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Montane Alternative Silvicultural Systems (MASS): Pre-treatment Breeding Bird Communities

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Canada

BC

Montane Alternative Silvicultural Systems (MASS): Pre-treatment Breeding Bird Communities

by

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ABSTRACT

Bird communities were surveyed to provide baseline data against which to measure the effects of forest harvesting. Between May 11 and June 7, 1992, birds were counted at 60 fixed-radius sampling plots in a contiguous block of montane hemlock old-growth forest at 700–800-m elevation. Counts lasted for 12 minutes per station, and each plot was surveyed four times. Birds detected more than 75 m from the observer were excluded. To obtain an index of nest predation rates, artificial nests containing fresh quail eggs were placed at 120 locations.

Bird communities in the study area are made up of relatively few species; the four most abundant species (Chestnut-backed Chickadee, Winter Wren, Varied Thrush, and Red-breasted Sapsucker) accounted for 64% of all bird detections, and the 10 most abundant species accounted for 96% of detections. Species-accumulation curves indicate that most common species were detected within the first four sampling plots in this habitat type, but more than 12 plots were needed to detect all species. The control area appears to represent bird communities in the study site quite well. Transect proximity to forest edges had no effect on bird richness, abundance, or Shannon-Weiner diversity. A few species (Pileated Woodpecker, Hairy Woodpecker, Gray Jay, and Steller's Jay) showed differences in abundance between edge and interior stations, but small sample sizes precluded testing. The artificial nest experiment determined that nest predation rates were positively correlated with increasing proximity to forest edges. Harvesting of montane old-growth forests will have impacts beyond the boundaries of cutblocks.

Current logging plans will lead to forest treatment blocks of a size (9 ha) that could contain only three bird sampling stations. Such small samples will make it difficult to measure bird community changes after logging. Pooling of three blocks treated using "shelterwood," "green tree retention," and "patch-cutting" methods is one alternative, but this would result in only nine sampling plots per harvest method. Because these plots will not be in contiguous blocks of forest, edge effects will also bias results.

ACKNOWLEDGEMENTS

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1 INTRODUCTION

MacMillan Bloedel Limited, with funding obtained under the Canada-British Columbia Forest Resource Development Agreement (FRDA), has begun to experiment with alternative harvesting systems at a study site near Campbell River (W. Beese, MacMillan Bloedel Limited, Nanaimo, pers. comm. 1992). An area of high-elevation old-growth forest is currently being harvested using a combination of clearcutting, clearcutting with leave patches (green tree retention), strip-cutting (shelterwood), and small clearcuts (patch-cutting). Current plans call for retention of some old-growth forest to serve as a control area, and for monitoring of harvested and unharvested areas in subsequent years using a combination of biological, biophysical, and economic methods (W. Beese, pers. comm. 1992). The study has adopted the acronym MASS (Montane Alternative Silvicultural Systems).

The objectives of this study were:

- to evaluate pre-harvest richness, diversity, and relative abundance of breeding forest birds in the MASS study area.
- to obtain baseline information on predation rates.

2 METHODS

2.1 Study Area

The MASS study area is located between 750 and 800 m above sea level within the Georgia Depression Ecoprovince of British Columbia (Demarchi 1988; Figure 1). The study area is typical of old-growth forests in this area, and is dominated by western hemlock (*Tsuga heterophylla*) with varying amounts of western redcedar (*Thuja plicata*), yellow-cedar (*Chamaecyparis nootkatensis*), mountain hemlock (*Tsuga mertensiana*), amabilis fir (*Abies amabilis*), and Douglas-fir (*Pseudotsuga menziesii*) (Campbell *et al.* 1990). The area comprises approximately 130 ha, of which 81 ha are slated for harvest.

2.2 Bird Survey Design

Sixty-four bird sampling stations were established within the study area (Figure 2). Four stations were disrupted by logging activities and abandoned. To permit testing for edge effects, the remaining 60 stations were grouped into five study transects, each made up of 12 stations located 150 m apart, as follows:

1. "Edge-line": all stations were 75–150 m from the forest edge.
2. "250-line": all stations were more than 250 m from the forest edge.
3. "400-line": all stations were more than 400 m from the forest edge.
4. "550-line": all stations were more than 550 m from the forest edge.
5. "Control": 12 stations at various distances from the forest edge in the 25-ha area that will remain unlogged.

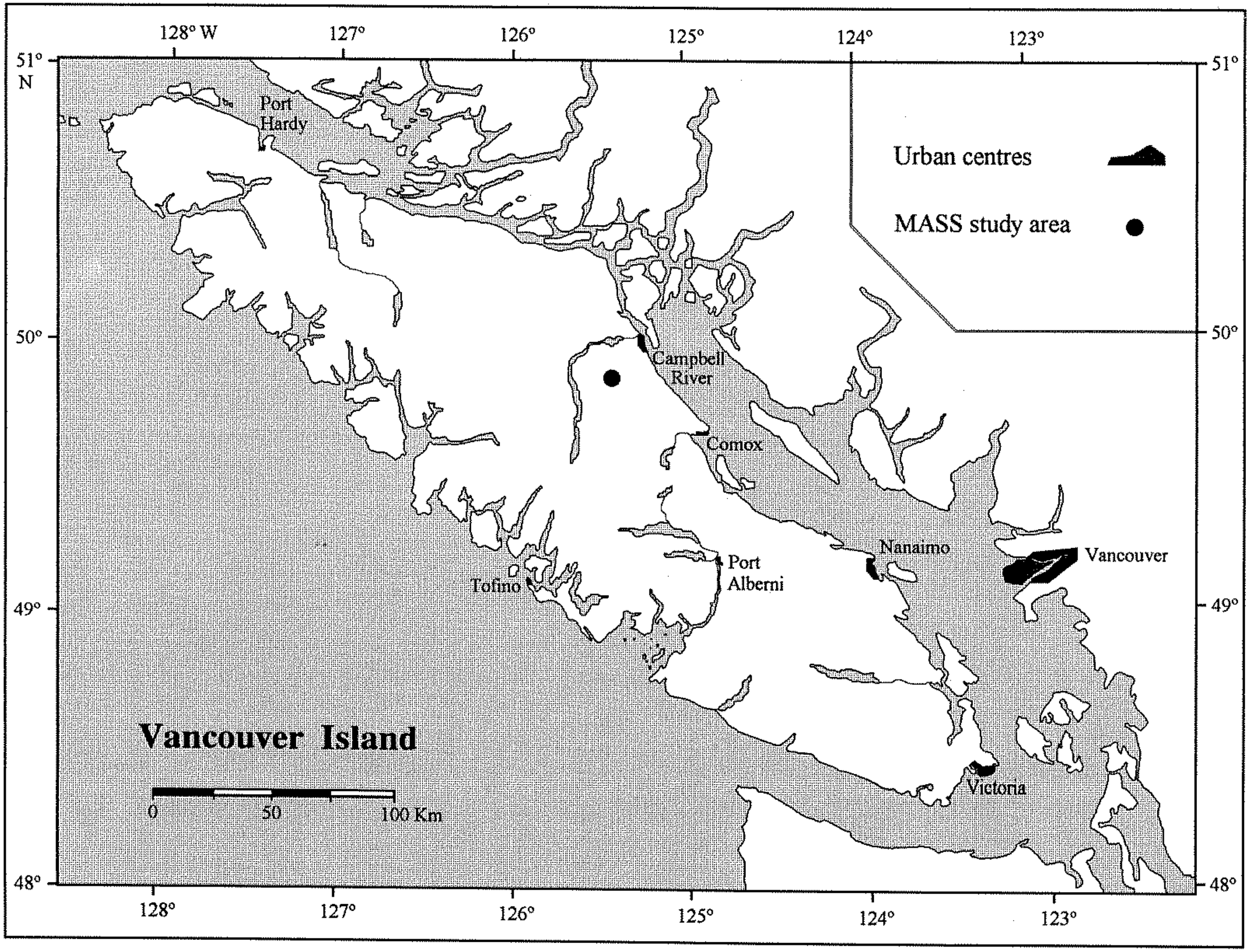


FIGURE 1. Location of MASS study area.

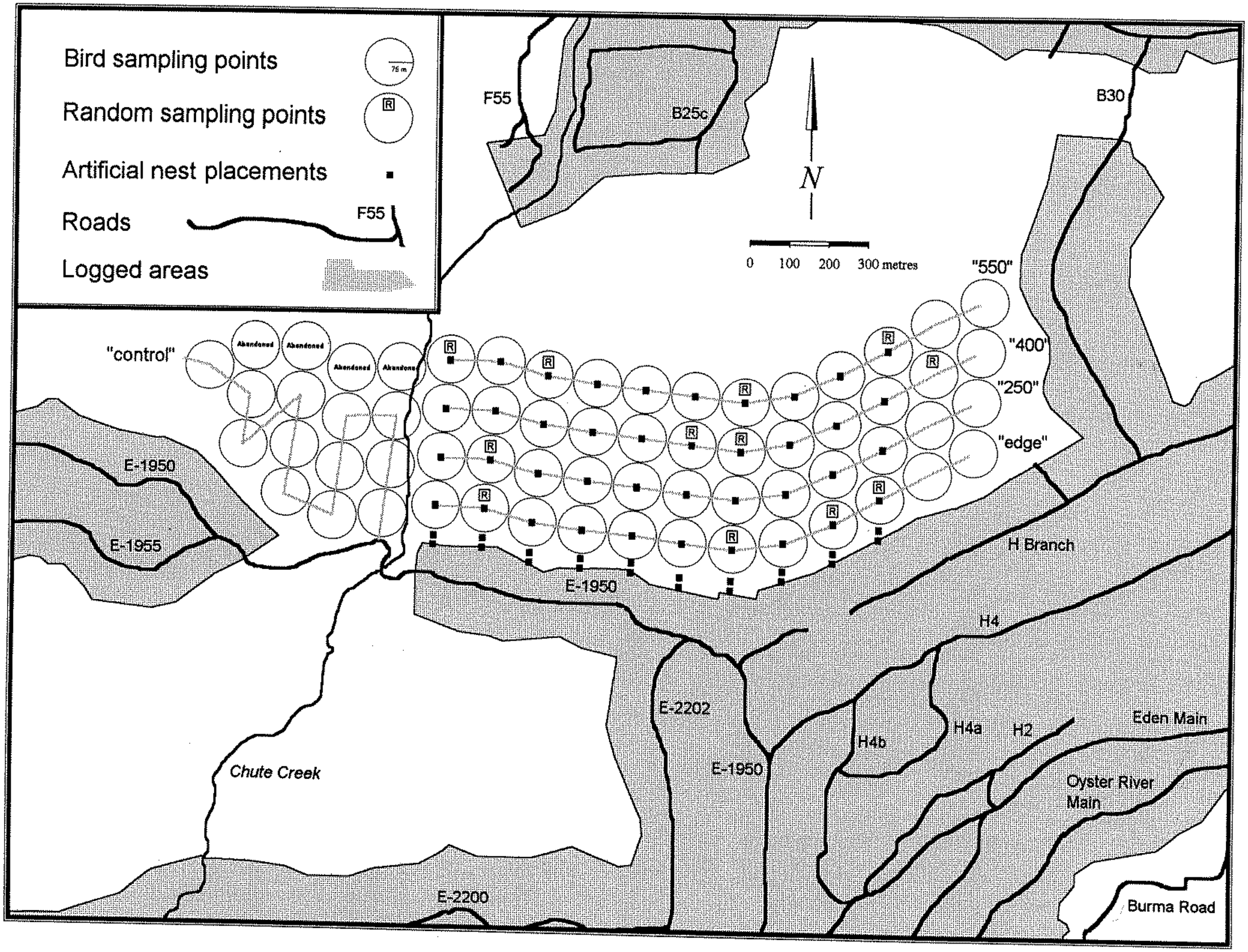


FIGURE 2. Detail of MASS study area.

2.3 Bird Counts and Data Compilation

Each transect was surveyed four times between May 9 and June 15, 1992. Observers recorded birds seen or heard within 75 m of a sampling station during a 12-minute period. Species, number of individuals, behaviour, and estimated distance from observer were noted. Surveys were carried out between 0430 hours and 0900 hours, and were not conducted during periods of heavy rain or high wind.

Some groups of species were excluded from analyses because point counts may not reflect their actual abundance or breeding status (Bryant *et al.* 1993). The single seabird species that nests in Vancouver Island old-growth forests (Marbled Murrelet) requires a specialized survey approach. This species is typically detectable only before 0700 hours, and there is an unclear relationship among vocalizations, habitat use, and nesting status (Rodway *et al.* 1991). Similarly, diurnal hawks may be missed if surveys are not conducted during March or April when males are vocal and easily detected, and owls are often missed unless tape-playback methods are used. In addition, birds that were not directly associated with the sampled habitat were excluded, including those flying over the plot or those detected outside the 75-m plot perimeter. Species observed foraging over the plot (e.g., Vaux's Swift), or that entered and landed in the plot during the count period (e.g., Red Crossbill) were included. When bird:observer distance was close to the 75-m perimeter but uncertain, birds were included.

Because the intention of this study is to describe breeding bird communities, the measure of relative abundance used is critical. Results from a single count are biased by differences in observer ability, weather, timing of territorial song among species, and random differences in individual bird behaviour. One method of reducing these biases is to conduct multiple counts and sum the total number of detections of each species. This includes all species detected, but does not provide useful estimates of breeding numbers. A second method is to use the maximum number of each species recorded; however, this includes individuals that may be migrating through the site and not breeding there. A third, and popular procedure, is to average the number of detections of each species across counts. This reduces the bias caused by nonbreeding migrants but does not eliminate it. With only four surveys, the average also tends to underestimate species that are early or late arrivals, since they may not be detected during early or late counts. Bryant *et al.* (1993) have suggested that with four surveys the median number of detections for each species would provide the most reliable estimate of actual breeding abundance, since this would exclude the highest and lowest counts. The maximum, average, and median indices for each species were calculated, but only the median index was used in statistical analyses. Because each transect contained multiple stations, detection rates for each species are expressed as $\bar{x}$±*s.e.* birds per station.

2.4 Nest Predation Study

Wilcove's (1985) example was followed to explore the relationship between nest predation rates and distance from the forest edge. Fresh Japanese Quail (*Coturnix coturnix)* eggs were placed in 120 artificial nests and monitored over time. Eggs, which were obtained from the Quail Research Unit of the University of British Columbia, measured approximately 28 x 23 mm and were either speckled brown or robin egg blue. Artificial nests were constructed from 12 x 12 x 10 cm brown fibre nursery baskets obtained from a garden supply shop, and lined with moss and detritus obtained from the study site. Three eggs were placed in each nest. Two nests were placed near each sampling location to test for the effect of nest position on predation rates; one buried flush in the forest floor; and one mounted at eye level in a shrub or tree. To test for the effect of spatial location within the study forest, artificial nests were placed at 60 locations as follows:

1. "0-line": 10 locations (20 nests) along forest edge.
2. "15-line": 10 locations (20 nests) 15 m from forest edge.

3. "Edge-line": 10 locations (20 nests), same as bird sampling stations.
4. "250-line": 10 locations (20 nests), same as bird sampling stations.
5. "400-line": 10 locations (20 nests), same as bird sampling stations.
6. "550-line": 10 locations (20 nests), same as bird sampling stations.

Nests were checked after 7 days and after 14 days. Survivorship was measured as "nest survival" (nest in good condition with at least one undamaged egg remaining) or "egg survival" (count of undamaged eggs).

2.5 Statistical Analysis

All statistical analyses were based on the median number of detections for each species. The adequacy of bird sampling efforts were assessed by generating species-accumulation curves for each of the five study transects, and comparing these with a curve fitted to the cumulative data using linear regression and log-transformed x values (Sokol and Rohlf 1981). Shannon-Weiner diversity H' indices were calculated for each transect following Whittaker (1975).

To determine whether the control transect was actually representative of the proposed treatment area, 12 stations were selected at random from the edge; 250, 400, and 550 transects to create a "random" transect within the proposed treatment area. Single-factor analysis of variance (ANOVA) was used to test for differences in diversity, species richness, and bird abundance between the control and random transects (Sokol and Rohlf 1981). Morisita's Index of Community Similarity was calculated using the simplified formula proposed by Horn (1966). ANOVA was also used to test for differences in diversity, species richness, and abundance among transects at different distances from the forest edge, and Morisita's index was calculated for each possible pairwise comparison. Chi-squared (χ^2) contingency tables were used to test whether individual bird species were equally distributed at different distances from the stand edge (Sokol and Rohlf 1981).

Chi-square tests were also used to test whether the frequency of predation was equal at different distances from the forest edge. To determine whether predation rates were significantly correlated with increasing distance from forest stand edge, Spearman rank correlations of distance-to-edge data were calculated against per cent survival data for eggs and nests (Zar 1974).

3 RESULTS AND DISCUSSION

3.1 Species Detected

Twenty-six forest bird species were recorded during the study (Table 1). Three species (Marbled Murrelet, Northern Pygmy Owl, and Saw-whet Owl) were excluded from analysis because survey methods used to assess their relative abundance were inappropriate (Section 2.3).

Five of the remaining 23 species (Blue Grouse, Western Wood Pewee, Hammond's Flycatcher, Common Raven, and MacGillivray's Warbler) were only detected on the first survey. Three additional species (Rufous Hummingbird, Hermit Thrush, and American Robin) were detected on multiple occasions but were not consistently recorded at any sampling station. These eight species are therefore

TABLE 1. Summary of bird detections

	Code	Species	Survey date				Total
			May 11–17	May 18–24	May 25–31	June 1–7	
1.	BlGr	Blue Grouse	2	0	0	0	2
2.	RuHu	Rufous Hummingbird	1	2	2	1	6
3.	RBSa	Red-breasted Sapsucker [a]	52	25	35	37	149
4.	HaWo	Hairy Woodpecker [a]	7	2	10	2	21
5.	PiWo	Pileated Woodpecker	4	1	3	0	8
6.	WWPe	Western Wood Pewee	2	0	0	0	2
7.	HaFl	Hammond's Flycatcher	1	0	0	0	1
8.	PSFl	Pacific Slope Flycatcher	17	17	25	29	88
9.	GrJa	Gray Jay [a]	4	15	12	18	49
10.	StJa	Steller's Jay	1	1	0	7	9
11.	CoRa	Common Raven	1	0	0	0	1
12.	CBCh	Chestnut-backed Chickadee [a]	50	50	80	72	252
13.	BrCr	Brown Creeper	22	19	10	9	60
14.	RBNu	Red-breasted Nuthatch [a]	42	41	48	15	146
15.	WiWr	Winter Wren	72	62	62	51	247
16.	GCKi	Golden-crowned Kinglet	31	36	24	26	117
17.	HeTh	Hermit Thrush	3	1	3	1	8
18.	VaTh	Varied Thrush	50	35	78	56	219
19.	AmRo	American Robin	3	3	1	0	7
20.	MGWa	MacGillivray's Warbler	1	0	0	0	1
21.	DEJu	Dark-eyed Junco	17	10	14	13	54
22.	PiSi	Pine Siskin	17	17	34	9	77
23.	ReCr	Red Crossbill	12	10	63	27	112
24.	MaMu	Marbled Murrelet			b	b	?
25.	SWOw	Saw-whet Owl		b			?
26.	NPOw	Northern Pygmy Owl			b		?
	Total number of species detected		23	18	17	16	23
	Total number of birds detected		412	347	504	373	1636

NOTES

[a] Breeding evidence found. See Appendix 2.

[b] Presence only. This species was excluded from analyses. See Appendix 1.

eliminated using the median index (Table 2). Since the timing of surveys encompassed the territorial season of these species in B.C. (e.g., Ehrlich *et al.* 1988; Campbell *et al.* 1990), their inconsistent appearance in the MASS area suggests that they did not establish breeding territories at this site. The remaining 15 species were all consistently encountered and presumably bred either at or near the site. Nesting evidence was obtained for five species (Appendix 2).

The choice of bird index used influences estimates of bird abundance (Table 2). For example, using the median index, an average of just over 0.5 Red-breasted Sapsuckers was detected at every sampling station. The maximum index yields an equivalent estimate of 1.37 sapsuckers per sampling station and the average index yields an intermediate value of 0.61 sapsuckers per sampling station. In general, for highly vocal and territorial species such as wood warblers or thrushes, the median index probably provides a reasonably accurate measure of singing males, and can therefore be used as an estimate of breeding density. However, for widely foraging groups such as the jays, corvids, and woodpeckers, the median index will probably underestimate true abundance, because this index requires that the bird be detected at the same sampling station on multiple surveys in order to be counted.

Most of the species (69–82%) recorded within any transect were detected within the first four sampling stations. In all cases, for samples larger than four sampling stations, additional sampling stations added fewer than a proportional number of new species. When all 60 sampling stations were pooled in random order, the first four stations resulted in detection of only 9 of 15 of the species (60%), while new species were added at the 53rd and 54th plots. A cumulative species-accumulation curve indicated that more than 80% of the variability in number of species recorded was explained by sampling effort (r^2=0.838). However, the curve never achieved a true asymptote (Figure 3). Ultimately, a sampling protocol using 12 fixed-radius plots of 150 m in diameter, combined with four repeated surveys, resulted in detection of most common species, but probably missed some rare species and underestimated the true abundance of widely foraging species.

3.2 Patterns of Rarity and Abundance

Bird communities at the MASS study area are made up of a relatively small number of species (Figure 4). Four species (Chestnut-backed Chickadee, Winter Wren, Varied Thrush, and Red-breasted Sapsucker) could be described as abundant (more than 0.5 individuals per sampling station), and accounted for 64% of all bird detections. An additional six species (Red-breasted Nuthatch, Golden-crowned Kinglet, Pacific Slope Fly-catcher, Pine Siskin, Brown Creeper, and Dark-eyed Junco) were common (0.1–0.5 individuals per station). Overall, the 10 abundant and common species accounted for 96% of all bird detections. The remaining five species (Gray Jay, Red Crossbill, Hairy Woodpecker, Steller's Jay, and Pileated Woodpecker) accounted for fewer that 4% of all detections, and therefore should be considered as truly rare inhabitants of the study area.

Increased sampling effort would probably have resulted in detection of some of the widely foraging species in additional areas (especially Hairy Woodpecker and Pileated Woodpecker). For these species, sampling methods used in this study must be considered marginal, and a protocol involving more than 12 sampling stations, or more than four counts, would be desirable. However, as rare species comprised fewer than 4% of the total number of birds detected, increased sampling effort would not have materially altered estimates of $\overline{x}$ richness or abundance per sampling station, and would have had only slight effects on Shannon-Weiner diversity or Simpson's evenness indices. Therefore, proceeding with analyses that used unadjusted data for all species seemed justified.

TABLE 2. Detection rates for individual bird species [a]

SPECIES	Abundance index: Median index $\overline{x} \pm$ s.e.	Average index $\overline{x} \pm$ s.e.	Maximum index $\overline{x} \pm$ s.e.
1. Blue Grouse	0 ± 0	0.008 ± 0.006	0.033 ± 0.023
2. Rufous Hummingbird	0 ± 0	0.025 ± 0.009	0.100 ± 0.038
3. Red-breasted Sapsucker	0.508 ± 0.067	0.621 ± 0.058	1.367 ± 0.108
4. Hairy Woodpecker	0.025 ± 0.018	0.087 ± 0.020	0.300 ± 0.064
5. Pileated Woodpecker	0.008 ± 0.083	0.033 ± 0.012	0.117 ± 0.041
6. Western Wood Pewee	0 ± 0	0.008 ± 0.006	0.033 ± 0.023
7. Hammond's Flycatcher	0 ± 0	0.004 ± 0.004	0.017 ± 0.017
8. Pacific Slope Flycatcher	0.283 ± 0.046	0.367 ± 0.037	0.900 ± 0.081
9. Gray Jay	0.092 ± 0.034	0.204 ± 0.043	0.633 ± 0.122
10. Steller's Jay	0.008 ± 0.008	0.037 ± 0.015	0.133 ± 0.055
11. Common Raven	0 ± 0	0.004 ± 0.004	0.017 ± 0.017
12. Chestnut-backed Chickadee	0.967 ± 0.074	1.050 ± 0.062	1.967 ± 0.115
13. Brown Creeper	0.125 ± 0.036	0.250 ± 0.028	0.750 ± 0.073
14. Red-breasted Nuthatch	0.492 ± 0.059	0.608 ± 0.053	1.333 ± 0.096
15. Winter Wren	0.958 ± 0.072	1.029 ± 0.058	2.000 ± 0.105
16. Golden-crowned Kinglet	0.400 ± 0.059	0.487 ± 0.052	1.117 ± 0.108
17. Hermit Thrush	0 ± 0	0.033 ± 0.012	0.133 ± 0.050
18. Varied Thrush	0.750 ± 0.092	0.912 ± 0.078	2.050 ± 0.150
19. American Robin	0 ± 0	0.029 ± 0.010	0.117 ± 0.041
20. MacGillivray's Warbler	0 ± 0	0.004 ± 0.004	0.017 ± 0.017
21. Dark-eyed Junco	0.117 ± 0.032	0.225 ± 0.033	0.667 ± 0.090
22. Pine Siskin	0.142 ± 0.047	0.321 ± 0.054	1.000 ± 0.158
23. Red Crossbill	0.075 ± 0.033	0.467 ± 0.125	1.717 ± 0.460
Cumulative (all species)	4.956 ± 0.242	6.832 ± 0.237	16.526 ± 0.618

NOTES

[a] Data are $\overline{x}$ ±s.e. number of birds per station as determined over 60 sampling stations.

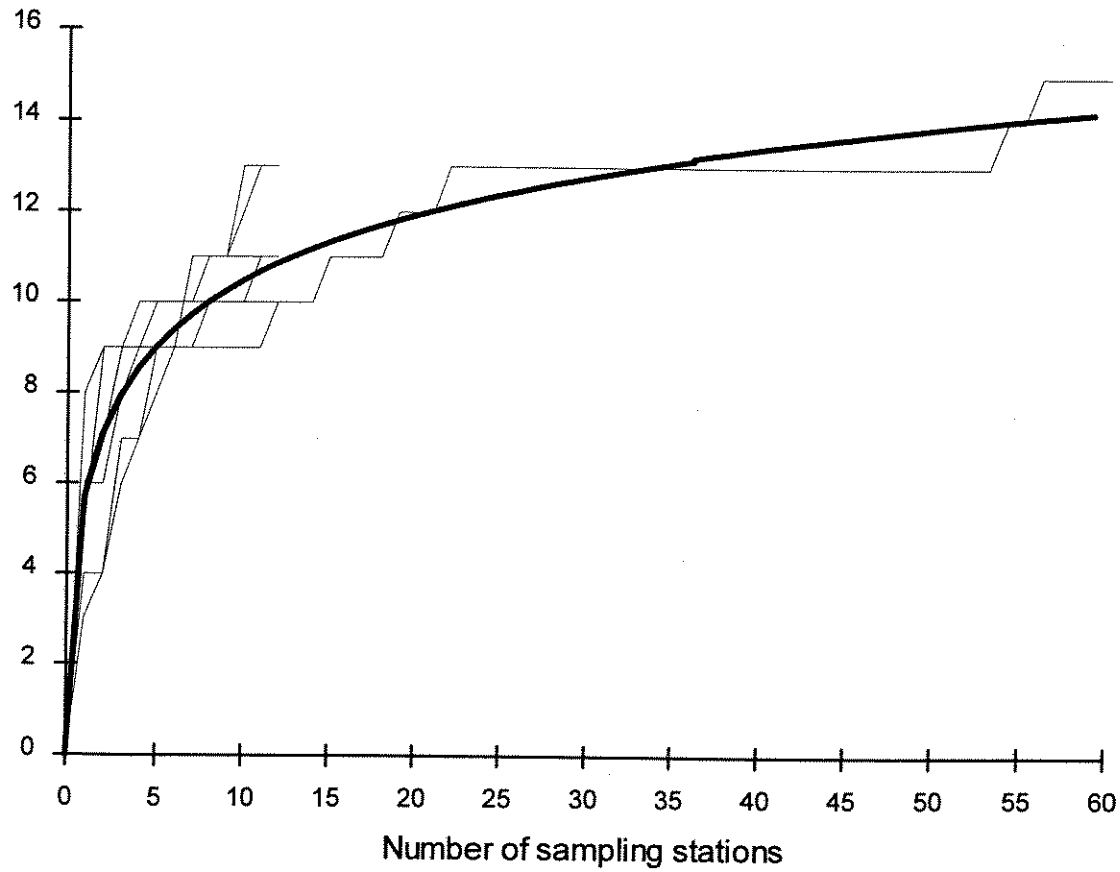


FIGURE 3. Species accumulation curves for each of the five study transects and the MASS area as a whole. The cumulative curve (bold line) was generated by linear regression (multiple y values for each x) of accumulated species against log-transformed numbers of sampling stations where slope $b = 4.81$ and constant $a = 5.65$. On this curve, more than four sampling stations lead to the acquisition of fewer than one additional species for each additional sampling station.

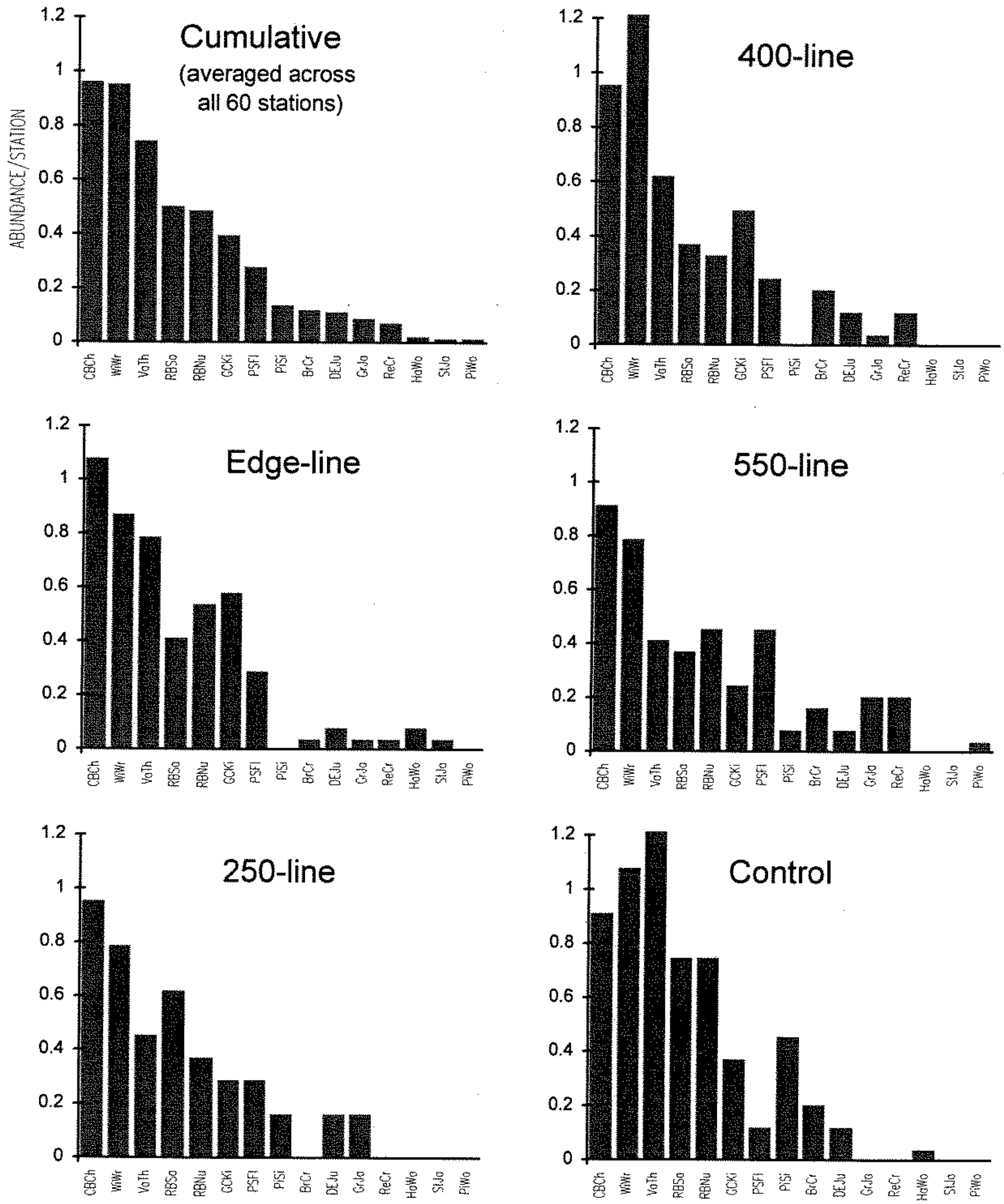


FIGURE 4. Patterns of bird abundance and rarity. Cumulatively, four species (Chestnut-backed Chickadee, Winter Wren, Varied Thrush, and Red-breasted Sapsucker) accounted for 64% of all bird detections within the MASS study area. Species codes are as given in Table 1.

3.3 Adequacy of the Control Transect

Comparison of the control versus random transects revealed no significant differences in bird richness, abundance, or diversity (Table 3). Morisita's index of community overlap, which reflects both species composition and bird abundance, was 0.920. Differences between the two transects were not, for the most part, caused by the presence or absence of rare species in one transect and not the other. Removal of the five rarest species (for these transects, Hairy Woodpecker, Gray Jay, Pine Siskin, Dark-eyed Junco, and Red Crossbill) caused only a trivial improvement in Morisita's index, to 0.922. In short, the control transect appears to be fairly representative of the area, and the small difference between it and the "treatment" area appears to be due to subtle shifts in the relative abundance of common species such as Chestnut-backed Chickadee or Red-breasted Nuthatch. Note that two species (Pileated Woodpecker and Steller's Jay) were not detected in either the control or random sample although they were consistently found at other transects.

TABLE 3. Comparison of control and random transects [a]

	Transect			
Measure	**Control**	**Random**	**t [b]**	**significance**
Richness indices				
Total N of species/transect	11.00	11.00		
$\bar{x}$ N of species/station	6.00	6.08	0.15	>0.05
s.e. of $\bar{x}$	0.43	0.36		
Abundance indices				
Total N of birds/transect	75.50	68.00		
$\bar{x}$ N of birds/station	6.29	5.67	0.83	>0.05
s.e. of $\bar{x}$	0.64			
Diversity indices				
Shannon-Weiner H'	2.09	2.16	0.18	>0.05
Simpson's C	0.86	0.86	0.02	>0.05
Morisita's Index of Community Overlap				
All species considered	0.920			
10 most abundant species only	0.922			
4 most abundant species only	0.936			

NOTES

a Data are based on the Median index.

b Student's T-test with 22 df. For a two-tailed test, $t_{critical}$=2.074 (Zar 1974).

TABLE 4. Effect of transect location on bird richness, abundance, and diversity [a]

	Transect location [b]					
Measure	Edge	250	400	550	Control	F [c]
Richness indices						
Total N of species/transect	13	10	11	13	11	
$\bar{x}$ N of species/station	5.67	4.58	5.17	5.75	6.00	1.98
s.e. of $\bar{x}$	0.31	0.58	0.55	0.43	0.43	
Abundance indices						
Total N of birds/transect	59	51.5	57.5	53.5	75.5	
$\bar{x}$ N of birds/station	4.92	4.29	4.79	4.46	6.29	0.36
s.e. of $\bar{x}$	0.40	0.52	0.53	0.47	0.64	
Diversity indices						
Shannon-Weiner H'	2.107	2.130	2.081	2.293	2.090	1.42
Simpson's C	0.856	0.862	0.847	0.879	0.856	1.21

NOTES

a Data are based on the Median index.

b See Section 2 for transect descriptions. The control transect contained stations at various distances from the forest edge and was excluded from this analysis.

c Single-factor ANOVA with 3/44 df. For a two-tailed test, $F_{critical}$=3.42 (Zar 1974).

3.4 Influence of Forest Edge on Bird Diversity and Abundance

Results indicate no significant difference in bird richness, abundance, or diversity as a function of increasing distance from the forest edge (Table 4). Morisita's index ranged from 0.854 to 0.960, suggesting high similarity in community composition (Table 5). Again, between-transect differences appeared to be largely independent of the chance presence or absence of rare species. Distance from the forest edge had only a slight influence on the frequency of occurrence of individual bird species (Table 6). Based on χ^2 tests, only two species (Winter Wren and Golden-crowned Kinglet) were not equally distributed among the four distance classes tested. The conclusion drawn is that most species encountered did not display a strong preference for either edge or interior conditions.

This finding is unusual, since other researchers have documented changes in bird communities as a function of proximity to forest edges (e.g., Forman *et al.* 1976; Galli *et al.* 1976; Anderson *et al.* 1977; Strelke and Dickson 1980; Whitcomb *et al.* 1981; Kroodsma 1984). However, much of that work has been carried out in eastern deciduous forests, and its applicability to montane Pacific Northwest coniferous forests is poorly understood (Harris 1984). These results may be partially caused by low bird abundance. Blue Grouse, Rufous Hummingbirds, Western Wood Pewees, Hermit Thrushes, American Robins and MacGillivray's Warblers were not consistently found at any station, thus precluding testing. Other species that may be either edge or interior specialists (Pileated Woodpecker and Steller's Jay) were so scarce that visible trends could not be tested (Table 6). Finally, several edge species common elsewhere on Vancouver Island (e.g., Yellow-rumped Warbler, White-crowned Sparrow, Song Sparrow, and American Goldfinch) were not encountered in the MASS area.

3.5 Rates of Predation Upon Artificial Nests

Survivorship of artificial nests was low. Overall, only 69 of 120 (57.5%) artificial nests and 173 of 360 (48.1%) quail eggs survived their first week after placement (Figure 5). After two weeks, overall survivorship declined to 16 of 120 (13.3%) nests and 32 of 360 (8.9%) eggs. Although artificial nests were more obvious than real songbird nests, this result indicates that nest predators are present in the MASS area in some numbers.

In general, it was not possible to identify predator species. The loss of single eggs from a nest in which other eggs survived probably indicated an avian predator (or perhaps a small terrestrial predator). Damaged eggs (pecked or gnawed) that were left in the nest suggested small bird or mammal predators. However, in many cases predation involved complete loss of eggs, and in several cases nests were found shredded or completely removed, implying a terrestrial predator such as a pine marten or black bear. Ground nests also suffered more predation that did nests placed at eye level in trees, again suggesting the importance of terrestrial predators.

The limitations of the artificial nest method should be noted. As Wilcove (1985) wrote, "...experimental nests were more conspicuous than the actual nests of migratory passerines. Thus, while the experiment could measure the *relative* magnitude of predation..., it could not measure the actual rate of predation that birds were experiencing." Note also that very few species found in the MASS study area (e.g., Hermit Thrush, Winter Wren, MacGillivray's Warbler, Dark-eyed Junco) construct low basket-type nests.

TABLE 5. Bird community overlap among study transects [a]

	Transect					
	Edge	**250-line**	**400-line**	**550-line**	**Control [b]**	**Random [b]**
Edge	1.000	0.953	0.959	0.942	0.919	0.984
250-line		1.000	0.936	0.960	0.893	0.950
400-line			1.000	0.939	0.884	0.934
550-line				1.000	0.854	0.937
Control					1.000	0.920
Random						1.000

NOTES

a Data are Morisita's Index of Community Overlap as calculated using Horn's (1966) simplified formula. The index varies from 0 (no similarity) to 1.0 (complete overlap).

b See Section 2 for transect descriptions. The control and random transects contained stations at various distances from the forest edge.

TABLE 6. Effect of transect location on frequency of bird occurrence [a]

	Transect location [b]						
Species	**Edge**	**250**	**400**	**550**	**Control**	**χ^2 significance**	
1. Blue Grouse	0	0	0	0	0	-	-
2. Rufous Hummingbird	0	0	0	0	0	-	-
3. Red-breasted Sapsucker	58.3	58.3	58.3	50.0	75.0	0.25	-
4. Hairy Woodpecker	8.3	0	0	0	8.3	-	-
5. Pileated Woodpecker	0	0	0	8.3	0	-	-
6. Western Wood Pewee	0	0	0	0	0	-	-
7. Hammond's Flycatcher	0	0	0	0	0	-	-
8. Pacific Slope Flycatcher	41.7	50.0	33.3	75.0	16.7	2.92	-
9. Gray Jay	8.3	16.7	8.3	33.3	0	3.60	-
10. Steller's Jay	8.3	0	0	0	0	-	-
11. Common Raven	0	0	0	0	0	-	-
12. Chestnut-backed Chickadee	91.7	83.3	91.7	83.3	83.3	0.76	-
13. Brown Creeper	16.7	0	25.0	25.0	33.3	3.60	-
14. Red-breasted Nuthatch	58.3	50.0	41.7	58.3	83.3	0.92	-
15. Winter Wren	100.0	66.7	100.0	83.3	91.7	8.38	<0.05
16. Golden-crowned Kinglet	83.3	33.3	50.0	33.3	50.0	8.00	<0.05
17. Hermit Thrush	0	0	0	0	0	-	-
18. Varied Thrush	75.0	58.3	75.0	66.7	83.3	1.07	-
19. American Robin	0	0	0	0	0	-	-
20. MacGillivray's Warbler	0	0	0	0	0	-	-
21. Dark-eyed Junco	16.7	25.0	16.7	16.7	25.0	0.41	-
22. Pine Siskin	0	16.7	0	16.7	50.0	4.36	-
23. Red Crossbill	8.33	0	16.7	25.0	0	3.8	-

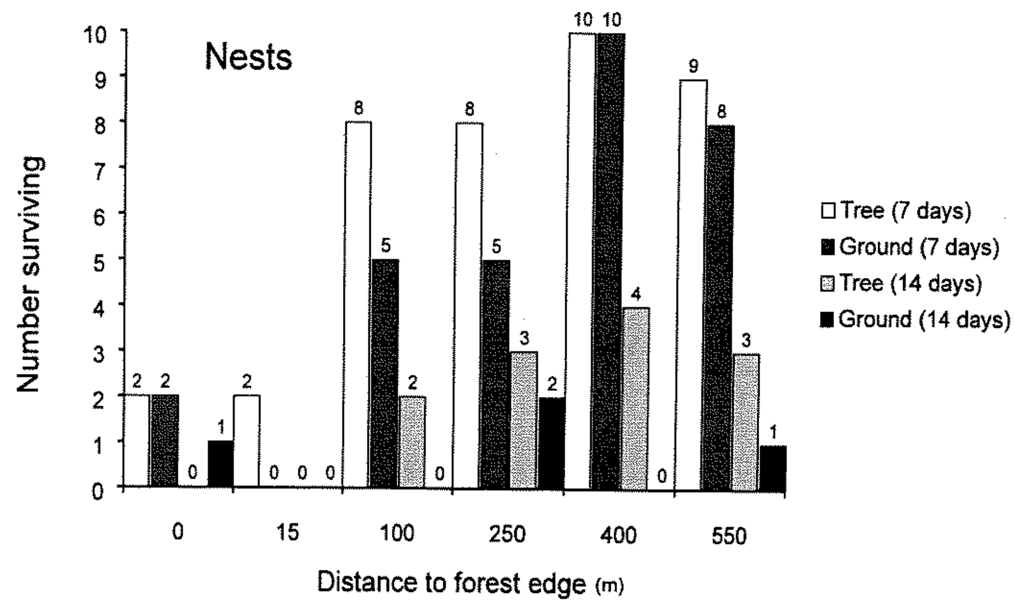
NOTES

[a] Data are % of sampling stations at which species were detected. Note that χ^2 tests were performed using frequency data; species for which expected cell frequencies <5 were excluded.

[b] See Section 2 for transect descriptions. The control transect contained stations at various distances from the forest edge and was excluded from analysis. For a two-tailed test, $\chi^2_{critical}$ with 3 df =7.81 (Zar 1974).

3.6 Effect of Forest Edge on Survival of Artificial Nests

Survival of eggs for tree nest placements was significantly different among distance categories (χ^2=24.79 with 5 df, p<0.01), but survival of nests was not (χ^2=9.77 with 5 df, p>0.05). For ground nest placements, survivorship of both eggs and nests was significantly different among distance categories (for eggs, χ^2=39.10 with 5 df, p<0.01; for nests, χ^2=13.67 with 5 df, p<0.05). These statistics reflect 7-day conditions. Extremely low survival rates after 14 days led to expected cell frequencies less than five and invalid chi-square statistics. For both tree and ground placements, egg and nest survival rates were positively and significantly correlated with increasing distance from the forest edge (Table 7).



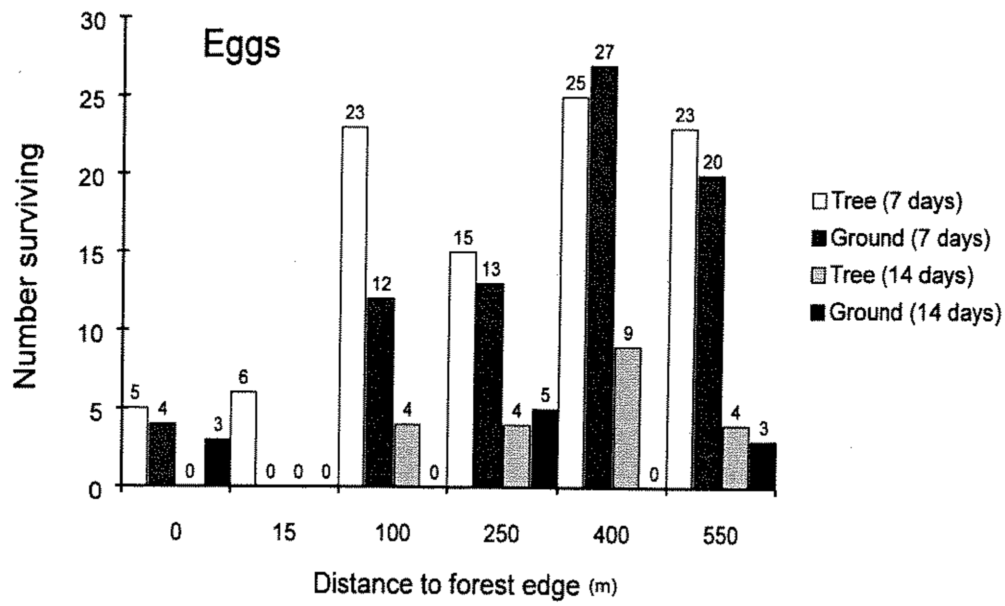


FIGURE 5. Observed survival of nests and eggs after 7 and 14 days.

TABLE 7. Influence of transect location on predation rates [a]

	Distance from forest edge							
% survival	0	15	100	250	400	550	Spearman r [b]	significance
Tree nests	0.20	0.20	0.80	0.80	1.00	0.90	0.912	<0.05
Tree eggs	0.17	0.20	0.77	0.50	0.83	0.77	0.832	<0.05
Ground nests	0.20	0	0.50	0.50	1.00	0.80	0.870	<0.05
Ground eggs	0.13	0	0.40	0.43	0.90	0.67	0.886	<0.05

NOTES

a Data are probabilities of survival of eggs and nests after 7 days. Due to the low overall survival rates, 14-day data were not tested.

b Spearman rank correlation test. With n = 6 observations, $r_{critical} = 0.829$ (one-tailed test, Zar 1974).

This result is consistent with the findings of Wilcove (1985) from the southeastern United States. In the MASS area, one possible cause of this may be the affinity of predator species such as Steller's Jay for forest edges. In any case, data suggest that logging in montane forests leads to "edge effects" over and above changes in bird species composition, and that these effects may extend for 100 m or more into unlogged forest.

3.7 Implications for Future Work

Given a plot radius of 75 m, each bird sampling station represents 1.76 ha of bird habitat. Species-accumulation curves suggest that most common species will be detected within the first four sampling stations, but some rare species will be missed even in transects with 12 or more stations. A necessary conclusion is that studies employing fewer sampling stations would underestimate actual bird richness. This result is in accordance with the findings of Manuwal and Carey (1991), and has ramifications for the MASS study.

Current logging plans call for the treatment of 81 ha, with three replicated treatment blocks harvested using each of "shelterwood," "patch," and "green tree retention" methods. An optimistic interpretation of this is that each replicated 9-ha treatment block could contain five bird sampling stations of 1.76 ha. In reality, because bird plots are circular and planned treatment blocks are rectangular, each block could realistically contain only three stations. Pooling data from the three blocks harvested with the same technique would lead to a maximum of nine bird sampling stations for each treatment type. Moreover, because the nine treatment blocks of each type will be discrete units, they will be essentially "edge" habitats, which may respond differently than would a single contiguous area with the same number of sampling stations.

It has been suggested that some of the sampling limitations could be resolved by reducing the size of the bird study plots or by increasing the number of counts. Simply reducing the size of the study plots is an untenable approach; subdividing a sample is not the same as increasing sample size. The only effects would be to reduce mean bird abundance per station and proportionally increase variance, since individual birds would have less room in which to be present or absent. Increasing the number of counts is a valid approach, and, would presumably result in detection of rare, widely foraging species at more sampling stations. In particular, if more than four counts are made the bias imposed by early or late migrants would be lessened, and differences between the median and average indices would be reduced (although the maximum index would still be biased by unusually high single counts). However, increasing the number of counts does not address a fundamental fact of old-growth bird communities—that they are spatially heterogenous, and some species are rare.

With small samples (unlike those used in this study) extreme caution will be necessary to ensure that the chance occurrence or absence of a single rare species does not invalidate between-area comparisons. Given that the number of sampling plots per treatment type is dictated by the geometry of the MASS project, the only recourse will be to limit bird community analyses to the more common species. This is unfortunate, given that some of the rare species (e.g., Pileated Woodpecker, Hairy Woodpecker, and Steller's Jay) may be the ones most influenced by landscape change.

4 CONCLUSIONS

Conclusions from the 1992 MASS bird survey are straightforward:

1) The 60 sampled stations in the MASS area were adequate to characterize breeding bird communities in montane hemlock old-growth forest. In practice, more than four stations are required to detect most of the common bird species in this habitat type, and more than 12 stations are needed to detect the rarer species.

2) Significant edge effects were not detected in terms of altered overall bird richness, abundance or diversity. A few species (Pileated Woodpecker, Hairy Woodpecker, Gray Jay, and Steller's Jay) showed visible differences in abundance between edge and interior stations, but small sample sizes precluded testing.

3) The artificial nest experiment determined that nest predation rates are likely to increase as a function of increasing proximity to forest edges. Harvesting of montane old-growth forests will have impacts beyond the boundaries of cutblocks.

4) The planned harvest strategy for the MASS area will result in study blocks that are too small to treat as "replicates" for the purpose of bird community analysis; they will contain a maximum of three sampling plots each. Pooling of three blocks treated using each of shelterwood, green tree retention, and patch-cutting methods will result in only nine sampling points per harvest method. Therefore, the ability to detect significant changes will be possible only for the species that are relatively abundant.

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APPENDIX 1

Other Bird Species Detected

Northern Pygmy Owl:

- One individual heard at 0654 hours on May 26 at "550-line" #12 (SM).
- One individual heard at 0752 hours on May 26 at "edge-line" #12 (SM).

Saw-whet Owl:

- One response to tape played along road 1950 at 0500 hours on May 21 (DA). The nearest station was "edge-line" #7.

Wilson's Warbler:

- One male heard singing on road 1950 on May 22 (DA).

Marbled Murrelet:

- One bird flying west above canopy at 0625 hours on May 21 at "control" #3 (DA).
- One bird flying west above canopy at 0514 hours on May 26 at "edge-line" #7 (SM).
- Several birds calling at 0511 hours on May 26 at "edge-line" #10 (SM).
- Several birds flying east at 0555 hours on May 27 at "control" #9 (DA).
- Several birds flying below canopy at 0445 hours on May 28 at "control" #10 (DA).
- Several birds flying west above canopy at 0500 hours on June 1 at "edge-line" #2 (SM).
- Several birds flying below canopy at 0502 hours on June 2 at "edge-line" #3 (DA). "Keer" calls were heard.

APPENDIX 2

Nest Records

Red-breasted Sapsucker:

- One adult was observed feeding three young at 0720 hours on May 22 (DA). The nest was located in a Western Hemlock approximately 14 m above the ground. Sampling station "250-line" #1. For future reference, there is a large dead cedar leaning against the nest tree.
- Two adults were observed feeding three young at 1021 hours on May 28 (AB). The nest was located in a snag (species unknown) approximately 8 m above ground. The nearest station was "400-line" #4.

Hairy Woodpecker:

- One adult and an indeterminate number of young birds were heard at 0902 hours on May 26 (SM). The nest cavity was in a western hemlock 11 m above ground at station "550-line" #9.

Gray Jay:

- One adult was seen with two newly fledged young at 0653 hours on June 3 at "400-line" #12 (DA).

Chestnut-backed Chickadee:

- Two adults and an indeterminate number of young were heard at 0625 hours on May 21 (DA). The nest cavity was approximately 14 m above ground in a snag (species unknown). Sampling station is "control" #3.

Red-breasted Nuthatch:

- Two adults were observed using a cavity in a western hemlock approximately 12 m above ground at 1430 hours on May 28 at "400-line" #2 (AB).