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Wildlife Use of Landscapes Resulting from Different Management Strategies in the Boreal Black Spruce Forest

SFM Network Project: The Landscape Structure and Biodiversity Project (LSBP): Avian Response

by

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ABSTRACT

In 1997, we have initiated a study that addresses three questions: (1) what are the impacts of natural Vs human disturbances on terrestrial ecosystems in terms of biodiversity, (2) what are the most effective methods for biomonitoring in terms of sustainable forest management, (3) and how can our knowledge be used to develop sustainable forest management? Our project is part of the Landscape Structure and Biodiversity Project (LSBP), a cross-taxa, cross-regional study which examines the relative contributions of stand Vs landscape structure and composition in determining the presence/absence, abundance and dynamics of several invertebrate and vertebrate species in managed and unmanaged forest landscapes.

The LSBP project is organized as a core project, which is done in a similar fashion across 3 regions: Alberta, New Brunswick and Quebec, with additional graduate student projects which complement the core project. Our regional project focuses on the eastern boreal black spruce (*Picea mariana*) forest. The natural landscape of this region consists in large black spruce forests affected by an important fire regime. Few studies have addressed questions relative to the maintenance of biodiversity and the sustainable management of this forest.

In this report we present the results of 3 studies conducted in the same area. The first one (core LSBP bird project) examines the relative contributions of stand level (100 m, e.g. local vegetation) and landscape level (250 to 1000 m) structure and composition to the distribution of 17 bird species in a logged landscape. We sampled 59 and 65 points in a 7 x 9 km grid in a boreal black spruce forest of eastern Quebec in 1997 and 1998, respectively. Bird presence was highly correlated with local and landscape (1000-m) variables. The five bird species that were most dependent on forest cover were the Boreal Chickadee, Nashville Warbler, Ruby-crowned Kinglet, Golden–crowned Kinglet, and Bay-breasted Warbler. Conversely, the White-throated Sparrow, Dark-eyed Junco, and Lincoln’s Sparrow positively reacted to clear-cutting.

The second study (LSBP satellite project) focuses on the relative contributions of stand level and landscape level structure and composition to bird nesting success. In the same plots as the core LSBP, we evaluated bird nesting success using ground and arboreal (5-m-high) artificial nests in which we left a Common Quail *Coturnix coturnix* egg and a plasticine egg. Nest predation was high over all the study area. Dominant predators were the Gray Jay *Perisoreus canadensis* and the Red Squirrel *Tamiasciurus hudsonicus*. Local vegetation was not a strong or consistent predictor of predation events in general. At the landscape level, predation by squirrels increased as spruce and clear-cut covers increased. Predation by Gray Jays was also related to the presence of water bodies at several scales. On short term, timber harvesting did not seem to increase predation pressure in our study area. We believe that long term studies including data on the abundance of nest predators and their predation events are required for a better understanding of the impacts of forest fragmentation.

The third study (concomitant project) compares breeding bird use of forest remnants resulting from different management strategies in the black spruce forest. In the same 7 x 9-km

quadrate used for the core LSBP project, we selected 5 replicates of 60-m wide riparian forest strips, 60-m wide upland forest strips, 200 to 300-m wide residual blocks, and >5 km^2 controls. We sampled birds at each point in 1997 and 1998. Short-distance migrants showed higher species and pair ($P < 0.005$) densities per sampling point in riparian strips compared to upland leave-strips and residual blocks. In neotropical migrants, species and pair densities were higher in controls than in riparian strips, upland strips, and blocks in 1997 and 1998 ($P < 0.01$). Resident species showed a difference among treatments in 1997 ($P = 0.01$): densities were 2-3 times lower in upland and riparian strips compared to controls, but there were no differences in 1998 ($P > 0.40$). Data were also collected in 1999 and the analysis is ongoing.

In our study area, timber harvesting done using the single-pass system (largest clear-cuts delimited with upland and riparian forest strips) could lead to a harvest of 85% of the forest. Our preliminary results show that forest remnants have lower densities of mature forest bird species compared to large forest tracts. One could argue that, whatever the densities are, remnants are still used by breeding birds and consequently that there is no problem from a conservation point of view. However, although we have no evidence that any bird species could have disappeared from our landscape, we conclude that bird community structure is altered in landscapes generated by the single-pass system. It is difficult to predict if these changes could lead to significant alteration for the future decades, or if such changes will regress as the forest matures and gradually recovers.

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INTRODUCTION

It is generally accepted that harvesting models should imitate natural disturbances to maintain natural processes of the ecosystems (Hunter 1993). Thus, the general principle for forest landscape management of is simple: management should mimic fire, the dominant natural factor of disturbance at this scale in the boreal forest. However, we have little information about how to apply this concept in the field.

In 1997, we have initiated a study that addresses three questions: (1) what are the impacts of natural Vs human disturbances on terrestrial ecosystems in terms of biodiversity, (2) what are the most effective methods for biomonitoring in terms of sustainable forest management, and (3) how can our knowledge be used to develop sustainable forest management? Our project is part of the Landscape Structure and Biodiversity Project (LSBP), a cross-taxa, cross-regional study which examines the relative contributions of stand Vs landscape structure and composition in determining the presence/absence, abundance and dynamics of several invertebrate and vertebrate species in managed and unmanaged forest landscapes.

The LSBP project is organised as a core project, which is done in a similar fashion across 3 regions: Alberta, New Brunswick and Quebec, with additional graduate student projects which complement the core project. The goals are: (1) to understand the patterns and mechanisms of species responses to changes in stand and landscape structure by natural and anthropogenic disturbances, (2) to use this understanding to provide industry with a set of appropriate umbrella and indicator species and stand and landscape metrics to monitor biodiversity, an important element of adaptive management and ecological sustainability, and (3) to work with members of the former Planning and Priorities theme and industry partners to use our data in planning and scenario models for impacts of alternative harvesting techniques on biodiversity. In 1997-98, we focussed principally on goal 1 through sampling wildlife and habitat.

Our regional project focuses on the eastern boreal black spruce (*Picea mariana*) forest. The natural landscape of this region consists in large black spruce forests affected by an important fire regime. Few studies have addressed questions relative to the maintenance of biodiversity and the sustainable management of this forest.

In this report we present the results of 3 studies conducted in the same area. The first one (core LSBP bird project) examines the relative contributions of stand level and landscape level structure and composition to bird distribution in a logged landscape. The second study (LSBP satellite project) by M.Sc. student Marylène Boulet focuses on the relative contributions of stand level and landscape level structure and composition to bird nesting success. The third study (concomitant project) compares breeding bird use of forest remnants resulting from different management strategies in the black spruce forest.

METHODS AND DATA ANALYSIS

LSBP Core And Satellite Projects

In 1997, we set up a 7 X 9 km grid divided into 1 X 1 km cells in a boreal black spruce forest north of the lake Saint-Jean (49^{o}09'N, 72^{o}58'W), Quebec. We placed a sampling point in each accessible cell (method shared by the LSBP core). Our grid totaled 59 sampling points in 1997 and 65 in 1998, including 5 sampling points that were located in highly forested areas within 5 km of the grid. These latter points were added to cover a larger continuum of forest covers.

Study site was mapped in a geographic information system (ArcView) using the same stratification as Quebec's Forest Inventory and 1 ha as the minimal size of stands. We reclassified cover types in 8 classes more relevant for birds (Table 1) and we generated 3 landscape buffers (250 m, 500 m and 1000 m) for each sampling point with ArcView. We then calculated the area of each class for the 3 buffers using FRAGSTATS (McGarigal and Marks 1995, see Table 2).

Table 1. Cover classification used for landscape composition analyses in our study area, in a black spruce forest north of Lake Saint-Jean, Québec.

Cover types	Codes	Descriptions
Spruce	SpruceX[1]	Stands dominated by black spruce > 7 m high
Pine	pineX	Stands dominated by jack pine > 7 m high
Fir	firX	Stands dominated by balsam fir > 7 m high
Deciduous	decidX	Stands dominated by deciduous trees > 7 m high
Sapling	sapX	Young stands 1.5 to 7 m high
Clearcut	cutX	Very young stands (< 8 years) < 1.5 m high, bare ground, outcrops
Wetland	wetX	Swamps, humid stands, alder stands, peatlands forested or not, islands
Water	waterX	Lakes, large rivers, pounds

[1] X corresponds to the different radii, e.g. spruce250 = spruce within a 250-m radius, etc.

We sampled vegetation in four 20 X 10 m plots, one located within the 50 m radius and the other 3 were located north, southeast and southwest of the first one, between the 50 m and the 100 m radius. We tallied all trees and all snags present within the 4 plots. We measured coarse woody debris present along the two 20 m lines and we noted their decay class and species when possible. We classified the % of cover of shrubs and ground cover into 5 categories: rare (< 1 %); few occurrences (1-10 %); several occurrences (10-20 %); frequent (20-50 %) and very common (> 50 %) in each plot. We estimated the height of ground cover and shrubs and we measured height of subcanopy and canopy. We also estimated canopy and subcanopy covers.

We measured correlation among 38 variables of structure and composition that we previously selected from our vegetation data set. We excluded 22 variables that were correlated with other variables or had poor biological relevance and summarized 6 variables into 3 new variables, for a total of 14 retained variables. A principal coordinate analysis was used to identify the variables that best summarized the structure and the composition of our ecosystem (Legendre and Legendre 1998). Three eigenvalues were significant and explained 71 % of the variance. Examination of the result graphs revealed that the ecosystem structure was highly associated with its composition. According to the position of the 14 variables in graphs and biological significance, we kept 11 of these variables, thereafter referred to as local vegetation variables (Table 3).

Table 2. Local vegetation variables selected for local scale analyses. Variables used are mean values of the 4 quadrats (20 X 10 m) for each sampling point, located in a black spruce forest, north of Lake Saint-Jean, Québec.

Variables	Description
Canopy	Ground cover (%) by canopy foliage (>10 m in height)
Subcanop	Ground cover (%) by sub-canopy foliage (2-10 m)
Shrub	Ground cover (%) by shrubs (<2 m)
Herb	Ground cover (%) by herbaceous plants
Decid	Mean number of trembling aspen and white birch trees > 8 cm dbh
Fir	Mean number of balsam fir trees > 8 cm dbh
Spruce	Mean number of black spruce trees > 8 cm dbh
Pine	Mean number of jack pine trees > 8 cm dbh
Debri	Mean number of coarse woody debris > 8 cm dbh and ≥ 50 cm long
Snags	Mean number of snags > 8 cm dbh and ≥ 50 cm high
Aldwi	Mean cover (%) of alder and willow shrubs < 2 high

Birds and squirrels were sampled over a 100 m radius at each point using three 10-minute point counts plus playback of not very vocal species such as woodpeckers and chickadees between the last week of May and the 30 June in 1997 and 1998 (Darveau et al. 1999).

An artificial nest experiment was conducted in the LSBP grid using the same points as for bird counts, except those that were located in clear-cuts which were omitted because there were no trees for hanging tree-nests. Thus, nests were placed at 50 forested points in 1997 of which 5 were cut during winter 1998 and replaced with six new points in 1998 for a total of 51 points sampled in 1998. Two arboreal nests (5-m-high) and two ground nests were placed within a radius of 25 m of each sampling point. A Common Quail egg and a painted plasticine egg mimicking the quail egg were put in each nest (Darveau et al. 1997). Nests were placed from 5 to 17 June in 1997 and 2 to 13 June in 1998 and were inspected 21 days later.

Statistical analyses of the relationships between bird count data (17 species present in at least 10 sampling points each year; Table 3) and local- and landscape-scale habitat variables were done using canonical correlation analysis. Because the landscape was currently altered by logging, we did a separate series of analyses for each year. Each series tested for correlation between bird and (1) local variables, (2) landscape variables with a 250-m radius, (3) landscape 500-m, (4) landscape 1000-m, and (5) local plus landscape 1000-m).

For the artificial nest experiment, we used a stepwise logistic regression with the ratio number of nests attacked / total number of nests at each sampling point as the dependent variable (Agresti 1996). In a first series of analyses, we ran our model 8 times, e. g. four scales (local, 250 m, 500 m and 1000 m) in two years with *n* = 50 sampling points in 1997 and *n* = 51 in 1998. In a second series including both years, we used the year as a random variable and we selected sampling points that were identical for both years of our experiment, e. g. had not been modified by logging activities (*n* = 40, 37, 34, and 28 sampling points for local, 250 m, 500 m, 1000 m scales respectively). We repeated these procedures three times, e. g. for: (1) all predation events; (2) predation by squirrels as revealed by marks on plasticine egg; and (3) predation by Gray Jays.

Table 3. Bird species observed in at least 10 sampling points per year in a black spruce forest, north of Lake Saint-Jean, Quebec, 1997-98.

Species	Code	Scientific name
American Robin	AMRO	*Turdus migratorius*
Bay-breasted Warbler	BBWA	*Dendroica castanea*
Boreal Chickadee	BOCH	*Poecile hudsonicus*
Dark-eyed- Junco	DEJU	*Junco hyemalis*
Golden-crowned Kinglet	GCKI	*Regulus satrapa*
Gray Jay	GRJA	*Perisoreus canadensis*
Hermit Thrush	HETH	*Catharus guttatus*
Lincoln’s Sparrow	LISP	*Melospiza lincolnii*
Magnolia Warbler	MAWA	*Dendroica magnolia*
Nashville Warbler	NAWA	*Vermivora ruficapilla*
Red-eyed Vireo	REVI	*Vireo olivaceus*
Ruby-crowned Kinglet	RCKI	*Regulus calendula*
Solitary Vireo	SOVI	*Vireo solitarius*
Swainson’s Thrush	SWTH	*Catharus ustulatus*
White-throated Sparrow	WTSP	*Zonotrichia albicollis*
Winter Wren	WIWR	*Troglodytes troglodytes*
Yellow-rumped Warbler	YRWA	*Dendroica coronata*

Concomitant Project: Wildlife Use Of Forest Remnants Resulting From Different Management Strategies

In the same 7 x 9 km quadrate used for the core LSBP project, we selected 5 replicates of 60-m wide riparian forest strips, 60-m wide upland forest strips, 200-300 m wide residual blocks, and >5 km^2 controls. In each, we placed 2-3 sampling points. As in the core LSBP, we sampled birds at each point with three 10-minute 50-m radius point counts plus playbacks of not very vocal species such as woodpeckers, etc.) between the last week of May and the 30 June in 1997 and 1998 (Darveau et al. 1999).

Before conducting statistical analyses, we tested for variance homogeneity (Bartlett's test) and we transformed data if necessary (log [x+1]). Comparisons among treatments were done using a randomized complete block design of analysis of variance and a LSD test for multiple comparisons among means. Analyses considering all species were done using the 2-3 points within each replicate as sub-samples within each experimental unit, whereas those considering different migratory status were done using the sum of 2-3 points per experimental unit.

Migratory status were : resident species (inhabit the region all year), irruptive species (with irregular migration patterns and in whose populations exhibit large fluctuations in relation with food availability), short-distance migrants (winter in United-States or southern Canada), and neotropical migrants (winter farther south).

RESULTS

LSBP Core Project: Bird communities

Local habitat variables explained 81% of the total variance in the bird communities in 1997 and 90% in 1998. Landscape variables alone did not do as best, as they explained respectively 73-65%, 64-62%, and 69-66% of the total variance at 250, 500, and 1000-m radii in 1997-1998 respectively. The full model with local and 3 radii variables had an excellent fit of 99% in 1997 and 97% in 1998. We also tested for a model including local and 1000-m radius variables and we obtained a good fit (90-93%) that was intermediate between local and full models.

Two axes were significant in the «local plus 1000-m radius» model in 1998 (Fig. 1; similar results in 1997 not shown here). The first axis (P = 0.0001; 52% of the variance explained by the model) represented a gradient from clear-cut sites with coarse woody debris (mostly slash) to mature forest with dense tree canopy dominated by spruce, fir or intolerant hardwoods at both scales. This suggests redundancy between local and landscape scales in our study area. The second axis (P = 0.05; 17% of the variance explained by the model) discriminated young forests at the sapling stage from pine forests and humid or riparian forests.

The Dark-eyed Junco, White-throated Sparrow, and Lincoln's Sparrow were mostly associated with clear-cuts, whereas the Boreal Chickadee, Nashville Warbler, Golden-crowned Kinglet, Ruby-crowned Kinglet, Bay-breasted Warbler, and Gray Jay were associated with mature forests with closed-canopy.

LSBP Satellite Project: Bird Breeding Success

Nest predation was high in both years of the study: 68 % of nests were attacked after 21 days of exposure in 1997, and 74 % in 1998. Predation was influenced by local variables, which differed between 1997 and 1998 (Table 4). Based on the model including both years, predation was higher in sites dominated by black spruce trees and with more snags. Only one landscape variable (fir cover) was entered in the model at the 250 m scale, and none at the 500 and 1000 m scales.

In 1997, 127 plasticine eggs were attacked and 143 in 1998. In 1997 and 1998 respectively, twenty-six and ten eggs were taken despite their metallic attachment, ten and five eggs remained unidentified and two and four eggs had marks of two different species of predators, for a total of 91 identifiable marks recorded in 1997 and of 132 in 1998. The most important predators were the Gray Jays, with 39 identifications in 1997 and 60 in 1998, and small sciurids (Red Squirrels, Northern Flying Squirrels, or Eastern Chipmunks), with 41 identifications in 1997 and 49 in 1998 (Figure 2). Red squirrels were probably responsible of most attacks attributed to small sciurids, because they accounted for 90 % of captures of small sciurids in a concurrent study in the same study area in springs 1997-1998 (Côté 1999). Other predators included small mammals (voles, mice and shrews), Snowshoe Hare *Lepus americanus*, Short-tailed Weasel *Mustela erminea*, and a small falconid (see Figure 2). Gray Jays attacked more arboreal nests than ground nests.

Predation attacks by squirrels were negatively associated to the local cover of alder and willow shrubs in 1997 and in the model including years 1997 and 1998 (Table 4). In 1998, predation by squirrels was greater in sites with greater cover of black spruce and clear-cut at small and intermediate scales. Predation by squirrels was also negatively related to the area of water (1000 m buffer) in 1998. Only black spruce cover (250 m scale) was significant in the analysis including both years. For the Gray Jay, only one landscape variable, the area of body water, was significant.

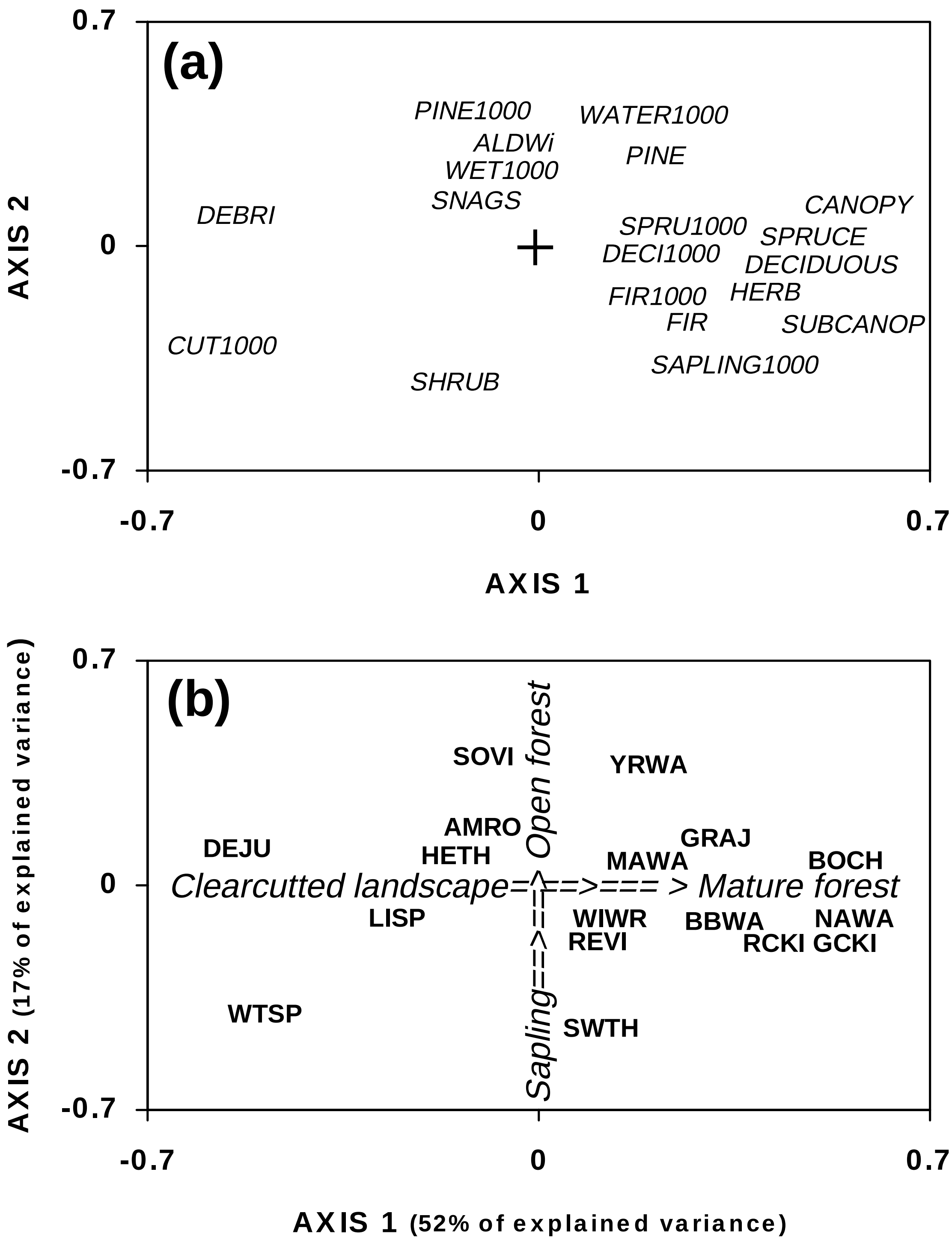

Figure 1. Canonical correlation between bird communities Vs local vegetation and landscape forest cover (1000-m radius) in an eastern boreal black spruce forest of Quebec, 1998. Variable codes are given in Tables 1-3. So as to increase comprehensibility, habitat (Figure 1a) and bird (1b) vectors were separated as overlays in two graphs.

Table 4. Results of stepwise logistic regressions that entered local vegetation variables and / or cover types variables for (1) all predation events; (2) predation by the squirrels; and (3) predation by the Gray Jay, in a black spruce forest north of Lake Saint-Jean, Quebec. Plus and minus signs indicate positive or negative relationships.

Scales	**1997**	**1998**	**1997-1998**
All events			
Local	spruce (+), debri (-)	aldwi (+)	spruce (+), snags (-)
250 m	fir250 (-)	-	-
500 m	-	-	-
1000 m	-	-	-
Squirrels			
Local	aldwi (-)	-	aldwi (-)
250 m	-	spruce250 (+), cut250 (+)	spruce250 (+)
500 m	-	spruce500 (+), cut500 (+)	-
1000 m	-	water1000 (-)	-
Gray jays			
Local	-	-	year (1997<1998)
250 m	water250 (+)	water250 (+)	water250 (+)
500 m	-	water500 (+)	water500 (+)
1000 m	-	water100 (+)	water1000 (+)

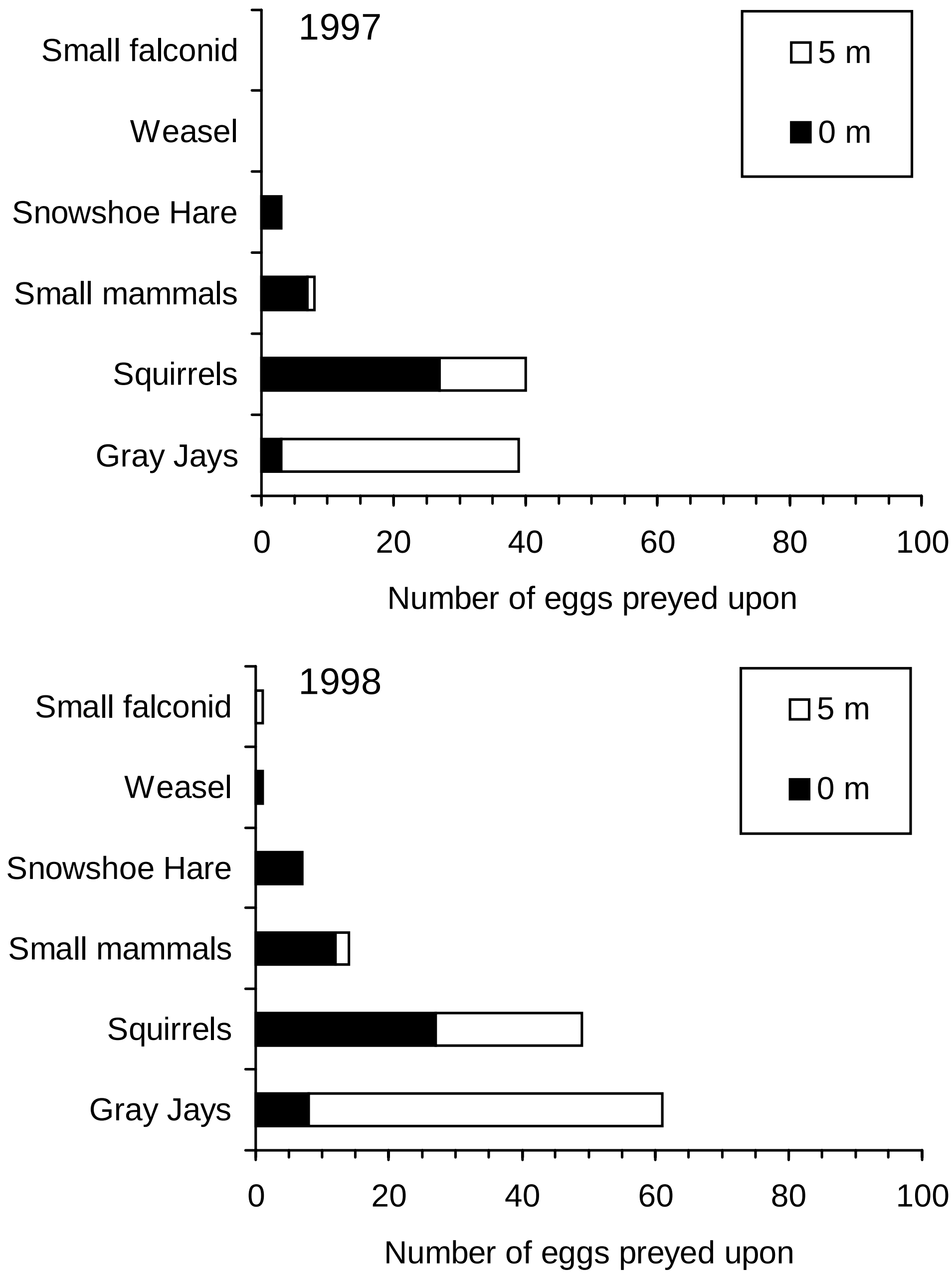

Figure 2. Frequency distribution of predators that left marks on plasticine eggs placed in artificial nests, in relation to nest height, in a black spruce forest, north of Lake Saint-Jean, Quebec.

Nest predators were abundant in our study area. During point counting, we detected the presence of nest predators in 94 % of the sampling points in 1997 and in 88 % in 1998 (the same sites where artificial nests had been placed). Predators most often seen were Gray Jays and Red Squirrels (Table 5). Ravens and American Crows were also locally present. We did not observe any Northern Flying Squirrels or Eastern Chipmunks, but we know they were present in small numbers in our study area (Côté 1999).

Table 5. Number of predators observed during point count (3 visits of 15 min) in 49 sampling points (over 50, one missing data) in 1997 and 51 sampling points (over 51) in 1998 where artificial nests were placed, in black spruce forest north of Lake Saint-Jean, Québec. Values are maximum number of individuals seen or heard in a 50 m radius for squirrels and in an unlimited radius for birds. Number of sampling points where predator were observed are in parenthesis.

Species	1997 (49 points)	1998 (51 points)
Birds		
Gray Jay (*Perisoreus canadensis*)	40 (20 points)	55 (30 points)
American Crow (*Corvus brachyrhynchos*)	6 (5 points)	1 (1 point)
Common Raven (*Corvus corax*)	7 (7 points)	11 (11 points)
Mammals		
Red Squirrel (*Tamiasciurus hudsonicus*)	71 (42 points)	50 (36 points)

Concomitant Project: Wildlife Use Of Forest Remnants Resulting From Different Management Strategies

We found a significant difference among treatments in the mean number of species (Anova, $F_{3,18} = 6.25$, $P = 0.004$) and pairs (Anova, $F_{3,18} = 7.54$, $P = 0.002$) per point that were higher in controls and residual blocks compared to riparian and upland leave-strips. Separate analyses by migratory groups reveal major differences in bird community composition: short-distance migrants, which were the dominant group in all treatments in 1998, showed higher species (Anova, $F_{3,18} = 5,35$, $P = 0,008$; Fig. 1) and pair (Anova, $F_{3,18} = 5.93$, $P = 0.005$) densities per sampling point in riparian strips compared to upland leave-strips and residual blocks. In neotropical migrants, species (Anova, $F_{3,18} = 5.07$, $P = 0.01$) and pair (Anova, $F_{3,18} = 7.40$, $P = 0.002$) densities was higher in controls than in riparian strips, upland strips , and blocks in 1997 and 1998. Resident species showed a difference among treatments in 1997, as species (Anova, $F_{3,16} = 5.24$, $P = 0.01$) and pair (Anova, $F_{3,16} = 5.19$, $P = 0.01$) densities were 2-3 times lower in upland and riparian strips compared to controls, but there were no differences in species (Anova, $F_{3,18} = 0.20$, $P = 0.90$) and pair (Anova, $F_{3,18} = 1.04$, $P = 0.40$) densities in 1998. Irruptive species were nearly absent from all treatments.

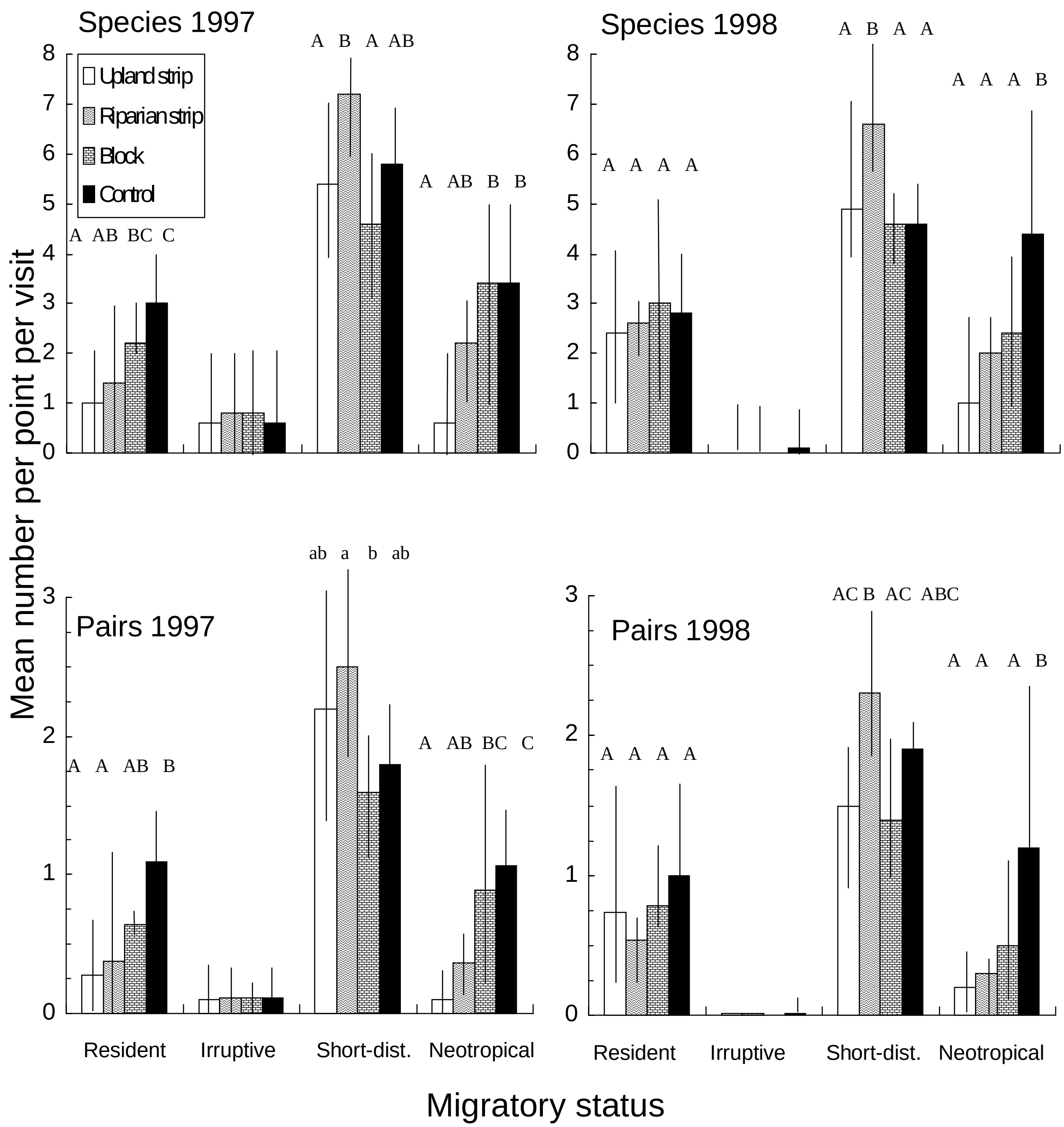

Figure 3. Species and pair densities (mean of 5 replicates with extreme values) of breeding birds in non riparian forest strips, riparian forest strips, residual forest blocks, and control (large forest tract) in a n eastern black spruce forest, Quebec, 1997-98. Treatments that did not differ are annotated with the same letter in uppercase or lowercase when $P \leq 0.05$ or $0.05 < P \leq 0.10$ respectively.

MANAGEMENT APPLICATIONS

Regional Characteristics Of Bird Communities

Our 2-yr data show that short-distance migrants dominate bird communities in our study area (67% of all birds Vs 15% in residents species, 15% in neotropical migrants and 1% of irruptive species (Fig. 1). Predominance of short-distance migrants has also been reported by Darveau et al. (1995) in second-growth, mature boreal balsam fir forests located 100 km south of our study area and by Imbeau (1996) in virgin black spruce forests 100 km north of our area. However, it contrasts with bird community composition observed in other boreal forests in North America and Europe, generally dominated by resident or neotropical species (Virkkala 1989, Haila et Järvinen 1990, Schmiegelow et al. 1997).

One could argue that, because several short-distance migrants are generally habitat generalists (e.g. American Robin) that use old-growth forests as well as young forests, bird communities of eastern black spruce forests could be of low priority for the conservation of bird populations. However, several short-distance migrants in our study area, including. Golden-crowned Kinglet, Ruby-crowned Kinglet, Yellow-rumped Warbler, and White-throated Sparrow, etc.) are of high Canadian responsibility (Dunn and Downes 1998). Moreover, except the White-throated Sparrow, those species are associated to mature forest and could be seriously affected by timber harvesting.

Landscape Structure And Indicator Species

Although our results are preliminary (in the sense that canonical correlation analyses investigated mostly processes occurring at the bird community scale and that separate analyses for each species are not achieved), bird communities clearly react to local vegetation as well as landscape structure and composition. The very high squared canonical correlation (>90%) obtained when combining local and landscape variables are surprising. We suggest that this could be interpreted as an indication of a relatively simple landscape contrasting few mature forest types with clear-cuts.

Our results suggest that, among the common species (present in at least 10 sampling points each year) the five that are most dependent on forest cover are the Boreal Chickadee, Nashville Warbler, Ruby-crowned Kinglet, Golden–crowned Kinglet, and Bay-breasted Warbler. Based on our observations and on current scientific literature, we suggest that the Boreal Chickadee and Golden–crowned Kinglet could be indicators of old-growth spruce-fir forest landscape, whereas Bay-breasted Warbler could be associated with mature mixed-wood forests.

Conversely, the White-throated Sparrow, Dark-eyed Junco, and Lincoln's Sparrow could serve as indicators of clear-cutting.

Bird Nest Predation

In our ecosystem, generalist predators such as American Crows were rare. They did not invade the landscape after clear-cutting and did not prey upon our artificial nests, leaving forest specialist predators such as the Gray Jay and Red Squirrel as the two dominant nest predators. We however have some evidence that there might be subtle changes in communities of predators. We found in fact a positive association between clear-cuts and squirrels. Although this result is equivocal, we know that as clear-cuts increased in our study area, spruce stands decreased. We hypothesize that squirrels crowded in the remaining spruce stands, which increased the probabilities of bird nest predation. This positive relationship between squirrels and clear-cuts is not unique to our study. In a managed forest of New Hampshire, King et al. (1998) reported increases in numbers of Red Squirrels near clear-cut borders. Such changes are likely to be temporary, as jay and squirrel densities will probably diminish rapidly and even go below pre-harvest levels (Darveau et al. 1995; Hagan 1996).

CONCLUSIONS

In our study area, timber harvesting done using the single-pass system (largest clear-cuts delimited with upland and riparian forest strips) could lead to an harvest of 85% of the forest (J.F. Gingras, FÉRIC, *pers. comm*.). Our preliminary results show that forest remnants have lower densities of mature forest bird species compared to large forest tracts. One could argue that, whatever the densities are, remnants are used by breeding birds and that nesting success does not seem to be lower in forest remnants (Darveau et al 1999), and consequently that there is no problem from a conservation point of view.

However, although we have no evidence that any bird species has disappeared from our landscape, we conclude that bird community structure is altered in landscapes generated by the single-pass system. It is difficult to predict if these changes could lead to significant alteration for the future decades, or such changes will regress as the forest matures and gradually recovers.

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