Bird Use of Wildlife Tree Patches 25 Years after Clearcutting

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Abstract

Group seed tree reserves were left in several large clearcuts between 1966 and 1970 in the southern interior of British Columbia. These mimic what are now being recommended as wildlife tree patches to mitigate the effects of timber harvesting on cavity-nesting species. In the 160-ha Gable Creek clearcut, mean reserve patch size was 0.9 ha, occupying 7% of the gross area, with a mean distance of 203 m to the nearest neighbouring patch. In the 1000-ha Wallace Creek clearcut, mean reserve patch size was 2.7 ha, occupying 10% of the gross area, with a mean distance of 201 m to the nearest neighbouring patch or the forest. At Gable Creek, winter bird relative abundance from transect counts, spring owl and woodpecker playback responses, and breeding bird relative abundances from point counts, were compared to unharvested forest and to a clearcut of the same age without patches. At Wallace Creek, breeding bird abundances derived from 50-m point counts were compared to an unharvested forest, and spot-mapping within patches was used to determine the effects of patch size. The wildlife tree patches at Gable and Wallace Creeks were habitat patches for many species of cavity-nesting and other forest birds that were absent from the regenerating clearcut without patches. Some bird species (i.e., Golden-crowned Kinglet, Red-breasted Nuthatch, Solitary Vireo, and Western Tanager) used the patches as isolated habitat within a matrix of unsuitable habitat. For these species, recommended patch size is 3.0 ha or greater to maintain at least one or more breeding territories of each species in most of the patches. Many cavity-nesting (i.e., Northern Pygmy Owl, Northern Flicker, Williamson's Sapsucker, Red-naped Sapsucker, Pileated Woodpecker, and Hairy Woodpecker) and other bird species (i.e., Gray Jay, Steller's Jay, and Spruce Grouse) used the patches as habitat elements within a matrix of what otherwise would have been unsuitable habitat if the patches had been absent. Wildlife tree patches did not appear to be

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successful at mitigating the effects of clearcutting on Boreal Chickadees, Brown Creepers, Three-toed Woodpeckers, Northern Saw-whet Owls, and Barred Owls. Larger reserves or alternative timber harvesting methods will have to be considered for these five species.

Seventy-six percent of cavity nests found were in western larch wildlife trees >50 cm dbh. Of the potential mitigation measures for cavity nesters, only wildlife tree patches will keep large decaying trees for nesting, large and decaying trees as feeding substrates for woodpeckers, large trees coming on stream for future feeding and nesting, and provide suitable habitat for other forest species.

Possible factors that may have overestimated the benefit of patches for woodpeckers and sapsuckers were: (a) there were more snags (8–27/ha) in the clearcuts between patches than are found in present clearcuts; and (b) Hairy and Pileated Woodpeckers probably relied on forest adjacent to the study sites as well as the patches. Radio-telemetry studies are recommended to distinguish these effects, as well as determine acceptable distances between patches for establishment of successful breeding territories.

Introduction

The conservation of wildlife trees—live or dead trees used by animals for nesting, feeding, or fulfilling other life functions—has received recent attention in British Columbia because of Workers' Compensation Board regulations requiring the falling of all standing diseased or dead trees in work zones, and the prevalence of clearcutting as the primary method of timber harvesting. The Wildlife Tree Committee (WTC) of British Columbia, a joint initiative of the B.C. Ministry of Environment, Lands and Parks, the Workers' Compensation Board, and the Silviculture Practices Branch of the B.C. Ministry of Forests, has been investigating methods that will provide for worker safety, forest regeneration goals, and for wildlife dependent on these trees within the same framework. One of the methods recommended for the maintenance of wildlife trees is in wildlife tree patches (WTC 1994). Wildlife tree patches are designated "no-work" zones where standing dead trees within the patches do not have to be felled for worker safety.

The dynamics of bird populations and bird habitat use in forest patches have been studied within agricultural mosaics (e.g., Blake 1991, Loman and von Schantz 1991, Opdam and Schotman 1987, Robbins *et al.* 1989). The common theme among these studies has been that species reliant on forest habitat are lost as patch size decreases or as isolation from other forest increases. However, potential comparisons to wildlife tree patches are limited because the matrices surrounding those woodlots were permanently unsuitable for forest species while the matrix surrounding wildlife tree patches after clearcutting will regenerate into managed forest. The bird populations of the patches are likely to change over time as the surrounding matrix becomes more suitable for some forest species. This change has not been studied, although it is essential for the management of bird species over the course of a timber rotation.

To begin to address how bird species, and cavity-nesting birds in particular, use forest patches within a matrix of regenerating forest, this study examined relative abundances of birds in wildlife tree patches 25 to 29 years after clearcutting. Between 1966 and 1970, Pope and Talbot Ltd. of Midway, B.C., retained group seed tree reserves within several clearcuts in the Gable Creek and Wallace Creek drainages in the southern interior of B.C. The retained forest patches were similar in size and total area to what are now being recommended as wildlife tree patches by the *Biodiversity Guidebook* of the Forest Practices Code (B.C. Min. Forests and BC Env. 1995). This provided a unique opportunity to investigate which bird species use wildlife tree patches within the matrix of a regenerating forest.

Study Sites

The study sites were in two drainages, Gable and Wallace Creeks, in the southern interior of British Columbia (Figure 1a). The drainages are in the Boundary Forest District of the Nelson Forest Region.

Gable Creek

Gable Creek drains into the Granby River about 40 km north of Grand Forks, British Columbia. The study area is about 8 km upstream of the confluence with the Granby River. The study site is within the Columbia-Shuswap Moist Warm Interior Cedar-Hemlock Variant

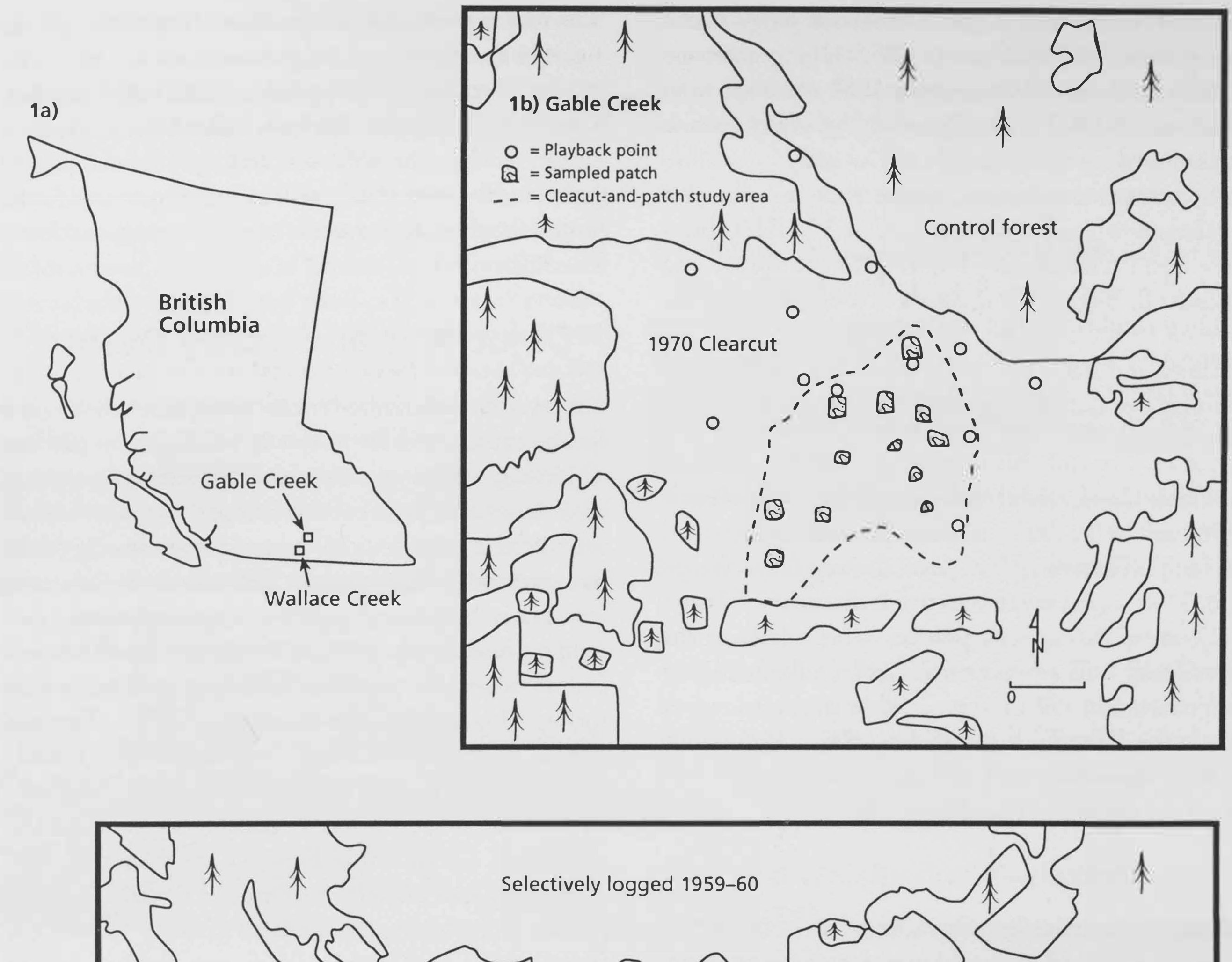

Figure 1. Study site locations: (1a) Study areas in southern British Columbia; (1b) Forest and clearcut habitats at Gable Creek study site; (1c) Forest and clearcut habitats at Wallace Creek study site.

(ICHmw2) and Okanagan Dry Cold Engelmann Spruce-Subalpine Fir Variant (ESSFdc1) biogeoclimatic zones (Braumandl 1992) between 1250 and 1650 m in elevation. The ICHmw2 forest at the study sites is characterized by mixed stands of Douglas-fir, western larch, western redcedar, western hemlock, and Engelmann-white hybrid spruce. The ESSFdc1 forest in the area is characterized by Engelmann spruce and subalpine fir forests. Seral stands of lodgepole pine are common in both zones. The boundary between the ICHmw2 and ESSFdc1 on the site is not distinct, and the entire area sampled appeared to be ecotonal between the two zones.

The Gable Creek study block was 160 ha and harvested in 1966 and 1970. Twelve seed tree patches were reserved at the time of harvest. Mean patch size was 0.9 ha (range 0.3–1.5 ha) with a mean interpatch distance to nearest neighbour of 203 m. The patches occupied 7% of the study block. A clearcut control block of about 160 ha was harvested in 1970 and no patches were retained. A forest control site was used to the northeast of the study cutblocks across Gable Creek with similar slope and elevational gradients. (See Figure 1b.)

Wallace Creek

Wallace Creek drains into Boundary Creek (a tributary of the Kettle River) about 3 km north of Greenwood, British Columbia. The study area is in Tree Farm Licence 8, managed by Pope and Talbot Ltd., Midway, B.C. The study site is entirely within the Kootenay Moist Cool Interior Cedar-Hemlock Variant (ICHmk1) biogeoclimatic zone (Braumandl 1992) between 1100 and 1400 m in elevation. Climax mesic sites are characterized by stands of western redcedar, Engelmann-white hybrid spruce, and subalpine fir, and a lack of western hemlock. However, actual forest stands in the valley are dominated by western larch and Douglas-fir of an average age of 200 years. Lodgepole pine is also a common seral species throughout the stands.

The Wallace Creek study block is approximately 1000 ha and was clearcut between 1968 and 1970 (with some additional clearcutting at the periphery of the site from 1974–1977). Twenty-nine seed tree patches were reserved at the time of harvest. Mean patch size was 3.6 ha (range 1.6–18.9 ha), and the patches occupied 10% of the gross area of the block. Mean interpatch distance to the nearest neighbour was 201 m. Most patches were small (median 2.3 ha) with only 3 patches larger than 4.3 ha (5.9, 14.4, and 18.9 ha). No clearcut control block of the same size and age was available in the area without reserved patches. An unharvested forest control site was selected to the east of the study cutblock. (See Figure 1c.)

Objectives and Study Design

The overall objectives were to determine which bird species established territories in wildlife tree patches within a 25- to 29-year-old matrix of forest regenerating after clearcutting, and to draw comparisons with unharvested forest and with a 25-year-old regenerating forest without wildlife tree patches. Three time periods were selected for bird sampling: winter (January) for winter-resident birds, early spring (March and April) as owls and woodpeckers establish breeding territories, and spring (May and June) for the majority of breeding bird species. Relative abundance of birds was assessed in mid-winter using transects, in early spring using playback-response point counts, and in spring using point counts. Additional assessment of breeding territory establishment using spot mapping was used at Wallace Creek to provide more thorough assessment of cavity-nesting and forest species within the wildlife tree patches, and to examine for correlations with patch size or isolation.

The group seed tree reserves reserved at time of clearcutting were termed "wildlife tree patches" or just "patches." The forest regenerating after clearcutting was referred to as "clearcut" habitat to distinguish it from the patches and continuous forest types. The "clearcut-between-patches" refers to the regenerating forest that is the matrix between the patches. For methods in which it was not always possible to reliably tell which part of the habitat the responses emanated from, the patches and clearcut-between-patches were considered one habitat termed "clearcut and patches." The continuous and unharvested forest is referred to as "forest" habitat.

The specific objectives and study designs were largely dictated by the available sites since this was a retrospective study, rather than a designed experiment. The possible study designs at Gable Creek were stronger than at Wallace Creek because Wallace Creek lacked a clearcut without patches for comparison to a clearcut with patches. Consequently, all the relative abundance methods were applied only at Gable Creek. At Gable Creek, a two-factor Analysis of Variance (ANOVA) study design was possible when the patches and surrounding matrix could be sampled independently. In the two-factor ANOVA, the effects of habitat (i.e., either forest or regenerating clearcut) and patches (i.e., either present or absent) could be evaluated. This design also allowed for assessment of an interaction effect between patches and habitat—in particular whether the effect of the patches on relative abundance of a species extended outwards from the patches into the surrounding clearcut. In the one-factor ANOVA, three habitats were contrasted. A one-factor ANOVA study design was used when the patches and surrounding matrix could not be sampled independently as in the playback-response counts at Gable Creek, or when there was no clearcut control without patches as at Wallace Creek.

Wildlife tree densities were estimated to characterize the wildlife trees available for use in each habitat. The use of each tree by woodpeckers was also estimated to allow for an assessment of woodpecker use of patches that was independent from methods that relied solely on bird detections.

Methods

Analyses were done separately within each time period of sampling and for each species that had more than 10 detections in either study area. Within one-factor ANOVA tests, alpha was set at 0.05 to test for statistical significance unless otherwise stated. When the habitat was a significant factor, Duncan's multiple range test was used to test for differences in habitat means.

Winter Bird Transects – Gable Creek

Winter-resident birds were only sampled at Gable Creek where the study design allowed comparisons to a clearcut without patches. Winter-resident birds were sampled using 2.4 km transects in the forest, the clearcut, and the clearcut matrix between the patches. Eight of the 12 patches were sampled by transects that totalled 0.9 km in length. The transects were travelled on snowshoes four times each between January 23 and 26, 1995, at rates varying between 0.5 and 1.5 km/hour. Transects were only sampled in dead calm conditions with frequent listening stops. Responses were elicited from quiet or inactive birds by "pishing" at least once every 200 m and listening and watching for responses. All birds seen or heard at any time along the transects were recorded.

The relative abundance of species in each habitat were adjusted for transect length (bird detections/km) and compared using two-factor ANOVA. Each sampling of the transect in a habitat was used as an independent observation so that the statistics tested are best viewed as "daily activity relative detection densities." The first factor was habitat (i.e., forest or clearcut), and the second factor was the continuity of the habitat (i.e., continuous or patchy habitat). The power of the study design was low when the probability of a Type I error (alpha) was set at 0.05 because each transect was only sampled four times, and detections of birds were relatively infrequent compared to breeding season surveys. To adjust for this low power, alpha was reset to 0.15 for this winter data analysis to keep the probability of a Type II error below 50% for large effect sizes (f = 0.4 as defined by Cohen 1988).

Owls and Woodpecker Playback Surveys – Gable Creek

Owls and woodpeckers were sampled as they established breeding territories using call playback responses. Four listening points were established on snowbound roads at the peripheries of each of the three habitats (Figure 1b). Sampling of the 12 points for nocturnal owls took 4–5 hours to complete beginning one-half hour after sunset. Nocturnal owl sampling was conducted on February 28, March 7, 19, 25, April 5, 18, 25, and 26. Woodpecker and Northern Pygmy Owl were sampled at the same points on each following morning between one-half hour before dawn and 1100 hours.

During nocturnal surveys, at each point the first minute was spent listening for calling owls. Then, for each owl species, the following procedure was used: 20-second playback, 60-second listening period, 20-second playback, and 60-second listening period. The order of species playback was from smallest to largest: first Northern Saw-whet Owls, then Boreal Owls, and finally for Barred Owls only at every second listening station.

During morning surveys, the first minute was spent listening and watching for woodpeckers or owls, then each woodpecker species' territorial calls and drumming were played every 30 seconds for a total of five minutes. The order of the call playbacks was: Three-toed, Hairy, and Pileated Woodpeckers. The call of the Northern Pygmy Owl was only included at the end of every second point to avoid silencing other birds. The species and number of all owls or woodpeckers detected within the study area were recorded. Additional detections of owls and woodpeckers outside the study area were noted, but have already been analyzed separately (Bennett 1995).

One-factor ANOVA was used to compare relative abundance of owls or woodpeckers detected in each of the three habitats (clearcut, clearcut and patches, and forest). Each listening point was considered independent with the sum of the detections made at each point over the eight visits used in the analysis.

Breeding Bird Point Counts – Gable and Wallace Creeks

Breeding bird relative abundance was estimated using 50-m radius point counts. All birds detected within 50 m of each point within a 10-minute period were recorded. Points were sampled between one-half hour before dawn and 10:00 hours. Territorial songs or drumming were treated separately for analysis from the sum total of all detections made. Points in the forest and clearcut were a minimum of 200 m from each other so that points could be considered independent samples, and a minimum of 100 m from other habitats. Within patches, points were situated approximately in the centre of the patches.

At Gable Creek in 1995, 12 points were established in the forest, 12 points in the clearcut matrix between patches, 1 point in each of the 12 patches (Figure 1b), and 12 points in the clearcut. Each point was sampled five times between May 29 and June 24, 1995. In six of the Gable Creek patches, the points were less than 50 m from one or more of the patch edges because of the small size of these patches. Birds detected within the 50-m radius, but not within the patch, were not included in the patch analysis. In addition, all detections of cavity-nesting birds were recorded at any distance from the point although this data was not amenable to analysis because of the unknown total area sampled and the difficulty in determining exactly which habitat the birds were detected in when they were outside the 50-m radius.

At Wallace Creek in 1994, 15 points were established in the forest, 15 points in the clearcut matrix between the patches, and one point in each of 15 wildlife tree patches (Figure 1c). Each point was sampled four times between May 26 and June 18, 1994. One-factor ANOVA was used to compare relative abundance per point between habitats (forest, forest patches, and clearcut between patches) for the most common species.

Breeding Bird Spot Mapping within Patches – Wallace Creek

Spot mapping was used to delineate breeding bird territories in the wildlife tree patches at Wallace Creek in 1995. Twenty-four of the 29 patches were selected for spot mapping. Four of the patches were not suitable for sampling since they were at the periphery of the site and the patch edges were very indistinct. The fifth unsampled patch was left due to topographical constraints (steep and rocky), and it also had indistinct boundaries. Spot mapping was only conducted for focus species, including cavity nesters, and those that appeared to be limited to forest habitat based on the point count results. Forest species selected were:

Brown Creeper	Golden-crowned Kinglet
Gray Jay	Hammond's Flycatcher
Pine Siskin	Red Crossbill
Solitary Vireo	Spruce Grouse
Steller's Jay	Western Tanager
Winter Wren	

Each patch was surveyed four times by each of two observers between May 25 and June 23, 1995. Observers searched for focus species at a rate of 10 minutes/ha, with a minimum search time of 20 minutes for patches smaller than 2 ha, between 04:30 and 10:00 hours. Every point within the patch was approached to within at least 25 m. All detections of focus species were recorded with the behaviour and exact locations recorded on 1:2500 scale maps of each patch. Focus species detected outside patch boundaries were also recorded although exact location was often difficult to determine. Attempts were made to follow cavity-nesting birds back to their nests within the patches whenever possible to obtain information about the nest tree and attempt to confirm successful breeding (i.e., young in the nest).

Detection of territorial behaviour on at least five of eight visits, or an active nest, indicated a breeding territory. We assessed whether breeding territories were entirely within the patch, appeared to include territory outside the patch, or was only a partial territory (<5 detections) within the patch. Analysis was limited to within-species comparisons.

Wildlife Tree Sampling

At Wallace Creek, wildlife tree densities were estimated using the tallies from 4–11 m radius (0.038 ha) plots at each bird count point. Wildlife tree plot centres were at random distances between 15 and 39 m from the bird count point along cardinal bearings. At Gable Creek, an additional 11-m radius plot was added at the actual bird count point with other plot centres between 22 and 39 m from the point along cardinal bearings. Only dead standing wildlife trees (decay classes 3–7, B.C. Min. of Forests and BC Env., 1995) were tallied. For each wildlife tree, species, diameter at breast height (dbh), height, and decay class were estimated. Feeding or nesting evidence that was diagnostic to bird species was recorded. Use was estimated as recent or older. Recent use was characterized by freshly exposed wood. Recent use probably included use within the previous 8 to 12 months.

Density of wildlife trees was compared between habitats using one-factor ANOVA. Standing height was recorded but was not analyzed because there was a significant correlation with the decay classes used by definition. Recent and old woodpecker feeding use were compared by species, dbh, and decay class. Feeding evidence was analyzed separately only for Pileated Woodpecker.

Results

Winter Bird Transects – Gable Creek

A total of 115 birds of 14 species were detected in 32.4 km of transects for an overall average of 3.55 birds/km. Only Mountain Chickadees and Red-breasted Nuthatches were detected frequently enough to analyze separately for habitat and patch effects (Table 1). For Red-breasted Nuthatches, both the habitat and patchiness factors were significant with the forest patches having the highest detection frequencies. For Mountain Chickadees, patchiness was a significant factor, as was the interaction of patchiness and habitat. The Mountain

Table 1. Mean winter bird relative abundance on transects and 2 × 2 ANOVA table of habitat and patch factor effects at Gable Creek

Species	Mean No. Detections/km ± S.E. n = 4 for each cell			Factor effect[a]	Test statistics				
	Patches (P)	Habitat (H) Clearcut	Forest		Mean square	$F_{1,44}$	P (a)	Effect size[b] (f)	Power (1-b)
Mountain Chickadee	Absent	1.5±0.6	0.8±0.5	H	22.96	2.43	.15	.39	.48
				P	31.64	3.34	**.09**	.46	.58
				H*P	36.50	3.86	**.07**	.49	.62
	Present	1.3±0.7	6.7±2.9						
Red-breasted Nuthatch	Absent	0	0.4±0.2	H	4.6	6.04	**.03**	.61	.77
				P	3.01	3.93	**.07**	.50	.64
				H*P3	1.74	2.27	.16	.38	.47
	Present	0.2±0.8	1.9±0.8						
All other Species	Absent	0.9±0.6	1.9±0.4	H	6.78	2.48	**.14**	.39	.48
				P	0.27	0.10	.76	.08	.17
				H*P	0.53	0.19	.67	.11	.18
	Present	0.8±0.3	2.5±1.5						

[a] H = Habitat-factor effect, P = Patch-factor effect and H*P = interaction effect.

[b] Effect Size (f) from Cohen (1988) where f = 0.4 is large, f = 0.25 is medium, and f = 0.1 is small effect size.

Chickadees were most frequently detected in the patches. For all other species combined, habitat was a significant factor, with detections most frequent in forests whether the forest was continuous or patchy.

Pileated Woodpecker, Hairy Woodpecker, and Red-breasted Nuthatch were absent from the clearcut without patches, but found in the clearcut surrounding the patches (Table 2). The Red-breasted Nuthatches were always observed in mixed flocks together with Mountain Chickadees, but were not observed foraging with the flocks of Mountain Chickadees that were observed in the clearcut without patches. Based on the transect samples and additional observations over the four-day period, two separate flocks of Mountain Chickadees were found in the clearcut with patches, one of which occasionally foraged in the clearcut without patches. Only grouse (Ruffed Grouse and Blue Grouse based on summer observations) appeared to be resident in the clearcut without patches. Golden-crowned Kinglets were only seen foraging where under-diameter trees had been left after clearcutting. No kinglets were seen foraging in the conifers that had regenerated since clearcutting.

Table 2. Counts of winter cavity-nesting birds at Gable Creek

	No. detected in each habitat			
Cavity-nesting bird species	**Clearcut N[a]=9.6 km**	**Clearcut between Patches 9.6 km**	**Patches 3.6 km**	**Forests 9.6 km**
Boreal Chickadee	0	0	0	4
Mountain Chickadee	14	12	24	8
Brown Creeper	0	0	0	1
Red-breasted Nuthatch	0	2	7	4
Hairy Woodpecker	0	1	0	0
Pileated Woodpecker	0	1	1	0
Three-toed Woodpecker	0	0	0	5
Unidentified woodpecker	0	0	0	1

[a] Sample size is the total length of transects sampled on the 4 visits.

Three-toed Woodpeckers, Boreal Chickadees, and Brown Creepers were only found in the control unharvested forest and never in the wildlife tree patches or clearcuts (Table 2). Four of the five Three-toed Woodpeckers detected were flaking bark from lodgepole pine trees and appeared to be feeding on mountain pine beetles.

Owl and Woodpecker Playback Surveys — Gable Creek

Six species of owls were detected (Table 3). No owls were detected in the clearcut, and only Northern Pygmy and Great Horned Owls were detected within the clearcut-and-patches habitat. Only the Northern Pygmy Owl was detected frequently enough to analyze on its own. It was detected at similar frequencies in the forest and patches. All other owls (as a group) were detected more frequently in the forest than the other two habitats.

Table 3. Counts of owls and woodpeckers detected at playback points at Gable Creek

	No. detected at 4 playback points sampled 8 times each		
Bird species	**Clearcut**	**Clearcut and patches**	**Forest**
Barred Owl	0	0	3
Boreal Owl	0	0	1
Great Gray Owl	0	0	1
Great Horned Owl	0	2	6
Northern Pygmy Owl	0	7	8
Northern Saw-whet Owl	0	0	7
Hairy Woodpecker	0	3	1
Northern Flicker	0	3	1
Pileated Woodpecker	0	0	5
Red-naped Sapsucker	0	4	5
Three-toed Woodpecker	0	0	6
Unidentified woodpecker	1	7	12

Five species of woodpeckers were detected (Table 3). No Pileated or Three-toed Woodpeckers were detected in the patch habitat, and it was unlikely that any of the unidentified woodpeckers were either Pileated Woodpeckers or Three-toed Woodpeckers since none were seen in the patches in spring or summer. Because 42% of the detections were of unidentified woodpeckers, habitat analysis was limited to woodpeckers as a group. The mean number of detections in the clearcut was significantly lower than in the forest but the patch habitat was not significantly different from the other two habitats.

Breeding Bird Point Counts

Gable Creek

At Gable Creek, 807 singing or drumming birds of 33 species were detected on 240 50-m radius point counts. An additional 274 non-singing or territorial bird detections brought the total to 43 species. Twenty-one species were detected more than 10 times and were analyzed for habitat and patch effects.

The habitat effect was significant, without any significant patch effect, for 11 species. Eight species were detected significantly more often in the clearcuts than the forest: Dark-eyed Junco, Fox Sparrow, MacGillivray's Warbler, Nashville Warbler, Orange-crowned Warbler, Ruby-crowned Kinglet, Warbling Vireo, and White-crowned Sparrow. Three were detected significantly more often in the forest, regardless of whether that forest was continuous or fragmented into small patches of 0.3–1.5 ha: Golden-crowned Kinglet, Townsend's Warbler, and Yellow-rumped Warbler. Only Townsend's Warbler showed any correlation with patch size ($r^2 = 0.63$; $p = 0.002$). No Townsend's Warbler territories (i.e., presence on >1 of 5 visits) were in patches less than 0.8 ha in size.

Four species showed no significant habitat or patch effects: Hermit Thrush, Mountain Chickadee, Gray Jay, and Pine Siskin. Even so, Gray Jays were never detected in the clearcut without patches, indicating that there still may be some dependency on forests or forest patches.

Significant patch effects were detected for five species: Red-breasted Nuthatch, Red-naped Sapsucker, Swainson's Thrush, Wilson's Warbler, and Dusky Flycatcher. The Red-breasted Nuthatch had a positive response to forest, to patches, and a positive interaction effect, indicating that relative abundances were higher in the forest patches than in continuous forest. Red-naped Sapsucker had highest densities in forest patches and was absent from continuous forest and virtually absent from the large clearcut. Swainson's Thrush had a positive response to patches and was found both in the patches and in the clearcut-between-patches (where it reached highest densities). Wilson's Warbler was most abundant in the clearcut between the forest patches, responding negatively to forest, but positively to patches. Only for the Dusky Flycatcher was the response to patches negative. Both Wilson's Warbler and Dusky Flycatcher habitat responses appeared to be due to canopy and shrub density effects within the clearcuts, and since these were not measured here, no other conclusions can be drawn from these two species.

Examination of the data collected for all cavity-nesting species (including those detected too infrequently for separate analysis), revealed that only Mountain Chickadees established entire breeding territories in the clearcut at Gable Creek. However, Red-naped Sapsucker, Northern Flicker, Red-breasted Nuthatch, and Hairy Woodpecker did establish breeding territories within the clearcut with patches. Boreal Chickadee, Brown Creeper, and Three-toed Woodpecker were absent in the patches and in the clearcut, but present in the forest.

Wallace Creek

At Wallace Creek, 776 singing or drumming birds of 31 species were detected on the 180 50-m radius point counts. An additional 440 non-singing or territorial bird detections brought the total to 43 species. Seventeen species were detected more than 10 times and were analyzed for habitat differences.

No significant differences in relative abundance were found between habitats for seven species that were detected frequently enough for analysis. Four of these species were probably truly abundant across all the habitats: Dark-eyed Junco, Townsend's Warbler, Evening Grosbeak, and Mountain Chickadee. However, for three of these species, other factors probably confounded the analysis. For Pine Siskins and Red Crossbills, this factor was the flocking behaviour that causes high variability on point counts even during the breeding season. The Solitary Vireo was absent from the smaller patches, so that high variability again lowered the power of the study design to detect true habitat differences.

Three species (Dusky Flycatcher, Orange-crowned Warbler, and Warbling Vireo) were most abundant in the regenerating clearcut and virtually absent from forest or forest patches. Five species (Golden-crowned Kinglet, Red-breasted Nuthatch, Ruby-crowned Kinglet, Western Tanager, and Yellow-rumped Warbler) were abundant in forests, whether the forest was continuous or in patches. The Gray Jay was significantly more abundant in forest patches than either continuous forest or the regenerating clearcut. Swainson's Thrushes were absent from the forest but abundant in both the forest patches and the regenerating clearcut between the patches.

Examining the data for all cavity-nesting species (even those not detected frequently enough to be analyzed separately), four times more woodpeckers and sapsuckers were detected in the patches than in the clearcut, and two to three times more in the patches than in the forest. The only woodpeckers detected in the clearcut between patches were Northern Flickers and Red-naped Sapsuckers, while five species were detected in the forest patches. Red-naped Sapsuckers and Northern Flickers were not detected in the forest, although sapsuckers occurred uncommonly there based on observations outside the point counts. No Williamson's Sapsuckers were positively identified during the 1994 sampling, but 1995 sampling showed that they were present and that some of the unidentified woodpeckers or sapsuckers may have been Williamson's Sapsuckers.

Breeding Bird Spot Mapping within Patches – Wallace Creek

While spot mapping was attempted within the patches for all the focus species, we found that spot mapping was unsuitable for certain of these species. Red Crossbills, an irruptive species, were simply not detected in 1995 sampling, although they appeared to become more common in the southern interior of B.C. by late June. Spruce Grouse were commonly detected in the clearcut between patches at both Gable and Wallace Creeks in 1995, and were therefore dropped from the focus species. Gray Jays and Pine Siskins were commonly detected in patches, but also commonly observed moving from patch to patch so that territories could not be accurately delineated. Six other focus species were detected very infrequently and probably did not breed within the patches. Black-capped Chickadees were detected once in one patch, and two were detected once in another patch; a Three-toed Woodpecker was detected only once in one patch; a Brown Creeper was detected once in a patch only 100 m from the forest; Hammond's Flycatchers were only detected once in each of three patches; Hairy Woodpeckers were detected once in each of five patches; and Steller's Jays were detected a total of nine times from within five different patches. All other focus species showed evidence of territoriality or breeding in the patches.

For species that were mostly limited to the mature forest and had small territories, the smallest patches had the lowest occurrence of complete territories for all species except Winter Wren (Table 4). Winter Wrens were only found in two of the patches adjacent to Wallace Creek and only one was considered a complete territory. Complete territories of Solitary Vireos and Western Tanagers were not found in patches smaller than 2.1 ha. Only for Golden-crowned Kinglets was more than one territory found in any patches smaller than 3.0 ha (Table 4). The Solitary Vireo, Red-breasted Nuthatch, and Western Tanager never had more than one territory in patches smaller than 3.0 ha, but more than one territory could be found in patches larger than 3.0 ha.

Table 4. Sizes of patches occupied by forest bird species at Wallace Creek

	Patch size range		
	1.6–2.0ha n=7	**2.1–2.6ha n=8**	**3.0–5.9ha n=9**
Species	**% patches with at least one whole territory**		
Golden-crowned Kinglet	71	100	89
Red-breasted Nuthatch	71	75	100
Solitary Vireo	0	38	78
Western Tanager	0	38	78
Winter Wren	14	0	0
	% patches with >one territory (incl. partial territories)		
Golden-crowned Kinglet	29	75	67
Red-breasted Nuthatch	0	0	33
Solitary Vireo	0	0	33
Western Tanager	0	0	33
Winter Wren	0	0	0

For cavity-nesting species that were not necessarily limited to the patch habitat, Mountain Chickadees were detected in every patch. Evidence of territoriality was found in 22 of the 24 patches, and they were also frequently seen and heard outside the patches. Northern Flickers were more often heard drumming outside the patches than inside, so no analysis of Northern Flicker territories was attempted. Some of that drumming may have actually been from nearby patches, but much of it also came from the regenerating clearcut. One possible Northern Flicker nest was found in one patch and there were almost certainly more within the regenerating clearcut.

Pileated Woodpeckers were detected more frequently outside the patches than inside (only 15 of 66 detections were in sampled patches), but we examined the data because of the management concern for this species requiring large areas of mature forest. One probable nest was found in a patch in the western part of the site where there were two breeding territories (based on males drumming in response to each other, Figure 2). The detections in the eastern part of the clearcut may have come from one or more pairs.

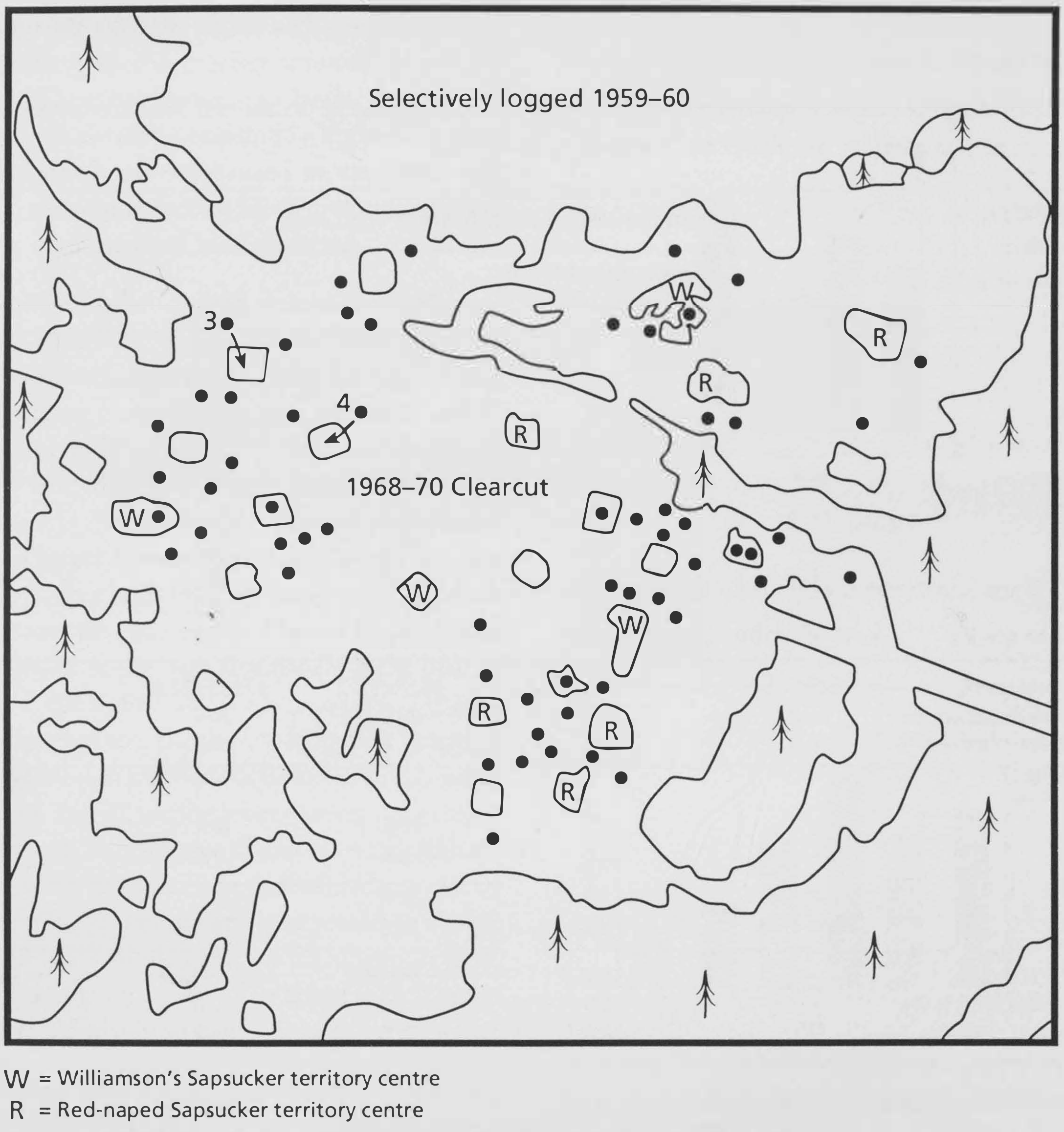

Figure 2. Williamson's and Red-naped Sapsucker territory centres, and Pileated Woodpecker detections at Wallace Creek.

We estimated four Williamson's Sapsucker territories within the study site based on two nests in two separate patches, and from concentrations of sightings including territorial drumming. There appeared to be six Red-naped Sapsucker territories within the study site based on three nests in patches with three additional territory centres based on concentrations of territorial activity. There may have been more Red-naped Sapsuckers nesting in the clearcut between patches (or in the adjacent forests) based on detections of Red-naped Sapsuckers in the western part of the study area where we could not delineate any territory centres. Sapsuckers were frequently detected outside the patches so that their habitat use is not entirely limited to the patches themselves.

Wildlife Trees

In each area, all habitats contained standing dead wildlife trees (Table 5). The densities were lowest in the regenerating clearcuts and higher in the forest. At Wallace Creek, the densities were significantly lower in the regenerating clearcut than in either the forest or patches. The densities and species composition were similar in the forest and patches, with lodgepole pine the most common, followed by Douglas-fir and western larch. At Gable Creek, the regenerating clearcut had the lowest number of wildlife trees, with 25% of them actually being high-cut stumps rather than wildlife trees. In the clearcut-between-the-patches, many western larch seed trees, standing dead trees, and cull trees were

Table 5. Mean densities of each species of wildlife trees in each habitat at Gable and Wallace Creeks, and percentages used by woodpeckers for feeding or nesting

	Mean density of wildlife trees* (No./ha)				
Tree species	Clearcut	Clearcut-between-patches	Patches	Forest	P (one-factor ANOVA)
Gable Creek					
Douglas-fir	0.4	0.0	0.4	17.1	
Western larch	1.8	10.5	9.6	1.3	
Spruce (Engelmann or hybrid)	0.0	0.4	8.8	0.4	
Western hemlock	0.0	1.8	3.1	0	
Lodgepole pine	0.4	0.0	3.5	146.4	
Subalpine fir	1.3	0.4	18.0	15.3	
Western redcedar	0.0	5.7	0.9	0	
Black cottonwood	0.0	4.8	0.4	0.0	
Other uncommon species	0.0	3.5	1.8	0.4	
Total density** (Mean±S.E.)	$5.3^{a}\pm1.6$	$27.2^{b}\pm5.0$	$46.5^{b}\pm5.8$	$179.3^{c}\pm24.0$	0.00
% with recent Woodpecker use	50.0	19.0	49.0	25.0	
% with recent and older use	58.0	32.0	61.0	43.0	
Wallace Creek					
Douglas-fir	–	1.3	16.2	10.1	
Western larch	–	0.0	8.3	7.0	
Lodgepole pine	–	1.8	36.8	53.5	
Other species	–	5.3	14.0	10.1	
Total density** (Mean±S.E.)	–	$8.3^{a}\pm2.7$	$75.4^{b}\pm13.4$	$80.2^{b}\pm12.9$	0.00
% with recent Woodpecker use	–	16.0	37.0	16.0	
% with recent and older use	–	58.0	71.0	56.0	

* Wildlife trees of decay classes 3–7 and 310 cm DBH.
** Means with like superscripts not significantly different using Duncan's Multiple Range Test.

left during clearcutting so that the densities were higher than in the clearcut and not significantly lower than inside the patches. The species composition was different between the patches and the continuous forest. The forest wildlife trees were principally lodgepole pine, Douglas-fir, and subalpine fir, while in the patches they were principally subalpine fir, western larch, and spruce.

Tree species, diameter, and decay class appeared to be much more important in determining woodpecker use of individual wildlife trees than habitat, since woodpecker feeding sign was found in all habitats studied (Table 5). Therefore, wildlife trees from all habitats were grouped for analysis. Examination of results by species allowed classification into species groups according to the relative amount of use by woodpeckers. Douglas-fir, western larch, spruce, and western hemlock showed consistently higher use than expected; lodgepole pine was used as expected; and subalpine fir, western redcedar, black cottonwood, and other species were used less than expected.

Greater than 70% of Douglas-fir, western larch, spruce, and western hemlock wildlife trees were used by woodpeckers for feeding across all decay diameter classes except for standing hard wildlife trees (classes 3 and 4) of less than 30 cm dbh (Figure 3). Very few lodgepole pine survive into decay classes 6 and 7, with most appearing to rot at the base and fall over before the boles soften. Use of larger diameter (>20 cm) lodgepole pine for feeding was very high (>80%), being primarily bark scaling for mountain pine beetle. The evidence of bark scaling disappears as the bark sloughs from the bole so that fewer lodgepole pine in the advanced decay classes showed woodpecker use. For the few lodgepole pine that did stand long enough for the bole to soften significantly (decay classes 6 and 7), woodpecker use was again high. Subalpine fir and other species of any diameter showed very little use while the bole remained solid (decay classes 3 and 4), but woodpecker use levels increased to 50% or more after the bole had softened. As for lodgepole pine, very few of these trees appeared to stand long enough to reach the most advanced decay classes.

Pileated Woodpeckers used large diameter (>29 cm dbh) wildlife trees for feeding more often than small diameter trees in both Gable and Wallace Creek areas (Figure 4). Small diameter wildlife trees were only heavily used in the most advanced stages of decay (class 7), but large

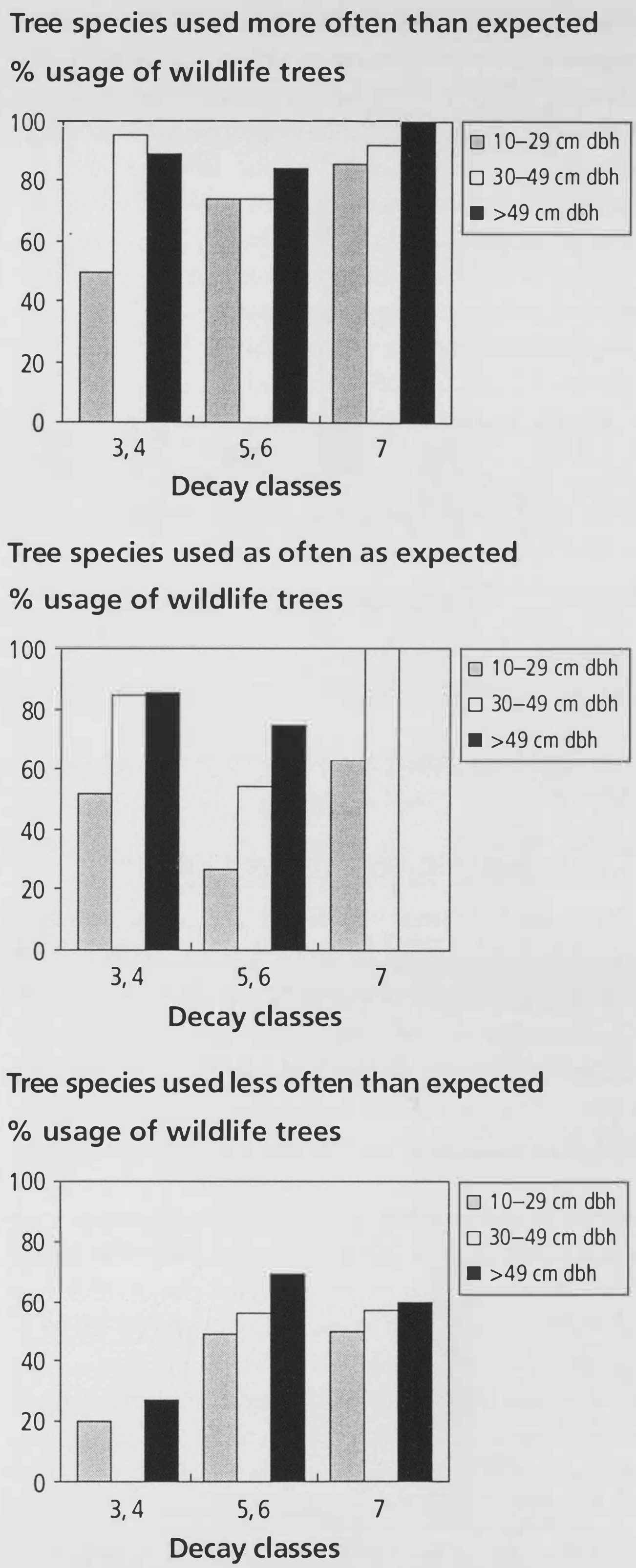

Figure 3. Percentage of wildlife trees showing use by woodpeckers broken down by species group, decay classes, and diameters at breast height (dbh).

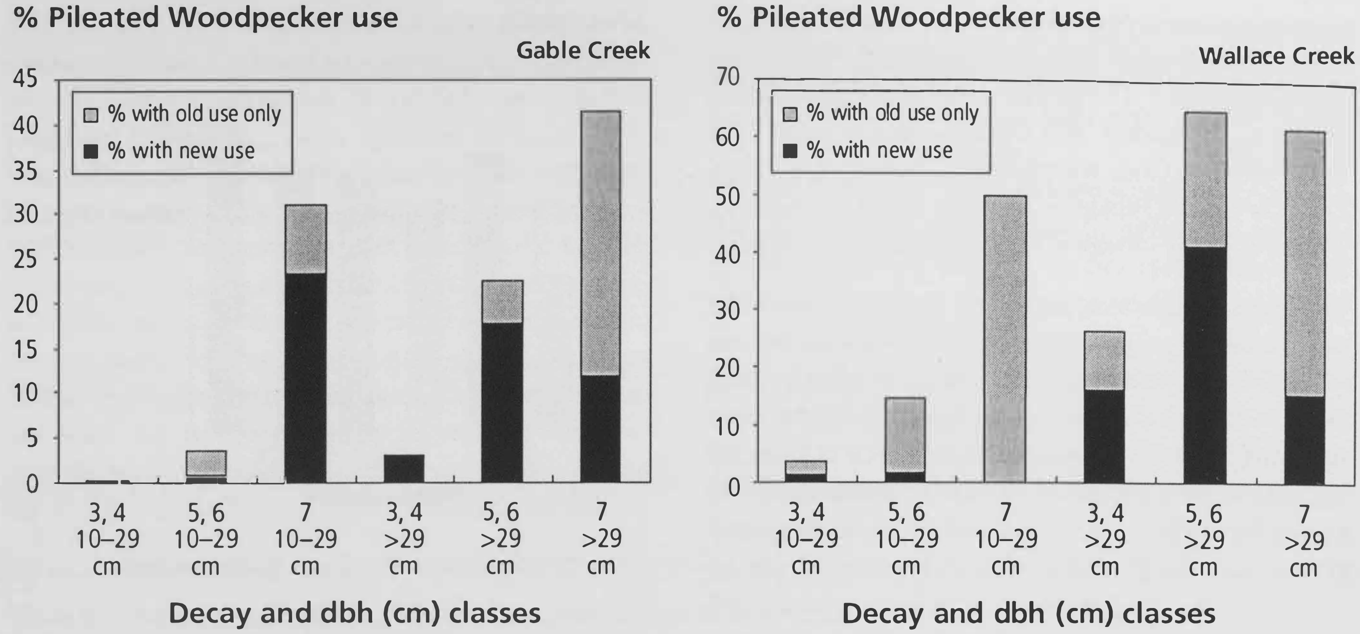

Figure 4. Pileated Woodpecker use of wildlife trees broken down by decay and diameter at breast height (dbh) classes in Gable Creek (right) and Wallace Creek (left).

diameter trees were frequently used as soon as the bole softened (decay classes 5 and 6).

Cavity Nests in Wildlife Tree Patches

Seventeen nest sites were found in the Wallace Creek wildlife tree patches in 1995. Eleven of these were confirmed by the presence of young. Nests were found of Mountain Chickadee (4), Northern Flicker (1), Pileated Woodpecker (1), Red-breasted Nuthatch (6), Red-naped Sapsucker (3), and Williamson's Sapsucker (2). The distribution of these nests were very different from availability (Figure 5), with large diameter (>50 cm dbh) western larch the most highly used for nesting. Although western larch >75 cm dbh were very uncommon (i.e., they were not detected in the 60 11-m radius plots in the wildlife tree patches so that densities must have been below 0.4/ha), 47% of the nests found were in western larch >75 cm dbh.

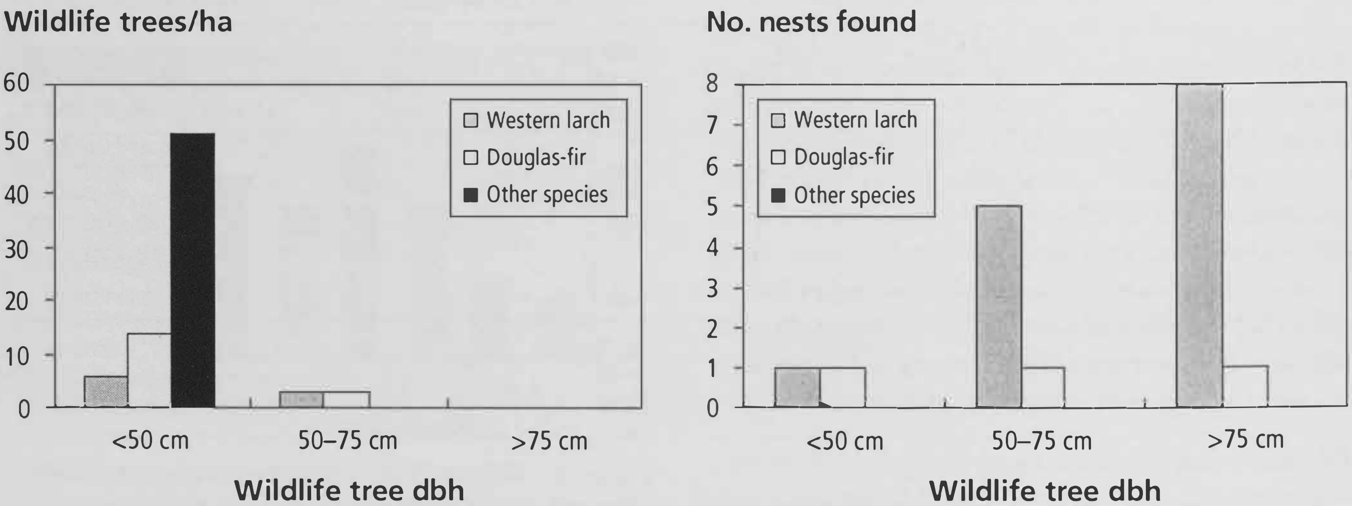

Figure 5. Density of wildlife trees (left) and numbers of cavity nests (right) classed by tree species and diameter at breast height (dbh) in the wildlife tree patches at Wallace Creek.

Discussion

Effectiveness of Wildlife Tree Patches

In this study, we adopted the simplest definition of whether wildlife tree patches are suitable as a mitigative measure for the effects of timber harvesting: if a species established breeding territories wholly within large clearcuts with wildlife tree patches, then wildlife tree patches were a suitable mitigative measure for that species. Because of the length of time (25–29 years) since clearcutting, there were unlikely to be any effects of "site tenacity" where individual birds continue to maintain territories even after disturbances have rendered the habitat unsuitable. Population density cannot be assumed to be equivalent to habitat suitability if habitats act as population sinks (Van Horne 1983). This was not directly assessed in this study. However, it was unlikely that the regenerating clearcuts with wildlife tree patches were "sink" habitats for most species. The habitats surrounding the study habitats were also fragmented forests of differing degrees of fragmentation, so that any theoretically high quality "source" habitat was not necessarily available adjacent to the study sites.

Wildlife tree patches appeared to be quite effective at mitigating the effects of clearcutting on many species. Within the 25-year-old forests without patches that we studied here, only one cavity-nesting bird (Mountain Chickadee) established breeding territories. In the 25- to 29-year-old forests with patches, eight additional cavity-nesting species were found, most of whom used the regenerating forest around the patches as well as the patches themselves. This advantage was not limited to the breeding season, but was also apparent for winter-resident bird species.

The patches also had positive effects for some non-cavity nesters that need mature forest. Some species of birds used the patches as isolated patches of forest habitat, but use appeared dependent on patch size (see "Effects of Patch Size and Dispersion"). Other species, particularly Gray Jays, Steller's Jays, and Spruce Grouse, used the matrix around the patches as well as the patches, but were largely absent from the 25-year-old forest without patches. The patches also appeared to have advantages for cavity-nesting or forest-requiring species other than birds, such as the Northern Flying Squirrels and Black Bears observed in this study at Wallace Creek.

In the simplest sense, retention of some wildlife trees within timber harvesting schemes is essential. The large and decaying wildlife trees that we found to be the most highly used for nesting by all species, and for feeding by woodpeckers, will not be found in even-aged forests within the 80–100 year rotations of clearcut silvicultural systems. Clearly, some method of retaining some large and decaying trees must be found. Wildlife tree patches appeared to be an attractive mitigative measure because they contained a wide variety of species, diameters, heights, and decay classes of wildlife trees for nesting, feeding, and roosting for a variety of species of birds.

A further advantage of wildlife tree patches appeared to be their relative permanence. Even 25–29 years after their creation, they still retained a wide variety of wildlife trees as well as live trees that will become suitable in the future for nesting, roosting, or feeding. While some windthrow of trees did appear to have occurred within the patches after clearcutting (especially on the southwest edges that face the prevailing winds), overall windthrow rates appeared to be fairly low. At any rate, the windthrow that did occur did not seem to have hampered the effectiveness of the patches as "forest" habitat or as a mitigative measure for cavity nesters.

Effects of Patch Size and Dispersion

The potential mitigative effects of wildlife tree patches on forest species, as well as cavity nesters, should not be ignored. They may permit relatively quick recolonization of regenerating clearcuts from within the patches rather than from areas completely outside the clearcut. This could not be assessed within this study, but would require an expanded study design or examination at several stages of regeneration. However, wildlife tree patches did allow some forest species to maintain small populations within clearcuts where there would otherwise be no opportunity. The Solitary Vireo and Western Tanager required at least 2.1 ha to maintain one territory per patch, and greater than 3.0 ha to maintain more than one territory within a patch. Golden-crowned Kinglets, Townsend's Warblers, and Red-breasted Nuthatches could use smaller patches. In the smallest patches at Gable Creek, Red-breasted Nuthatches were observed flying from patch to patch and several small patches may have been used as one larger territory. However, 0.8-ha patches were the bare minimum for

Townsend's Warblers which appeared to maintain territories only within whole patches.

Making patches of the minimum size to contain a single pair of birds of each species is probably not the best policy in the long term. Only one-third of forest fragments in the Netherlands that were big enough to support one pair of European Nuthatches (*Sitta europa*) were actually occupied because of high extinction rates in the small patches (Verboom *et al.* 1991). Only when patches were large enough to support four pairs was the extinction rate low enough to be unmeasurable in their three-year study. In our study sites, extinction rates in small patches were most likely masked by "commuters" between patches and by very high colonization rates from patches that were much closer (i.e., 200 m) than in the Netherlands study where patches were often isolated by more than 1 km. In the southern interior of B.C., 3 ha would be a minimum patch size to have at least some probability of retaining more than one pair each of Solitary Vireos, Western Tanagers, and Red-breasted Nuthatches within individual patches.

The effects of patch dispersion was not tested within this study because the mean interpatch distance was the same at both study sites (mean 200 m). The *Biodiversity Guidebook* of the Forest Practices Code (B.C. Min. Forests and B.C. Env., 1995) recommends 500 m as the maximum interpatch distance but does not specify a mean or range. For species that established small territories almost wholly within single patches, increasing interpatch distance would probably not alter the results found here, with the exception that fewer patches might be occupied because of lower colonization rates after local extinctions. For species that used more than one patch within a territory—particularly woodpeckers and sapsuckers—it was not possible to project how increased isolation of the highest quality habitat patches would affect the ability to establish breeding territories. However, by examining the patches and/or adjacent forest used by each pair, it may be possible to determine maximum distances between patches that will ensure use within single territories.

Effect of Stage of Regeneration After Clearcutting

Certain species may recolonize a regenerating clearcut at different stages after clearcutting. One of the biggest advantages of this study was being able to examine a regenerating forest at a point much further along than could be studied in any short-term experiment. Typical forest-inhabiting species that can recolonize 25- to 29-year-old forests need not be of particular management concern since suitable habitat will be available to them for a long period over the timber harvesting cycle.

In the 25- to 29-year-old forests examined here, Ruby-crowned Kinglets seemed to be at peak numbers, while Hermit Thrushes and Swainson's Thrushes also appeared to have successfully recolonized the regenerating forest. Yellow-rumped Warblers and Mountain Chickadees appeared to be recolonizing the clearcut, but relative numbers were still below those in mature forest.

Townsend's Warblers were beginning to recolonize the clearcuts, but only where coniferous canopies were dense. At Wallace Creek, Townsend's Warblers were as abundant inside the patches as they were outside, probably because most of the point samples were from the regenerating forests on the north aspects where conifers were typically denser than on south aspects. At Gable Creek, Townsend's Warbler were only found at two points in the clearcut between the patches where regenerating coniferous canopies were densest. As canopy densities continued to increase over time on most aspects, Townsend's Warblers might be expected to recolonize most of the forest. The only exception might be if the forests were composed entirely of lodgepole pine (Gyug 1995), where they might never recolonize the site in the 80–100 years between clearcutting.

This study did not address the needs of some of the cavity-nesting birds that may typically use regenerating clearcuts at an earlier stage than those studied here; in particular, the American Kestrel, Tree Swallow, and Mountain Bluebird (Gyug and Summers 1995; Gyug 1995). These species might be able to use wildlife trees at the edges of wildlife tree patches for nesting, but will also use 3-m high stumps or other trees within clearcuts for nesting. This study did not address these species because they were absent from these clearcuts where the canopy had already closed in enough to be unsuitable for them.

Possible Confounding Factors

Wildlife Trees Within the Clearcut

The assessment of the mitigative effects of patches were somewhat confounded because the clearcutting methods of the late 1960s between the patches did not mirror present clearcutting methods. Many non-merchantable trees and snags were left standing throughout the cuts between the patches. Only the Gable Creek control clearcut (cut in 1970) appeared similar to a modern clearcut in that virtually no snags or trees were left standing. Consequently, the bird abundance results from the 25-year-old control clearcut were likely representative of future trends within present clearcuts, but the results from the matrices between the patches may not be representative, and if anything, may be over optimistic.

Woodpeckers and sapsuckers both nest in wildlife trees, as well as forage on insects living in or on the trees. For the Northern Flickers and sapsuckers that appeared to establish breeding territories entirely within the boundaries of the clearcuts with patches, we do not know how much they depended on foraging on snags between the patches. Similarly, for the Hairy and Pileated Woodpeckers that established territories that appeared to rely on forest adjacent to the sites as well as the wildlife tree patches, we do not know to what extent they relied on snags as foraging sites between the patches.

This confounding factor might be removed simply by cutting down and removing all the remaining snags from the clearcut. However, this would be expensive, not entirely practicable, and we might lose information on a successful timber harvesting strategy that allows these species to co-exist with clearcutting. A better approach would be to quantify habitat use and foraging sites through radio-telemetry to indicate the relative extent that these species relied on the patches or clearcut portions of the habitats, and the exact placement and extent of the resources used within the clearcut.

Forest Use Outside Study Sites by Species With Large Territories

It is not certain if wildlife tree patches will be entirely successful for Hairy and Pileated Woodpeckers. There was only one Hairy Woodpecker territory partially in the patches at Gable Creek, and none at Wallace Creek. Pileated Woodpeckers used the patches at Wallace Creek in the breeding season, but only used the patches at Gable Creek in the winter. At Gable Creek, 7% of the area in patches may be simply not be enough foraging habitat for successful establishment of entire breeding territories. Pileated Woodpeckers in interior Douglas-fir forests need a minimum of 200 ha of mature forest (and an average of 364 ha) within breeding territories. Since territories are a maximum of 1500 ha when this resource is scattered (Bull and Holthausen 1993), this would suggest a minimum area of 13.3% (200 ha/ 1500 ha) for successful territory establishment of Pileated Woodpeckers—which is below the level found in either Gable or Wallace Creeks. In Wallace Creek, Pileated Woodpeckers must have made significant use of the surrounding forest as well as the wildlife tree patches. Radio-telemetry could prove useful by determining the relative extent to which these woodpeckers rely on wildlife tree patches and mature forest within single breeding territories.

Species Requiring Other Mitigation Methods

It appeared that wildlife tree patches may have only provided suitable breeding habitat for Pileated Woodpeckers and Hairy Woodpeckers when adjacent larger forest stands were available, or when snags for foraging were available between the patches. However, there were five relatively common species identified in this study for which neither of these factors appeared to confound the results, and for which wildlife tree patches of either the size or dispersion considered here did not provide adequate habitat. Three-toed Woodpeckers, Northern Saw-whet Owls, Boreal Chickadees, Brown Creepers, and Barred Owls did not occur in the patches even though they were establishing breeding territories in the forested habitats immediately adjacent.

Three-toed Woodpeckers in the unharvested forest at the Gable Creek site appeared to be feeding heavily on lodgepole pine attacked by mountain pine beetle. Since there were very few lodgepole pine in the patches, perhaps only habitat differences explained their absence from the patches. Theoretically, wildlife tree patches could be designed for use by bark-beetle-feeding specialist woodpeckers, although the density of attacked trees in a patch would probably have to be high. At Gable Creek, there were 146 dead standing lodgepole pine per ha in the control forest where Three-toed Woodpeckers were resident year round. At Wallace Creek, there were 37 dead standing lodgepole pine per ha in the forest patches, and Three-toed Woodpeckers were absent. Although we cannot separate the effects of low feeding-tree density and patches, it appeared that either, or both, factors may be rendering the patches unsuitable for Three-toed Woodpeckers.

Northern Saw-whet Owls were found in the "high-graded" forest adjacent to the Gable Creek study site, and we have observed Boreal Chickadees during the breeding season in forest elsewhere in the southern interior regenerating after "high grading." Common to those sites was the retention of almost all undersize trees, cull trees, and snags. These forests, cut 30–40 years ago, contain many standing dead trees, a much wider variety of tree diameters and heights, and often a greater density of trees than regenerating clearcuts. It would appear that silvicultural systems that remove fewer trees and/or protect dense understory regeneration, while also preserving wildlife trees throughout the harvested area (in patches or otherwise), might provide adequate long-term habitat for these species, although that hypothesis was not tested here.

Brown Creepers did not establish breeding territories in any of the patches. Robbins *et al.* (1989) found that Brown Creeper abundance at a point was correlated with the forested area within two km. The wildlife tree patches under study here were likely too small to contain whole Brown Creeper territories, too isolated to be combined into larger territories of several patches, and/or were possibly below a threshold percentage of forested area within a mosaic of non-habitat that would allow their persistence.

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