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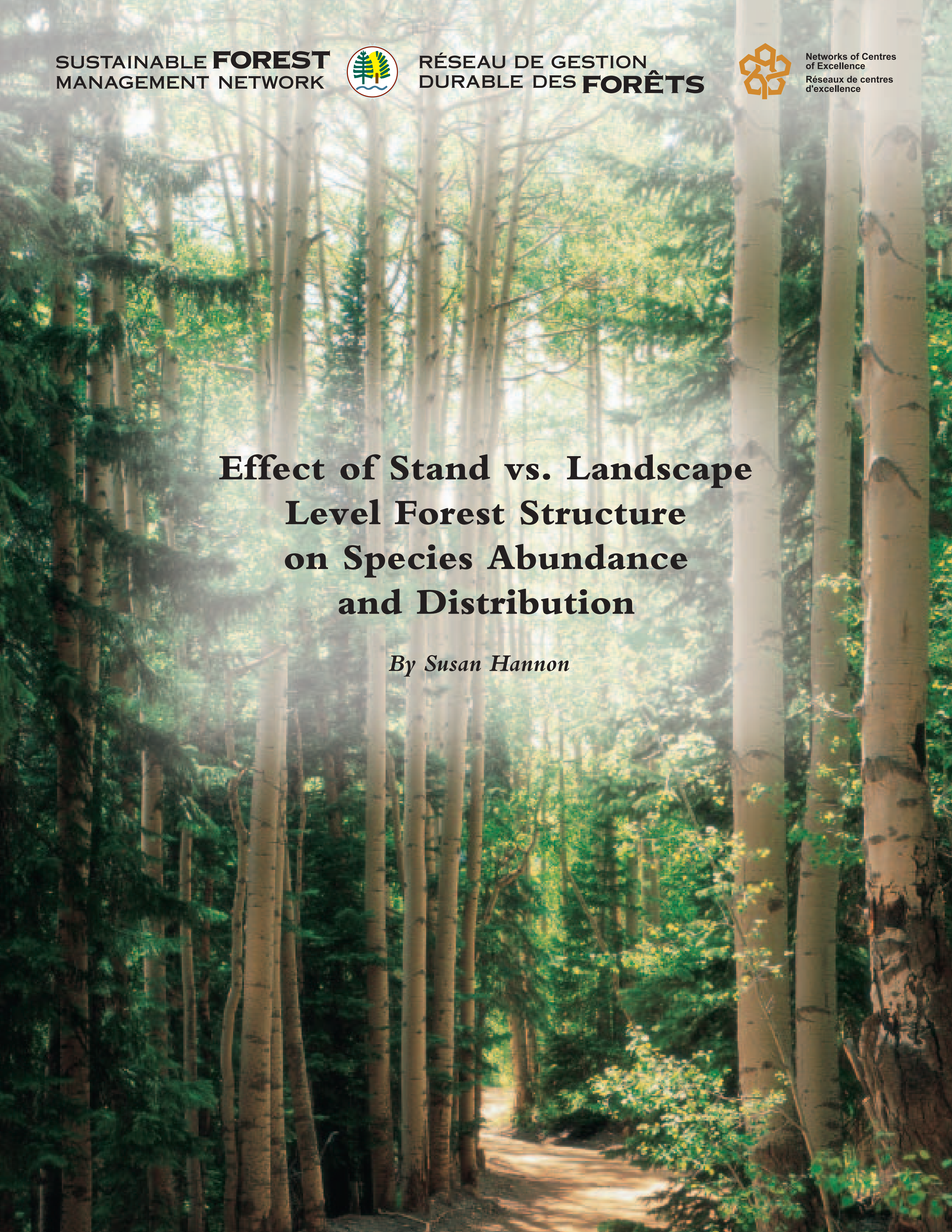


Effect of Stand vs. Landscape Level Forest Structure on Species Abundance and Distribution

By Susan Hannon

THE SUSTAINABLE FOREST MANAGEMENT NETWORK

Established in 1995, the Sustainable Forest Management Network (SFM Network) is an incorporated, non-profit research organization based at the University of Alberta in Edmonton, Alberta, Canada.

The SFM Network's mission is to:

- Deliver an internationally-recognized, interdisciplinary program that undertakes relevant university-based research;
- Develop networks of researchers, industry, government, Aboriginal, and non-government organization partners;
- Offer innovative approaches to knowledge transfer; and
- Train scientists and advanced practitioners to meet the challenges of natural resource management.

The SFM Network receives about 60% of its $7 million annual budget from the Networks of Centres of Excellence (NCE) Program, a Canadian initiative sponsored by the NSERC, SSHRC, and CIHR research granting councils. Other funding partners include the University of Alberta, governments, forest industries, Aboriginal groups, non-governmental organizations, and the BIOCAP Canada Foundation (through the Sustainable Forest Management Network/BIOCAP Canada Foundation Joint Venture Agreement).

KNOWLEDGE EXCHANGE AND TECHNOLOGY EXTENSION PROGRAM

The SFM Network completed approximately 300 research projects from 1995 – 2004. These projects enhanced the knowledge and understanding of many aspects of the boreal forest ecosystem, provided unique training opportunities for both graduate and undergraduate students and established a network of partnerships across Canada between researchers, government, forest companies and Aboriginal communities.

The SFM Network's research program was designed to contribute to the transition of the forestry sector from sustained yield forestry to sustainable forest management. Two key elements in this transition include:

- Development of strategies and tools to promote ecological, economic and social sustainability, and
- Transfer of knowledge and technology to inform policy makers and affect forest management practices.

In order to accomplish this transfer of knowledge, the research completed by the Network must be provided to the Network Partners in a variety of forms. The KETE Program is developing a series of tools to facilitate knowledge transfer to their Partners. The Partners' needs are highly variable, ranging from differences in institutional arrangements or corporate philosophies to the capacity to interpret and implement highly technical information. An assortment of strategies and tools is required to facilitate the exchange of information across scales and to a variety of audiences.

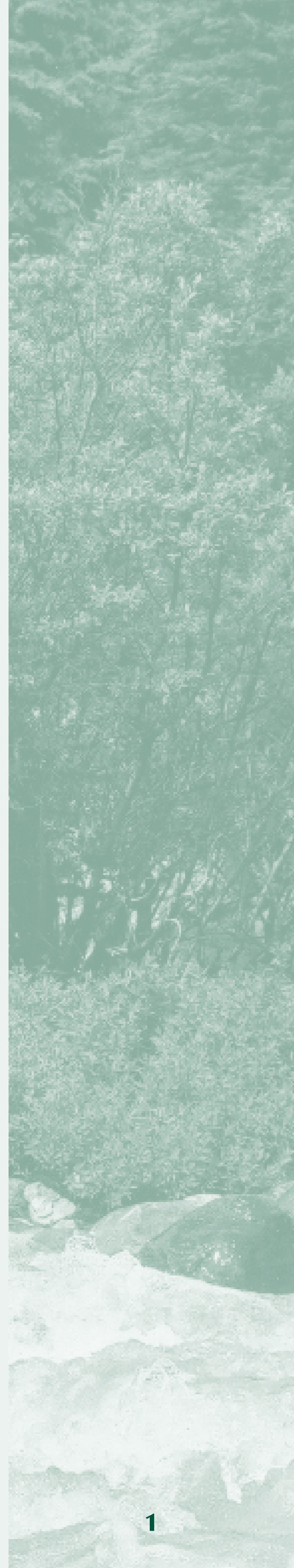
The KETE documents represent one element of the knowledge transfer process, and attempt to synthesize research results, from research conducted by the Network and elsewhere in Canada, into a SFM systems approach to assist foresters, planners and biologists with the development of alternative approaches to forest management planning and operational practices.

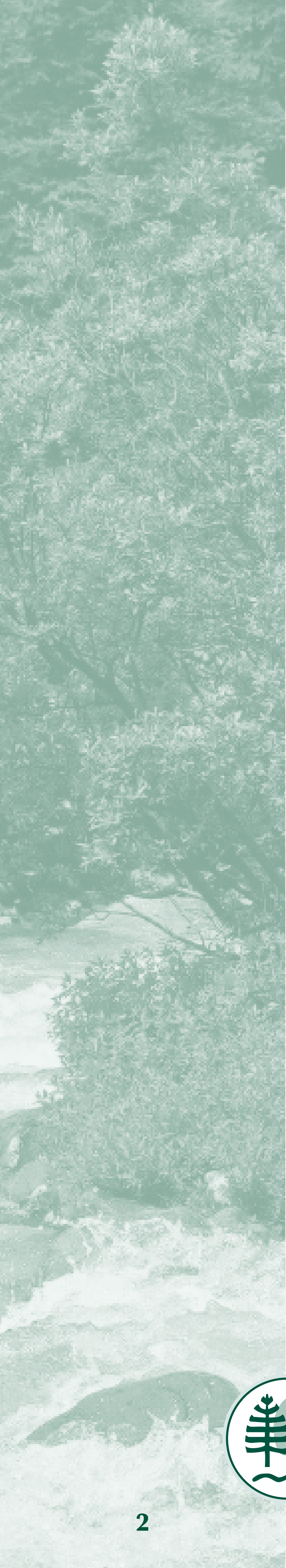
Knowledge Exchange and Technology Extension Program (KETE)
Sustainable Forest Management Network

Effect of Stand vs. Landscape Level Forest Structure on Species Abundance and Distribution

By:

Susan Hannon
University of Alberta
January 2005





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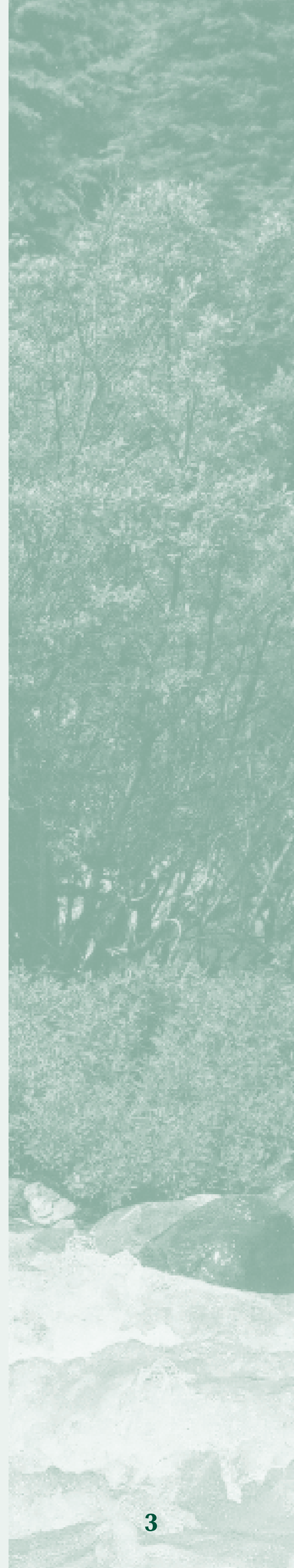


EXECUTIVE SUMMARY

This document is a synthesis of the results from the Landscape Structure and Biodiversity Project (LSBP) - a cross-taxal, cross-regional study that examined the relative contributions of stand versus landscape structure and composition in determining the presence/absence, abundance, and species dynamics in managed and unmanaged forest landscapes. The core project was organized around 4 central questions: (1) What are the relative influences of stand versus landscape structure and composition in explaining patterns of distribution and abundance in boreal forest animals? (2) Are these influences consistent across taxa? (3) Are these influences consistent across disturbance types? and (4) for the same species (or guild of species), are these patterns consistent across forest types and regions? In addition, concurrent graduate student research investigated the following questions: (1) What is the influence of clearcutting and partial harvesting on reproductive success? (2) How do animals respond to edges created by forest harvesting? and (3) How do old growth and fire-associated species select habitat and respond to forest harvesting?

Field data were collected in 3 locations across Canada: Lac La Biche-Goodwin area of northern Alberta; Appalachian highlands of northwestern New Brunswick; and the Abitibi region of northwestern Quebec. In Alberta and New Brunswick, local vegetation structure and abundance best explained small mammal responses. Among birds, the importance of local vegetation structure and composition versus landscape forest composition was species-dependent in Alberta. Variables such as forest age and forest type explained much of the variation in bird communities in Quebec. Generally, most passerine bird species were influenced more by forest structure and composition at the stand scale than by forest clearing at the landscape scale.

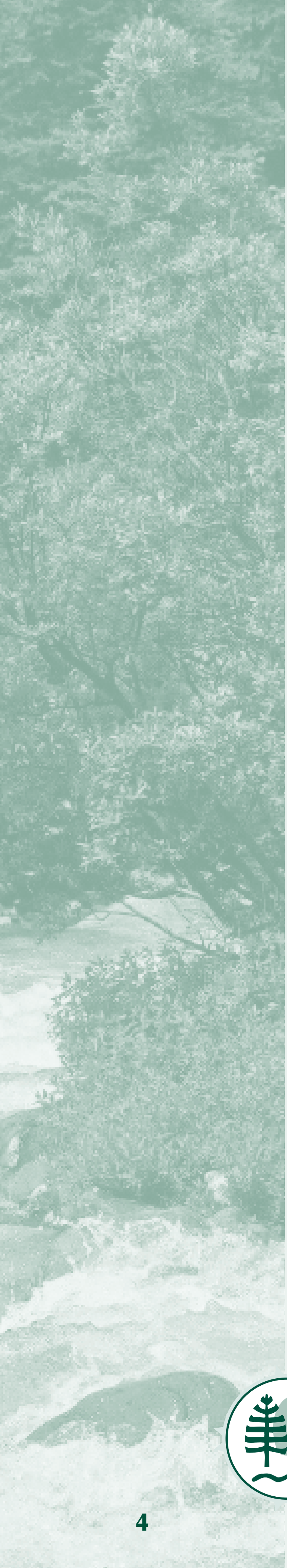
There were no consistent major effects of proximity to edge on reproductive success in birds, or artificial nest predation rates. In Alberta, Black-backed Woodpeckers and Three-toed Woodpeckers were both found in burned jack pine stands, were absent from mature stands, and were at low densities in older forests. Three-toed woodpeckers were most abundant up to 3 yrs after fire, Black-backs were found up to 8 yrs after fire.

General conclusions and recommendations from the LSBP include:

1) most passerine species are influenced more by forest structure and composition at the stand level than by clearing at the landscape level;

2) there are no clear answers to habitat thresholds or species responses relative to harvest levels, therefore no single silvicultural prescription will affect the responses of all organisms in the same way- do not do the same thing everywhere;

3) there are 2 options for retaining passerines: set aside uncut forests, or conduct partial harvesting of some stands;



4) overall, harvested edges did not produce consistent effects, therefore partial cutting will effect reproductive success of bird species differently;

5) fire specialists might be lost if salvage logging removes most dead trees, or fire is replaced by logging on the landscape; and

6) to retain fire specialists, some recently burned forest blocks should be protected from salvage, and, salvage should be delayed 3-4 yrs to allow woodpecker reproduction.

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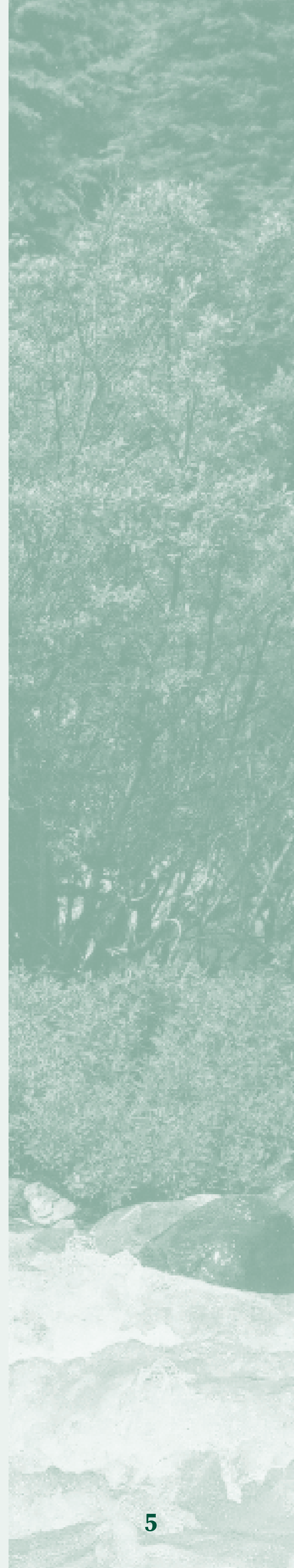
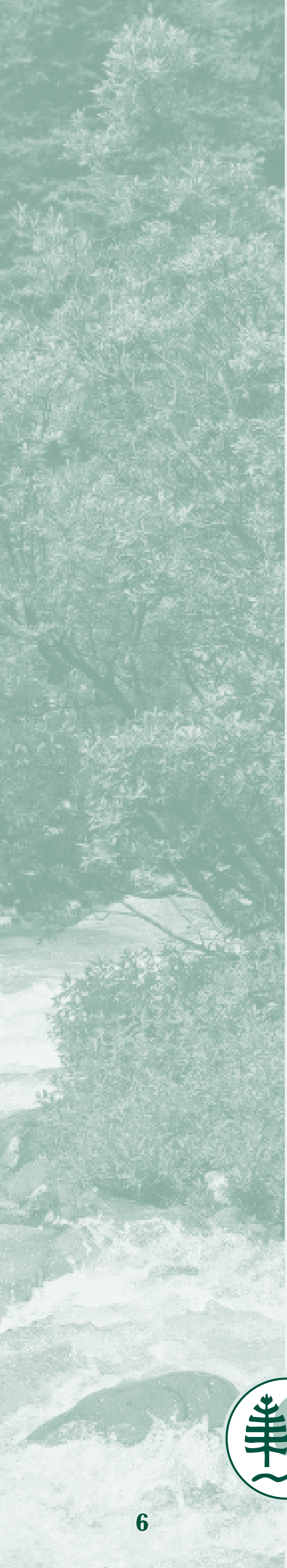




INTRODUCTION

The Landscape Structure and Biodiversity Project1 (LSBP) was a cross-taxal, cross-regional study that examined the relative contributions of stand versus landscape structure and composition in determining the presence/absence, abundance and dynamics of several species in managed and unmanaged forest landscapes. The project was organized as a core project, which was done in a similar fashion across 3 regions: Alberta, New Brunswick and Quebec, with additional graduate student and single-species projects that complemented the core project and provided resolution into mechanisms that explain the patterns observed in the core project.

The LSBP examined relative contributions of stand vs landscape structure and composition in determining presence/absence, abundance and dynamics of species

The core project addressed the following questions:

1. What are the relative influences of stand versus landscape structure/composition in explaining patterns of distribution and abundance in boreal forest animals?
2. Are these influences consistent across taxa?
3. Are these influences consistent across disturbance types?
4. For the same species (or guild of species), are these patterns consistent across forest types and regions?

Graduate student projects addressed the following questions:

1. What is the influence of clearcutting and partial harvesting on reproductive success?
2. How do animals respond to edges created by forest harvesting?
3. How do species that may be sensitive to forest harvesting select habitat and respond to forest harvesting? Focal groups were associated with burns and with old growth forest.

This paper is organized by component: the core project then the graduate student projects. For each component the following is provided: a list of key questions to be addressed by the research, some background on forest management issues related to those questions, location, methods used, results and finally some comments on management relevance, cautionary notes and future research questions.

[1] This paper covers the vertebrate portion of the LSBP only. Research on tent caterpillars was also conducted by Jens Roland, Department of Biological Sciences, University of Alberta. Also, some parts of the project were initially supported by the Sustainable Forest Management Network (SFMN) but were not renewed. As such, information on the progress of those projects was not available to the author if these studies were not published.

Scientific names for all species mentioned are found in Appendix 1. Work funded by the Sustainable Forest Management Network (SFMN) is highlighted in **bold** print.

CORE PROJECT

Key Questions

1. **What are the relative influences of stand versus landscape structure/composition in explaining patterns of distribution and abundance in boreal forest animals?**
2. **Are these influences consistent across taxa?**
3. **Are these influences consistent across disturbance types?**

Forest Management Issues

Landscape management has not been widely implemented since landscape-based approaches are not currently supported in many Canadian jurisdictions

Although forest planning units are large-scale, detailed planning is predominantly focused on the stand and cutblock scale. Even though the forest industry may be interested in landscape management, it has not been widely implemented since landscape based approaches are not currently supported by provincial regulatory frameworks or tenure arrangements in many jurisdictions in Canada. Additionally, there may be inadequate understanding of the influence of structure and composition of the landscape on ecological processes that may occur at the stand scale. Recent studies indicate that, for some organisms, processes and patterns occurring at the landscape scale may influence their presence, abundance and ecological relationships. In addition, there is some debate as to whether the amount of forest or its configuration on the landscape is more important for maintaining biodiversity. This is of direct importance to spatial harvest planning, cutblock layout and the planning of protected areas.

Location of Research

The core project consisted of 3 nodes located in Alberta, Quebec, and New Brunswick

The core project consisted of 3 nodes located in Alberta, Quebec and New Brunswick (Table 1). The results within regions will be presented first, followed by attempts at integration across regions.

Table 1. Location, habitat and investigators for the core project.

Location	**Habitat**	**Principal Investigators** (graduate students/post doctorate fellows are in brackets)
Alberta: Lac la Biche-Goodwin Lake region (between latitude 54o55’N and 55 o25’N; longitude 111 o 55’W)	-uplands mature to old aspen, aspen/ spruce and aspen/pine mixedwood, clearcuts; lowlands bogs, black spruce	Susan Hannon, Stan Boutin (Cristine Corkum, Jason Fisher)
New Brunswick: Appalachian highlands of northwestern New Brunswick (47oN, 67oW	-uplands sugar maple, yellow birch, American beech and lowlands of black and white spruce, eastern white cedar and balsam fir, harvested areas (shelterwood systems, group selection (partial cutting- 30% of the basal area on a 20-year cutting cycle), commercial clearcut with natural regeneration, and silvicultural clearcut with black spruce plantations	Graham Forbes (Jeff Bowman, Mark Edwards) Marc-André Villard
Quebec: Abitibi region, northwestern Que, (48oN, 79oW)	-mixedwood, balsam fir, black and white spruce, paper birch, aspen, clearcuts, cultivated fields	Pierre Drapeau, Yves Bergeron

Methods

Studies conducted by Hannon and Boutin used the same 3 study sites in Alberta: one had been logged (clearcut with reserves) in the winter of 1993-1994 (Owl River), one had been burned by wildfire in the summer of 1990 (Goodwin Burn), and one served as a reference (no recent logging or fire). Prior to disturbance all landscapes were of similar origin (most stands had burned between 1920 and 1940) and forest composition. At Owl River and the reference site a large grid of approximately 7 X 11 km with 58 points regularly placed at 1000m intervals was

In Alberta, 3 study sites were used: recently logged, recently burned, and a control

established. At Goodwin, due to poor access, 29 points a minimum of 1000 m apart were laid out along access routes. Hannon sampled birds using point counts and Boutin sampled murid rodents (red-backed voles and deer mice) by trapping and red squirrels using point counts. Fisher *et al.* (in press) describes the study area and design in more detail.

Forest cover was reclassified into 10 classes for Owl River and the reference site and 3 burn classes were added for the Goodwin site (**Hannon 2000**). Each grid point was given 4 buffers: radii of 100m, 250m, 500m and 1000m. Forest cover for each class was calculated for each buffer area using FRAGSTATS to produce compositional variables. To create an index of the configuration of the different landscape cover classes, a composite variable, called "heterogeneity", was created. This was a Principal Components Analysis of the following configuration variables produced by FRAGSTATS (edge density, mean shape index, patch density, patch richness, patch evenness, largest patch size, mean patch size) (**Fisher 1999**). Local vegetation was sampled within a 100m radius of the point count stations using a relevé technique for shrub and ground cover (abundance classified by cover classes) per species. Trees and snags were tallied by species and diameter at breast height (dbh) class within each plot. Structural characteristics were also measured: % cover and height of ground cover, shrub layer, sub-canopy, and canopy.

In New Brunswick, 2 sites were sampled, a moderately managed area (30% CC) and an intensively managed area (>50% CC)

In New Brunswick a similar grid system was laid out in a moderately-managed area (30% clearcut and replanted with black spruce) and in an intensively-managed area (over 50% clearcut and replanted). Vegetation and bird abundance were measured in a similar way and small mammals were live-trapped as in Alberta.

In Quebec, 3 areas were sampled: natural disturbance, pre-industrial, and industrial

In Quebec, they studied a 350 km2 area that was divided into 3 parts: natural (not harvested, affected by natural disturbances such as fire and spruce budworm outbreaks), pre-industrial (agricultural clearing (1930's), old burning and clearcutting in 1940's- now second growth) and industrial (clearcuts (late 1970's), plantations, second growth forest). Sampling was done over the entire mosaic of forest types and ages. Birds were surveyed using point counts on 1.2-2.5 km long transects. Local vegetation was sampled on quadrats2 within 50m of the point count station and 24 variables were measured (see Table 1 of **Drapeau *et al.* 2000**). Forest composition and configuration was classified into 42 classes within 500m and 1km of the sampling stations (see Table 2 of **Drapeau *et al.* 2000**).

Results

Small mammals

For red-backed voles and deer mice in Alberta, local vegetation best explained abundance

For red-backed voles and deer mice in Alberta, local (detailed measures within 100m of sampling station) vegetation characteristics best explained abundance,

[2] A rectangular plot used in ecological or population studies.

with very low amounts of the variation explained by landscape composition or configuration (**Corkum 1999**). However, results were not consistent across seasons (spring, fall), nor across the 3 study sites, and the amount of variance explained in the models was generally low. Both species were more abundant at sites with higher amounts of young forest surrounding the sampling points, suggesting that harvesting will not deleteriously affect abundance, at least at the amounts currently harvested (11% of area was clearcut) (see Table 2).

Red-backed voles and deer mice were more abundant at sites with higher amounts of young forest

Response of red squirrels in Alberta to landscape structure differed between years and between small and large grain sampling grids at the same site, and between sites (**Fisher 1999,** Fisher *et al.* in press). This lack of consistency makes it difficult to assess the impacts of harvest on this species at any spatial scale. Amount of cut forest did not enter the models in the harvested landscape and **Fisher (1999)** found squirrels in cutblocks traveling and foraging. Given that aspen forest is marginal habitat for this species anyway, harvesting aspen is likely not a major issue for squirrels, although harvesting coniferous species might be. Squirrels were less likely to be present in burned deciduous stands (50m radius) and more likely to be found in burned pine at 100m radius (Table 2).

Red squirrel response in Alberta was mixed making it difficult to assess harvest impacts on this species

In New Brunswick, results were very similar to those in Alberta for small mammals (red-backed voles, deer mice, short-tailed shrews and woodland jumping mice). Vegetation structure and composition at the stand level explained most of the variance in the abundance patterns of these species and these were primarily related to amount of shrubs and woody material (snags or downed woody material) (**Bowman *et al.* 2000, Bowman *et al.* 2001**). In general, red-backed voles and woodland jumping mice were most abundant in conifer sites, whereas deer mice and shrews were most abundant in hardwood stands and clearcuts. Clearcuts had little to no effect on abundance of small mammals (Table 2), whereas conifer plantations reduced abundance of small mammals between 2-19 times. The landscape context affected only red-backed voles. They were less abundant (magnitude not given) at sites with more conifer plantation around them, but only at a scale of 100-250m (**Bowman *et al.* 2001**). **Bowman *et al.* (2000)** also found that red-backed voles were positively associated with the amount of coarse woody material in the oldest decay classes; features absent in plantations. In addition, herbicides had been used in the plantations resulting in reduced cover and forage for small mammals.

In New Brunswick, vegetation structure and composition at the stand level explained most of the variance

In general, red-backed voles and woodland jumping mice were most abundant in conifer sites while deer mice and shrews were most abundant in hardwood sites and clearcuts

Edwards (1998) examined abundance patterns (using live trapping) and movements (using snow tracking) of short-tailed weasels in New Brunswick on the same grids that Bowman worked on. Weasel presence was not influenced by prey abundance but was positively affected by a high abundance of hardwood understory stems 1-4m in height. These conditions were associated with canopy gaps and existed in selective cutting sites, along roads and in areas of windthrow.

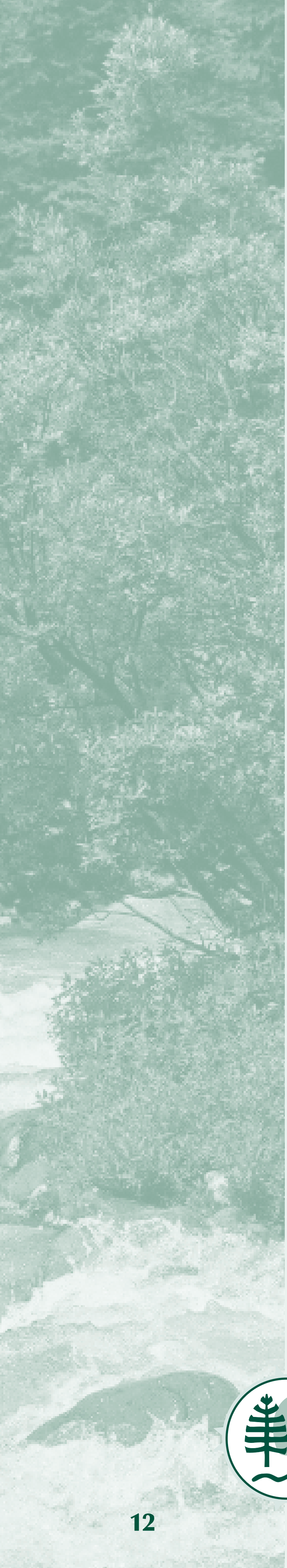


Table 2. Abundance response of species to forest management treatments at the stand and landscape scale relative to unharvested habitats (0=no effect on abundance, +=abundance increased, -=abundance decreased). Empty cells indicate that there was no data available. The magnitude of difference between harvested and unharvested sites is in brackets.

Species	**Location**	**Stand scale**			**Landscape context**		
		Clearcut	**Conifer plantation**	**Burn**	**Conifer plantation**	**Clearcut**	**Burn**
Red-backed Vole	AB					+(1.2-2)	0
Deer Mouse	AB					+(6) [b]	+(2) [b]
Red Squirrel	AB	0		-for burned decid@50 m ;+for burned pine @100m		0	0
Red-backed Vole	NB	0	- (10-19) [a]		- @100-250m		
Deer Mouse	NB	0	- (4-5)		0		
Woodland jumping Mouse	NB	0	- (none found)		0		
Short-tailed Shrew	NB	0	- (2.5-3.5)		0		
Birds							
White-throated Sparrow	AB	+ (3)		+ (2.2)		+@ 500, 1000m	+@ 500, 1000 m
Ovenbird	AB	- (4)		- (29)		-@ 500, 1000m	0
Tennessee Warbler	AB	0		- (1.7)		0	0
Yellow-rumped Warbler	AB	- (3)		- (1.6)		-@ 500m	0
Early successional species	Que					+	
Neotropical migrants	Que					0	
Residents	Que					0	
Blackburnian Warbler	Que					- (2.34) [c]	
Golden-crowned Kinglet	Que					- (1.34)	
Veery	Que					+ (1.6)	
Black-throated blue Warbler	Que					- (2.15)	

Species	Location	Stand scale			Landscape context		
		Clearcut	Conifer plantation	Burn	Conifer plantation	Clearcut	Burn
Red-breasted Nuthatch	Que					- (1.31)	
Dark-eyed Junco	Que					0	
Magnolia Warbler	Que					+ (1.23)	
Bay-breasted Warbler	Que					- (1.5)	
Least Flycatcher	Que					+ (1.9)	
Black-throated green Warbler	Que					- (1.45)	
Ruby-crowned Kinglet	Que					0	
Yellow-rumped Warbler	Que					0	
Swainson's Thrush	Que					- (1.17)	
Evening Grosbeak	Que					0	
Canada Warbler	Que					- (1.18)	
Brown Creeper	Que					0	
Yellow-bellied Sapsucker	Que					0	
Winter Wren	Que					- (1.15)	
Black-and-white Warbler	Que					+ (1.41)	
Ovenbird	Que					0	
American Redstart	Que					0	

a Indicates abundance was 10-19 times lower in the conifer plantation compared with the habitat where the species was most abundant.

b Indicates the increase in magnitude (x times higher) over the reference landscape, abundance is measured by trapping over the entire landscape.

c For all Quebec measures, the G-test was recalculated to compare the industrial forest landscape to a natural landscape (see Table 9 of **Drapeau *et al.* 2000**). The number in brackets is the relative increase or decrease in proportion of stations where birds were detected.

Birds

In Alberta, the importance of local vegetation structure and composition versus landscape forest composition varied by bird species

In Alberta, the importance of local (vegetation structure and composition within 100m of sampling stations) versus landscape-level (up to 1000m from sampling station) forest composition varied depending on the species. Hannon (in prep) analysed data for 12 species (White-throated Sparrow, Yellow-rumped Warbler, Tennessee Warbler, Rose-breasted Grosbeak, Chipping Sparrow, Yellow-bellied Sapsucker, Ovenbird, Red-eyed Vireo, Connecticut Warbler, Mourning Warbler, Hermit Thrush and Least Flycatcher). Detailed measures of local vegetation composition and structure at the point count station were the best predictors of presence/absence for 4 species (White-throated Sparrow, Yellow-rumped Warbler, Tennessee Warbler and Rose-breasted Grosbeak), whereas forest cover data measured at 100m radius were best predictors for the presence of Chipping Sparrow, Ovenbird, Red-eyed Vireo, Connecticut Warbler and Yellow-bellied Sapsucker. Variables measured at the 500m scale entered the final models of 7 of the 12 species. However, the presence of most species was best predicted by models that contained variables from several scales.

The presence of most species was best predicted by models that contained variables from several scales

Hannon had sufficient abundance data for 4 species to examine the effect of clearcutting and burning at local (100m) and larger scales (500m-1km; Table 2). White-throated Sparrows were more numerous and Ovenbirds and Yellow-rumped Warblers were less numerous in clearcuts and burns than in deciduous forest. Tennessee Warblers had similar abundance in clearcuts and deciduous forest, but lower abundance in burns. Abundance of Ovenbirds and Yellow-rumped Warblers was also lower in forest patches surrounded by clearcuts at the 500m scale, whereas abundance of White-throated Sparrows was increased in forest patches surrounded by clearcuts (Table 2).

In Quebec, bird communities varied primarily with landscape composition, not with configuration. Forest age and type explained much of the variation.

In Quebec, bird community composition overlapped among pre-industrial, industrial and natural landscapes and it changed along a gradient from natural to industrial to pre-industrial. **Drapeau *et al.* (2000)** found that the composition of the surrounding landscape did influence bird community composition as much as local vegetation composition. However, bird communities varied primarily with landscape composition, not with configuration (e.g. amount of edge). Compositional variables such as forest age (e.g. amount of young forest) and forest type (e.g. amount of conifer) explained much of the variation in the bird community. This relationship is consistent with that found by **Song (1998)** in the boreal mixedwood in Alberta.

Landscapes managed for forestry had higher abundance of early succession bird species and a lower abundance of mature forest species than natural landscapes (Table 2). The lack of a landscape configuration effect may be because the forest was cut in an aggregated way, minimizing the amount of edge habitat. One interesting aspect of the Quebec study was the inclusion of landscapes that had been logged in the 1930's, allowing the authors to predict longer-term changes in bird communities after logging. Forest composition changed from conifer and mixedwood-dominated stands to deciduous forest types after logging. Clearly, if this pattern persists, species associated with conifer will decrease. Another conclusion of this study was that grouping species by migratory category (e.g. residents, neotropical migrants) is not useful, as species within these categories react differently to forestry.

Analysis of abundance and distribution data for New Brunswick has not yet been completed.

4. For the same species (or guild of species), are these patterns consistent across forest types and regions?

This analysis was conducted by Drapeau in collaboration with Hannon and Villard (as yet unpublished). The passerine species in Alberta, Quebec and New Brunswick were examined and their sensitivity to loss of forest cover at both the stand (within 100m of the sampling station) and landscape (within 1km of sampling station) scales was assessed. Twenty-two species of the 56 forest species analysed showed lower abundances or absences in stands and/or landscapes with reduced forest cover (Table 3). Of these, 8 are considered to be older forest specialists (**Schmiegelow and Mönkkönen 2002**) and 3 are rare in commercial forest types in Alberta (**Hannon *et al.* 2004**). Tittler *et al.* (2001) worked in partially harvested blocks in Alberta mixedwood (3-39% of original trees retained, 10-133 trees/ha, basal area 0.5-10.65 m2). Of the 10 forest species they examined, only Swainson's Thrush, Yellow-rumped Warbler and American Redstart increased in abundance with increasing basal area in the stand. In other words, partial retention at the level operationally feasible in boreal mixedwood (maximum 39% green tree retention) is not an option to retain all forest species.

Partial retention in the boreal mixedwood (max. 39% retention) may not retain most passerine bird species

Table 3. Species that were negatively affected by loss of forest cover in at least one of the 3 locations (Alberta, Quebec, New Brunswick) at either or both the stand or landscape scale. Species with "#" are old forest specialists, those with "@" are considered rare species in commercial forest types in Alberta (**Hannon *et al.* 2004**), and those with "&" are species that increased in abundance with increasing basal area in partial cuts. Resident species are in **bold.**

Species	Responded negatively at the stand scale	Responded negatively at the landscape scale
Brown Creeper#@	*	*
Blackburnian Warbler	*	*
Bay-breasted Warbler#@	*	*
Black throated blue Warbler	*	*
Golden crowned Kinglet#@	*	*
Red breasted Nuthatch#	*	*
Yellow-rumped Warbler&	*	
Veery	*	
Black-throated green Warbler#	*	
Ovenbird	*	
Red-eyed Vireo	*	
Ruby crowned Kinglet	*	
Rose-breasted Grosbeak		*
Swainson's Thrush#&		*
Black-capped Chickadee		*
Boreal Chickadee#*		*
Yellow-bellied Sapsucker		*
Purple Finch		*
Northern Waterthrush		*
Northern Parula Warbler		*
Connecticut Warbler		*
Magnolia Warbler#		*

Management Relevance

Mice, voles, and red squirrels will probably not be negatively affected by clearcutting in aspen and mixedwood stands

Murid rodents (mice and voles) and red squirrels will probably not be negatively affected by clearcutting in aspen and mixedwood or shade tolerant hardwoods, if harvesting continues at present levels. However, conifer plantation forests in New Brunswick provided poor or no habitat for small mammals due to lack of dead and downed wood and destruction of shrub cover by herbicides.

No single silvicultural prescription will affect the responses of all organisms in the same way

Species differ quite a bit in their response to forest harvesting and their responses to landscape loss of forest cover. Hence, no single silvicultural prescription will affect the responses of all organisms in the same way. Therefore, it is important not to do the same thing everywhere.

Most passerine species are influenced more by the structure and composition of the forest at the stand level than by forest clearing at the landscape scale, at least at the level of harvesting currently found in the boreal mixedwood of Alberta (where 11% of the landscape is harvested in first pass clearcuts, with 5-10% green tree retention). However, forest clearing at the landscape scale does negatively affect some species (Table 3).

Most passerine species are influenced more by forest structure and composition at the stand level

A number of passerine species, especially older forest specialists, are negatively affected (in terms of abundance or presence at a site) by loss of forest cover at either the stand or landscape scale. These include several rare species and four resident species.

As landscapes come under intensive forest harvesting, the proportion of mixedwood and conifer forests may decline in both Quebec and Alberta. Such a reduction in the proportion of mixedwood stands has already taken place in northwestern New Brunswick. This will change wildlife community composition substantially. Foresters should strive to maintain natural forest composition in managed landscapes. Suggestions for how this may be accomplished is presented in **Bergeron and Harvey (1997)**, Gauthier *et al.* (1996), **Lieffers and Grover (2004)**, and **Huggard (2004)**.

Maintain natural forest composition intensive forestry can substantially change wildlife community composition

Forest managers have two options for retaining forest passerines in working landscapes: either set aside blocks of uncut forest or conduct partial harvesting of some stands. Partial green tree retention, at a level operationally feasible using feller bunchers (up to 40% green tree retention), is not an option to retain most forest passerine species. Hence, retention of representative ecosystems within the managed landscape (**Huggard 2004**) may better protect forest passerine species. Protection of representative ecosystems can act as source populations or “life boats” for species while logged stands are regenerating.

Two options for retaining passerines are: set aside uncut forests, or conduct partial harvesting of some stands

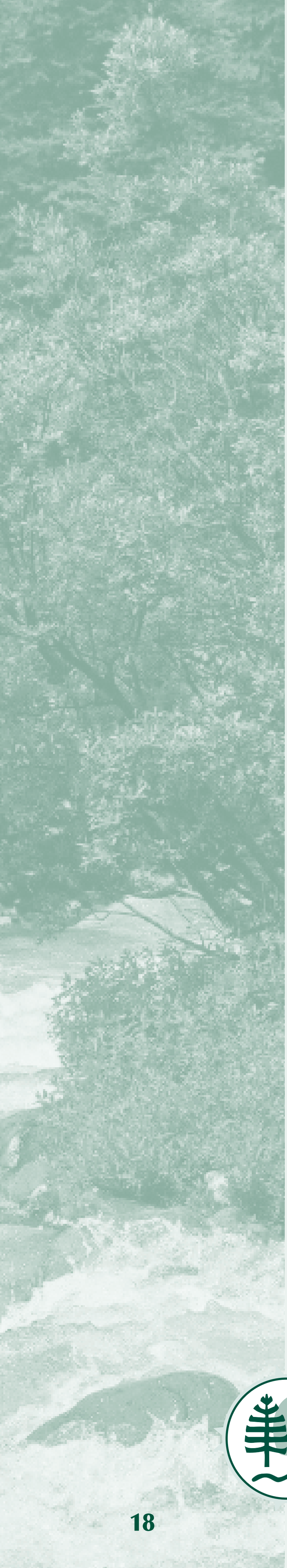
At this point in time there are unfortunately, no clear answers to ‘absolute’ habitat thresholds or species responses relative to harvesting levels that can help forest managers reduce the risk of loss of ecosystem function and processes.

There are no clear habitat thresholds or species responses relative to harvest levels

Cautionary Notes

1) The logged landscapes in Alberta used in the study had only about 11% of the area in recent first pass clearcuts. This is not a high level of harvest and may be far above a threshold level of forest cover that might deleteriously affect forest wildlife. Results could be different after the second pass of harvesting.

2) Studies on birds focused on terrestrial passerines that could be surveyed using point counts. The results may not be applicable to non-passerines such as raptors, woodpeckers or grouse.



3) Studies were short-term. Many of the species studied fluctuate markedly in abundance over years and hence long-term trends should be studied.

4) Studies were based on presence/absence or abundance of species. Reproductive success or survival of the species was not studied and are important in assessing population persistence.

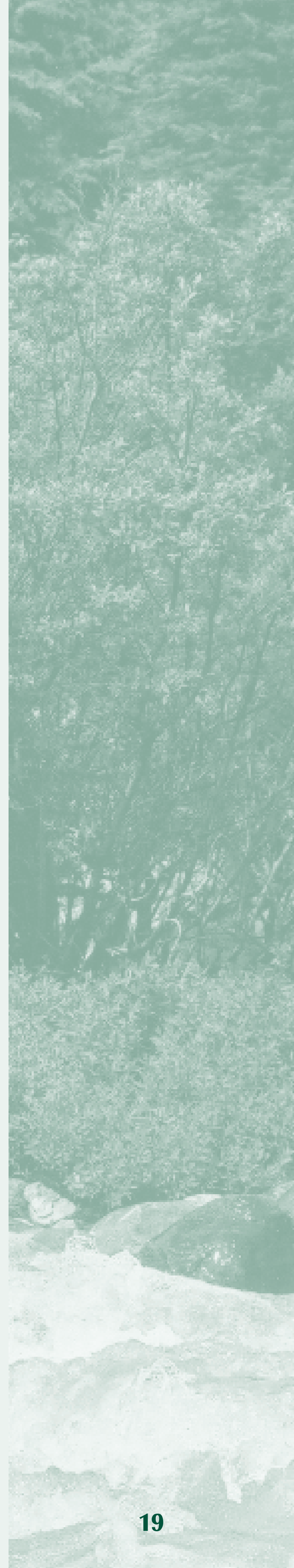
5) Note that boreal passerine communities are typically composed of approximately 50-55% neotropical migrants, 35% short-distance migrants and 10% residents. Forest managers have no control over activities and mortality sources on wintering grounds for migrants so the effectiveness of management practices on breeding areas remains uncertain. Operations to retain both breeding and wintering habitat of residents should be effective.

Future Research Questions

1) What are critical thresholds in the amount of forest cover for a variety of species? This question is currently being examined by Boutin, Schmiegelow, Hannon and Villard under SFMN funded projects. These studies have expanded the range of forest cover remaining on landscapes and have included other land uses in addition to forestry.

2) How does reduction in forest cover affect population persistence of species sensitive to forest removal? Long-term demographic studies should be employed with particular emphasis on effects of forest loss on reproductive success.

3) Does configuration affect population distribution and abundance in landscapes with less forest cover? Although forest configuration did not appear to be as important as overall forest cover, the studies did not cover a range of possible configurations. This could be done experimentally in conjunction with #2.



The Core Project: Habitat Amount vs Configuration Key Points

- ➢ This study primarily addressed the debate as to the relative importance of habitat amount (the net amount of habitat) versus habitat configuration (the way habitat is spatially arranged in the landscape) in maintaining biodiversity.
- ➢ For small mammals in Alberta and Quebec, local vegetation composition best explained abundance, with very little variation explained by landscape composition or configuration.
- ➢ Most passerine bird species are influenced more by forest structure and composition at the stand scale than by forest clearing at the landscape scale. Bird communities varied primarily with landscape composition, not configuration.
- ➢ Several passerine species are negatively affected by forest loss at both scales.
- ➢ Grouping bird species by category (e.g., neotropical migrants, residents) for management purposes is not useful since species within these groups responded differently to forest practices.
- ➢ Partial retention (in this case up to a maximum of 39% retention) did not effectively retain all forest bird species.
- ➢ Managers should strive to retain the natural composition of forests.
- ➢ There are two options for retaining passerines: set aside uncut forests, and partial cutting of some stands.
- ➢ There are no clear answers and no single silvicultural prescription that will affect all organisms in the same way -- do not do the same thing everywhere.

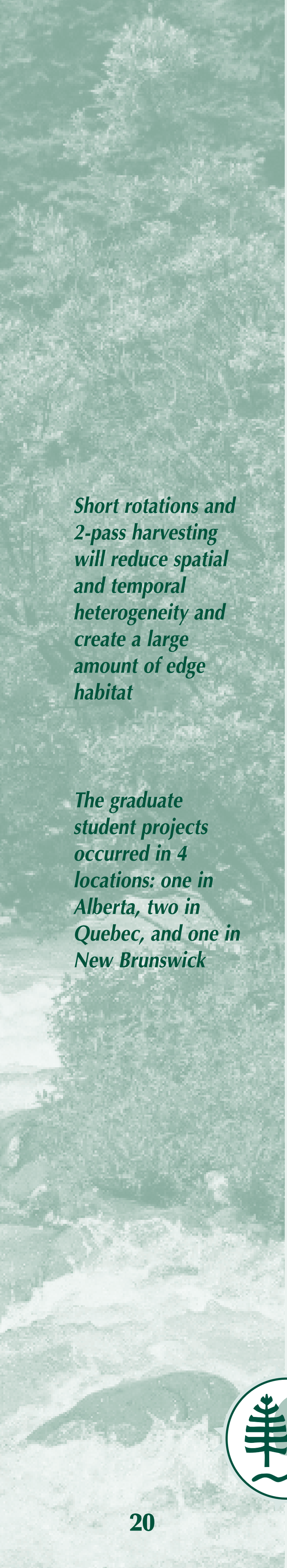
GRADUATE STUDENT PROJECTS

Key Questions

1. **What is the influence of clearcutting and partial harvesting on reproductive success?**

2. **How do organisms respond to edges created by forest harvesting?**

Forest Management Issues



Short rotations and 2-pass harvesting will reduce spatial and temporal heterogeneity and create a large amount of edge habitat

A short harvest rotation period (70-90 yr depending on dominant species) and two-pass forest harvesting will impose a narrow range of cutblock sizes, shapes and rotations, reducing the spatial and temporal heterogeneity created by natural disturbances. In addition, a large amount of edge habitat will be created. Numerous studies in North America and Scandinavia have indicated that processes at edges, such as increased predator or parasite activity, can decrease reproductive success of organisms such as birds.

Location of Research

The graduate student projects occurred in 4 locations: one in Alberta, two in Quebec, and one in New Brunswick

The graduate student projects investigating reproductive success and response to edge occurred at 4 locations, one in Alberta, two in Quebec and one in New Brunswick (Table 4).

Table 4. Locations of the graduate student projects studying the effects of harvesting on reproductive success and response of organisms to clearcut/forest edges.

Location	**Habitat**	**Principal Investigators (graduate students/post docs in brackets)**
Alberta: Calling Lake area, (55oN ,113o W)	-mature to old aspen, aspen spruce mixedwood, clearcuts	Susan Hannon (Samantha Song)
New Brunswick: Appalachian highlands of northwestern New Brunswick (47oN, 67oW); Acadian forest region	-sugar maple, yellow birch, American beech and lowlands of black and white spruce, eastern white cedar and balsam fir, harvested areas (shelterwood systems, group selection (partial cutting- 30% of the basal area on a 20-year cutting cycle), commercial clearcut with natural regeneration, and silvicultural clearcut with black spruce plantations	Marc-André Villard (Vincent Carignan, Julie Bourque, John Gunn*) *Gunn co-supervised by Tony Diamond
Quebec: Abitibi region, northwestern Que, (48oN, 79oW) Lac St Jean (49oN, 72oW)	-mixedwood, balsam fir, black and white spruce, paper birch, aspen, clearcuts, cultivated fields -black spruce riparian and leave strips, clearcuts	Pierre Drapeau/Yves Bergeron (Daniel Brongo, Héloïse Rheault) Belanger/Marcel Darveau (Maryléne Boulet)

Methods and Results

Reproductive success

The study locations, forest type and investigators are summarized in Table 4. These studies focused mainly on birds using two main approaches: developing an index of reproductive success based on avian response to a mobbing call and examining

These studies focused mainly on birds and used 2 approaches: developing an index of reproductive success, and examining artificial nest success

success of artificial nests. These studies are summarized in Appendix 2. The major conclusions are presented below.

Overall, there were no major effects of proximity to edge on reproductive success

Overall, there did not appear to be major effects of proximity to edge on reproductive success. The predator communities did not appear to change after logging. However, in most studies the variables that predicted the success of a nest differed between areas and years. This is partly due to the stochastic nature of predation (some predators are opportunistic), but also because predator numbers vary temporally (e.g. small mammal cycle; **Carignan and Villard 2002**) as do the numbers of prey. The presence of other disturbances such as tent caterpillar outbreaks influenced predation rates.

Partial cutting affects reproductive success of bird species differently

Bourque and Villard (2001) examined density and reproductive success of two species, Black-throated Blue Warbler and Ovenbird (both considered old forest specialists), in uncut and first-entry selection cut forests in New Brunswick and found that the Black-throated Blue Warbler had higher density and overall productivity in selection cuts, whereas Ovenbirds had lower density and reproductive success in selection cuts. Hence, partial harvesting will affect the reproductive success of bird species differently. High intensity silviculture (clearcutting and plantations) in New Brunswick reduced the reproductive output of two of 8 focal species (**Gunn *et al.* 2000, Gunn 2004**). Only one study in Quebec found higher predation rates in anthropogenic landscapes (agriculture, clearcuts) than natural landscapes (**Brongo 2002**). It appears that harvesting does affect reproductive output of some species.

Density at edges

Of 15 mature-forest bird species, only 5 showed any significant response to edge, but this was not consistent over years and edge type. Overall, there was not a big effect.

Two studies examined whether avian density varied at edges (i.e. do birds avoid clearcut edges?). **Brongo (2002)** did point counts along 475m transects from edge (agriculture, burn and clearcut edges) to interior of forest stands and controlled for local habitat differences in the analysis. For 15 mature forest species monitored, only 5 showed any significant response to edge, but this was not consistent over years and not at all edge types. Golden-crowned Kinglets avoided edge in both years in the clearcut landscape only. Ovenbirds avoided edge both years in the fire landscape only. For mature forest species, more showed probable reproductive activity at interior vs edge in agricultural and clearcut landscapes; there was no difference for the burned landscape. When separated out by species, Ovenbird had higher reproductive activity in interior burn sites, and Black-throated Blue Warbler and Ruby-crowned Kinglet showed higher reproductive success in interiors of clearcut landscapes. Overall, no large effect was demonstrated. Landscape forest cover was still above 30%, so effects of fragmentation were not severe.

Song (1998) compared bird communities at aspen clearcut and aspen-spruce edges with aspen interior sites in Alberta. Songbird communities (species richness, composition) were quite similar across treatments and songbird density was higher at aspen-clearcut edges, but only in first year after harvest, presumably due to crowding of birds displaced by the clearcuts. White-throated Sparrow, Least Flycatcher and Mourning Warbler were attracted to clearcut edges and were also found in clearcuts, but their density was not higher at edges. None of the other 13 species examined were attracted or repelled by clearcut edges. Abundance of species was driven by forest structure (age) and composition (amount of conifer) and not to edge type nor to insect biomass. Song concluded that there was no loss of habitat to songbirds at clearcut edges (other than the loss of habitat in the clearcut) for mature forest species. With rapid regrowth of aspen in clearcuts, the vegetation stucture at edges should not alter significantly. Note again, however, that forest cover was still very high in these landscapes (first pass of logging only).

In Alberta, bird abundance was driven by forest structure and composition; not by edge or insect biomass

Carignan and Villard (2002) found no evidence of edge effects on the predation of artificial nests placed perpendicular to edges between mature deciduous stands and spruce plantations in New Brunswick.

In New Brunswick, there were no edge effects on artificial nest success

Lichen biomass at edges

Rheault *et al.* (2003) studied 3 species of epiphytic lichens on transects extending from clearcut edges 100m into the interior of old black spruce forest in Quebec. E. mesomorpha and Usnea spp, but not Bryoria, had lower mass within 50m of edge compared with interior. Forest fragment size (.03 to >4ha) had no effect on lichen biomass but there was a trend for lower mass of Usnea in the smallest fragments.

Management Relevance

Narrow forest strips (60 m wide) left along riparian areas and between clearcuts in Quebec black spruce forests are not suitable habitat for forest birds. Short-term predation on nests by red squirrels also occurred shortly after harvest in strips. Hence, larger leave areas must be left.

In Quebec, retained narrow forest strips (60m wide) are not suitable forest bird habitat – larger areas must be left

Epiphytic lichen mass decreased within 50m of a clearcut edge in Quebec black spruce forests. This suggests that most riparian buffer strips and upland strips between cutblocks are too narrow to allow persistence of these species. Leaving peninsulas or large islands of old forest tracts in cutblocks should enhance epiphyte colonization of second-growth forest stands.

Mass of the lichen Usnea could be used to indicate how large forest fragments should be to ensure interior habitat.

Lichen mass could be used to determine the size of forest fragments required to provide interior habitat

In Quebec, there was some indication that reproductive activity of birds might suffer at clearcut edges for a few species. However, studies at other sites found no such effects.

Artificial nest predation rates did not consistently increase at forest edges

Overall, predation rates of artificial nests did not consistently increase at forest edges in any region. In general very little of the variation in nest predation was explained by local or landscape variables. This is likely because of the high variability in predator numbers spatially and temporally and the stochastic element involved in nest detection and predation.

In New Brunswick, increasing management intensity will significantly affect populations of some species.

In New Brunswick, observed reductions in the reproductive activity of two wood warbler species and the productivity of a third species indicate that increasing management intensity will significantly affect their populations. Uniform application of selection harvest systems, in particular, poses a clear threat to the Ovenbird. Some mature and old shade-tolerant deciduous stands should be put under longer rotation across management units.

In Alberta mixedwood forests, there was direct habitat loss of old forest on cutblocks for mature forest bird species, but this was not compounded by additional negative edge effects extending into the remaining forest.

Forestry activities did not appear to change predator communities

Predator types were similar among regions: micromammals, red squirrels, corvids (e.g. gray jays); although their relative importance differed depending on year and forest type. Overall, forestry activity did not appear to change predator communities.

There are concerns that generalist predators (e.g. corvids, skunks, raccoons, cats, etc.) that increase with sustained human presence (agriculture, towns, dumps) could increase as human density increases in managed forest landscapes. This could lead to increased nest predation in managed forests.

Cautionary Notes

1) Studies were usually short term (1-2yr) and often right after logging occurred. Longer- term effects were not measured, but presumably as clearcuts regenerate any negative effects should be ameliorated.
2) Most studies did not compare edge effects at clearcut edges to those created by fire or other natural edges. Hence, whether or not effects at clearcut edges are higher than at natural edges was not determined.
3) Many studies used artificial nests to examine nest predation levels. These may not represent natural levels or patterns of nest predation.
4) The index of reproductive activity and artificial nests used in New Brunswick provide relative indices of local productivity, not absolute measures.

Future Research Questions

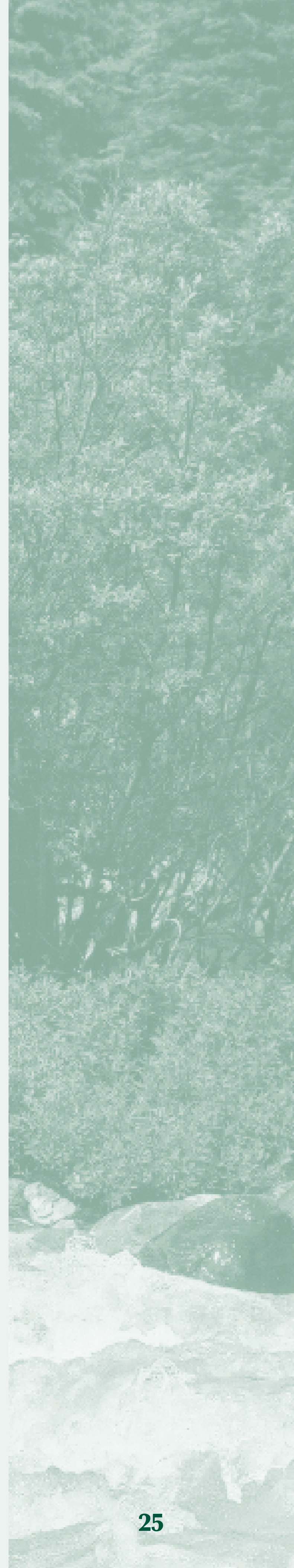
1) Do species persist as landscapes change through time? Studies on forest species should be over a longer term or repeated at intervals as the clearcuts regenerate and as other areas are harvested on the landscape. The emphasis should be on determining longer-term persistence of organisms (i.e. demographic data should be collected).

2) How large should reserves of old forest be and where should they be placed to maintain natural biodiversity? Which species should be used as evaluative indicators to determine whether forest reserves are maintaining biodiversity?

3) How does predator abundance and behaviour change as landscapes come under intensive forest management?

Graduate Student Projects: Harvesting and Edge Effects Key Points

- ➢ These studies primarily addressed the influence of clearcutting and partial cutting on reproductive success of birds, and their responses to harvest edges.
- ➢ Short rotations and two-pass harvesting systems are predicted to reduce spatial and temporal heterogeneity of forests and increase amounts of edge.
- ➢ There were no consistent major effects of proximity to edge on reproductive success in birds, or artificial nest predation rates.
- ➢ Due to mixed responses, partial cutting seems to affect reproductive success of bird species differently.
- ➢ In Alberta, bird abundance was driven by forest age and composition (eg. amount of conifer), and not by edge or insect biomass.
- ➢ Lichen biomass was lower for some species within 50 m of edge, however fragment size had no effect on species.
- ➢ In Quebec, narrow forest retention strips (60m) are not suitable forest bird habitat – larger areas must be left.
- ➢ Forestry activities did not change predator communities.



Key Question

3. **How do species that may be sensitive to forest harvesting select habitat and respond to forest harvesting? Focal groups were associated with burns and with old growth forest.**

   a) **Fire-associated species**

Forest Management Issues

Logging and fire do not create similar forest structure or composition. However, bird communities converge over time on burned and logged areas

Fire associated species might be lost if salvage logging removes most dead trees, or if fire is replaced by logging on the landscape

Logging and fire do not create similar forest structure or composition, hence plant and animal communities are often not similar in young stands after fire and logging (reviewed in Schieck and Song 2002). In burns, the bird community is dominated by cavity nesters and species that forage on beetle infestations in the dead trees, whereas clearcuts are dominated by open country species: species that forage and nest in snags were absent in logged stands. Bird communities on burned and logged areas converge over time (possibly within 13-25 years, Hobson and Schieck 1999).

In Quebec, primary cavity nesters were lost from the oldest black spruce stands (>200yr) (**Drapeau *et al.* 1999, 2002, Imbeau *et al.* 1999**) because snag availability, particularly larger snags (>15cm dbh) used for feeding and nesting by birds is lower than in 100-120 year old forests. Some silvicultural techniques, such as leaving residual tree patches on cutblocks, aim to increase structural diversity of young stands but do not provide enough standing dead trees for fire associates. Fire associated species are species that reach their highest abundances for a few years after fires. These species might be lost if salvage logging removes most dead trees or if fire is replaced by logging on the landscape.

Location of Research

The locations of the graduate student projects involving fire associated species included Alberta, Quebec and Ontario (Table 5).

Table 5. Locations of graduate student projects involving fire-associated species.

Location	Habitat	Principal Investigators (graduate students/post docs in brackets)
Alberta: Mariana Lake, 55o05’N, 111o55’W	- burned black and white spruce and jack pine	Susan Hannon (Jeff Hoyt)
Quebec: Abitibi region, northwestern Que, (48oN, 79oW) Ontario: Lake Abitibi Model Forest (49oN, 80oW)	- burned black and white spruce and jack pine	Pierre Drapeau (Antoine Nappi)

Methods and Results

Black-backed Woodpeckers and Three-toed Woodpeckers exploit recently burned coniferous forest to forage on wood-boring insect larvae (Cerambycidae and Buprestidae) and bark beetle larvae (Scolytidae). In Alberta, both species were found in burned stands of jack pine and white and black spruce (50-140 yrs of age prior to burn), both species were absent from mature (50-100yr) forests and were found at low density in older growth (>110yr) forest (**Hoyt 2000, Hoyt and Hannon 2002**). Hoyt found that Black-backed Woodpeckers were more abundant in old growth forest >75km from recent burns than in old growth forest adjacent to recent burns, suggesting that they had moved out of old forest into the burns. Species such as Northern Hawk-owls, Hairy and Downy Woodpeckers, Northern Flicker, House Wrens, Bluebirds, Tree Swallows and American Kestrels were also abundant in post-fire stands.

In Alberta, Three-toed Woodpeckers seemed to be most abundant in sites with large diameter, lightly burned spruce up to 3 yrs after fire. This is probably because bark beetles, the primary food for Three-toed Woodpeckers are most prevalent in this type of tree (jack pine has thick bark and is more resistant to insect attack, and heavily burned spruce trees are not infested at a high rate). Sites where Three-toed Woodpeckers occurred had a minimum density of lightly burned spruce trees of 2150 stems/ha. Black-backed Woodpeckers were found in stands up to 8yrs post-fire. Black-backed Woodpeckers forage primarily on the larvae of wood boring insects (Cerambycidae and Buprestidate) that invade dead

In Alberta, black-backed woodpeckers and three-toed woodpeckers were both found in burned jack pine and spruce stands, but were absent from mature stands, and were at low densities in older forests

Three-toed woodpeckers were most abundant up to 3 yrs after fire, Black-back woodpeckers were found up to 8 yrs after fire

Woodpeckers preferred to forage on moderately burned large-diameter (>15 cm) standing jack pines

Trees should be > 20 cm DBH to ensure high use by both insects and woodpeckers

Woodpeckers and secondary cavity nesters were more abundant in unsalvaged burns

and dying trees. Since they are stronger foragers than Three-toed Woodpeckers and can excavate wood-boring insect larvae, it is possible that they can persist longer in burns by foraging on burned pine. Pine has thicker bark than spruce and hence does not dessicate as quickly. Across stand types, Woodpeckers were found at sites with a minimum density of standing trees of 3000 stems/ha with at least 1100 stems/ha of at least 15cm dbh. At least half of the trees were lightly burned.

Hoyt (2000) also observed Black-backed Woodpeckers foraging in the summer in black spruce and jack pine stands 3 years after a stand-replacing fire at Mariana Lakes area of Alberta. At this point the majority of burned trees were still standing. Woodpeckers preferred (i.e. they selected them at a greater rate than expected by their availability on the territory) to forage on moderately burned (100% burned, but 80-100% of the bark intact) large diameter (>15cm dbh) standing jack pine trees, although standing and downed spruce was also used. Insect abundance depends on moisture content of the trees, and moderately and heavily burned spruce dessicates within a few months of the fire. Since jack pine has thicker bark than spruce, it does not dessicate as quickly. Hoyt suggested that woodpeckers might forage more often on spruce in the first year after fire, and given the results for Three-toed Woodpeckers above, lightly burned spruce trees are likely important for them as well.

Nappi *et al.* (2003) studied foraging of Black-backed Woodpeckers in summer in a black spruce/jack pine stand one year after fire in Quebec. The stand was 86 yr old prior to the burn. Signs of foraging (bark flaked off), direct observation of woodpeckers and measured wood boring insect abundance using larval entrance and exit holes in the tree were used to determine use. Woodpeckers foraged on both pine and spruce snags. Large diameter trees that were lightly burned and had retained most of their branches were most likely to be used by woodpeckers because they had a higher abundance of wood-boring insects. For example, trees of 15cm dbh had an 80% probability of being used if they were lightly burned and only a 12% probability of being used if they were heavily burned. Nappi et al's deterioration classes 1-3 encompassed trees that were killed in the fire (as opposed to those that were already dead before the fire). In those classes, trees of 15cm dbh had a minimum probability of 60% of being used, those in the 20cm dbh category had a minimum probability of 80% of being used and those greater than 25cm dbh had a minimum probability of 93% of being used. Hence, data from Nappi and Hoyt combined suggest that retained trees should be at least 20cm dbh to ensure high use by both insects and woodpeckers. Given that the minimum diameter of nest trees is 18cm, 20cm dbh would also provide nest trees.

Trees that are salvaged are in the same diameter classes that woodpeckers use for foraging and nesting (**Hoyt 2000, Nappi 2000, Nappi *et al.* 2003**) resulting in lower densities of Three-toed Woodpeckers, Black-backed Woodpeckers, Downy Woodpeckers and Hairy Woodpeckers in salvage-logged burns one year post-fire than in unsalvaged burns (Schmiegelow *et al.* 2001). In addition, secondary cavity nesters such as House Wrens, American Kestrels and Brown Creepers were more abundant in unsalvaged versus salvaged-logged burns (Schmiegelow *et al.* 2001). Similar results were obtained in black spruce forests for the Winter Wren and Eastern Bluebird in unsalvaged versus salvaged-logged burns (**Drapeau *et al.* 2003**).

Hannon and Drapeau (in press) reviewed studies of fire-associated species in the boreal forest. The following species appear to be associated with fire in the following stand types (i.e. they reached significantly higher abundance in burns when compared with unburned stands of the same forest type):

Aspen/spruce mixedwood: American Kestrel, Downy Woodpecker, Hairy Woodpecker, Black-backed Woodpecker, Northern Flicker, Gray Jay, Tree Swallow, Brown Creeper, Winter Wren, Hermit Thrush, American Robin, Connecticut Warbler and Yellow-rumped Warbler;

Aspen: White-throated Sparrow, Brown Creeper, House Wren, Chestnut-sided Warbler, Chipping Sparrow, Olive-sided Flycatcher, Least Flycatcher;

Jack Pine: Black-backed Woodpecker, Three-toed Woodpecker, Dark-eyed Junco, Olive-sided Flycatcher, American Robin, Western Wood Pewee, Winter Wren;

Black Spruce: Black-backed Woodpecker, American Kestrel, Tree Swallow, Eastern Bluebird, American Robin, Hermit Thrush, Cedar Waxwing.

Management Relevance

To protect fire-associated species protect some large forest blocks (see next point) that have been recently burned from salvage logging, particularly blocks containing large (>20cm dbh) lightly to moderately burned trees. Retain a minimum density of standing trees of 3000/ha with at least 1100 of these trees with a dbh at least 20cm.

Protect some recently burned forest blocks > 40 ha from salvage logging

The area of retained trees should be at least 40ha to encompass one pair of Black-backed or Three-toed Woodpeckers. It is not known how many pairs of woodpeckers are required for population persistence, but if the 50/500 rule suggested by population genetics studies is used, over the landscape 20,000 ha of habitat should be retained. Habitat for these birds is transient (i.e. burns are only occupied at high densities up to 8 yrs after fire) so this means on average, 20,000 ha of habitat has to be retained every 8 years. Note that it is not known how woodpeckers find burns, how far woodpeckers move to colonize burns or how large a burn has to be to be detected. Hence, recommendations as to the spatial distribution of habitat cannot be made at this time. Note also that how large a retained stand should be to hold the full cavity nesting community is not yet known.

20,000 ha of habitat should be retained over the landscape to maintain the population

Delay salvage logging on some stands for 3-4 yr post-fire to allow woodpeckers to reproduce. However, this creates a conflict with the forestry industry, since damage to trees from beetle infestations and desiccation usually restricts salvage logging operations to up to 2 yr post-fire.

Delay salvage logging on some stands for 3-4 yrs post-fire

Old growth conifer stands (>110yr old) should be maintained as a reservoir for Three-toed and Black-backed Woodpeckers, where populations can persist in years without suitable early post-fire stands.

Old growth conifer stands should be maintained as reservoirs

Woodpecker use of post-fire snags depends on stand composition and age

Cautionary Notes

1) Woodpecker use of snags after fire depends on the species composition and age of the stand prior to fire and the severity of the fire, hence the studies cannot necessarily be used to predict woodpecker abundances in all burns.

2) Fire regimes are highly variable from one region to another and future climatic changes will alter fire cycles (**Flannigan *et al.* 1998**). In the west, the central Boreal Plains, western shield and taiga are predicted to have longer, warmer, drier summers and hence more fires. This would mean increased habitat supply for fire-associated species. Since the 1970's in Alberta, however, there has been an increase in both the area burned and logged, suggesting that logging is not replacing fire but is additive to it (Lee and Bradbury 2002). This will result in a landscape dominated by young forest stands with a concomitant reduction in old growth habitat. Hence, in the western boreal there may be more concern with a loss of old growth habitat than a reduction in burned habitat, assuming the salvage logging is controlled.

3) In the mixed or coniferous forest regions of northeastern Ontario and Quebec, summers are predicted to be wetter and cooler and the historical intermediate fire cycle (around 150 years (**Bergeron *et al.* 2001**)) should persist or lengthen. Hence, habitat for fire-associated species is predicted to decrease. Secondary disturbances, such as insect outbreaks and windthrows that occur in the absence of fire, are likely to become more important in northwestern Quebec and may provide suitable standing dead trees to maintain viable populations of species like the Black-backed Woodpecker (Goggans *et al.* 1989, Thompson *et al.* 1999, Setterington *et al.* 2000)

Future Research Questions

1) How do fire-associated species find recent burns? How large should burns be to attract birds? Are isolated burns detected by woodpeckers? How large should protected areas of burns be to conserve the full fire-associated community?

2) How many burned residual trees are required on a cutblock to attract fire-associated species? How intensely burned should the trees be?

3) How does the spatial distribution and amount of burns and old-growth forest affect the population dynamics of fire-associated species?

4) How will the supply of burned and old-growth habitats change under various climate warming scenarios, predicted levels of forestry development and other land uses?

Graduate Student Projects: Fire-Associated Species and Salvage Logging
Key Points

➢ Logging and fire do not create similar forest structure or composition. However, bird communities converge over time on burned and logged areas – possibly with 13-25 years.

➢ Fire-associated species might be lost if salvage logging removes most dead trees, or fire is replaced by logging on the landscape.

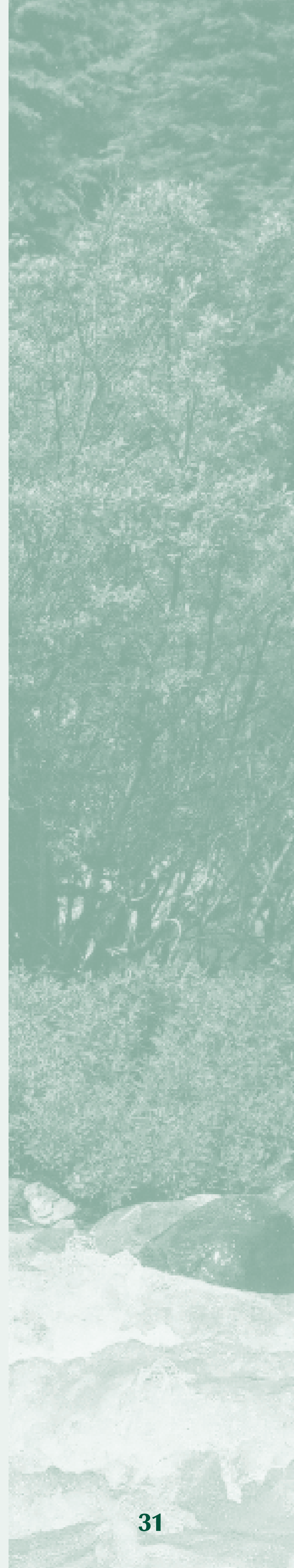
➢ In Alberta, Black-backed Woodpeckers and Three-toed Woodpeckers were both found in burned jack pine stands, but were absent from mature stands, and were at low densities in older forests.

➢ Three-toed Woodpeckers were most abundant up to 3 yrs after fire, Black-backs were found up to 8 yrs after fire.

➢ Trees should be > 20 cm DBH to ensure high use by both insects and woodpeckers.

➢ Woodpeckers and secondary cavity nesters were more abundant in unsalvaged versus salvaged-logged burns.

➢ To retain fire-associated species, some recently burned forest blocks should be protected from salvage and salvage should be delayed 3-4 yrs on other blocks to allow woodpecker reproduction. Area of retained burnt forest should be > 40 ha.



Old-growth forest will be reduced in the face of short-rotation, even-aged management. In Quebec, forests 100-150 yrs should be conserved. In Alberta, old growth conifer (100-150 yrs) and aspen and mixedwood (>80 yrs) should be conserved.

b) Old-growth associated species

Forest Management Issues

Old growth (>100yr) forest cover will be reduced in the face of short-rotation (70-100yr) even-aged management systems. Old growth forests tend to have high species diversity and high abundances of species, particularly for resident species. This is because of the high structural heterogeneity of these forests and the presence of standing and downed dead wood. Clearcut harvesting reduces dead wood availability, not only within individual stands but across entire landscapes, and reduces structural heterogeneity. Reduction of dead wood is one of the main causes of biodiversity loss in the Fennoscandian forest, particularly for cavity nesters. In Quebec black spruce forests, the oldest forests (>200yr) are unlikely to be harvested to a high degree because they have low productivity due to paludification (**Boudreault *et al.* 2002**). Forests in the 100-150 yr age bracket seem most important to conserve, since they contain bird communities that rely on old forest characteristics, such as dead wood and large diameter trees. In Alberta, old growth conifer stands (100-150yr) and aspen and mixedwood stands (>80yr) should be conserved for old-growth species.

Location of Research

Graduate student projects investigating old-growth associated species were located in four areas, one in Alberta, two in Quebec and one in Ontario (Table 6).

Table 6. Locations of graduate student projects involving old-growth associated species.

Location	Habitat	Principal Investigators (graduate students/post docs in brackets)
Alberta: Calling Lake, north-central Alberta (55? 15′ N, 113? 19′ W).	-mature to old aspen, aspen spruce mixedwood, clearcuts	Susan Hannon (Ben Olsen)
Quebec: Lac Saint-Jean, Que (48o49′N, 73o08′W) Abitibi region, northwestern Que, (48oN, 79oW) Ontario: Lake Abitibi Model Forest (49oN, 80oW)	-black spruce, jack pine, balsam fire, white birch, aspen, tamarack - black Spruce/moss forests in Que/Ontario claybelt	André Desrochers (Louis Imbeau) Pierre Drapeau (Catherine Boudreault)

Methods and Results

Bryophyte and Lichen Communities in black spruce/moss old growth forests of Quebec

Boudreault *et al.* 2002 examined four age classes of black spruce forest (80-120 years, 120-160 years, 160-200 years, >200 years). Bryophyte and lichen community composition was influenced by forest age, tree species composition and extent of paludification. Twenty-five percent of all species (n=139) were only found in one age class and the highest species richness was found in sites between 120 and 160 years of age. Mature forests (80-120 years) on well-drained sites were dominated by mosses such as Pleurozium schreberi, Ptiliumcrista castrensis, Polytrichum commune, and Dicranum polysetum and an abundance of Tuckermannopsis americana, Hypogymnia physodes, and Bryoria furcellata was highest in mature forests.

In black spruce forests of Quebec, highest bryophyte and lichen species richness was found in sites between 120 and 160 yrs

Pleurozium schreberi dominated the ground cover in the oldest sites (200yr+) (poorly drained sites with thick organic matter). These sites had high richness and cover of Sphagnum spp, particularly Sphagnum fuscum, Sphagnum angustifolium, and Sphagnum capillifolium. Cladina rangiferina, Cladina stygia, Aulacomnium palustre, and Dicranum undulatum, Mycoblastus sanguinarius, Bryoria trichodes, and Usnea spp. were more abundant in older forests. The abundance of epiphytic lichens increased with tree age, and species richness was highest where trembling aspen and jack pine were present.

Bird Communities in black spruce/moss old growth forests of Quebec

Drapeau *et al.* (2003) found that birds had highest species richness in the structurally complex old growth forest of 100-150 years of age. Communities were characterized by species associated with closed forests (such as Swainson's Thrush, Golden-crowned Kinglet and Bay-breasted Warbler), species that feed on large diameter tree trunks (such as the Brown Creeper and Red-breasted Nuthatch), and those associated with dead wood (such as Black-backed and Three-toed Woodpeckers and Yellow-bellied Sapsucker). Bird assemblages in the oldest forests (>200yr) were similar to those found in young more open forests (such as the Palm Warbler and the Common Yellowthroat, and the Yellow-rumped Warbler and the Gray Jay). The oldest forests are too open and don't have enough standing dead wood to serve as a refuge or alternative habitat for species found in the 100-150yr old forests.

In black spruce forests of Quebec, bird species richness was highest in forests of 100-150 yr

Forests >200 yrs had similar bird assemblages to young open forests

Three-toed Woodpeckers are closely associated with old growth spruce stands because they require large diameter trees (>17.5cm dbh) for nesting and roosting and snags for foraging on phloem-boring bark beetles (scolytids). **Imbeau and Desrochers (2002)** examined the foraging behaviour of this species northwest of

Three-toed woodpeckers are closely associated with old growth spruce because they require large diameter trees for nesting and roosting

Lac Saint-Jean, Quebec in summer and winter of 1997 and 1998 in continuous forest and in strips of forest left between clearcuts. The most common foraging strategy was to scale bark in search of bark beetles. Birds preferred to forage on standing snags as opposed to live trees or fallen snags in both summer and winter. These snags had mean dbh of 19cm and were in deterioration categories (based on Bergeron *et al.* 1997) of 4-6.5 (less deteriorated than unused snags) with bark cover of at least 90%. These were larger (mean dbh 20.4cm) and more deteriorated than available snags. When living trees were used for foraging, they were larger (mean dbh 20.4cm) and more deteriorated than available living trees. In concert, the results suggest that recently dead or dying large spruce trees are important habitat for foraging. Trees that have been dead for longer periods of time have lower numbers of bark beetles. Drumming trees were also predominantly snags, but they had less bark cover and a lower deterioration class.

Recently dead or dying large spruce trees are important habitat for foraging

Barred Owls in boreal mixedwood in Alberta

The barred owl is presumed to be an indicator of old-growth biological communities in the boreal ecoregion because of its association with late-succession forest (James 1993, Mazur *et al.* 1998). Their habitat requirements in the Alberta boreal mixedwood were unknown. **Olsen (1999)** examined habitat selection of this species in north central Alberta boreal mixedwoods at 3 spatial scales: nest site, foraging locations within the home range and the home range. Owls nested in cavities in old aspen or balsam poplar trees: the average diameter at breast height of trees used for nesting was 51 cm; the smallest nest tree was 34 cm dbh. Trees chosen as nest sites were taller and had greater diameter at breast height than unused sites.

The barred owl is an indicator of old-growth communities in the boreal because of its association with late-succession forests

To determine if snags were limiting, the density and size class distribution of snags between nesting sites, unused sites and randomly chosen sites from greater landscape were compared. The area directly around the nest tree contained a greater number of large diameter snags (30-60cm dbh) compared with unused sites on the territory and at randomly chosen sites across the landscape. The density of potential nest trees (i.e. >34cm dbh) was significantly lower at unused versus used sites. Similarly, the density of snags at the landscape sites was significantly lower than at the nesting sites. Olsen found densities of 27 old trees/ha around nest sites, 7.5 old trees/ha at other spots in the home range and 3 old trees/ha across the landscape. This suggests a high selection for groups of old trees and also that these old trees are not plentiful across the landscape.

In Alberta, barred owls prefer groups of old trees, and chose trees with an average DBH of 51 cm for nesting

Some owls nested in large patches of forest but most occurred in patches less than or equal to 15 ha, with some as small as 2 ha in size. While birds foraged in both old and young forest and did not appear to avoid cutblock edges, Olsen noted that several birds with territories near cutblocks were killed by Great-horned Owls, a species that increases at moderate levels of forest fragmentation.

Management Relevance

Recently dead or dying large (>17.5 cm dbh) spruce trees are important habitat for foraging woodpeckers. Groups of trees should be left in cuts, however this is a short-term solution, given the short window of time that trees are suitable for foraging.

Recently dead or dying large spruce trees are important habitat for woodpeckers

Old live, dying and dead deciduous trees such as aspen and poplar are important elements to retain in the landscape as they serve as source of propagules for the inoculation of conifers with lichens, as nest trees for woodpeckers (>17.5cm dbh), and as nest trees for Barred Owls (>33-77cm dbh, mean 51cm dbh). Patches of old trees around nest sites are also used by young barred owls for a few weeks after nesting.

Old deciduous trees serve as inoculation sources for lichens, and nest trees for woodpeckers and barred owls

Preservation of healthy trees or groups of healthy trees has to be made to allow recruitment over time of senescent or standing dead trees in various stages of decomposition for woodpeckers, cavity nesters and epiphytic lichens. For owls, clumps of standing live trees (patches of 2-15 ha with at least 27 trees/ha) should be left in cutblocks to develop into old trees that can be used by owls as the forest ages. However, it is not known whether Barred Owls will use isolated clumps of old trees in the middle of cutblocks. Another option might be to extend the rotation period of some forest blocks to allow them to develop some old-growth characteristics.

For owls, clumps of standing live trees (2-15 ha, > 27 trees/ha) should be left in cutblocks

To conserve species such as the Three-toed Woodpecker, the Barred Owl and other cavity nesting species over the long-term, large blocks of old forest should be maintained to ensure an adequate supply of appropriate foraging and nesting trees. We suggest that the large blocks of old forest be 1200 ha in size based on winter home range size of Barred Owls in Saskatchewan (Mazur *et al.* 1997), however, this is just a guess and more work is required to determine forest reserve size that will maintain all old-growth species. Since lichen communities change as the forest ages, there is also a need for protected areas representing each stage of the mature to old-growth sequence.

To conserve cavity nesting species over the long term, large blocks (≥1200 ha) of old forest should be maintained

Imbeau *et al.* (2001) listed 8 species in eastern coniferous forests that would be most threatened by clearcutting: Three-toed Woodpecker, Black-backed Woodpecker, Pileated Woodpecker, Boreal Owl, Boreal Chickadee, Brown Creeper, Barrow's Goldeneye and Bufflehead. **Schmiegelow and Mönkkönen (2002)** noted that the following species are old forest specialists in western boreal forests: Bay-breasted Warbler, Three-toed Woodpecker, Black-backed Woodpecker, Pileated Woodpecker, Black-throated Green Warbler, Cape May Warbler, Boreal Chickadee, Brown Creeper, Black-poll Warbler, Canada Warbler, Downy Woodpecker, Hairy Woodpecker, Golden-crowned Kinglet, Magnolia Warbler, Red-breasted Nuthatch, Swainson's Thrush, Western Tanager, Winter Wren, White-winged Crossbill. The Barred Owl should be included as well, due to its need for large diameter snags for nesting.

To conserve bryophytes and lichen, minimize disturbances to ground cover during harvest, and use partial cutting

To conserve bryophytes and lichens, minimize disturbances to the ground cover during harvest and use partial cutting or selective harvesting. Scarification and controlled burning of sites after cutting might mitigate the differences between fire-origin stands and logged stands for lichens.

Future Research Questions

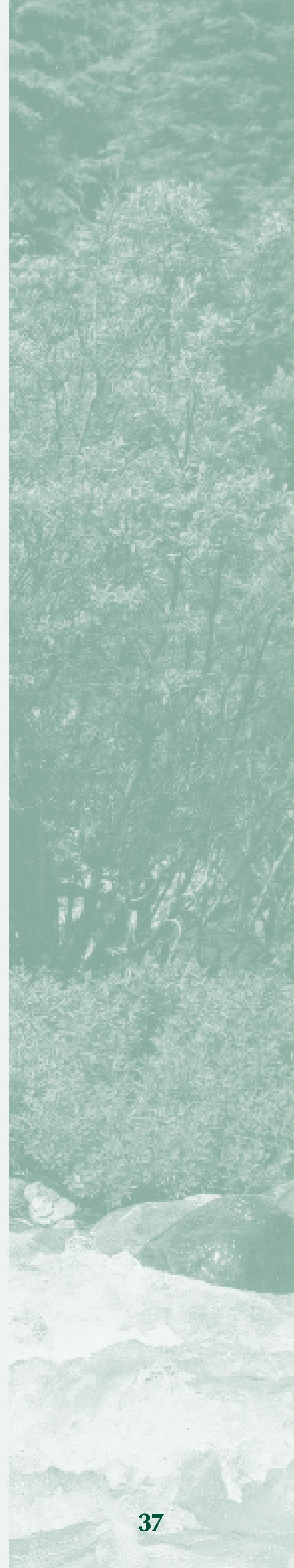
1. How large should old forest reserves be to maintain old forest dependent species? Where should these be located (upland, riparian?)? How many reserves should there be?

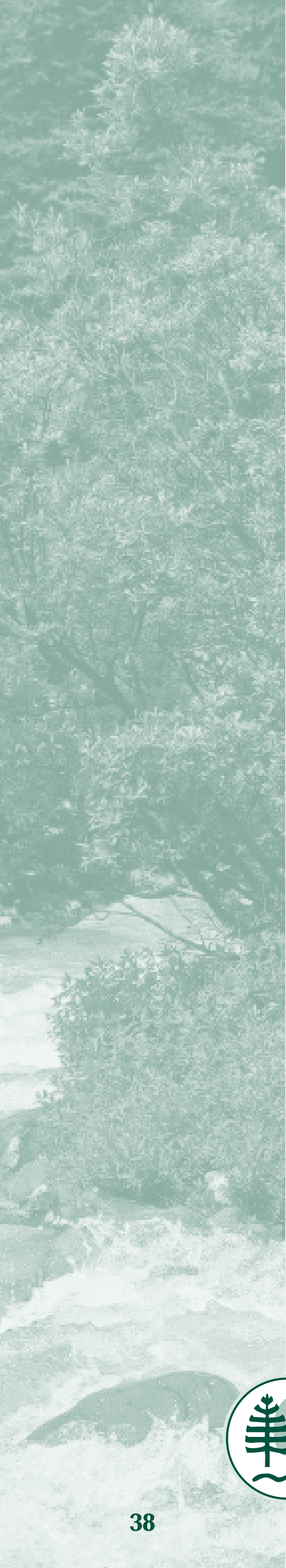
2. Will retention of groups of trees within cuts maintain old growth species? How many trees, what species and what dbh classes should be left?

3. Will partial or selective harvesting techniques retain old forest species over the long-term?

Graduate Student Projects: Old-growth Associated Species Key Points

- Predictably, old-growth forest will be reduced in the face of short-rotation, even-aged management.
- In Quebec, forests 100-150 years old seem most important to conserve. In Alberta, old growth conifer (100-150 yrs) and aspen and mixedwood (>80 yrs) should be conserved.
- In black spruce forests of Quebec, highest bryophyte and lichen species richness was found in sites between 120 and 160 years old.
- In black spruce forests of Quebec, bird species richness was highest in forests of 100-150 years of age.
- Recently dead or dying large spruce trees are important habitat for foraging.
- The Barred Owl is presumed to be an indicator of old-growth communities in the boreal ecoregion because of its association with late-succession forests.
- In Alberta, Barred Owls demonstrated high selection for groups of old trees, and chose trees with an average DBH of 51 cm for nesting.
- Recently dead or dying large (>17.5 cm DBH) spruce trees are important habitat for woodpeckers.
- Old live, dying and dead deciduous trees are important to retain since they serve as inoculation sources for lichens, and nest trees for woodpeckers and Barred Owls.
- To conserve cavity-nesting species over the long term, large blocks of old forest (≥1200 ha) should be maintained.
- To conserve bryophytes and lichen, minimize disturbances to ground cover during harvest, and use partial cutting.





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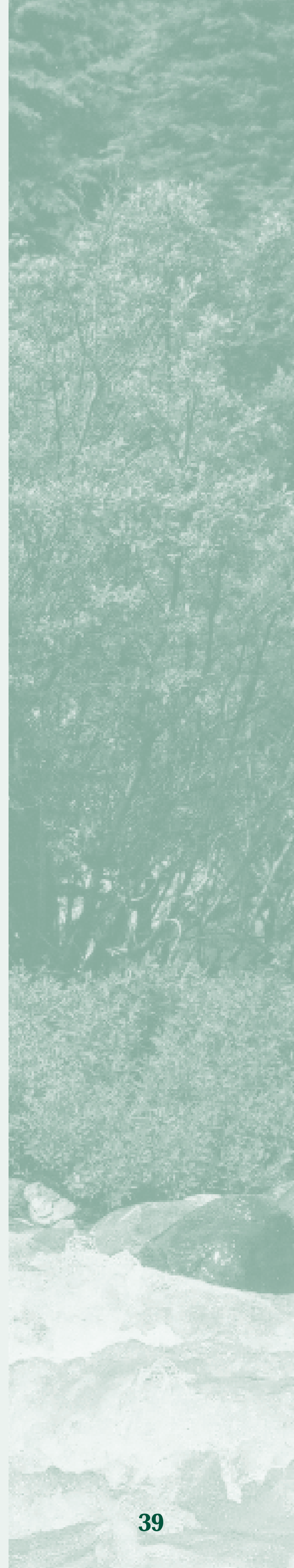

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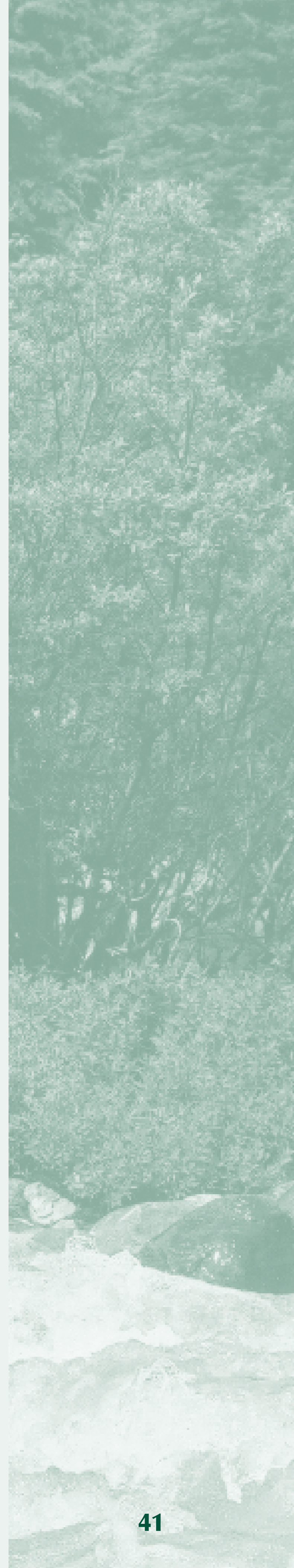

Appendix 1.

Scientific names for all mammal and bird species mentioned in paper, ordered alphabetically.

Common name	Scientific name
Mammals	
deer mouse	*Peromyscus maniculatus*
red-backed vole	*Clethrionomys gapperi*
red squirrel	*Tamiasciurus hudsonicus*
short-tailed shrew	*Blarina brevicauda*
short-tailed weasel	*Mustela erminea*
woodland jumping mouse	*Napaeozapus insignis*
Birds	
Alder Flycatcher	*Empidonax alnorum*
American Kestrel	*Falco sparvarius*
American Redstart	*Setophaga ruticilla*
American Robin	*Turdus migratorius*
Barred Owl	*Strix varia*
Barrow's Goldeneye	*Bucephala islandica*
Bay-breasted Warbler	*Dendroica castanea*
Black-and-white Warbler	*Mniotilta varia*
Black-backed Woodpecker	*Picoides arcticus*
Blackburnian Warbler	*Dendroica fusca*
Black-poll Warbler	*Dendroica striata*
Black-throated Bue Warbler	*Dendroica caerulescens*
Black-throated Green Warbler	*Dendroica virens*
Boreal Chickadee	*Poecile hudsonicus*
Boreal Owl	*Aegolius funereus*
Brown Creeper	*Certhia americana*
Bufflehead	*Bucephala albeola*
Canada Warbler	*Wilsonia candensis*
Cape May Warbler	*Dendroica tigrina*
Cedar Waxwing	*Bombycilla cedrorum*
Chestnut-sided Warbler	*Dendroica pensylvanica*
Chipping Sparrow	*Spizella passerina*
Chipping Sparrow	*Spizella passerina*
Connecticut Warbler	*Oporornis agilis*
Common Yellowthroat	*Geothlypis trichas*
Connecticut Warbler	*Oporornis agilis*
Dark-eyed Junco	*Junco hyemalis*
Downy Woodpecker	*Picoides pubescens*
Eastern Bluebird	*Sialia sialis*
Evening Grosbeak	*Coccothraustes vespertinus*

Common name	Scientific name
Golden-crowned Kinglet	*Regulus satrapa*
Gray Jay	*Perisoeius canadensis*
Great-horned Owl	*Bubo virginianus*
Hairy Woodpecker	*Picoides villosus*
Hermit Thrush	*Catharus guttatus*
House wren	*Troglodytes aedon*
Least Flycatcher	*Empidonax minimus*
Magnolia Warbler	*Dendroica magnolia*
Mourning Warbler	*Oporornis philadelphia*
Northern Flicker	*Colaptes auratus*
Northern Hawk-Owl	*Surnia ulula*
Northern Parula Warbler	*Parula americana*
Northern Waterthrush	*Seiurus noveboracensis*
Olive-sided Flycatcher	*Contopus borealis*
Orange-crowned Warbler	*Vermivora celata*
Ovenbird	*Seiurus aurocapillus*
Palm Warbler	*Dendroica palmarum*
Philadelphia Vireo	*Vireo philadelphicus*
Pileated Woodpecker	*Dryocopus pileatus*
Pine Siskin	*Carduelis pinus*
Purple Finch	*Carpodacus purpureus*
Rose-breasted Grosbeak	*Pheucticus ludoviciana*
Red-breasted Nuthatch	*Sitta canadensis*
Red-eyed Vireo	*Vireo olivaceus*
Ruby-crowned Kinglet	*Regulus calendula*
Ruffed Grouse	*Bonasa umbellus*
Swainson's Thrush	*Catharus ustulatus*
Tennessee Warbler	*Vermivora peregrina*
Tree Swallow	*Tachycineta bicolor*
Three-toed Woodpecker	*Picoides tiydactylus*
Veery	*Catharus fuscescens*
Western Tanager	*Piranga ludoviciana*
Western Wood Pewee	*Contopus sordidulus*
White-throated Sparrow	*Zonotrichia albicollis*
White-winged Crossbill	*Loxia leucoptera*
Wilson's Warbler	*Wilsonia canadensis*
Winter Wren	*Troglodytes troglodytes*
Yellow-bellied Sapsucker	*Sphyrapicus varius*
Yellow-rumped Warbler	*Dendroica coronata*

Appendix 2. Results of studies on harvesting and reproductive success in the LSB Project.

Location	Forest type	Approach	Results	Applications	Researchers
Lac St.-Jean, Que 49°09'N, 72°58'W	Black spruce left in buffer strips, leave strips, forest blocks -recent (1990) clearcuts covered 50% of area	Artificial nests (quail egg, plasticine egg) placed in forest on grid 1km apart -looked at local vs landscape effects -1997, 1998	-nest predation high 67% (1997) and 74% (1998) - gray jays predators on arboreal nests -small squirrels (mostly red, but also northern flying, eastern chipmunk) predators on arboreal and ground nests -factors influencing predation rate varied over years and scales -clearcutting only important for squirrels at 250 and 500m radius around nests (+ve)	- at this level of harvest, clearcutting did not affect gray jay predation but increased squirrel predation -red squirrel avoid clearcuts, crowd into remaining forest and find nests opportunistically	**Boulet *et al.* 2000**
Lac St.-Jean, Que 49°09'N, 72°58'W	Black spruce riparian strips (60m wide), leave strips (60m wide), (strips created 1996), forest blocks (>1km ^{2}) -recent (1990) clearcuts covered 50% of area	-artificial nests as above -point counts in breeding stage -mobbing calls in nestling stages -predators counted during breeding point counts 1997,1998	-gray jays and red squirrels most common predators -gray jays similar abundance in strips and controls and attacked more arboreal nests - red squirrel a bit more common in controls and attacked more ground nests -nest predation same in strips and controls -lower numbers of breeding forest species in strips (especially Bay Breasted Warbler, golden-crowned kinglet, boreal chickadee)	-logging did not change predator community (i.e. no increase in generalist predators) or increase predation -but concern about some forest species avoiding strips	**Boulet *et al.* 2003**
Appalachian highlands, northwestern NB (47°N, 67°W);	-sugar maple, yellow birch, American beech and lowlands of black and white	- chickadee mobbing calls at stations in grids on intensively managed and moderately managed	Northern Parula Warbler had 2 times higher reproductive activity and Black-capped chickadees had 5.4 times higher reproductive activity on the moderately	- high intensity management reduced reproductive activity of 2 of 8 focal species	**Gunn 2004**

Location	Forest type	Approach	Results	Applications	Researchers
	spruce, eastern white cedar and balsam fir. Two landscapes : moderately managed (plantations and commercial clearcuts covered < 10% of the surrounding landscape; partial cuts in tolerant hardwood stands covered < 15% of the landscape) and intensively managed (plantation silviculture covered > 30% of the surrounding landscape ; moderate level of partial harvesting).	landscapes. -measured proportion of stations where reproductive activity recorded for 8 focal species.	managed area than on the intensively managed grid.		
Riley Brook, NB $47^{o}11'N, 67^{o} 13'W$	Mature hardwoods (maple, beech, birch) and adjacent black spruce plantations	-artificial nests (plasticine) placed across edge between hardwoods and plantations	-26% (1998) 38% (1999) nests depredated -most common predators were black bear, coyote, eastern chipmunk, red squirrel,	- difficult to predict patterns of predation due to variation in abundance of predator communities	**Carignan & Villard 2002**

Location	Forest type	Approach	Results	Applications	Researchers
	(8-11yr old)	1998,1999	micromammals (deer mice, voles, shrews) and corvids -black bears important in one year, micro-mammals in another year -no consistent effects of vegetation structure or whether nest in plantation or mature stands between years -predation near edge not higher		
Riley Brook, NB 47°11'N, 67° 13'W	Mature hardwoods (maple, beech, birch)	-2 landscapes- intensively harvested (45% forest cover) and moderately harvested (70% forest cover) -used uncut and selection cuts - Black throated blue Warbler, Ovenbird -abundance and reproductive success 1998,1999	-sample sizes small -Black throated blue Warbler positive density and reproductive success to selection cutting -Ovenbird- negative -no influence on reproductive success of the larger landscape context (moderate vs intensive harvest)	-selection cutting not good for Ovenbird as understory too developed -need some closed canopy forest stands	**Bourque & Villard 2001**
Calling Lake, AB 55°19'N, 113° 27'W	Mature and old boreal mixedwood (aspen, white spruce), clearcuts (8% harvested in (1993,1994)	-artificial nests, placed at forest recent clearcut edges, interior aspen stands, aspen-spruce edges 1995,1996	-predators red squirrels, murid rodents -33% (1995) to 19% (1996) predation on arboreal nests, 20% to 9% on ground nests -predation level not different for between interior and clearcut edges -no consistency between years on predictors of predation risk	-predation levels varied annually -probably not a forestry issue, but difficult to measure given high annual variability	**Song & Hannon 1999**

Location	Forest type	Approach	Results	Applications	Researchers
Boreal mixedwood, Abitibi, Que 48°N 79'W	Mature mixedwood (aspen, spruce) -fires (3yr), clearcuts (<5yr), agriculture (60yr)	-artificial and real nests at forestry and agricultural edges and natural edges -reproductive index using mobbing call 2000	-52% predation rate overall -predators mainly red squirrel, chipmunk, corvids, micromammals -predation on artificial nests was higher in anthropogenic landscapes than natural ones and was higher on nests that had more concealment -distance from edge did not affect predation rate and predation at edges of anthropologic and natural disturbance did not differ -mammals probably the predators as they are abundant in areas with high understory, common in fragmented areas -note that a tent caterpillar outbreak in some areas affected the results	-landscape effect on predation, possibly due to higher understory development and larger small mammal abundances	**Brongo 2002**

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