Strip-cutting: nest predation and breeding bird response to strip regrowth

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Abstract

We compared breeding bird abundance and nest predation rate in strip-cut stands of different age of cut and in clearcuts using the spot-mapping method. The forest was 50-70 years old and dominated by conifers. Timber harvesting created 20 m wide clearcut strips separated by 20 m interstrips of mature forest. Strip-cut plots had higher breeding bird densities and richness than clearcuts and final cuts (where the interstrip was cut). Strip-cut stands provided breeding opportunities for 28 forest-associated species not found in clearcuts or final cuts, whereas the latter habitats were used for nesting by 8 species not found in strip-cuts. Strip-cutting allowed the addition to the forest bird community of a few open country species such as Common Yellowthroat and Chestnut-sided Warbler. The abundance of these species decreased with forest regeneration. The regrowth dominated by deciduous trees and shrubs created suitable habitat for deciduous forest species such as Veery, Ovenbird, Canada Warbler and Rose-breasted Grosbeak. Predation rates on artificial nests did not differ between treatments or between strips and interstrips. Shrub nests, however, were more frequently preyed upon than ground nests, while well-concealed ground nests suffered the lowest predation. Bird communities were extremely dynamic, responding to changes in vegetation structure and composition. Strip-cuts permitted the retention of a large proportion of the forest bird community at least until the final cut. Thus, our results suggest that strip-cutting is an efficient compromise between forest harvesting and conservation, but only when interstrips are retained several years after the cut.

Résumé

Nous comparons l'abondance des oiseaux nicheurs et le taux de prédation des nids dans des coupes par bandes d'âges différents et dans des coupes à blanc en utilisant la méthode des plans quadrillés. La forêt avait de 50 à 70 ans et était dominée par des conifères. La coupe forestière a créé des bandes de 20m de largeur séparées par des interbandes intactes de 20 m. Les parcelles dans les coupes par bandes avaient des densités et des richesses plus grandes d'oiseaux nicheurs que les coupes totales et les coupes finales (où l'interbande intacte a été coupée aussi). Les parcelles de coupe par bandes supportèrent 28 espèces d'oiseaux forestiers absentes des coupes totales et finales qui elles, ne supportèrent que 8 espèces absentes des parcelles de coupe par bandes. Les coupes par bandes ont permis l'addition de quelques espèces de milieux ouverts à la communauté d'oiseaux forestiers, par exemple, la Paruline masquée et la Paruline à flancs marrons. L'abondance de ces espèces a diminué avec la repousse de la végétation de la bande coupée. Cette repousse, dominée par des arbres et des buissons feuillus, a créé un habitat propice pour les espèces associées aux forêts feuillues telles que la Grive fauve, la Paruline couronnée, la Paruline du Canada et le Cardinal à poitrine rose. Le taux de prédation sur les nids artificiels ne différait pas entre les types de coupes ou entre les bandes et les interbandes. Cependant, les nids localisés dans les buissons ont été victimes de prédation plus fréquemment que les nids au sol. Les nids au sol bien cachés étaient aussi ceux ayant subis le moins de prédation. Les communautés d'oiseaux étaient très dynamiques, réagissant aux changements dans la composition et la structure de la végétation. Les coupes par bandes ont permis la rétention d'une grande proportion de la communauté des oiseaux forestiers, du moins jusqu'à la coupe finale. Alors, nos résultats suggèrent que la coupe par bandes est un compromis acceptable entre l'exploitation forestière et la conservation, mais seulement lorsque les interbandes sont préservées intactes pour plusieurs années.

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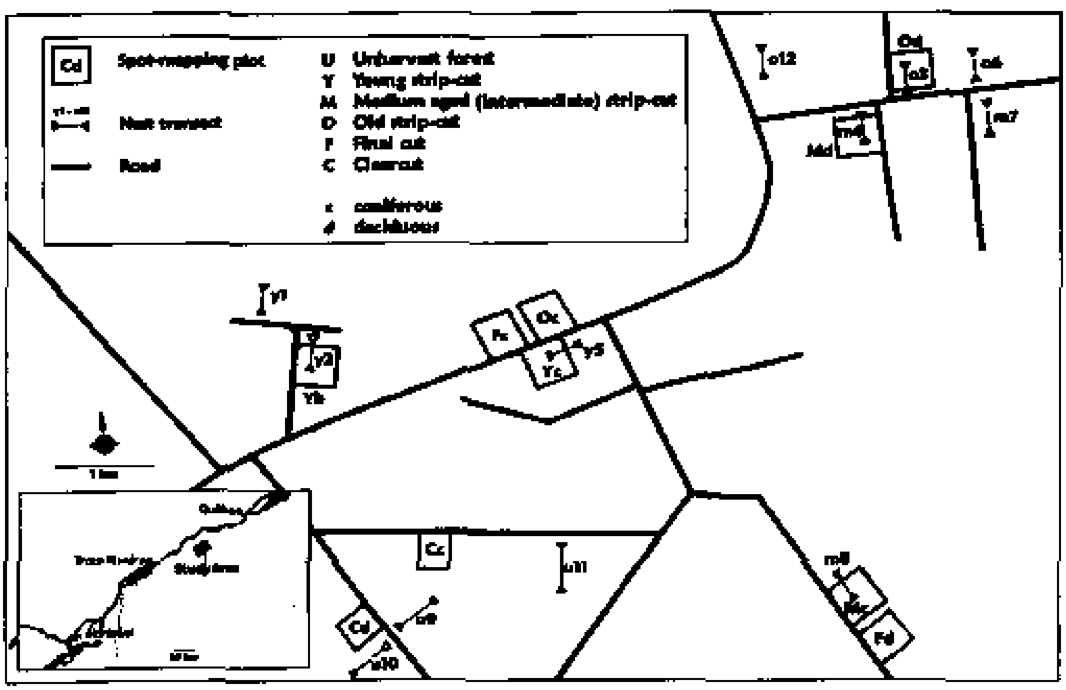
Introduction

With Canada's ratification of the Convention on Biodiversity in 1992 the sustainable development of our forests has become a prominent issue (Biodiversity Science Assessment Team 1994). Sustainable forestry implies that harvesting activities are sustainable and do not permanently affect biodiversity in managed forest ecosystems (Hunter 1990; Salwasser 1990; Middleton 1994).

To achieve sustainable development of our forests and to be able to use harvesting practices as biodiversity management tools, it is essential to quantify the positive and negative impacts of each practice and regime of practices on biological diversity. The impact of forestry practices on birds is becoming increasingly quantified (Titterington et al. 1979; Crawford et al. 1981; Morgan and Freedman 1986; Welsh 1987; Hagan et al. 1997) and birds are often used as umbrella species to protect other components of biodiversity (Welsh 1987; Savard 1994).

Strip cutting is most often used when a seed source needs to be preserved for natural regeneration, but is occasionally used as a compromise to clearcutting as a way of maintaining a temporary forest structure while extracting some wood. The impact of strip-cutting on birds is poorly known (Freedman et al. 1981; Doyon et al. 1994) and the response of birds to strip regrowth has yet to be studied. Little is known either of the impact of strip-cutting on breeding success of birds. Several studies have shown that in heavily fragmented agricultural or urban landscapes, nests located close to edges suffered higher probability of failure than nests located further away from edges (Gates and Gysel 1978; Andrén and Angerstam 1988). However, studies in fragmented landscapes still

Figure 1. Sketch map of study area south-west of Québec City showing relative location of study plots and transects.



dominated by forest did not report similar trends (Yahner and Wright 1985; Rudnicky and Hunter 1993). Strip-cutting creates a large amount of edges. Such an increase in the proportion of habitat near edges could have significant impacts on the reproductive success of birds.

The goal of this study is threefold: (1) to document the changes in the composition of bird communities as harvested strips undergo succession; (2) to contrast bird communities of strip-cut areas with those of clearcuts and of final cuts, which are harvested areas whose interstrip has been removed several years after the initial cut; and (3) to compare nest predation in natural, strip-cut and clearcut forest stands.

Study area

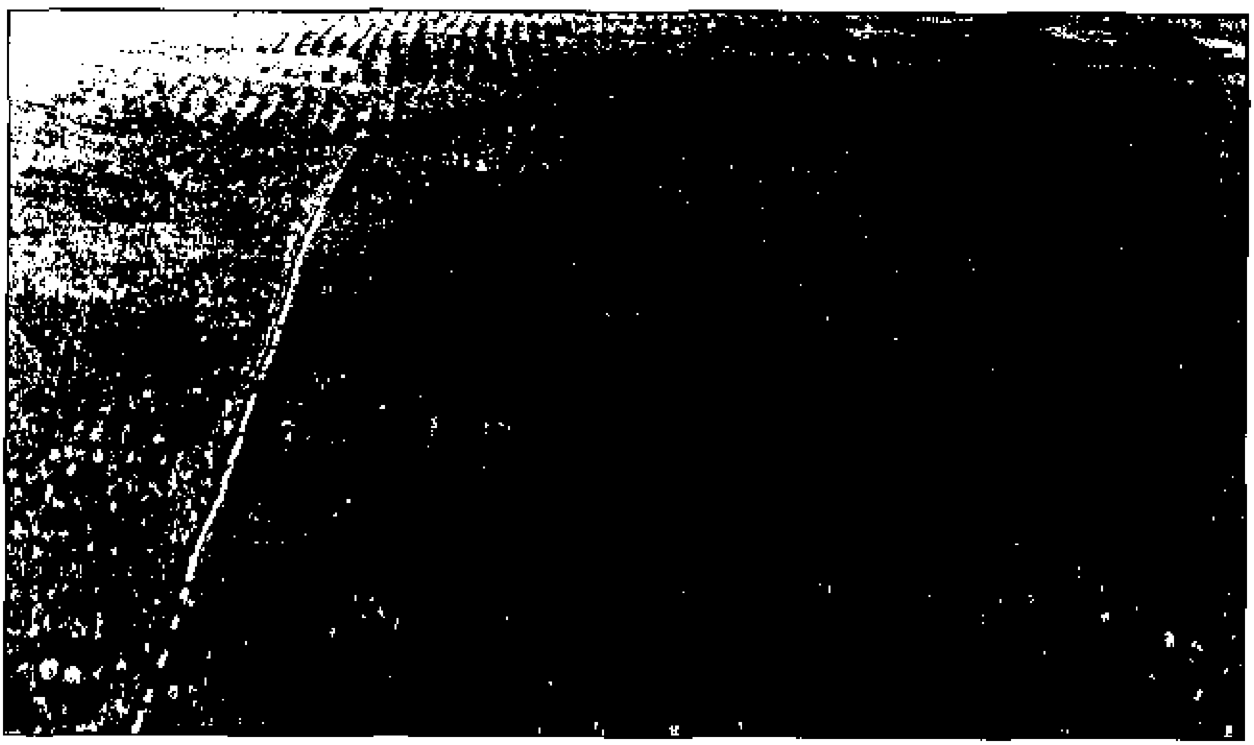
The study area, located about 60 km south-west of Québec city (Figure 1), was strip-logged from 1978 to 1990. Timber harvesting was done systematically with 20m wide harvested strips separated by 20m interstrips (Figure 2). The conifer forest was dominated by 50-70 year-old balsam fir and spruce trees ranging between 12 and 17 m in height. Located in the St. Lawrence lowlands, the area is rather flat and poorly drained due to a gleyed mineral soil (Dubé et al. 1993; Dubé et Plamondon 1995). Temperatures average -13°C in January and 19°C in July, with an average annual precipitation of 1228 mm (Environment Canada 1993).

Methods

Bird surveys

Breeding bird density was estimated using the spot-mapping technique (Williams 1936; Bibby et al. 1992). Ten spot-mapping plots of 10 to 14 ha each were surveyed in 1995. Two plots were located in five forest types: (1) recent strip-cuts (6 years old); (2) medium-aged or intermediate strip-cuts (10 years old); (3) old strip-cuts (14-15 years old); (4) final cuts (strip-cuts where the interstrip is cut after about 5-10 years of strip regrowth); and (5) clearcuts (3-5 years old). In each type, one spot-mapping plot sampled regeneration dominated by conifers and one by deciduous vegetation. Each plot was grided at 40 m intervals to facilitate positioning of the birds except in clearcuts where a 50 m grid was laid. Plots were surveyed seven to eight times between 5 June and 4 July 1995. All censuses were conducted between sunrise and 1030h EDT, and observers were rotated between plots.

Figure 2. Aerial view of 20 m wide strip-cuts, also showing two final cut areas.



Vegetation surveys

For each spot-mapping plot, except clearcut plots, vegetation cover was estimated visually at 80 points in the grid (40 in the strip, 40 in the interstrip). In clearcut plots 36 points positioned systematically throughout the plot were sampled. At each point we quantified regrowth in terms of proportion of conifer and deciduous species using five classes (conifer; conifer-deciduous; mixed; deciduous-conifer; deciduous). In the strip, we assigned a height class to the vegetation (<2 m, 2-5 m, >5 m) and evaluated the percent cover of the regrowth (<30%, 30-60%, >60%). At points located in interstrips, we estimated the percent cover of shrubs and trees <6 m (<10%, 10-40%, >40%). For trees taller than 6 m, we recorded only the coniferous-deciduous proportion because the overall tree cover was very uniform. Results were compiled using the number of stations classified visually in each height or cover categories.

Artificial nests

We used artificial nests containing two Japanese Quail (*Coturnix coturnix japonica)* eggs to estimate predation in four forest types: uncut forest and three ages of strip-cut forest (young, intermediate, old). In each type we positioned three transects of 20 nests each oriented perpendicularly to the strips with nests located 20 m apart so that in strip-cut areas, 10 nests were located in strips and 10 in interstrips. Alternating nests were positioned in the following manner: 2 on the ground (1 in the strip, 1 in the interstrip), 2 at 1-2 m height (1 in the strip, 1 in the interstrip) and so on. Nests in shrubs were made of chicken wire and filled with mosses and leaves. Ground nests were depressions filled with dead leaves. We positioned a plastic chip under each ground nest to ensure relocation of depredated nests. Nests were visited at 7-, 14- and 21-day intervals. For each nest we recorded the number of eggs preyed upon. One observer classified each nest in three qualitative concealment categories: well, moderately and poorly hidden.

Data analysis

The number of breeding pairs in each plot was estimated according to IBCC criteria (International Bird Census Committee 1970). Statistical analysis was limited due to small sample sizes. Species richness and breeding density were compared using a 2 factors ANOVA (forest type, regrowth type) with one observation per cell using the GLM procedure of the SAS software (SAS Institute, Inc. 1990a). As SAS cannot calculate the interaction between the two factors when there is only one observation per cell, we used a test developed by Tukey (Montgomery 1984: 212-213). Homogeneity of variance was verified by plotting residuals against predicted values and normality of data was tested with the Shapiro-Wilk test of the UNIVARIATE procedure (SAS Institute, Inc. 1990b). We also used the number of detections during a census as a unit and averaged it over the seven or eight visits. This provided a relative abundance estimate for transient or non-territorial species (Appendix 1). To compare community structure among treatments, we used cluster analysis performed with the average linkage method (SAS Institute, Inc. 1990a). The similarity matrix obtained with Horn's index of similarity computed between each combination of plots was used as input data.

Artificial nest data were analysed with the SAS/INSIGHT unit of SAS, which allows adjustment of generalized linear models (SAS Institute Inc., 1993). Because the dependent variable was binary (1 = nest predation, 0 = no predation), we adjusted logistic regression models. The first model contained only strip-cut forest data with age of strip (young, intermediate, old), height of nest (ground or shrub), location (strip or interstrip) and concealment index (well, moderately, poorly hidden) as explanatory variables. The second model included data from both strip-cut and uncut forests with type of forest, height of nest and degree of concealment as explanatory variables. In both analyses interactions between explanatory variables were included in the model.

An adjustment was made to account for the over-dispersion of the data and Wald tests were used to determine if explanatory variables significantly improved the fit of the model.

Results

Habitat features

For a given age, the vegetation of the strip varied greatly according to whether the regrowth was predominantly coniferous or deciduous (Table 1). Conifer-dominated regrowth was more open and shorter than deciduous-dominated regrowth because of variation in rates of growth. The two intermediate (10 years old) strip-cuts were the most contrasting of the paired plots in term of vegetation structure and composition. In fact, from a structural perspective, the deciduous-dominated intermediate plot was quite similar to the conifer-dominated old-aged plot.

Table 1. Vegetation features of spot-mapping plots based upon 30-40 points within each plot (% of sampling points classified in the category). Vegetation types: Con = >60% conifer; Mixed = 40-90% deciduous; Dec = >90% deciduous.
Plot types: Y = young (6 yr old); M = medium (10 yr); O = old (14-15 yr); F = final cuts (interstrip removed); C = clearcut (3-5 yr old); c = conifer-dominated; d = deciduous-dominated.

Plot	Vegetation height in strip				Vegetation type in strip			Vegetation type in interstrip			>40% cover in interstrip
	<2m	2-5m	>5m	>60% cover	Con	Mixed	Dec	Con	Mixed	Dec	
Yc	55	55	-	3		63	37	93	7	-	80
Yd	42	58	-	70	-	2	98	63	22	15	97
Mc	100	-	-	5	-	85	15	100		-	68
Md	22	57	21	44	2	45	53	65	35	-	20
Oc	24	58	18	51	8	36	56	49	51	-	23
Od	15	85	-	75	-	7	93	58	40	2	93
Fc	84	16	-	0	11	81	8	21	72	7	-
Fd	57	43	-	7	-	90	10	13	87	-	-
Cc	81	19	-	19	-	78	22	-	-	-	-
Cd	47	53	-	56	-	14	86	-	-	-	-

Breeding densities

The type of forest had an effect on breeding bird densities ($F_{4,4}$ = 9.0, p = 0.03) and species richness ($F_{4,4}$ = 37.2, p = 0.002). Strip-cut plots had higher breeding bird densities ($\bar{x}$ = 51.2 ± 3.1 pairs / 10 ha, n=6) than plots with no interstrips ($\bar{x}$ = 37.1 ± 2.5, n=4) (Table 2). Species richness was also higher in strip-cut plots ($\bar{x}$ = 26.3 ± 0.6 species, n=6) than in other plots ($\bar{x}$ = 11.5 ± 1.3, n=4). Species richness did not differ significantly between plots with conifer- and deciduous-dominated regrowth ($F_{1,4}$ = 0.1, p = 0.76) but conifer-dominated plots tended to have higher breeding bird densities ($F_{1,4}$ = 9.0, p = 0.04). However, differences were relatively small (< 7 pairs) except for plots with 10 year old regrowth where the coniferous plot had 18 more breeding pairs. Two species accounted for that difference, the Common Yellowthroat (12.2 versus 2.6 pairs) and the White-throated Sparrow (8.4 versus 1.8 pairs). These two species still found suitable habitat in the shorter and more open coniferous regrowth but not in the higher and denser deciduous regrowth. Strip-cuts provided breeding opportunities for 28 forest-associated species not found breeding in final cuts and clearcuts. These latter habitats provided breeding habitat for eight species not found in strip-cuts. Final cuts supported more species than clearcuts.

Vegetation regrowth in strips reduced the density of species associated with open areas. Four species, abundant in final cuts and clearcuts, found adequate breeding habitat in newly-created strips but were much less abundant in older strips where vegetation regrowth formed a closed canopy. Those were the Chestnut-sided Warbler ($\bar{x}$ = 6.9 ± 0.6 pairs / 10 ha, n=2 in young strips vs 2.3 ± 1.1, n=2 in old strips), Mourning Warbler (1.0 ± 0.2 vs 0), Common Yellowthroat (8.9 ± 0.2 vs 1.5 ± 0.7), and White-throated Sparrow (8.7 ± 0.8 vs 5.1 ± 1.9). Three other species of open areas (Alder Flycatcher, Song Sparrow, Lincoln's Sparrow), although abundant in final cuts and clearcuts, did not use the open areas created by strip-cutting, likely requiring openings wider than 20 m. A few species responded positively to the increase in deciduous cover as the strip regrew, breeding at higher densities in the old deciduous strip-cut than in the young one (Veery, Nashville Warbler, Ovenbird, Canada Warbler, Magnolia Warbler, Black-and-white Warbler, Rose-breasted Grosbeak).

Vegetation structure and composition had a significant effect on bird communities. This is best illustrated by the intermediate strips which, although of similar age, were quite different in regrowth height (<2m in MC and >2m up to 5m in MD) and composition (coniferous vs deciduous). The more

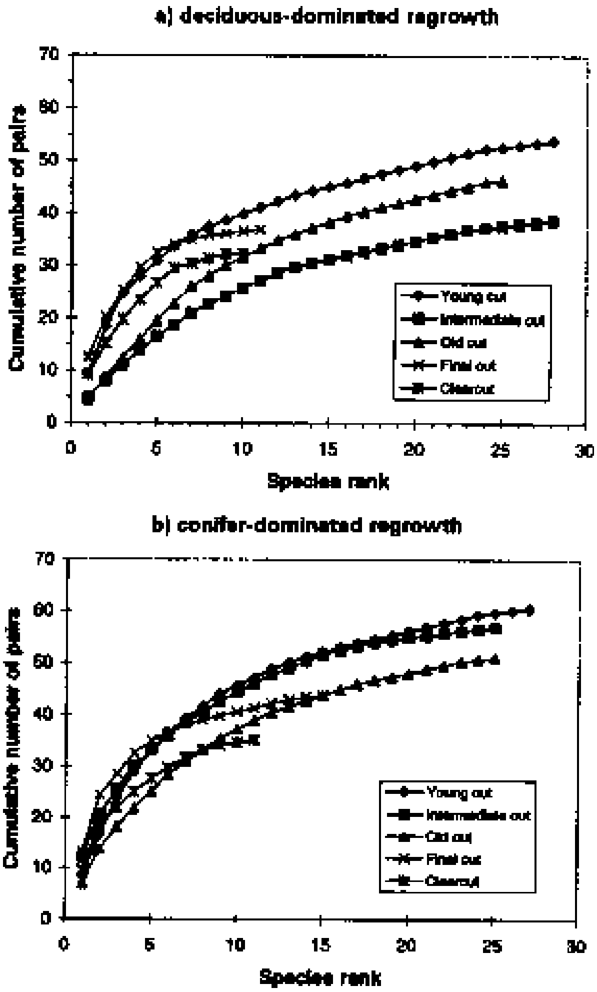
Table 2. Breeding bird densities (pairs / 10 ha) in various forest types.

	Strip-cuts						Final cuts		Clearcuts	
	Young		Medium		Old					
Species	Con (12.6 ha)	Dec (12.8 ha)	Con (11.9 ha)	Dec (13.6 ha)	Con (13.7 ha)	Dec (12.5 ha)	Con (12.3 ha)	Dec (12.3 ha)	Con (9.8 ha)	Dec (10.9 ha)
Ruffed Grouse		0.8			0.7	0.8				
Ruby-throated Hummingbird							0.8			
Yellow-bellied Sapsucker	0.8	0.8	1.7	0.7	1.1	0.8				
Hairy Woodpecker		0.4		0.7						
Black-backed Woodpecker	0.8									
Northern Flicker	0.8	0.4	0.4			0.4	0.8			
Pileated Woodpecker				0.4						
Eastern Wood-pewee	0.4	1.2								
Alder Flycatcher			0.4				4.1	4.5	2.0	2.8
Least Flycatcher		0.4								
Great Crested Flycatcher			0.4	0.4						
Tree Swallow										0.9
Blue Jay	0.8	0.8	0.8	0.7	0.7	0.8				
Black-capped Chickadee	2.4	0.8	1.3	0.7	1.1	1.2			0.5	
Red-breasted Nuthatch	0.8	0.8	0.8	0.4	0.7	0.8				
Brown Creeper				0.7						
Winter Wren	1.6	2.3	1.7	2.2	1.8	3.6				
Golden-crowned Kinglet	0.8		2.1			1.6				
Veery				0.7	3.3	1.2				
Hermit Thrush	2.8	0.8	1.7	1.5	2.6	2.0				
American Robin	0.4	0.8		0.7		0.8				
Cedar Waxwing	0.8	0.8	0.8	0.4	0.7	0.8	1.6	0.8	2.0	0.9
Solitary Vireo	1.2	1.2	2.9	0.7	0.4					
Red-eyed Vireo	0.8	1.6	0.4	2.9	1.1	1.2				
Nashville Warbler	1.2	1.2	2.1	3.3	3.6	3.2	0.8		1.5	
Chestnut-sided Warbler	7.5	6.3	2.9	4.8	3.3	1.2	4.1	4.9	1.0	
Magnolia Warbler	4.8	0.8	4.6	2.9	6.9	4.4	0.8			
Black-throated Blue Warbler	4.4	2.7	0.4	2.2	2.2	3.6				
Yellow-rumped Warbler	0.8	0.8	1.3	0.7	0.7					
Black-throated Green Warbler	3.6	3.1	2.5	1.5	1.5	4.4				
Blackburnian Warbler	2.4	3.1	3.0	0.4	1.1	0.8				
Palm Warbler							0.8	0.8		
Black-and-white Warbler	3.2		1.3	1.1	4.4	3.6	0.4			
American Redstart					0.7					
Ovenbird		1.2	0.4	1.5	1.1	2.0				
Mourning Warbler	0.8	1.2					1.6	0.4		
Common Yellowthroat	8.7	9.8	12.2	2.6	2.2	0.8	13.4	12.6	9.7	9.2
Canada Warbler					0.4	1.6				
Scarlet Tanager				0.7						
Rose-breasted Grosbeak	1.6	0.8	0.4	1.5	1.8	1.6				
Song Sparrow								2.8	3.6	4.6
Lincoln's Sparrow							2.4	1.6	3.1	3.2
Swamp Sparrow	0.4									
White-throated Sparrow	7.9	9.4	8.4	1.8	6.9	3.2	11.0	7.7	8.7	6.0
Dark-eyed Junco		0.4					0.4	0.4	2.6	3.7
Purple Finch								0.4		
American Goldfinch							0.8		0.5	0.9
Number of species	27	28	25	28	25	25	15	11	11	9
Number of pairs	60.3	53.5	57.1	39.0	51.1	46.4	43.9	37.0	35.2	32.1

open plot still had high breeding densities of Common Yellowthroat and White-throated Sparrow, whereas the more closed plot had higher breeding densities of Red-eyed Vireo, Chestnut-sided Warbler and Ovenbird, three species associated with deciduous vegetation. The breeding density of Magnolia Warbler increased from 0.8 pairs/10 ha in the deciduous-dominated young strip-cut to 4.4 pairs in the deciduous-dominated old strip. Conifer-dominated strip-cuts had high and similar breeding densities of Magnolia Warblers in young and intermediate strips (4.8 and 4.6 pairs), with the highest breeding density in the conifer-dominated old strip (6.9 pairs).

Bird community structure varied considerably between sampled forest types (Figure 3). The young strip-cut with deciduous regrowth had a bird community structure dominated by a few species, a situation similar to final cuts and clearcuts. The similarity in structure was due mainly to Common Yellowthroat and White-throated Sparrow, two species quite abundant in final cuts and clearcuts. Young strip-cuts, however, had twice as many species as final cuts or clearcuts. Bird communities of intermediate and old-aged strip-cuts, however, were less dominated by a few species. The importance of forest structure in defining bird communities is illustrated by the conifer-

Figure 3. Bird community structures in relation to forest types.



dominated plots (Figure 3) where open area species found adequate conditions in the short conifer regrowth of intermediate strip-cuts, which supported a bird community similar to young strip-cuts. This was not so in the taller deciduous regrowth.

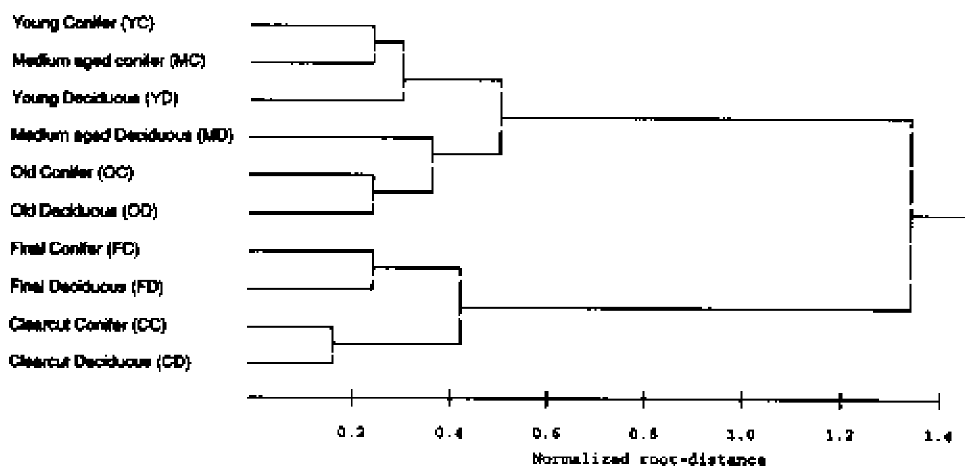
Bird communities of strip-cuts had a similar composition that differed as a whole from the communities of final cuts and clearcuts (Figure 4). They also differed more along their deciduous-conifer regrowth component than across ages. Intermediate plots with conifer regrowth, however, supported bird communities more similar to young strip-cuts than to older strip-cuts.

If we compute the number of individuals of each species seen during a spot-mapping survey and average this number over the total number of surveys, we obtain an estimate of relative abundance of species in the plot with an associated error estimate (Appendix 1). This is useful to obtain estimates for transient and non-territorial species. Generally these indices of relative abundance confirmed population trends observed from the breeding bird surveys, i.e. more species present in strip-cut plots ($\bar{x} = 42.2 \pm 1.5$, n=6) than in final and clearcut plots ($\bar{x} = 28.0 \pm 2.0$, n=4). Relative densities, however, were similar ($\bar{x} = 52.5 \pm 2.7$ vs 53.7 ± 3.4 birds). Results for individual species are quite variable but trends are similar to those observed using the number of territories (Appendix 1).

Predation rates of artificial nests

As expected, predation rates increased with exposure time but did not differ significantly between forest types in any of the exposure periods (Figure 5, Table 3). After 7 days of exposure, nests in shrubs suffered

Figure 4. Similarity of breeding bird communities (Horn index; average linkage clustering method).



the highest rates of predation, a pattern which persisted throughout the trials (Table 3). After 14 and 21 days of exposure, height and concealment interacted significantly to affect predation rates in the following manner; at first glance, it appears that ground nests were less frequently depredated than shrub nests (Figure 6) but a closer analysis taking into account nest concealment indicates that only well concealed ground nests experienced lower predation (three times less) than other nests (Table 4).

Because the number of nests in each concealment category varied greatly with nest height (more nests well concealed on the ground) and forest type, we adjusted predation rates by assuming a uniform distribution of nests in concealment categories among nest locations and forest types. Differences in predation rates between forest types that were not significant with unadjusted data differed even less after adjustments. However, shrub nests still suffered higher predation rates than ground nests, although the difference is now smaller. No differences in predation rates were found between nests in strips and interstrips (1st week : $\chi^2 = 0.19$, $p = 0.66$; 2nd week : $\chi^2 = 0.21$, $p = 0.64$; 3rd week : $\chi^2 = 0.52$, $p = 0.47$).

Table 3. Logistic regression of predation rate in relation to forest type, nest height and degree of concealment for exposure times of 7,14 and 21 days. df = degrees of freedom; significance (p) calculated using Wald test.

Source	df	χ^2	p
a) 7 days-exposure			
Forest type	3	2.43	0.49
Nest height	1	5.12	0.024
Concealment	2	1.38	0.50
Type x height	3	2.05	0.56
Type x concealment	6	5.66	0.46
Height concealment	2	4.29	0.12
b) 14 days-exposure			
Forest type	3	3.07	0.38
Nest height	1	10.13	0.002
Concealment	2	2.12	0.35
Type x height	3	4.03	0.26
Type x concealment	6	1.32	0.97
Height x concealment	2	6.72	0.034
c) 21 days-exposure			
Forest type	3	2.57	0.46
Nest height	1	7.33	0.007
Concealment	2	6.16	0.046
Type x height	3	6.30	0.098
Type x concealment	6	4.16	0.65
Height x concealment	2	6.40	0.041

Table 4. Relationships between predation rates, nest height and nest concealment.

	Concealment		
Nest height	**Good**	**Average**	**Poor**
Ground	0.21*	0.71	0.69
Shrub	0.71	0.63	0.83

* predation rate

Discussion

As expected, strip-cut areas retained several forest-species which continued to breed in the modified habitat. However, these species disappeared following the cut of the interstrip. Theoretically, the longer the removal of the interstrip is postponed the more vegetated the strip will become and the site might then attract and retain more forest-associated species than observed in this study. Strip-cutting permits the addition of open land species into the forest bird community. In this study, 20 m strips proved quite acceptable to Common Yellowthroat and Chestnut-sided Warbler, two species associated with open shrubby areas (Titterington et al. 1979, Morgan and Freedman 1986, Hagan et al. 1997) and which readily invade small openings (0.4 ha) in northern hardwood forests (Germaine et al. 1997).

The attraction of harvested strips to Common Yellowthroat may be due in part to the wet and humid soil conditions resulting from poor drainage. Some strips even had cattails growing in depressions created by machinery during harvesting. However, harvested strips proved too small for Song Sparrow, Lincoln Sparrow and Alder Flycatcher. Wider strips may be needed to attract these species. On the other hand, wider strips may reduce the use of strip-cuts by some forest species, as some species apparently included more than one interstrip in their territory. Rail et al. (1997) showed that the probability of crossing a gap larger than 20 m decreased rapidly for forest specialist

Figure 5. Predation rate in relation to forest type and exposure type.

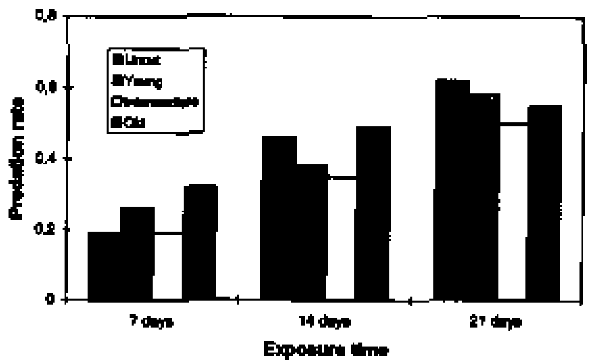
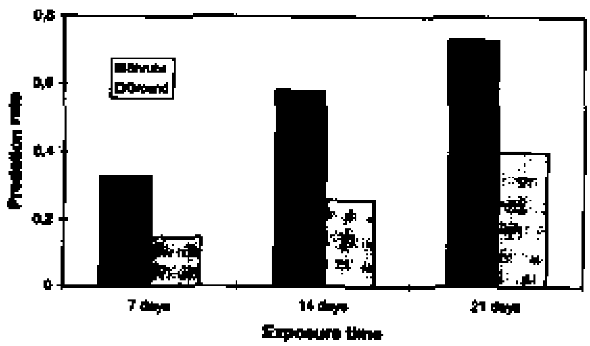


Figure 6. Predation rate in relation to nest height and exposure time.



birds. The slower growing conifer- dominated strips supported open area species longer than strips with more rapidly growing deciduous trees and shrubs.

Species associated with deciduous trees and shrubs (Rose-breasted Grosbeak, Ovenbird, Canada Warbler, Veery) invaded strip-cut areas with dense deciduous regeneration but not those with conifer-dominated regrowth. These species were rare in the uncut conifer-dominated forest (Falardeau and Savard 1999).

There have been few studies which have measured the impact of strip-cutting on breeding birds. Freedman et al. (1981) surveyed two small strip-cut plots (2.9 and 6.2 ha) in a hardwood forest of Nova Scotia, where breeding birds densities were 47.5 pairs and 57.5 pairs respectively, which is similar to our results. However, their species richness was much lower, only 13 and 10 species compared to 25-28 species in our study. This difference may reflect in part not only the smaller size of their plots but also the greater heterogeneity of our conifer-dominated mixed forest. Three species (Chestnut-sided Warbler, Mourning Warbler, Common Yellowthroat), absent from their control hardwood forest, used strip-cut areas, as we also found. Song Sparrows did not use their strip-cut plots, but used clearcut plots, confirming their need for wider and more open areas (Freedman et al. 1981). Doyon et al. (1997) compared the relative abundance of birds in strip-cut and uncut hardwood forests in northwestern Québec. Their experimental design differed considerably from ours as they sampled strips 30, 60 and 90 m wide, separated by interstrips twice as wide as the strips and presented the data combined for these strip-cuts contrasting them with uncut forest. Four species (Chestnut-sided Warbler, American Redstart, Canada Warbler, Magnolia Warbler), were more abundant in strip-cut areas than in uncut forest. Interestingly, White-throated Sparrow and Common Yellowthroat were not abundant in their study area.

Nest predation rates

In contrast to predation studies conducted in agriculture and urban landscapes, studies in forest landscapes generally have not reported higher predation rates along edges. Some studies even recorded predation rates higher away from edges (Yahner and Wright 1985, Yahner and Cypher 1987, Rudnicki and Hunter 1993, Darveau et al. 1997). Our study supported those results, as we found no difference in rate of nest predation among and between strip-cut and uncut forests. This may in part be due to the recent origin of edges in forested landscapes compared to agricultural or urban areas where predator densities may be higher due to human sources of foods (Rudnicki and Hunter 1993).

The relatively narrow strips (20 m) we studied, may not create ecological edges as they are surrounded by 20 m strips of intact forest. Though questioned, the use of artificial nests still provides useful indications on predation risk (Major and Kendall 1996, Wilson et al. 1998). Our experiment did not reveal any major differences in nest predation rates between forest types or between strips and interstrips. Ground nests had lower probability of predation than shrub nests, which suggests that corvids and squirrels may be the most common predators in the type of forests we studied. However, caution is required in our conclusions as the fledging success of real broods in each forest type remains to be studied.

Clearly, more studies are needed to fully understand the dynamics of bird communities in relation to strip-cutting. Our study indicates that a substantial number of species can persist in a strip-cutting regime, at least until the final cut. Of course the width of strips and interstrips will affect bird communities, with narrow strips favouring the retention of a greater part of the forest bird community and wider strips attracting more open land species. Bird communities were extremely dynamic, responding to changes in vegetation structure and composition. Strip-cuts where the interstrip is left uncut may prove to be effective in maintaining some forest-associated birds locally and to promote bird diversity. However, their value when the interstrip is removed will depend on the age of the regrowth at the time of removal. The younger the age, the more strip-cuts will approximate clearcuts, but older regrowth (greater than 20 years) may help retain some forest bird species.

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Appendix 1. Relative abundance of birds in the spot-mapping plots (mean [± S.E.] number of birds per 10 ha recorded during the spot-mapping survey). Vegetation types: Con = conifer, Dec = deciduous.

Strip age / type	Young strips		Medium strips		Old strips		Final cuts		Clearcuts	
	Con	Dec	Con	Dec	Con	Dec	Con	Dec	Con	Dec
Species	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.
American Bittern								0.23 ± 0.15		
Great Blue Heron				0.11 ± 0.11						
Northern Harrier						0.10 ± 0.10			0.15 ± 0.15	0.13 ± 0.13
Northern Goshawk										0.13 ± 0.13
Broad-winged Hawk		0.10 ± 0.10						0.12 ± 0.12	0.29 ± 0.19	
American Kestrel				0.11 ± 0.11				0.12 ± 0.12	0.15 ± 0.15	0.26 ± 0.17
Ruffed Grouse		0.98 ± 0.87		0.11 ± 0.11	0.46 ± 0.27	1.10 ± 0.68				
Virginia Rail									0	0.13 ± 0.13
Mourning Dove	0.10 ± 0.10						0.23 ± 0.23			
Black-billed Cuckoo				0.21 ± 0.21		0.20 ± 0.20				
Northern Saw-Whet Owl						0.10 ± 0.10				
Chimney Swift			0.11 ± 0.11	0.74 ± 0.42	0.09 ± 0.09	0.60 ± 0.25				
Ruby-throated Hummingbird				0.11 ± 0.11	0.09 ± 0.09		0.35 ± 0.16	0.12 ± 0.12		
Belted Kingfisher				0.11 ± 0.11						
Yellow-bellied Sapsucker	0.89 ± 0.35	0.68 ± 0.23	1.79 ± 0.37	0.74 ± 0.28	0.73 ± 0.31	0.90 ± 0.49	0.23 ± 0.15			
Downy Woodpecker	0.10 ± 0.10				0.09 ± 0.09	0.20 ± 0.20				
Hairy Woodpecker	0.10 ± 0.10	0.29 ± 0.21		0.63 ± 0.25	0.09 ± 0.09	0.10 ± 0.10		0.12 ± 0.12		
Black-backed Woodpecker	0.30 ± 0.21	0.10 ± 0.10	0.11 ± 0.11						0	0.13 ± 0.13
Northern Flicker	0.39 ± 0.48	0.10 ± 0.10	0.53 ± 0.27	0.32 ± 0.22	0.09 ± 0.09	0.40 ± 0.21	0.70 ± 0.28	0.23 ± 0.15	0.15 ± 0.15	
Pileated Woodpecker	0.20 ± 0.13		0.11 ± 0.11	0.42 ± 0.22	0.09 ± 0.09	0.10 ± 0.10	0.12 ± 0.12			
Olive-sided Flycatcher							0.23 ± 0.23		0.15 ± 0.15	
Eastern Wood-Pewee	0.40 ± 0.21	1.66 ± 0.58		0.21 ± 0.14						
Yellow-bellied Flycatcher		0.20 ± 0.13	0.21 ± 0.21		0.09 ± 0.09	0.20 ± 0.20				
Alder Flycatcher			0.32 ± 0.22	0.21 ± 0.14			4.07 ± 1.16	5.11 ± 1.00	2.04 ± 0.70	2.1 ± 0.79
Least Flycatcher		0.39 ± 0.21								
Eastern Phoebe				0.11 ± 0.11						
Great Crested Flycatcher	0.20 ± 0.13		0.32 ± 0.22	0.21 ± 0.14	0.18 ± 0.18	0.10 ± 0.10				
Tree Swallow								0.35 ± 0.35	0.29 ± 0.29	1.44 ± 0.19
Gray Jay			0.11 ± 0.11							
Blue Jay	1.19 ± 0.40	1.27 ± 0.44	0.84 ± 0.42	0.63 ± 0.19	1.37 ± 0.58	0.90 ± 0.21	0.23 ± 0.15	0.23 ± 0.23	0.15 ± 0.15	0.13 ± 0.13
American Crow			0.11 ± 0.11	0.11 ± 0.11						
Common Raven				0.11 ± 0.11	0.09 ± 0.09					
Black-capped chickadee	2.98 ± 0.82	1.17 ± 0.47	1.26 ± 0.48	0.63 ± 0.25	1.37 ± 0.56	2.70 ± 1.09	0.81 ± 0.59	0.12 ± 0.12	0.58 ± 0.21	0.26 ± 0.17
Red-breasted Nuthatch	0.89 ± 0.28	0.98 ± 0.38	0.53 ± 0.15	0.84 ± 0.63	0.55 ± 0.30	0.80 ± 0.34				
Brown Creeper	0.10 ± 0.10	0.10 ± 0.10		0.63 ± 0.34		0.10 ± 0.10				
Winter Wren	1.49 ± 0.69	1.95 ± 0.64	1.89 ± 0.67	1.47 ± 0.52	2.28 ± 0.51	3.10 ± 0.51	0.35 ± 0.16	0.12 ± 0.12		
Golden-crowned Kinglet	0.60 ± 0.30		2.94 ± 0.94	0.11 ± 0.11	0.09 ± 0.09	1.00 ± 0.47				
Ruby-crowned Kinglet										0.13 ± 0.13
Veery	0.20 ± 0.13	0.30 ± 0.20		0.53 ± 0.31	2.46 ± 0.66	1.30 ± 0.48	0.46 ± 0.16			
Swainson's Thrush	0.20 ± 0.20					0.10 ± 0.10		0.58 ± 0.58		
Hermit Thrush	2.18 ± 0.60	0.88 ± 0.40	2.31 ± 0.71	1.58 ± 0.37	3.01 ± 0.77	3.30 ± 0.62		0.23 ± 0.23		
American Robin	0.90 ± 0.40	0.99 ± 0.24		0.42 ± 0.15	0.27 ± 0.27	0.50 ± 0.21	0.35 ± 0.24	0.12 ± 0.12	0.44 ± 0.30	0.13 ± 0.13
Cedar Waxwing	1.49 ± 0.64	1.07 ± 0.86	1.26 ± 0.78	0.32 ± 0.22	1.28 ± 0.74	0.70 ± 0.38	3.02 ± 1.05	2.21 ± 0.46	3.25 ± 1.53	2.73 ± 1.33
Solitary Vireo	1.59 ± 0.56	1.95 ± 0.61	2.84 ± 0.45	0.63 ± 0.25	0.36 ± 0.2	0.30 ± 0.21			0.15 ± 0.15	
Red-eyed Vireo	0.90 ± 0.21	2.64 ± 0.61	0.63 ± 0.26	2.84 ± 0.25	1.64 ± 0.56	1.40 ± 0.52		0.70 ± 0.37		
Nashville Warbler	1.09 ± 0.33	0.88 ± 0.37	1.79 ± 0.40	2.73 ± 0.78	3.28 ± 1.20	2.40 ± 0.83	1.39 ± 0.55	0.35 ± 0.35	2.62 ± 0.86	
Northern Parula	0.10 ± 0.10	0.10 ± 0.10					0.12 ± 0.12			
Yellow Warbler							0	0.23 ± 0.23		
Chestnut-sided Warbler	6.85 ± 1.97	6.45 ± 0.83	2.63 ± 0.51	4.73 ± 0.70	2.74 ± 0.86	2.30 ± 1.75	3.25 ± 0.81	5.11 ± 1.49	1.02 ± 0.39	
Magnolia Warbler	4.27 ± 1.13	0.49 ± 0.23	5.46 ± 1.39	2.42 ± 0.38	5.47 ± 1.18	3.30 ± 0.65	1.63 ± 0.89	0.12 ± 0.12	0.44 ± 0.30	
Black-throated Blue Warbler	4.07 ± 1.13	2.25 ± 0.45	0.42 ± 0.22	2.63 ± 0.88	1.64 ± 0.27	3.60 ± 0.60				0.13 ± 0.13
Yellow-rumped Warbler	0.69 ± 0.32	0.88 ± 0.40	1.16 ± 0.45	0.63 ± 0.25	0.55 ± 0.30			0.12 ± 0.12		
Black-throated Green Warbler	1.79 ± 0.80	3.03 ± 0.93	2.73 ± 1.10	2.00 ± 0.55	1.20 ± 0.33	3.60 ± 0.81				
Blackburnian Warbler	2.08 ± 0.75	2.15 ± 0.82	2.94 ± 0.94	1.05 ± 0.93	1.09 ± 0.31	0.80 ± 0.26			0.15 ± 0.15	
Palm Warbler							0.58 ± 0.23	0.58 ± 0.23		
Black-and-white Warbler	3.67 ± 1.56	0.29 ± 0.21	1.16 ± 0.61	2.52 ± 0.60	4.47 ± 1.84	4.20 ± 1.55	1.51 ± 0.70	0.23 ± 0.23		
American Redstart		0.49 ± 0.33	0.11 ± 0.11		0.27 ± 0.19					
Ovenbird	0.10 ± 0.10	1.17 ± 0.42	0.21 ± 0.14	1.26 ± 0.31	0.73 ± 0.50	1.90 ± 0.21				0.13 ± 0.13
Mourning Warbler	0.50 ± 0.26	1.17 ± 0.55	0.21 ± 0.21	0.32 ± 0.22	0.18 ± 0.18		1.06 ± 0.34	0.35 ± 0.24		

Appendix 1. (continued)

Strip age / type	Young strips		Medium strips		Old strips		Final cuts		Clearcuts	
	Con	Dec	Con	Dec	Con	Dec	Con	Dec	Con	Dec
Species	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.	x̄ ± S.E.
Common Yellowthroat	5.95 ± 1.26	6.64 ± 1.28	4.24 ± 1.01	4.52 ± 1.37	3.28 ± 1.30	1.50 ± 0.43	20.91 ± 4.54	15.33 ± 2.11	13.70 ± 3.47	11.27 ± 2.24
Canada Warbler	0.10 ± 0.10			0.11 ± 0.11	0.27 ± 0.19	1.40 ± 0.47				
Summer Tanager			0.11 ± 0.11							
Scarlet Tanager	0.10 ± 0.10	0.10 ± 0.10		0.63 ± 0.25	0.18 ± 0.12					
Rose-breasted Grosbeak	2.08 ± 0.54	0.78 ± 0.30	0.32 ± 0.15	1.68 ± 0.26	2.01 ± 0.55	1.80 ± 0.60	0.23 ± 0.15			
Indigo Bunting		0.10 ± 0.10								
Song Sparrow			0.11 ± 0.11				0.12 ± 0.12	2.79 ± 0.61	4.81 ± 0.99	6.03 ± 1.37
Lincoln's Sparrow							2.21 ± 0.42	1.97 ± 0.58	2.92 ± 0.75	6.03 ± 1.18
Swamp Sparrow	0.20 ± 0.13						0.12 ± 0.12		0.15 ± 0.15	0.13 ± 0.13
White-throated Sparrow	7.54 ± 0.92	6.15 ± 1.21	8.72 ± 1.30	3.36 ± 0.89	7.12 ± 1.22	3.00 ± 1.03	13.94 ± 1.52	8.01 ± 1.03	17.64 ± 1.99	7.86 ± 1.80
Dark-eyed Junco	0.10 ± 0.10	0.29 ± 0.14					0.58 ± 0.39	0.81 ± 0.40	3.35 ± 0.69	5.24 ± 1.11
Red-winged Blackbird							0.12 ± 0.12			
Common Grackle	0.10 ± 0.10					0.10 ± 0.10				0.13 ± 0.13
Brown-headed Cowbird	0.10 ± 0.10	0.29 ± 0.21				0.20 ± 0.20				
Purple Finch	0.30 ± 0.21	0.10 ± 0.10		0.11 ± 0.11			0.23 ± 0.15	0.35 ± 0.16		
White-winged Crossbill	2.78 ± 1.75		1.16 ± 0.83	0.21 ± 0.14					1.31 ± 1.31	
Pine Siskin		0.10 ± 0.10	0.42 ± 0.42		0.09 ± 0.09		0.35 ± 0.24		0.58 ± 0.58	0.13 ± 0.13
American Goldfinch	0.10 ± 0.10	0.98 ± 0.98				0.10 ± 0.10	0.70 ± 0.28	0.23 ± 0.15	0.58 ± 0.30	3.47 ± 2.54
Evening Grosbeak	0.30 ± 0.30	0.30 ± 0.30			0.27 ± 0.27	0.10 ± 0.10		0.12 ± 0.12		0.26 ± 0.26
Number of species	46	43	37	46	40	41	31	32	25	24
Mean number of individuals	62.5	52.4	57.1	46.1	52.2	44.6	60.2	47.4	59.1	48.2