

AVIAN USE OF HABITAT CONFIGURATIONS CREATED BY FOREST CUTTING IN SOUTHEASTERN WYOMING¹

MARY E. KELLER² AND STANLEY H. ANDERSON

University of Wyoming, Cooperative Wildlife and Fisheries Research Unit, Laramie, WY 82070

Abstract. Timber harvest in western forests initially interrupts large expanses of old-growth forest with smaller clearcuts. Although the vegetation within the remaining old-growth is still present and intact, there is an increase in forest edges and a reduction in the continuity of the original forest. We compared avian species composition and abundance in four pairs of sites, each pair having an uncut site and one fragmented by small clearcuts in southeastern Wyoming. Fragmented stands were interrupted with strip or patch clearcuts. The abundance of species was also compared among the habitat configurations present on these sites such as forest interiors, meadow edges and clearcuts. Of 16 bird species, Brown Creepers (*Certhia americana*) and Hermit Thrushes (*Catharus guttatus*) were the most negatively influenced by fragmentation; Pine Siskins (*Carduelis pinus*) were the most positively influenced by fragmentation. The distribution of birds among forest interiors and edges suggested the responses to fragmentation were not generally mirrored by preferences or avoidance of forest edges and interiors. The effect of fragmentation may result from the loss of resources from clearcutting or preferences for the type of habitat adjacent to the forest stand (meadows or clearcuts).

Key words: Fragmentation; edges; clearcuts; forest interiors; nongame birds; Brown Creepers; subalpine forest.

INTRODUCTION

In western forests, large expanses of old-growth forest are gradually changed to a mosaic of clearcuts, regenerating stands and remnant tracts of old-growth as a result of timber harvest (Harris 1984). The original stand is initially interrupted with cutover areas, reducing forest interiors and increasing forest edges. If the vegetation within the remaining old-growth forest is still present and intact, does the proximity to clearcut/forest edges and reduced continuity of the remaining old-growth influence the use of these areas by birds?

Forest fragmentation can be thought of as a process where large continuous stands of forest are progressively cut until only small isolated tracts of the original stands are left. In the eastern deciduous forest, this process began with the original settlement of the country. Clearing for agriculture or urban development has progressed to where the remaining forested tracts are isolated by unforested areas (Whitcomb et al. 1981, Whitney and Somerlot 1985). In western conif-

erous forests, the process of forest fragmentation is only beginning and results from timber harvest. Initial forest cutting introduces a few cutover patches, and eventually the landscape becomes a mosaic of smaller old-growth stands and cutover areas in various stages of succession (Harris 1984). Remnant forest tracts may or may not become isolated depending on the spatial distribution of cutover areas (Franklin and Forman 1987). In both eastern and western forests, however, as the proportion of cutover area increases from 0 to 50%, there is an increase in forest edge and a loss of forest interior (Franklin and Forman 1987). In these early stages of forest fragmentation, increases in forest edges and reduced continuity of forest tracts may influence their use by birds.

Studies of birds in forest fragments in the east have found that several neotropical migrant species are less likely to occur in small isolated woodlots than in large continuous stands (Anderson and Robbins 1981, Ambuel and Temple 1983, Lynch and Whigham 1984, Blake and Karr 1987, Robbins et al. 1989). One explanation for this pattern is that the extensive edge and reduced interior of smaller woodlots subjects breeding birds to higher rates of nest predation and parasitism found near woodlot edges (Gates and Gysel 1978, Brittingham and Temple 1983,

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² Present address: U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD 20708.

Wilcove 1985). Demographic effects related to local extinction and dispersal among woodlots may also be important (MacArthur and Wilson 1967).

In the Pacific Northwest, Rosenberg and Raphael (1986) used measures of stand area and isolation at three different scales to evaluate the effect of forest fragmentation in a western forest setting. Unlike the results from studies in the east, Rosenberg and Raphael (1986) found that resident birds or species with large home ranges were most sensitive to measures of fragmentation. It was unclear whether those differences were due to inherent differences in western species, or the more recent fragmentation occurring in the west.

In the Rocky Mountains, Scott et al. (1982) described changes in avian density before and after patch-clearcutting in Colorado forests. But the resulting differences in birds were most attributable to the loss of forest habitat, as intended by the study. Loss of forest habitat is a major component of the fragmentation process, but the influence of the resulting increase in edge and proximity to clearcuts was not specifically addressed.

The present study compared the avian community in the fragmented forest left after clearcutting to uncut forest in southeastern Wyoming. We use the term fragmented forest to describe the tracts that were interrupted by stripcuts or patch cuts, though the pattern of cutting did not result in isolated stands. Our objectives were (1) to compare the avian community and species abundance in paired unfragmented (uncut) and fragmented study sites, and (2) to determine how species were distributed in relation to forest interiors and forest edges.

STUDY AREA AND METHODS

The study was conducted in the Medicine Bow National Forest in southeastern Wyoming in 1985 and 1986. As in other western forests (Harris et al. 1982), timber harvest historically began in lower elevations and gradually progressed upslope. Thus, most remaining large, uncut stands of old-growth are at high elevations and are dominated by Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) (Romme and Knight 1981). The study was conducted on four pairs of fragmented and unfragmented stands between 3,048 m (10,000 ft) and 3,109 m (10,200

ft.) These high elevation stands had 1–2 m of snow in May of each year, which did not melt completely until late July. The two stands within each pair were located at the same elevation, aspect, and general topography and were in close proximity.

Sites 1 and 2 were located on the west slope of the Medicine Bow Mountains (Fig. 1). Fragmented stands at these sites were approximately 45-ha areas that had 50% of the forest stripcut in the late 1950s, leaving alternating 100-m strips of old-growth and clearcuts. Regeneration had occurred primarily around scattered trees left in the clearcuts and resulted in clumps of young fir 2–3 m tall. The uncut stands were 100 ha and 40 ha of old-growth forest surrounded by meadows. At site 2, there had been some selective cutting in both the “uncut” stand and in the remnant strips but the total volume removed was very small.

Sites 3 and 4 were on the east slope of the Medicine Bow Mountains (Fig. 2). Fragmented stands were 25 ha forest areas containing numerous 1–3 ha patch cuts (spotcuts) made in the late 1960s. Spotcutting had removed approximately 20% of the stand area. Regeneration in these spotcuts was very sparse and consisted of scattered seedlings less than 1 m tall. Future harvest of subalpine forest is likely to use this patch or spotcut pattern because this configuration is best for holding snow and increasing water yields downstream (Smith 1987). A few natural meadows occurred in the spotcut and adjacent uncut stands. Uncut stands consisted of 20 ha of old-growth primarily surrounded by other forest.

In order to sample bird use of the remnant forests, and to evaluate bird use of the forest edges and interiors, we stratified stands by distance to the forest edge (Table 1). In uncut stands, sample plots were placed on the edge, 50 m, 100 m, or ≥ 150 m from the edge. Plots were established 100 m apart along transects within a stratum using a random starting point. Each stripcut area was sampled with 12 plots located in the center of the remnant strips of forest (50 m from the edge) and six plots on the edge of the clearcut. Plots in spotcut stands were distributed at 100 m intervals along a transect with a random starting point. If a plot fell in a clearcut it was moved to the closest edge. We did not allow plots to fall within clearcut areas because we did not want stand comparisons to reflect avian use of unfor-

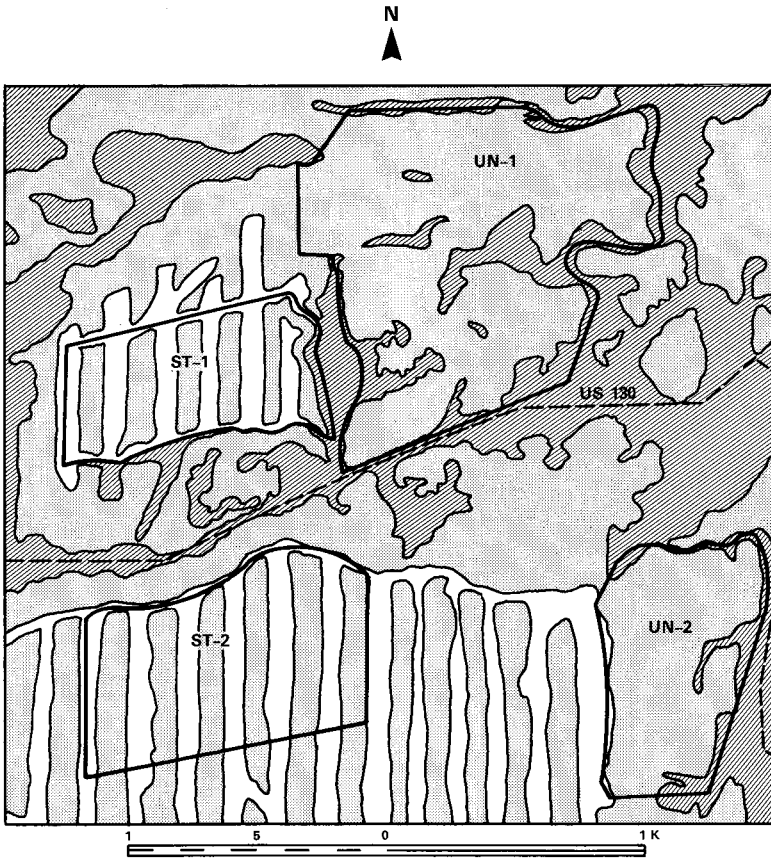


FIGURE 1. Sites 1 and 2 on the west side of the Snowy Range, in Medicine Bow National Forest, Wyoming, illustrating old-growth forest (stippled), natural meadows (diagonal lines) and clearcut (open areas). Each site consists of a pair of stripcut (ST) and uncut (UN) stands.

ested areas compared to forested areas. No areas within fragmented stands were farther than 50 m from a clearcut edge (Table 1).

MEASURING AVIAN ABUNDANCE

Avian relative abundance was determined using point-counts (Reynolds et al. 1980) conducted for 6 min between 06:00 and 11:00. During a count, each bird was recorded by species and its estimated distance from the center of the plot. Observations of birds beyond 50 m were not used because estimates of detection distance were considered too unreliable.

Plots were surveyed three times during the 1985 breeding season and five times during the 1986 breeding season with the help of an additional observer. In 1986, all plots were surveyed with equal effort by both observers. Both observers

were present on a plot during the first survey as training for the new observer, and each observer independently surveyed the same plots two more times. All surveys were conducted between 1 June and mid-July.

The relative abundance of a species was determined by computing the mean number of birds detected per survey at each plot. These plot means are thus the average number of birds detected within a 50 m radius (0.78 ha) during a 6 min census. Plot means were then used to calculate the abundance of a species in each stand or in plots grouped by habitat configuration. Final results are presented as relative abundance per 10 ha.

There were too few birds detected from each plot to calculate a species-sighting function using line transect methods (Burnham et al. 1980).

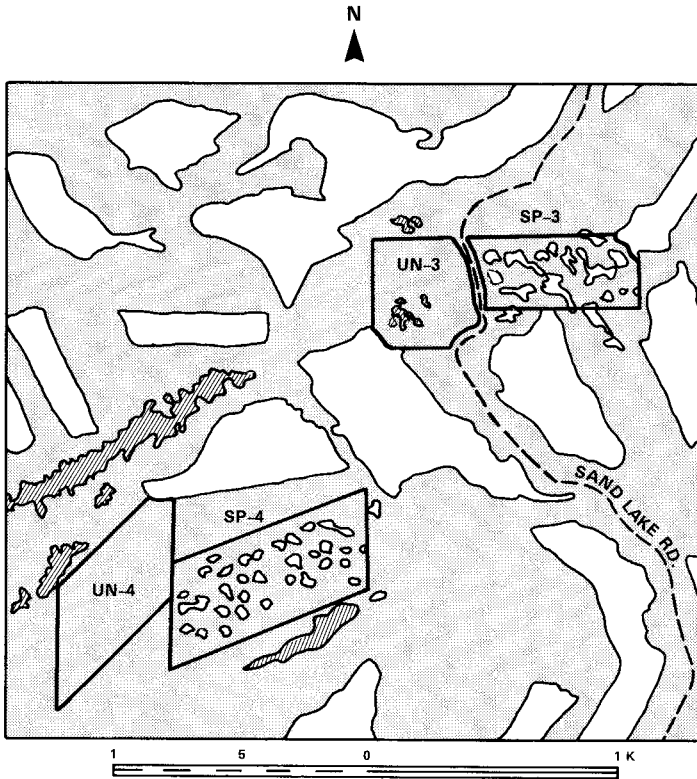


FIGURE 2. Sites 3 and 4 on the east side of the Snowy Range in Medicine Bow National Forest, Wyoming, illustrating old-growth forest (stippled), natural meadows (diagonal lines) and clearcut (open areas). Each site consists of a pair of spotcut (SP) and uncut (UN) stands.

However, we evaluated whether detectability of any species differed between fragmented and unfragmented stands by visually comparing species' detection curves (densities in bands at increasing distance from plot centers), and by statistically comparing each species' mean detection distance in fragmented and unfragmented stands. There were no significant differences indicated for any species ($P < 0.05$), and we concluded that relative abundance could be meaningfully compared between paired fragmented and unfragmented stands. Raphael (1987) found simple counts of birds in a fixed area were highly correlated with densities adjusted for detectability using line transect methods (Burnham et al. 1980) indicating that differences in detectability among several forested habitats were not substantial.

VEGETATION AND FRAGMENTATION VARIABLES

Although the fragmented and unfragmented stands within each pair were chosen to be similar

in site and vegetation, we measured features of the vegetation to assess any potential differences that might confound our comparisons. Vegetation characteristics were measured in 0.04 ha plots using a modification of the James and Shugart (1970) method. Vegetation plots were centered on the bird survey plots with the exception that plots located on a forest edge were moved

TABLE 1. Number of sample points in each stand by distance to forest edge.

Stand	Area (ha)	Total no. of sample points	Distance to forest edge			
			0	50	100	≥150
UN1	100	57	10	14	15	18
ST1	40	18	6	12	—	—
UN2	38	18	5	4	3	6
ST2	48	18	6	12	—	—
UN3	21	11	1	3	3	4
SP3	24	13	7	6	—	—
UN4	20	12	0	2	2	8
SP4	25	14	8	6	—	—

TABLE 2. Mean values of habitat variables used to cluster plots into five habitat configurations.

Habitat configuration	Number of plots	Amount of habitat type within 100 m of plot			
		% Forest	% Clearcut	% Meadow	Length of edge (m)
Stripcut	(32)	51	49	0	425
Spotcut	(33)	74	18	8	473
Meadow edge	(28)	65	0	35	334
Mid-forest	(34)	93	0	7	151
Forest interior	(34)	100	0	0	0

completely within the old-growth stand because we only wanted to compare forest vegetation. Thus we sampled forest vegetation within fragmented and unfragmented old-growth stands, and not in clearcuts or meadows. All trees taller than 2 m were counted and recorded by species and size based on diameter at breast height (dbh) grouped into 10 cm size classes. Snags were classified by decay stage (Thomas et al. 1979) and dbh size class.

To describe the habitat configuration around each plot, we measured the percentage of old-growth, clearcut, meadow and the length of forest edge within 100 m of each survey plot (3.1 ha). Measurements were made using a digitizer on enlarged maps made from aerial photographs.

ANALYSES

We compared the avian community in fragmented and unfragmented stands using the mean percent similarity in species abundance between the pairs of fragmented and unfragmented stands (Bray and Curtis 1957). Percent similarity was calculated as follows:

$$\text{Percent similarity} = \frac{\sum (2 \cdot W_i)}{A + B} \times 100$$

where W_i = the lower abundance of a species (i) that occurs in both stands, A = the total number of individuals in stand A, and B = the total number of individuals in stand B. This is the percentage of the total avian abundance that is shared in the two samples, and is 100% for two samples with the same species in identical abundances. In our analyses, the numbers of species in the two groups were always similar, thus avoiding most of the problems with similarity indices (Wolda 1981). These comparisons were made to assess the relative influence of fragmentation, year-to-year differences, and site-specific differences on the avian community.

We evaluated the effects of fragmentation by

clearcuts on each species by comparing differences in its abundance in the paired fragmented and unfragmented stands using a paired-sample *t*-test (Zar 1984). Vegetation variables were also analyzed in this manner to determine whether the vegetation of stands adjacent to clearcuts were different from the vegetation in uncut stands.

To assess avian use of forest interiors and edges and to distinguish between meadow edges and clearcut edges, we compared bird abundance in groups of plots that differed in the percentage of forest, clearcut, meadow, and the length of forest edge within 100 m of the plot. From a cluster analysis of plots, using a chi-square metric and centroid linkage (Dixon 1983), we retained five habitat configuration groups (Table 2). The "Stripcut" group was approximately 50% forested and 50% clearcut. These plots were primarily from stripcut stands but a few plots in stripcut stands that were on meadow edges were not in this habitat configuration. The "Spotcut" group was approximately 75% forested and had the most forest edge. Plots were mostly from spotcut stands but included a few plots from other stands. The "Meadow edge" group was 65% forested and contained plots generally on or near edges of uncut stands. The "Mid-forest" group contained plots that had some meadow and edge within 100 m, whereas "Forest Interior" plots were entirely forested and occurred only in the interior (> 100 m to any edge) of uncut stands.

All five habitat configurations were represented at two of the four sites; the remaining two sites had three and four of the five configurations. To evaluate species patterns of abundance among these habitat configurations while controlling for differences in abundance among sites and years, we normalized the overall abundance of each species at a given site and year to zero. Within a site in one year, we determined the abundance of a species in each habitat, then subtracted the mean abundance of that species for the entire site from the abundance in each habitat group.

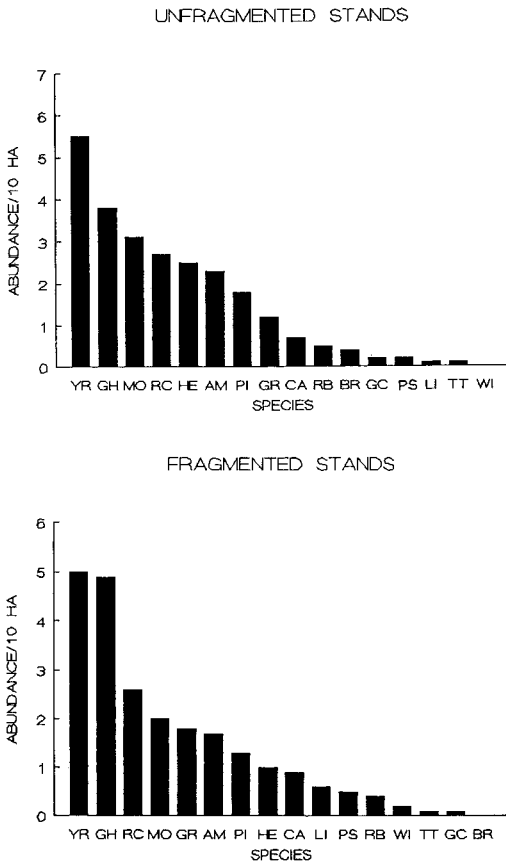


FIGURE 3. Comparison of mean species abundance in unfragmented and fragmented stands. Abundance/10 ha is the mean of all stands in both years. Species are YR = Yellow-rumped warbler, JU = Dark-eyed Junco, MO = Mountain Chickadee, RC = Ruby-crowned Kinglet, HE = Hermit Thrush, GR = Gray Jay, AM = American Robin, PI = Pine Grosbeak, CA = Cassin's Finch, RB = Red-breasted Nuthatch, BR = Brown Creeper, GC = Golden-crowned Kinglet, PS = Pine Siskin, LI = Lincoln Sparrow, TT = Three-toed Woodpecker, WI = Williamson's Sapsucker (see Table 3 for scientific names).

A one-way analysis of variance was used to test for differences in site-adjusted species abundances among the habitat configurations. We used data from both years in a single analysis, resulting in a maximum sample size of eight (four sites in two years). We recognize that samples from the same site in different years may not be completely independent, but the results of the analysis of variance (ANOVA) were used to describe the pattern of a species abundance among habitat configurations. For presentation, the mean abundance was added back to the values so that the

abundance in each cluster group in the tables is centered on the overall mean abundance for each species.

RESULTS

AVIAN COMMUNITY IN FRAGMENTED AND UNFRAGMENTED STANDS

Sixteen species were detected from survey plots at all four sites. Over half of the birds in both fragmented and unfragmented stands were Yellow-rumped Warblers (*Dendroica coronata*), Dark-eyed Juncos (*Junco hyemalis*), Mountain Chickadees (*Parus gambeli*) and Ruby-crowned Kinglets (*Regulus calendula*) (Fig. 3). Hermit Thrushes (*Catharus guttatus*) were the fifth most common species in unfragmented stands; Gray Jays (*Perisoreus canadensis*) were the fifth most common species in fragmented stands.

Although the number of birds in these subalpine forests was never high, there was a 34% decrease in total bird abundance between 1985 and 1986. There was no difference in the magnitude of this decrease between fragmented ($\bar{x} = 36\%$) and unfragmented ($\bar{x} = 31\%$) stands for total birds or for any species (t -test, $n_1 = 4$, $n_2 = 4$). Declines in abundance occurred in both migrant and resident species and among most foraging guilds and were most likely related to climatic factors.

The percent similarity in species composition between paired unfragmented and fragmented stands within a year averaged 78% (range 71–85%, $n = 8$). Between 1985 and 1986, the avian community within a stand averaged 67% similarity (range 58–80%, $n = 8$). Comparisons of the avian community in stands with the same fragmentation type but located on different sites averaged 62% similarity (range 50–76%, $n = 12$). This suggests that differences in site produced the largest differences in the avian community (38% difference), year to year differences were second largest (33%), and fragmentation was associated with a 22% difference in the avian community.

SPECIES ABUNDANCE IN FRAGMENTED AND UNFRAGMENTED STANDS

A paired sample t -test comparing the density of large (>40 cm dbh) and small (≤ 40 cm dbh) spruce trees, fir trees and snags between unfragmented and fragmented stands did not reveal any significant differences. Thus basic features of the vegetation in fragmented and unfragmented

TABLE 3. Results of paired sample *t*-test on species abundance per 10 ha in four pairs of stands, and mean abundance in unfragmented and fragmented stands. Species listed in approximate order from those more abundant in unfragmented stands to those more abundant in fragmented stands.

Species	Year	Mean of unfragmented stands (n = 4)	Mean of fragmented stands (n = 4)	Mean within pair difference	<i>t</i>	<i>P</i>	
Hermit Thrush	1985	3.18	2.24	0.94	2.25	0.06	+
	1986	1.89	1.51	0.38	1.94	0.07	+
American Robin (<i>Turdus migratorius</i>)	1985	2.60	2.16	0.44	1.60	0.11	
	1986	1.94	1.30	0.64	2.76	0.04	*
Brown Creeper (<i>Certhia americana</i>)	1985	0.36	0	0.36	1.50	0.12	
	1986	0.71	0	0.71	2.77	0.04	*
Mountain Chickadee	1985	3.20	2.53	0.67	3.09	0.03	*
	1986	2.93	2.65	0.27	0.58	0.30	
Red-breasted Nuthatch (<i>Sitta canadensis</i>)	1985	1.30	0.83	0.47	0.75	0.25	
	1986	0.09	0	0.09	1.86	0.08	+
Yellow-rumped Warbler	1985	8.99	6.96	2.03	2.85	0.03	*
	1986	2.90	2.93	-0.03	-0.11	0.46	
Pine Grosbeak (<i>Pinicola enucleator</i>)	1985	2.26	1.59	0.67	1.24	0.15	
	1986	1.28	1.27	0.02	0.03	0.47	
Golden-crowned Kinglet (<i>Regulus satrapa</i>)	1985	0.09	0.00	0.11	1.50	0.12	
	1986	0.31	0.22	0.02	0.08	0.47	
Ruby-crowned Kinglet	1985	2.61	2.49	0.07	0.21	0.42	
	1986	3.77	3.90	-0.13	-0.24	0.41	
Three-toed Woodpecker (<i>Picoides tridactylus</i>)	1985	0.11	0.10	0.02	1.50	0.11	
	1986	0.14	0.17	-0.05	-0.40	0.35	
Lincoln's Sparrow (<i>Melospiza lincolni</i>)	1985	0.16	0.49	-0.27	-0.70	0.27	
	1986	0.14	0.76	-0.49	-0.80	0.24	
Cassin's Finch (<i>Carpodacus cassinii</i>)	1985	1.26	1.50	-0.24	-0.54	0.31	
	1986	0.22	0.39	-0.17	-1.28	0.14	
Gray Jay	1985	1.29	2.16	-0.87	-1.41	0.13	
	1986	1.12	1.39	-0.27	-0.56	0.31	
Dark-eyed Junco	1985	4.55	5.91	-1.37	-1.45	0.12	
	1986	3.05	3.88	-0.83	-1.52	0.11	
Williamson's Sapsucker (<i>Sphyrapicus thyroideus</i>)	1985	0.00	0.28	-0.31	-2.80	0.03	*
	1986	0.00	0.16	-0.17	-3.60	0.01	**
Pine Siskin (<i>Carduelis pinus</i>)	1985	0.26	0.83	-0.58	-1.53	0.11	
	1986	0.07	0.20	-0.13	-3.32	0.02	*
Total birds	1985	32.13	30.06	2.23	2.38	0.05	*
	1986	20.55	20.72	-0.23	-0.30	0.39	

+ $P < 0.10$, * $P < 0.05$, ** $P < 0.01$.

stands were not different, and differences in species use of fragmented and unfragmented forest tracks are not likely to result from differences in forest vegetation.

American Robins, Brown Creepers, Mountain Chickadees and Yellow-rumped Warblers were more abundant ($P < 0.05$) in unfragmented stands in at least one year (Table 3). American Robins and Brown Creepers were most consistent in these differences between the two years. Brown Creepers were never found in fragmented stands even though sample sizes were sufficient to detect them had they occurred in similar densities. They were

consistently seen in the same areas throughout the summer suggesting that observed birds were breeding pairs. Hermit Thrushes had somewhat higher abundance in unfragmented stands ($0.05 < P < 0.10$) and this pattern was present in both years. The abundance of Hermit Thrushes and American Robins in fragmented stands was approximately 75% of their abundance in unfragmented stands. Total avian abundance was significantly greater in unfragmented stands in 1985 but no differences were seen in 1986.

Pine Siskins and Williamson's Sapsuckers were statistically more abundant in fragmented stands

TABLE 4. Species relative abundance per 10 ha among habitat configurations and results of ANOVA comparing mean abundance in habitat configurations $n = 8$ (four sites in two years). Values with different letters are significantly different ($P \leq 0.05$) using Tukey multiple comparisons.

Species	Habitat configuration cluster groups					F	P	
	Strip-cut	Spot-cut	Meadow edge	Mid-forest	Forest interior			
Hermit Thrush	1.40 ^a	1.48 ^a	2.13 ^{ab}	1.78 ^{ab}	2.43 ^b	3.81	0.01	**
Brown Creeper	0.00	0.00	0.17	0.32	0.62	2.52	0.06	+
American Robin	1.45	1.33	2.57	1.75	1.39	1.81	0.15	
Red-breasted Nuthatch	0.40	0.15	0.46	0.47	0.70	1.10	0.37	
Mountain Chickadee	2.15	2.16	2.29	2.95	2.39	0.96	0.44	
Yellow-rumped Warbler	3.96	4.15	3.85	5.36	4.71	1.74	0.17	
Pine Grosbeak	0.87	1.41	1.08	1.70	1.40	1.04	0.41	
Dark-eyed Junco	2.92	3.24	3.02	1.96	3.45	1.24	0.31	
Ruby-crowned Kinglet	2.78	2.88	2.12	2.35	2.58	0.49	0.75	
Gray Jay	1.91	1.29	1.05	1.03	0.59	2.03	0.12	
Cassin's Finch	1.11 ^a	0.59 ^{ab}	0.23 ^b	0.55 ^{ab}	0.69 ^{ab}	4.28	0.01	**
Pine Siskin	0.75 ^a	0.20 ^b	0.17 ^b	0.03 ^b	0.19 ^b	7.40	0.001	***

($P < 0.05$) in at least one year. Williamson's Sapsuckers, however, were very rare in these stands and we do not consider these data sufficient to document a pattern for this species. The remaining species had little difference in their abundance between fragmented and unfragmented stands.

SPECIES ABUNDANCE AMONG HABITAT CONFIGURATIONS

The abundance of the 12 most common species was compared among the habitat configurations present in these sites (Table 4). Hermit Thrushes were less abundant in stripcut and spotcut configurations than forest interiors, which may at first suggest an avoidance of forest edges. But there was no significant difference between meadow edges and forest interiors (Table 4). As stated previously, Brown Creepers were only found in uncut stands and thus were not present in stripcut and spotcut configurations.

Pine Siskins were more abundant in stripcut configurations than any other configuration (Table 4). Cassin's Finches were most abundant in stripcut configurations and least abundant on meadow edges. The abundance of the remaining species did not differ among habitat configurations.

DISCUSSION

Overall, stands interrupted by small clearcuts had a similar species composition to paired uncut stands, the major exception being the absence of

Brown Creepers from fragmented stands. The major differences in species abundances that appeared related to fragmentation were the lower abundance of Hermit Thrushes and increased abundance of Pine Siskins in fragmented stands. Although American Robins were more abundant in uncut stands, this resulted from their use of the meadows that surround the uncut stands. Robins used wet meadows for foraging and adjacent trees for nesting. Although Mountain Chickadees and Yellow-rumped Warblers were more abundant in unfragmented stands in 1985, the lack of differences in 1986 suggests that fragmentation is probably not a consistent factor influencing the abundance of these two species.

While less clear from these data, Red-breasted Nuthatches (*Sitta canadensis*) may also be influenced by fragmentation. In 1985 they were much more abundant in the uncut stand in three of the four pairs but were completely absent from the unfragmented stand at Site 2 that had been selectively cut, resulting in no significant difference in the overall test of four pairs. The pattern seen in three of the four pairs may be more representative, but more comparisons are needed. In 1986, the few Red-breasted Nuthatches that were present were in unfragmented stands.

Pine Siskins and Cassin's Finches were most abundant in stripcut habitat configurations (Table 4) but this did not suggest simple preferences for forest edges. The abundance of these species was not similarly high in the other edge habitats of spotcuts and meadow edges. There was no evidence that *any* species preferred or avoided

simple forest edges. The abundances of Hermit Thrushes, Cassin's Finches and Pine Siskins all demonstrate differences in abundance between meadow edges and clearcut edges. Stripcut configurations have the largest amount of clearcut (50%); these larger clearcuts with greater regeneration may have been the important habitat features to Cassin's Finches and Pine Siskins.

The results of the present study are different from the study of forest fragmentation in the Pacific Northwest (Rosenberg and Raphael 1986). In that study, the abundance of Brown Creepers, Hermit Thrushes, and Red-breasted Nuthatches was not related to stand area, distance of stand to a clearcut, or percent of stand perimeter that was clearcut edge. This may be partly a result of different definitions and scales at which fragmentation variables were measured in the two studies. Rosenberg and Raphael measured features of plots, stands, and 1000 ha areas surrounding the stand, and used the Forest Service delineation of stands as single covertypes of timber maps. In this study, we defined fragmented and unfragmented stands by management practices (uncut, stripcut, and spotcut areas). We examined the influence of the habitat compositions in the stand and in the 100 m (3.1 ha) area around plots, smaller areas than those analyzed by Rosenberg and Raphael.

The results reported here are most similar to studies comparing unlogged old-growth stands to managed stands where timber has been removed. Franzreb and Ohmart (1978) found Brown Creepers, Hermit Thrushes, Red-breasted Nuthatches, Mountain Chickadees, Ruby-crowned Kinglets and Yellow-rumped Warblers all less abundant in a stand having 70% of the tree density removed compared to an unharvested stand. The abundance of Gray-headed Juncos was higher in the logged stand. Mannan and Meslow (1984) compared birds in mature, unmanaged forests to younger thinned stands and found Brown Creepers, Hermit Thrushes, and Red-breasted Nuthatches more abundant in the mature unmanaged forests. Juncos and Cassin's Finches were more abundant in managed stands. These patterns were also evident in comparisons of clearcuts and old-growth in California (Hagar 1960). The similarities of these results to the present study suggest that stands interrupted with stripcuts and spotcuts may be similar to stands that have been more uniformly thinned or logged.

Perhaps the most important effect of the early stages of fragmentation by clearcutting is the absolute loss of habitat and reduced density of associated resources.

In this study, the response to fragmentation did not appear to result from simple preference or avoidance of forest edges or interiors. Cassin's Finches and Pine Siskins were significantly more abundant in stripcut plots with clearcut edges than in the edges adjacent to meadows. Hermit Thrushes did not appear to avoid meadow edges of large stands, but were less abundant in fragmented stands with the most clearcut edge. It appears that the nature of the adjacent habitat is more important than the existence of a forest edge per se. Pine Siskins, Cassin's Finches and, to some extent, Gray Jays are probably attracted to the larger openings of stripcuts and the remnant strips of forest among these openings. Austin and Perry (1979) found both Pine Siskins and Cassin's Finches more abundant in clearcuts than mature lodgepole forest.

Brown Creepers may avoid stripcut and spotcut areas simply because of the reduction of resources by adjacent clearcuts. Franzreb (1985) found that Brown Creepers selected larger trees for foraging and suggests this relates to a preference for larger trunks where more food is available and more energy can be obtained before flying to a new site. For similar energetic reasons there must be a minimum density of foraging sites per territory before a habitat is suitable. If the resources provided by 50 ha of old-growth are spread out over 100 ha because of interspersed clearcuts, the resource density may be reduced below acceptable levels. Resource density may be especially important at these high elevations where overall productivity is low and resources may be marginal even in the best sites.

Differences between sites and years produced larger differences in the avian community than fragmentation by clearcuts. However, this does not suggest that fragmentation is insignificant. The harsh climates at high elevations would be expected to result in strong year to year differences in bird use of these areas. These harsh conditions reduce growth rates and regeneration of subalpine forest at higher elevations (Alexander 1974, Nobel and Alexander 1977). Loss of resources by clearcutting in this harsh environment may make marginal environments no longer suitable for some avian species.

These results are only the first glimpse of the effect of forest fragmentation on nongame birds in a few subalpine forests of the Rocky Mountains. Results suggest that forest tracks interspersed with clearcuts have different abundances of only a few species compared to uncut forest tracts. Differences in these species did not appear to result from increases in forest edge or loss of forest interiors. These changes may result simply because clearcutting creates openings that attract some species, but also removes forest making the distribution of remaining forest resources more dispersed. Resources must occur in sufficient density within a defendable area to permit species to occur in a stand. If this is the major reason Brown Creepers were not found in fragmented stands, we would expect them to have the greatest sensitivity to fragmentation at high elevations and greater tolerance to fragmentation at lower elevations or other areas where forest productivity is higher and resources may be more concentrated. Additional research is needed to evaluate these possibilities.

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