal, pure jack pine (*Pinus banksiana* Lamb.) forests have low density and diversity of birds compared with other forest types, or mixtures of pine with other species (Kirk *et al.* 1996; Hobson and Bayne 2000). The high density of trees, low canopy height, and few tree species probably contribute to the low species diversity and density of birds in pine forests (James and Wamer 1982).

Few studies have reported the response of birds to clearcutting or partial cutting in various types of pine forest. Austin and Perry (1979) found clearcuts and mature lodgepole pine forest to have similar species richness, although a much higher density of birds occurred in the clearcuts. Some species occurred in both age classes, but other species were associated with only one or the other seral stage. In jack pine forests, significant differences are apparent in abundance for some species depending on stand age (Kirk and Hobson 2001). Studies in other forest types documented that young clearcuts tend to have bird communities that are distinct in composition compared with older seral stages (Kirk *et al.* 1996; Davis *et al.* 1999; Simon *et al.* 2000). Studies of partial cutting in other forest types across Canada show that low levels of removal (about 30%) do not substantially change bird communities associated with mature to old forest (Waterhouse and Dawson 1998; Simon *et al.* 2000; Leupin *et al.* 2004), although cutting 50–60% of the trees causes declines in some species and increases in species associated with early seral stages (Waterhouse and Dawson 1998; Simon *et al.* 2000).

High density of trees, low canopy height, and few tree species probably contribute to the low species diversity and density of birds in pine forests.

We had a unique opportunity to study the breeding bird response to partial cutting in pure stands of mature to old lodgepole pine in west-central British Columbia. These forests provide winter habitat for northern caribou (*Rangifer tarandus caribou* Gmelin), which are classified as "threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and qualify for protection and recovery under the federal Canadian Species at Risk Act (SARA). Clearcutting, on short rotations of about 80 years, is not compatible with the maintenance of lichens, the caribou's primary winter forage, especially in the very dry, cold ecosystems of the west Chilcotin. Therefore, a provincial government strategy, implemented through the Cariboo-Chilcotin Land-Use Plan (Province of British Columbia 1995), designated 181 000 ha of the caribou range to be managed through "modified harvesting" (Youds *et al.* 2002). In 1995, a major research project (Itcha-Ilgachuz Alternative Silvicultural Systems) was developed to test three silvicultural systems as options to manage caribou habitat: two irregular group shelterwood systems (whole-tree and stem-only), based on 50% removal (openings 30 m diameter) every 70 years, and a group selection system based on 30% removal (openings 15 m diameter) every 80 years.

The immediate objective of our study is to measure the early post-harvest (within 5 years) response by the bird community (species richness, diversity, abundance) and individual species to the three partial-cutting silvicultural systems and the no-harvest treatment.

Study Area

The study area is located about 110 km northwest of Alexis Creek, B.C., on a gently rolling, high-elevation plateau near Satah Mountain (52°28'N, 124°43'W). The five replicate study blocks, which occur in the very dry, very cold Montane Spruce (MSxv) and very dry, cold Sub-Boreal Pine–Spruce (SBPSxc) biogeoclimatic subzones, are located in northern caribou habitat. The blocks are spread along a 30 km section of road that rises in elevation from 1260 m in the east (SBPSxc) to 1640 m in the west (MSxv). Blocks 1 to 3, in the SBPSxc, are flat while blocks 4 and 5, in the MSxv, are gently sloped (≤ 20%) and aspect is easterly. The five blocks are located within stands that were initiated after stand-destroying wildfires. Based on tree-core data, in four blocks trees in the main canopy were of similar age (220–250 years). Block 2 has a layer of predominantly 150-year-old trees, with a scattering of trees over 300 years. Soils are Orthic Dystric Brunisols, and have a sandy loam texture and a mor humus type (2–6 cm thick).

The study blocks are composed almost entirely of lodgepole pine with a small amount of hybrid spruce (*Picea glauca* [Moench] Voss × *engelmannii* Parry ex Engelm.) in the understorey of the higher-elevation blocks (Figure 1). In the MSxv blocks, the Lodgepole pine – Grouseberry – Feathermoss mesic site type (MSxv/01) (Steen and Coupé 1997) is dominant; in the SBPSxc blocks, the Lodgepole pine – Kinnikinnick – Feathermoss mesic site type is prevalent (SBPSxc/01) (Steen and Coupé 1997). In 2000, vegetation data (percent cover and modal height) was collected from 900 2-m² plots, located on permanent grids, across all blocks and treatments. The understorey vegetation is dominated by mosses and lichens (19–32%) and dwarf shrubs (13–19%), while shrubs (6–8%) and herbs (3–5%) are sparse (Table 1).

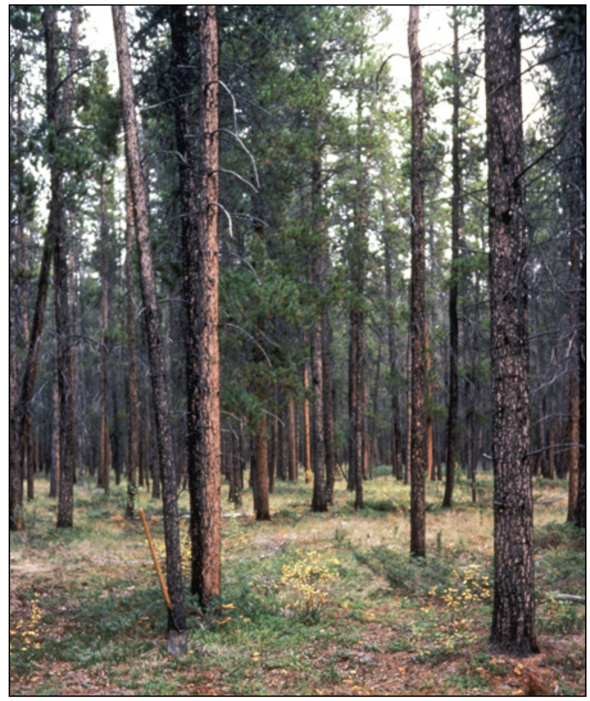

FIGURE 1. Typical stand structure found in the Sub-Boreal Pine–Spruce trial blocks.

In the higher-elevation MSxv blocks, crowberry (*Empetrum nigrum* L.; 1–9%), twinflower (*Linnaea borealis* L.; 4–7%), and grouseberry (*Vaccinium scoparium* Leib.; 3–7%) are the most common dwarf shrub species. The species composition shifts to kinnikinnick (*Arctostaphylos uva-ursi* [L.] Spreng.; 14–17%) in the SBPSxc blocks. Across all five blocks,

TABLE 1. Mean and standard deviation of percent cover and modal height of vegetation layers in 2000

	No-harvest (n = 229)	IGS–SO[a] (n = 225)	IGS–WT (n = 223)	GS (n = 222)
Shrub cover (%)	8 ± 11	7 ± 11	6 ± 11	7 ± 8
Shrub height (cm)	29 ± 13	26 ± 11	28 ± 13	29 ± 11
Dwarf shrub cover (%)	13 ±	16 ± 11	16 ±15	19 ± 17
Dwarf shrub height (cm)	5 ± 2	5 ± 2	5 ± 3	5 ± 2
Herb cover (%)	3 ± 4	5 ± 9	5 ± 8	5 ± 7
Herb height (cm)	9 ± 5	11 ± 5	11 ± 6	10 ± 6
Tree regeneration cover (%)	0.4 ± 1.3	0.7 ± 1.7	0.7 ± 2.7	0.7 ± 1.6
Moss and lichen cover (%)	32 ± 19	19 ± 15	27 ± 18	22 ± 17

[a] IGS–SO = irregular group shelterwood–stem only; IGS–WT = irregular group shelterwood–whole tree; GS = group selection.

soopalallie (*Shepherdia canadensis* [L.] Nutt.; 1–4%) occurs in small patches. Common juniper (*Juniperus communis* L.) is the most abundant shrub in the SBPSxc blocks, averaging 8–9% cover, but drops to less than 1% cover in the MSxv blocks. Across the blocks, individual species of herbs, such as northwestern sedge (*Carex concinnoides* Mack.) and bunchberry (*Cornus canadensis* L.), occur at low abundance (1–2%). In the highest-elevation blocks, feathermosses (e.g., *Pleurozium schreberi* [Brid.] Mitt. and *Dicranum* spp.) are very abundant (32–37%) and ground lichen cover is lower (6–7%). In the lowest-elevation blocks, mosses are sporadic (1%) and ground lichens (*Cladonia*, *Cladina*, *Stereocaulon*, *Cetraria*, and *Peltigera* spp.) are abundant (15–16%). Dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) is commonly found in SBPSxc study blocks, but not in the MSxv blocks.

The trial blocks in the SBPSxc are generally more open than those in the MSxv due to drier site conditions. Within the SBPSxc stands, cohorts of young pine regeneration are common. Much less pine regeneration is found beneath the canopy on the MSxv blocks (Figure 2). In these stands, trees tend to be taller and more vigorous than in the SBPSxc. Gross merchantable volume in the MSxv and SBPSxc blocks is about 294 m^3/ha and 100 m^3/ha, respectively. Density of live trees over 12.5 cm at breast height (1.3 m) ranges from 607 to 1721 stems per hectare, and average diameter (DBH) is 16.9–21.6 cm. Before harvesting, the proportion of standing dead trees was high in each block (7–21%) due mostly to a mountain pine beetle infestation in the early 1980s.

FIGURE 2. Typical stand structure and partial cutting in the Montane Spruce trial blocks.

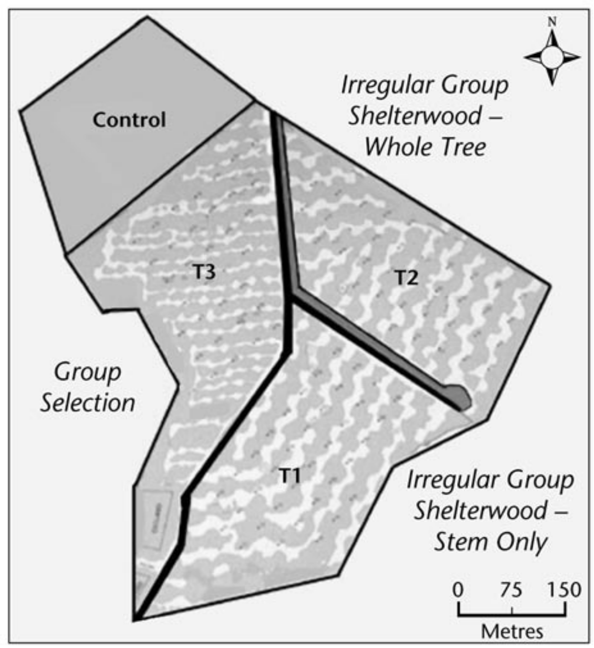

FIGURE 3. Layout of block 5 showing the treatments: No-harvest (control), IGS–WT (irregular group shelterwood–whole tree harvesting), IGS–SO (irregular group shelterwood–stem only harvesting), and GS–SO (group selection–stem-only harvesting).

Methods

Experimental Design

A complete randomized block design was chosen for the study. Five blocks were selected from current blocks laid out for operational harvesting in the Satah Mountain area. Each block was between 60 and 113 ha and was divided into four equal-sized treatment units of approximately 15–28 ha. The three partial-cutting treatments and a no-harvest treatment (control) were randomly assigned to the treatment units in each block (Figure 3).

Silvicultural Systems and Harvesting Description

Two irregular group shelterwood (IGS) systems were designed to harvest 50% of the stand area every 70 years in openings ranging from 20 to 30 m in diameter (Figure 3). These systems were developed to provide partial shade for terrestrial lichen in the harvested openings. Different harvesting methods distinguish the two IGS treatments: stem-only (SO) and whole-tree (WT) harvesting. With stem-only harvesting, debris from topping and de-limbing was left in the harvested openings to maintain long-term site productivity (Wei *et al.* 2000), but aggregated to minimize the impact on terrestrial lichens and plantable spots. With whole-tree harvesting, which is the typical practice in the central interior of British Columbia, debris from topping and de-limbing is piled and burned at the roadside. The third silvicultural system, a group selection (GS) system in combination with stem-only harvesting, was designed to harvest approximately one-third of the stand in 15 m wide openings every 80 years. This system was developed for sites with abundant arboreal lichen. All treatments were cut with a feller-buncher in the winter of 1996 (January to April). A post-harvest GPS survey of the blocks found that the average amount cut was 39% in the IGS and 28% in the GS, and that the opening sizes were within the targeted range.

Data Collection

The variable point count survey method (Resources Inventory Committee 1999) was used to sample the bird community. Two point count stations were set up in every treatment unit in 1995 and the same locations were used for surveys in 1996, 1997, 2000, and 2001. Station centres were a minimum of 200 m apart and their outer perimeters were at least 50 m from treatment edges. Data were recorded at each point count station for 12 minutes, and distance and behaviour were recorded for each observation. The stations were surveyed three times during the breeding season between dawn and 0900 hours. A valid observation was based on the following behaviours: singing, calling, moving through the forest, resting, aggressive encounters, drumming, feeding young, and nesting. A subset of observations was called territorial; these included singing, nesting, feeding young, and drumming. Community variables (species richness [number of species], total number of observations, territorial observations, and Shannon-Weiner diversity index [natural log]) (Krebs 1989) were calculated for each block and treatment (treatment unit) by year. Flocking species (bohemian waxwings [*Bombycilla garrulus* L.], pine siskins [*Carduelis pinus* Wilson], and red crossbills [*Loxia curvirostra* L.]) were excluded from calculations of total observations and the diversity index. Data were collected equally from all point count stations in all years except in 1995; block 1 was not sampled due to lack of road access.

Data Analyses

Summaries and analyses were based on observations that fell within 75 m of each point count station centre. Observations were summed from the two point count stations in each treatment unit; the mean of the three survey dates was then calculated. This resulted in one value per treatment unit per year. Even after summing the observations, many of the 26 species recorded on the point count stations occurred too infrequently to analyze; however, they were used in calculations of richness, diversity, and abundance.

For the community variables and nine commonly occurring species (> 4% of the population in any one year), normality was tested using PROC UNIVARIATE (SAS Version 9.1.3; SAS Institute Inc. 2004) and the residuals output by the repeated measures analysis were examined. Data for the American robin (*Turdus migratorius* L.), dark-eyed junco, gray jay, red crossbill, Townsend's solitaire (*Myadestes townsendi* Audubon), and yellow-rumped warbler were reasonably fit by the normal distribution. For three other species (pine siskins, boreal chickadees [*Poecile hudsonicus* Forster], and ruby-crowned kinglets [*Regulus calendula* L.]), data were not normally distributed because of many zero values and were, therefore, not analyzed.

Post-treatment data for community variables and normally distributed species were analyzed using a repeated measures method in PROC MIXED (SAS Version 9.1.3) based on the randomized block design. The analyses were used to test for significant year by treatment interactions, treatment effects, and year effects. Pre-treatment (1995) and annual post-harvest data were analyzed using analysis of variance in PROC MIXED (SAS Version 9.1.3).

The following *a priori* contrast hypotheses were tested to look at specific treatment effects:

1. Is the No-harvest treatment different from the two Irregular Group Shelterwood treatments?
2. Is there a difference between the Whole-tree and Stem-only Irregular Group Shelterwood treatments?
3. Are the Irregular Group Shelterwood and the Group Selection (both whole-tree) treatments different?
4. Is the No-harvest treatment different from the Group Selection treatment?

All results are considered significant at $\alpha = 0.05$.

Results

A total of 26 species were recorded at the point count stations within the study blocks over 5 sample years (Table 2). Before partial cutting, nine species made up 95% of the breeding bird community. The most common species were yellow-rumped warblers (33%), red crossbills (14%), dark-eyed juncos (12%), and gray jays (11%). Other species included pine siskins (8%), Townsend's solitaires (5%), boreal chickadees (5%), ruby-crowned kinglets (4%), and American robins (3%). In the post-harvest period, we found these species remained common, though the proportions within the total population varied from year to year, especially for red crossbills and pine siskins. For example, yellow-rumped warblers and red crossbills made up 48–53% of the total observations in the years when the crossbill population was high (1995–1997), while yellow-rumped warblers and dark-eyed juncos made up 50–51% of the observations in low crossbill years (2000 and 2001).

Results from the repeated measures analysis for the post-harvest period showed treatment differences for some variables (Table 3) that were confirmed with *a priori* contrasts (Table 4). The detections of robins, juncos, and yellow-rumped warblers varied significantly from year to year. The dark-eyed junco significantly used the partial cuts (group selection and irregular group shelterwoods) more intensely than the no-harvest treatment for the whole post-harvest period. Red crossbills had significant

TABLE 2. Mean and range of number of detections per species per year ($n = 5$), averaged by block and survey in the no-harvest experimental units (3.53 ha)

		Mean	Minimum	Maximum
Yellow-rumped warbler	*Dendroica coronata*	1.71	1.47	2.13
Dark-eyed junco	*Junco hyemalis*	0.84	0.33	1.53
Gray jay	*Perisoreus canadensis*	0.61	0.20	1.00
Red crossbill	*Loxia curvirostra*	0.54	0	1.00
American robin	*Turdus migratorius*	0.49	0	0.93
Townsend's solitaire	*Myadestes townsendi*	0.44	0.27	0.60
Ruby-crowned kinglet	*Regulus calendula*	0.25	0.07	0.33
Pine siskin	*Carduelis pinus*	0.22	0	0.50
Boreal chickadee	*Poecile hudsonicus*	0.12	0	0.27
Brown creeper	*Certhia americana*	0.11	0	0.27
Red-breasted nuthatch	*Sitta canadensis*	0.07	0.07	0.08
Bohemian waxwing	*Bombycilla garrulus*	0.05	0	0.13
Three-toed woodpecker	*Picoides tridactylus*	0.05	0	0.17
Mountain chickadee	*Poecile gambeli*	0.04	0	0.13
Golden-crowned kinglet	*Regulus satrapa*	0.04	0	0.13
Spruce grouse	*Falcipennis canadensis*	0.04	0	0.13
Common raven	*Corvus corax*	0.01	0	0.07
Greater yellowlegs	*Tringa melanoleuca*	0.01	0	0.07
Wilson's snipe	*Gallinago delicata*	0.01	0	0.07
Black-backed woodpecker	*Picoides arcticus*	+[a]		
Chipping sparrow	*Spizella passerina*	+		
Great gray owl	*Strix nebulosa*	+		
Pine grosbeak	*Pinicola enucleator*	+		
Solitary sandpiper	*Tringa solitaria*	+		
Varied thrush	*Ixoreus naevius*	+		
Western wood-pewee	*Contopus sordidulus*	+		

[a] = present on the trial blocks.

TABLE 3. Post-harvest repeated measures analyses to test year by treatment interaction, year, and treatment responses by bird species and community variables

	Year by treatment interaction			Year			Treatment		
Species	**df**	***F***	***p***	**df**	***F***	***p***	**df**	***F***	***p***
American robin	9, 36	1.27	0.28	3, 12	7.90	0.003	3, 12	1.21	0.35
Dark-eyed junco	9, 36	0.67	0.73	3, 12	6.98	0.006	3, 12	8.45	0.003
Gray jay	9, 36	2.03	0.06	3, 12	0.91	0.47	3, 12	1.96	0.17
Red crossbill	9, 36	3.58	0.003	3, 12	5.29	0.02	3, 12	7.06	0.006
Townsend's solitaire	9, 36	1.14	0.36	3, 12	1.71	0.22	3, 12	1.35	0.31
Yellow-rumped warbler	9, 36	1.35	0.25	3, 12	5.73	0.01	3, 12	1.93	0.18
Richness	9, 36	2.75	0.01	3, 12	2.39	0.12	3, 12	3.39	0.05
Diversity	9, 36	1.17	0.34	3, 12	3.45	0.05	3, 12	0.81	0.51
Total observations	9, 36	2.18	0.05	3, 12	13.26	0.0004	3, 12	6.97	0.006
Territorial observations	9, 36	1.85	0.09	3, 12	15.41	0.0002	3, 12	14.59	0.0003

TABLE 4. Significant ($\alpha = 0.05$) contrasts for the post-treatment period (1996–2001) for those species without significant year by treatment interactions

Species	**Contrast**[a]	**df**	***F***	***p***
Dark-eyed junco	No-harvest vs. IGS–SO and IGS–WT	1, 12	24.41	0.0003
Dark-eyed junco	No-harvest vs. GS–SO	1, 12	13.03	0.0036
Gray jay	No-harvest vs. IGS–SO and IGS–WT	1, 12	4.54	0.0545
Yellow-rumped warbler	No-harvest vs. IGS–SO and IGS–WT	1, 12	5.65	0.0350
Territorial observations	No-harvest vs. IGS–SO and IGS–WT	1, 12	39.40	0.0001
Territorial observations	No-harvest vs. GS–SO	1, 12	20.18	0.0007

[a] IGS–SO = irregular group shelterwood stem only; IGS–WT = irregular group shelterwood whole tree; GS–SO group selection.

interactions between year and treatment, while robins, solitaires, and yellow-rumped warblers did not have significant treatment differences in the overall model. However, *a priori* contrasts found that over the post-harvest period both yellow-rumped warblers and gray jays did use the shelterwood treatments more than the no-harvest treatments. Territorial observations were significant for both treatment and year and the *a priori* contrasts showed fewer observations in the no-harvest treatment compared with the three partial-cutting treatments. Richness interacted significantly between treatment and year, while the diversity index varied significantly by year but not treatment. Total observations showed a significant interaction between site and treatment.

The data were further analyzed to investigate treatment effects by year. American robin was the only variable that showed significant pre-treatment differences (Table 5), due to higher detections in the irregular shelterwood (stem only) treatment (Table 6; Figure 4a). A significant difference in use also occurred in 1997 due to more frequent observations in the group selection treatment than in the shelterwood (stem-only) treatment (Table 6). Dark-eyed juncos used the shelterwoods significantly more than the no-harvest treatment in three post-harvest years (Table 6; Figure 4b), while use of the group selection treatment exceeded the no-harvest in only two post-harvest years. Yellow-rumped warblers and gray jays used the treatments significantly differently only in 2000 (Table 5; Figures 4c and 4d). In this year, use of the shelterwoods exceeded the no-harvest treatment (Table 6). For yellow-rumped warblers, this result should be tempered by the significant pre-harvest (1995) *a priori* contrast between the no-harvest and the shelterwood treatments (Table 6). In 1996, red crossbills used the shelterwoods significantly more than the no-harvest treatment, whereas in 1997 only the use between the shelterwoods differed (Table 6; Figure 4e). In 2000, use of the group selection exceeded the no-harvest treatment

TABLE 5. Univariate analysis of variance to test annual response of species and community variables to treatments

Species	1995			1996			1997			2000			2001		
	df	*F*	*p*	df	*F*	*p*	df	*F*	*p*	df	*F*	*p*	df	*F*	*p*
American robin	3, 9	6.69	0.01	3, 12	0.16	0.92	3, 12	4.03	0.03	3, 12	0.95	0.45	3, 12	0.02	0.99
Dark-eyed junco	3, 9	1.10	0.40	3, 12	4.06	0.03	3, 12	1.00	0.43	3, 12	4.84	0.02	3, 12	2.45	0.11
Gray jay	3, 9	0.38	0.77	3, 12	2.27	0.13	3, 12	2.26	0.13	3, 12	4.46	0.03	3, 12	0.49	0.69
Red crossbill	3, 9	1.21	0.36	3, 12	5.98	0.01	3, 12	3.79	0.04	3, 12	3.79	0.04	3, 16	0.94	0.45
Townsend's solitaire	3, 9	0.73	0.56	3, 12	1.05	0.41	3, 12	1.14	0.37	3, 12	1.48	0.27	3, 12	0.32	0.81
Yellow-rumped warbler	3, 9	3.32	0.07	3, 12	1.45	0.28	3, 12	0.44	0.73	3, 12	3.48	0.05	3, 12	0.49	0.69
Richness	3, 9	2.69	0.11	3, 12	6.72	0.007	3, 12	1.07	0.40	3, 12	5.45	0.01	3, 12	1.19	0.35
Diversity	3, 9	2.25	0.15	3, 12	1.09	0.39	3, 12	0.29	0.83	3, 12	4.05	0.03	3, 16	0.58	0.63
Total observations	3, 9	1.01	0.43	3, 12	19.38	0.0001	3, 12	0.18	0.91	3, 12	11.03	0.0009	3, 12	0.68	0.58
Territorial observations	3, 9	0.57	0.65	3, 12	14.66	0.0003	3, 12	0.84	0.50	3, 12	7.49	0.004	3, 12	2.46	0.11

TABLE 6. Significant ($\alpha = 0.05$) contrast comparisons among treatments in the pre-treatment year (1995) and in each of the post-treatment years

Species	Year	Contrast[a]	df	*F*	*p*
American robin	1995	No-harvest vs. IGS–SO and IGS–WT	1, 9	9.35	0.0136
	1995	IGS–SO vs. IGS–WT	1, 9	8.65	0.0164
	1995	IGS–SO vs. GS–SO	1, 9	12.46	0.0064
	1997	IGS–SO vs. GS–SO	1, 12	8.31	0.0138
Dark-eyed junco	1996	No-harvest vs. IGS–SO and IGS–WT	1, 12	10.91	0.0063
	1996	No-harvest vs. GS–SO	1, 12	7.51	0.0179
	2000	No-harvest vs. IGS–SO and IGS–WT	1, 12	13.42	0.0032
	2000	No-harvest vs. GS–SO	1, 12	6.74	0.0234
	2001	No-harvest vs. IGS–SO and IGS–WT	1, 12	7.30	0.0193
Gray jay	2000	No-harvest vs. IGS–SO and IGS–WT	1, 12	11.42	0.0055
Red crossbill	1996	No-harvest vs. IGS–SO and IGS–WT	1, 12	17.37	0.0013
	1997	IGS–SO vs. IGS–WT	1, 12	8.30	0.0138
	2000	No-harvest vs. GS–SO	1, 12	10.13	0.0080
Yellow-rumped warbler	1995	No-harvest vs. IGS–SO and IGS–WT	1, 9	5.94	0.0375
	2000	No-harvest vs. IGS–SO and IGS–WT	1, 12	7.77	0.0164
Richness	1996	No-harvest vs. IGS–SO and IGS–WT	1, 12	14.11	0.0027
	1996	No-harvest vs. GS–SO	1, 12	16.22	0.0017
	2000	IGS–SO vs. IGS–WT	1, 12	13.45	0.0030
Diversity	2000	IGS–SO vs. IGS–WT	1, 12	11.86	0.0049
Total observations	1996	No-harvest vs. IGS–SO and IGS–WT	1, 12	48.21	0.0001
	1996	No-harvest vs. GS–SO	1, 12	43.30	0.0001
	2000	No-harvest vs. IGS–SO and IGS–WT	1, 12	30.59	0.0001
	2000	No-harvest vs. GS–SO	1, 12	9.46	0.0096
Territorial observations	1996	No-harvest vs. IGS–SO and IGS–WT	1, 12	34.78	0.0001
	1996	No-harvest vs. GS–SO	1, 12	29.18	0.0002
	2000	No-harvest vs. IGS–SO and IGS–WT	1, 12	21.54	0.0006
	2001	No-harvest vs. IGS–SO and IGS–WT	1, 12	5.84	0.0325

[a] IGS–SO = irregular group shelterwood–stem only; IGS–WT = irregular group shelterwood–whole tree; GS–SO group selection.

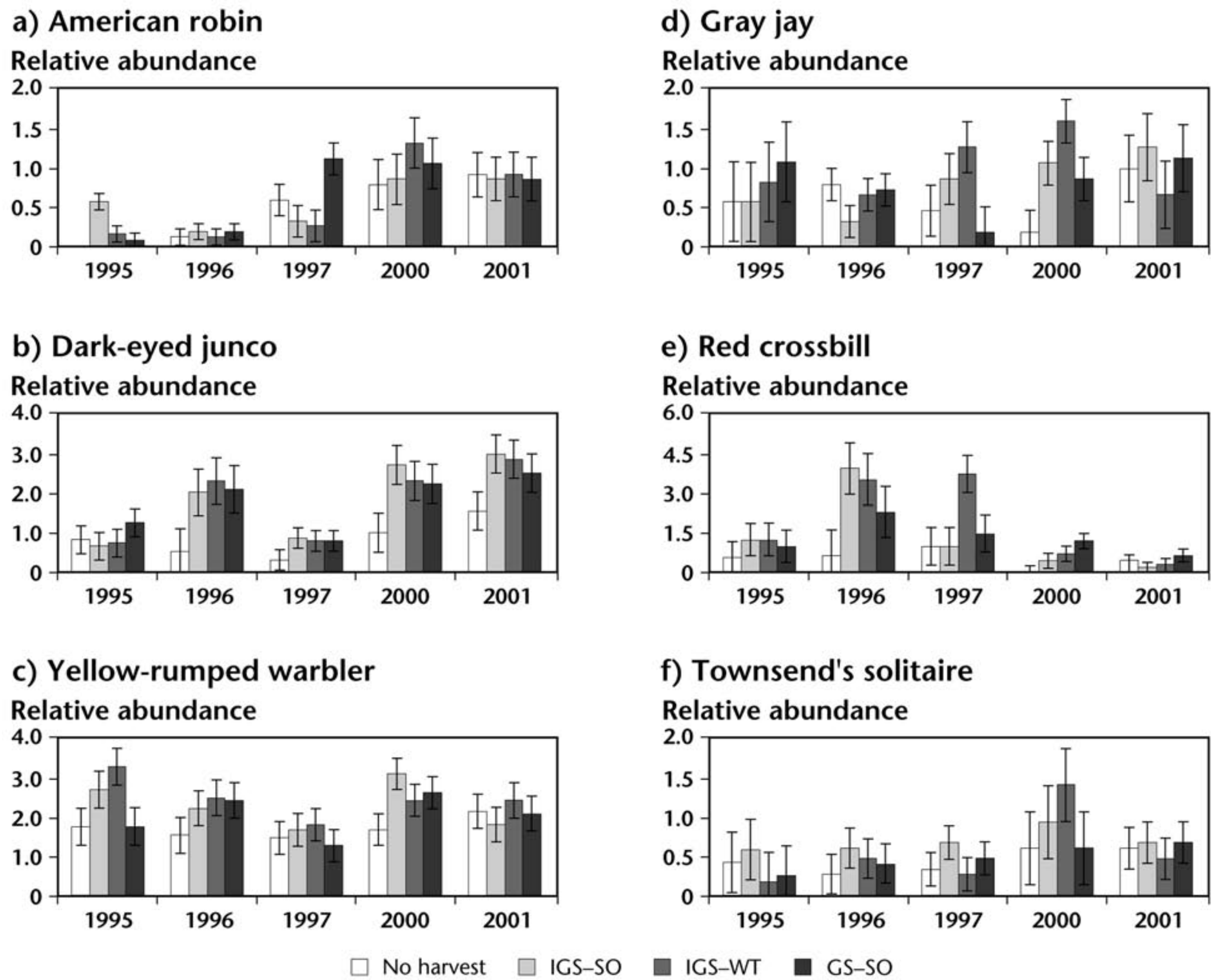

FIGURE 4. Least square means and standard errors for treatments, based on analyses of variance by year for each species.

(Table 6). No differences in use were evident among treatments in any year for Townsend's solitaires (Table 5; Figure 4f).

Species richness was similar among treatments in 1995, 1997, and 2001 (Table 5; Figure 5a). Significant differences in 1996 were caused by more species in the three partial-cutting treatments than in the no-harvest treatment (Table 6). In 2000, more species of birds were detected in the whole-tree shelterwood than in the stem-only shelterwood (Table 6). The diversity index only varied among treatments in one of four post-harvest years (2000) when there was a higher value in whole-tree shelterwood than in the stem-only shelterwood (Table 6; Figure 5b). The total and territorial observations in the three partial cuts significantly exceeded the no-harvest treatment in 1996 and 2000, and territorial observations were higher in shelterwoods than the no-harvest in 2001 (Tables 5 and 6; Figures 5c and 5d).

Discussion

Our research shows that the number and density of bird species were very low in the upland mature lodgepole pine forests of the MSxv and SBPSxc in west-central British Columbia. This result is similar to studies in lodgepole pine forests in the United States (Austin and Perry 1979; Taylor and Barmore 1980). Hein (1980), in a review of literature from Colorado, concluded that species richness is typically low in lodgepole pine forests compared with other forest types. Similarly, Hobson and Bayne (2000) found lower richness and abundance in jack pine forests compared with white spruce (*Picea glauca* [Moench] Voss) or trembling aspen (*Populus tremuloides* Michx.) in the boreal region of Saskatchewan. This is also the case in the central interior of British Columbia, where richness, abundance, and

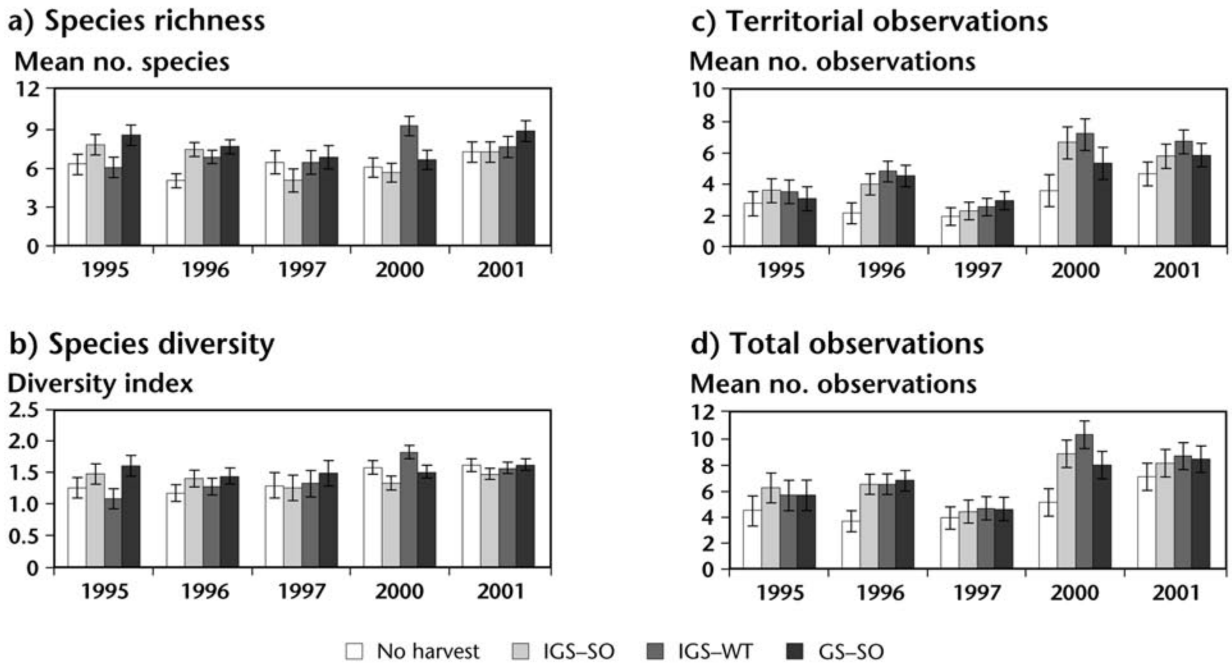

FIGURE 5. Least square means and standard errors for treatments, based on analyses of variance by year, for community variables.

diversity in lodgepole pine are lower compared with Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) forests (Waterhouse and Dawson 1998) and Engelmann spruce (*Picea engelmanni*i Parry)–subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) forests (Davis *et al.* 1999; Leupin *et al.* 2004).

James and Wamer (1982) pointed out that species richness and density are minimal in conifer forests with few tree species, low canopy, and high tree density. Wilson (1974) described positive correlations of species diversity with foliage height diversity and total percent vegetation cover, while DeGraaf *et al.* (1998) documented stand structure as the best predictor of bird abundance. Certainly, the forests in our study have low vegetation cover, low canopy, and a single tree species. Erskine (1977) observed that jack pine stands on xeric sites do not have a shrub layer due to acidification by pine needles, and this consequently limits the habitat to canopy- and ground-dwelling birds. On the trial blocks, the shrub layer is sparse, soils are poorly developed, and climate is dry compared with other biogeoclimatic zones (Sagar *et al.* 2005). Also, resinous foliage of pine trees may limit insect communities (Capen 1979) and their predators.

Old, slow-growing lodgepole pine trees have high-density wood that is difficult for cavity-nesters to excavate. Martin *et al.* (2004) found that pine is not a preferred tree species for cavity-nesters in the Cariboo-Chilcotin. The lack of suitable nest trees may ultimately affect the density and richness of primary and secondary cavity-nesters in pure lodgepole pine forests. In this trial, only two primary excavators (three-toed [*Picoides tridactylus* L.] and black-backed [*Picoides arcticus* Swainson] woodpeckers) and two weak excavators (red-breasted nuthatch [*Sitta canadensis* L.] and boreal chickadees) were observed. In contrast, Martin *et al.* (2004) reported nine species in the adjacent Interior Douglas-fir biogeoclimatic zone, where there is a mix of Douglas-fir, trembling aspen, pine, and hybrid spruce.

The bird species composition in our study area was very similar to that reported for lodgepole pine by Hein (1980), Austin and Perry (1979), and Taylor and Barmore (1980). Hein (1980) noted that species dominance (where one or two species accounted for 25–50% of the population) is high. This was also the case in our study where yellow-rumped warblers and red crossbills made up 48–53% of the observations in some years, and yellow-rumped warblers plus dark-eyed juncos constituted 50% in low population years for crossbills. Kirk and Hobson (2001) found that the yellow-rumped warbler was the most common species in boreal jack pine forest in Saskatchewan. Other abundant species, in common with our study, include pine siskin, ruby-crowned kinglet, and gray jay. Dark-eyed junco and yellow-rumped warbler are the two most common breeding species in boreal regions of Canada, and the American robin and ruby-crowned kinglet are in the top 10 (Blancher 2003).

Overall, our study indicates that the complex of species within the community did not shift substantially due to the partial-cutting treatments (28–39% area cut). Species occurred in similar proportions pre- and post-harvest in the treatments. The species diversity index remained fairly constant from year to year and among treatments. Harvesting caused a positive response in richness and abundance in some years, resulting from an increase in the species common in the stands pre-harvest (dark-eyed juncos, gray jays, and yellow-rumped warblers) and not from an influx of new species. In response to partial cutting, most studies show that shifts in individual species abundance and the introduction of species typical of early seral habitat usually result in increased diversity and abundance of the whole bird community (Waterhouse and Dawson 1998; King and DeGraaf 2000; Simon *et al.* 2000; Lance and Phinney 2001). High resistance to change is evident when low levels of cutting (≤ 30%) are used, although a few species shift in abundance (Steventon *et al.* 1998; Waterhouse and Dawson 1998; Robinson and Robinson 1999; Simon *et al.* 2000; Leupin *et al.* 2004). At higher levels of tree removal (50–60%), the bird community in the partial cuts becomes more distinct from the uncut forest and some species may be sufficiently reduced in abundance to cause management concern (Steventon *et al.* 1998; Waterhouse and Dawson 1998; Simon *et al.* 2000). The amount of partial cutting and the ecosystem are both factors in the degree of response. Old lodgepole pine forests have a simple bird community made up of generalist species that adapt to a range of habitats; therefore, the community is fairly resilient to the habitat changes caused by partial cutting up to 40%.

Dark-eyed Junco

Generally, there was no response or a positive response by individual bird species to the partial-cutting treatments, depending on the year. However, the dark-eyed junco used all the partial-cutting treatments significantly more than the no-harvest treatments over the post-harvest study period. This species forages mostly on the ground and in the litter (Nolan *et al.* 2002). Microclimate data from trial blocks showed that clearcuts had warmer soil temperatures than the partial cuts; within the partial cut the centres and south-aspect edges were warmer than the north aspects (Sagar *et al.* 2005). Increased warming in parts of the gaps may promote insect activity and productivity. Austin and Perry (1979) found greater abundance of juncos in earlier seral stages, while Taylor and Barmore (1980) described this species as ubiquitous through all seral stages of lodgepole pine forest. On young clearcuts near the study blocks, dark-eyed juncos were about two times more abundant than in uncut, old forest (Waterhouse 1997). In the interior of British Columbia, this common species is more abundant in partially cut and clearcut stands compared with mature and old undisturbed forest (Steventon *et al.* 1998; Waterhouse and Dawson 1998; Davis *et al.* 1999; Lance and Phinney 2001; Leupin *et al.* 2004). In the boreal forest, this species occurs most frequently in young seral forest (Kirk and Hobson 2001) and clearcuts with low retention (Schieck *et al.* 2000; Harrison *et al.* 2005).

Yellow-rumped Warbler

The yellow-rumped warbler was the most common species in this study. In the post-treatment period, and especially in the year 2000, significantly more were observed in the shelterwood treatments than in the no-harvest treatment; however, this pattern of use was also significant in the pre-harvest year. After reviewing the literature, Hunt and Flaspohler (1998) concluded that this species can maintain normal, or near normal, breeding densities as long as some mature trees are left on site for nesting. This conclusion is also supported by various British Columbia studies (Steventon *et al.* 1998; Waterhouse and Dawson 1998; Leupin *et al.* 2004) that tested 40% or more retention. Steventon *et al.* (1998) reported the highest densities of yellow-rumped warblers in a 40% retention treatment. Others report lower numbers in clearcuts with 20% or less retention (Schieck *et al.* 2000; Simon *et al.* 2000; Lance and Phinney 2001; Harrison *et al.* 2005). Kirk and Hobson (2001) reported yellow-rumped warblers in all seral stages of jack pine forest (although density was positively correlated with stand age), whereas Austin and Perry (1979) recorded highest numbers in 40-year-old lodgepole pine clearcuts. Seip (1996) in the Sub-Boreal Spruce biogeoclimatic zone in British Columbia found abundant yellow-rumped warblers in all age classes over 20 years. The adaptability of the yellow-rumped warbler to various habitats is due to its generalist foraging strategies for insects (i.e., hawking and gleaning [bark and foliage]) during the breeding season (Hunt and Flaspohler 1998).

Red Crossbill

The red crossbill is strongly dependent on conifer seed for forage (Benkman 1993) and populations make large nomadic movements in search of good cone crops (Adkisson 1996). Observations from our study site certainly varied from year to year. Lodgepole pine trees at northern latitudes hold mostly serotinous cones that remain on the trees for many years (e.g., 15 years in Alberta [Hellum 1983]) and provide a reliable food supply from year to year. Holimon *et al.* (1998) suggested that mature stands are essential for maintaining crossbill populations. Benkman (1993) described cone production as more consistent and prolific in mature and old-growth forest and, therefore, recommended the designation of no-harvest areas, the extension of the rotation age, and the use of partial cuts to maintain habitat. In our study, partial-cutting treatments did not adversely affect crossbills. In fact, crossbills were far more common in the partial-cutting treatments than in the no-harvest treatment in 1996. Perhaps, these birds were taking advantage of the cones left on the ground and in the slash after harvesting. From cones on the ground, Waterhouse *et al.* (2001) estimated 2.8 million viable seeds per hectare in the IGS–WT treatment and 0.9 million seeds per hectare in the IGS–SO treatment. Of the available seed in the cones on the ground, 46–86% of the seed was released by September 1996. A huge amount of seed was also stored in the slash piles left in the stem-only shelterwood treatment ($\leq$ 23.1 million seeds per hectare). Waterhouse and Dawson (1998) noted no differences in the number of crossbill observations from heavily partially cut to no-harvest treatments in old Douglas-fir forests, although crossbill abundance was positively correlated with increased amounts of old forest on the landscape.

Gray Jay

Gray jays are usually associated with spruce or spruce-mix forests, not pine forests (Strickland and Ouellet 1993; Campbell *et al.* 1997). These birds have large, year-round breeding territories (41–146 ha) (Strickland and Ouellet 1993), and a single territory probably overlaps several treatment units within any one block in our study. In the post-treatment period, there were fewer observations in the no-harvest treatment than in the shelterwoods, although this difference was obvious in only one of the four years post-harvest. Gray jays are generalist foragers that eat berries, seeds from berries and conifers, fungi, insects, small mammals, eggs, and nestlings (Strickland and Ouellet 1993). Only a slight increase in the percentage cover of dwarf shrubs and herbs was evident on the partial-cutting treatments compared with the no-harvest treatment, implying no corresponding increase in berry supply. Perhaps the slash piles and serotinous cones found in the slightly warmer openings in the partial cuts attracted small mammals and insects. Also, the increase in dark-eyed juncos, presumably nesting in the partial cuts, may interest foraging jays. Campbell *et al.* (1997) noted that this species prefers to nest in more open areas such as forest edges rather than dense forest. In boreal jack pine forests, gray jays prefer relatively open canopy (Kirk and Hobson 2001). Most studies report gray jays as ubiquitous in various seral stages (Taylor and Barmore 1980; Kirk and Hobson 2001) and various degrees of partial cutting to clearcutting (Steventon *et al.* 1998; Waterhouse and Dawson 1998; Simon *et al.* 2000), although others found lower abundance in recent clearcuts with little retention of trees (Schieck *et al.* 2000; Lance and Phinney 2001).

Townsend's Solitaire

In a general review, Bowen (1997) stated that Townsend's solitaires prefer coniferous forests including lodgepole pine, and particularly thinned stands or selectively logged stands with a sparse shrub layer and little vegetative ground cover. In Douglas-fir forests in the central interior of British Columbia, Townsend's solitaires were common particularly in stands where there was heavy removal of trees (Waterhouse and Dawson 1998). In our study, the Townsend's solitaire showed no preferential use of the partial-cutting treatments. Of interest, this species was consistently more abundant ($\leq$ five times) in the lower-elevation SBPS blocks than the MS blocks. This may be due to the more open stand structure and greater abundance of common juniper in the SBPS zone. Bowen (1997) cites several studies that mention juniper berries as an important forage for solitaires.

American Robin

American robins did not respond to the treatments although their density varied greatly from year to year. Other studies in the interior of British Columbia have shown robins to be more common in early seral stages or heavily logged forest types (Steventon *et al.* 1998; Waterhouse and Dawson 1998; Davis *et al.* 1999).

Management Implications

In stands that have a live component after the beetle epidemic subsides, silvicultural systems other than clearcutting should be considered to maintain the complex of bird species associated with older pine forest.

Historically, the lodgepole pine forests throughout the northern caribou range in the west Chilcotin (about 1.5 million ha) were a mosaic of even-aged stands of varying sizes and age classes resulting chiefly from wildfire. Fire suppression, especially since the 1960s, resulted in more mature to old forest in some parts of the Itcha-Ilgachuz caribou winter range beyond what natural disturbance patterns would have generated. Conversely, forest clearcutting has substantially reduced the mature and old-forest component on other parts of the winter range. Under the Cariboo-Chilcotin Land Use Plan, a large and fairly contiguous area in the heart of the northern caribou winter range was placed in parks and protected areas (35%), or set aside for "modified harvesting" (13%) (Youds *et al.* 2002).

The large area designated for "modified harvesting" (> 181 000 ha) raises the concern for impact on other species. Within 5 years of the first harvest entry, the effect of the group selection and shelterwood silvicultural systems on the composition of the bird community and relative abundance of common bird species was low. We did not find new species, typical of early seral stands, occupying the new partial cuts, but some species (dark-eyed juncos, yellow-rumped warblers, and gray jays) already common in old lodgepole pine forest became increasingly abundant in some years. In other studies, a high level of retention was generally shown to maintain the species composition of uncut forest although shifts in abundance do occur for some species and new species are introduced (Steventon *et al.* 1998; Waterhouse and Dawson 1998; Simon *et al.* 2000; Leupin *et al.* 2004; Harrison *et al.* 2005). Kirk and Hobson (2001) recommended use of shelterwoods, selective cuts, and extended rotations to conserve the unique bird communities associated with older jack pine forests of boreal Saskatchewan.

The effect of subsequent harvesting entries associated with group selection and shelterwood systems in lodgepole pine stands is not known. However, we expect in the group selection system that the bird community would remain similar over time due to low removal and long cutting cycles. In the irregular group shelterwood system, stands consist of openings and old pine forest at the initial entry, but will become a mosaic of two age classes in alternating small patches. After the second entry, one part of the stand will be 0–70 years old and the other portion will have trees 70–140 years of age. We expect that the common species, statistically tested in the study, should remain abundant. It is possible that low abundance species associated with old forest such as red-breasted nuthatches, brown creepers, boreal chickadees, and woodpeckers may decline for a short interval after the second harvest until nesting trees are recruited.

Kirk and Hobson (2001) concluded that jack pine, when mixed with other tree species, becomes suitable habitat for new species of birds. Throughout most of the caribou wintering area, the forests are pure lodgepole pine. In moister areas adjacent to marshes and creeks, and in seepage areas, a varying amount of hybrid spruce is mixed in with the pine. These areas have greater diversity of bird species (Waterhouse 1995). In another component of Itcha-Ilgachuz research trial, Daintith *et al.* (2005) found that hybrid spruce had good survival and reasonable growth in all of the partial-cutting treatments, especially in the MSxv. To maintain caribou habitat, lodgepole pine should be the primary reforestation species; however, spruce could be planted in moist areas, shady edges, or areas with a high risk of mistletoe infection. The mixing of spruce into the forest could have an overall positive effect on the bird community.

In areas not designated for modified harvesting systems, including 52% of the caribou winter range, clearcutting on a short rotation (80 years) is the most typically applied silvicultural system. Clearcutting is accelerating throughout the interior of British Columbia in response to the current mountain pine beetle outbreak. By 2013, Eng *et al.* (2006) estimate 80% mortality in pine units for the timber producing land base in British Columbia. In stands that have a live component after the beetle epidemic subsides, silvicultural systems other than clearcutting should be considered to maintain the complex of bird species associated with older pine forest. At a minimum, reserving patches of dead and live trees in clearcuts may contribute to the conservation of habitat attributes required by some species (Klenner 2006; Martin *et al.* 2006).

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Test Your Knowledge . . .

Forest bird response to partial cutting in lodgepole pine forests on caribou winter range in west-central British Columbia

How well can you recall some of the main messages in the preceding Research Report? Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. Compared with other forest types in British Columbia, what level of abundance and diversity of birds are found in lodgepole pine forests?
   A) Low
   B) Moderate
   C) High

2. How will applying "modified harvesting" systems in northern caribou habitat affect the bird community in the short term?
   A) Strongly positive
   B) Minimal change
   C) Strongly negative

3. Generally, in British Columbia forests, at what level of partial cutting in mature to old forest will the composition of the breeding bird community start to change substantially?
   A) 30% removal
   B) 60% removal
   C) 80% removal

Answers

1. A 2. B 3. B