# PROJECT REPORT 1999-9

sustainable forest management network

réseau sur la gestion durable des forêts

## Landscape-scale changes in the forest cover of eastern boreal mixed-wood forests and their effects on bird communities

A Network of Centres of Excellence
Un réseau de centres d'excellence

**Pierre Drapeau and Jean-François Giroux**

For copies of this or other SFM publications contact:

Sustainable Forest Management Network
G208 Biological Sciences Building
University of Alberta
Edmonton, Alberta, T6G 2E9
Ph: (780) 492 6659
Fax: (780) 492 8160
http://www.biology.ualberta.ca/sfm/

ISBN 1-55261-023-3

# Landscape-scale changes in the forest cover of eastern boreal mixed-wood forests and their effects on bird communities

**SFM Network Project: Influence of landscape structure on songbirds dynamics in the boreal mixed-wood forest**

by

**Pierre Drapeau and Jean-François Giroux**

Groupe de recherche en écologie forestière interuniversitaire (GREFi),
Département des sciences biologiques, Université du Québec à Montréal,
C. P. 8888, Succursale Centre-Ville, Montréal, Québec, Canada H3C 3P8.

**May 1999**

# ABSTRACT

Bird community response to landscape-scale changes in forest cover was studied in three mixed-wood landscapes in Quebec's boreal forests modified by different types of disturbances: (1) a pre-industrial landscape where human settlement, agriculture and logging activities date back to the early 1930's, (2) an industrial timber managed forest and (3) a forest dominated by natural disturbances. Birds were sampled at 459 sampling stations distributed among the three landscapes. Local habitat and landscape characteristics of the context surrounding each sampling station (500 m and 1-km radius) were also computed. Bird communities were influenced by landscape-scale changes in the forest cover. In both human-disturbed landscapes the higher proportion of early-successional habitats resulted in significantly higher abundance of early-successional bird species. Landscape-scale conversion of mature forests from mixed-wood to deciduous cover in human-disturbed landscapes was the main explanatory factor for changes in species composition of mature forest bird communities. In these landscapes, the abundance of species associated with mixed and coniferous forest cover was lower whereas species that preferred a deciduous cover were more abundant. Decreases outnumbered increases. Our results indicate that this large-scale conversion of the southern portion of the boreal forest may be one of the most important threat to the integrity of bird communities in these forest mosaics. Implications for both sustainable forest management and bird habitat management are discussed.

## INTRODUCTION

In the last forty years, commercial timber management has become the prevalent perturbation in many parts of the boreal forest (Franklin and Forman 1987; Spies et al. 1994; Enoksson et al. 1995; Anglestam 1996). Timber management can considerably modify the structure and composition of forest mosaics (Carleton and McLellan 1994; Edenius and Elmberg 1996; Spies et al. 1994; Gauthier et al. 1996; Bergeron and Harvey 1997). Timber rotation length for even-aged silvicultural systems change the age-class distribution of forest types at the landscape scale (Spies et al. 1994; Hejl et al. 1995; Thompson et al. 1995). Mature and old-growth forest types become less common while the proportions of early-successional and young forest types increase (Hansen et al. 1991; Hunter 1992; Cumming et al. 1994; Hejl et al. 1995; Hagan et al. 1997). In boreal mixed-wood forests, short return intervals between logging activities also change the tree-species composition of forest mosaics, usually with an increase in deciduous forest cover (Gauthier et al. 1996; Bergeron and Harvey 1997).

These landscape-scale changes in forest cover raise concerns on how successfully can managed forests substitute for natural forests in offering suitable habitat conditions to maintain biodiversity (Noss 1993; Hejl et al. 1995). Large-scale changes to forests under management and their effects on birds have been documented in northern European boreal landscapes, (Helle and Järvinen 1986; Väisänen et al. 1986; Edenius and Elmberg 1995). In North American boreal forests however, few studies have addressed the issue of forest management and its impacts on birds at the landscape level (but see McGarigal and Mc Comb 1995; Schmiegelow et al. 1997). Most research has been conducted at the stand or habitat level (Freedman et al. 1994; Hejl et al. 1995).

In this report, we examine how bird communities respond to landscape changes in forest cover that result from large-scale disturbances, using research results in three Quebec's boreal mixed-wood forest landscapes. We assess relationships between bird communities and forest mosaic characteristics and focus on the consequences for bird communities of differences between landscape patterns created by human-disturbances and natural disturbances.

## STUDY AREA AND METHODOLOGICAL APPROACH

The study was conducted in the Abitibi region, northwestern Quebec ($48^0$ N, $79^0$ W), an area that is part of the Northern Claybelt of Quebec and Ontario. Located at the southern limit of the boreal forest, this area is characterized by a mixed-wood composition dominated by balsam fir (*Abies balsamea*), black spruce (*Picea mariana*), and paper birch (*Betula papyrifera*) with white spruce (*Picea glauca*) and trembling aspen (*Populus tremuloides*) as co-dominants (Rowe 1972). Relationships between bird communities and forest mosaic characteristics were determined in a study area of 350 $km^2$, characterized by different types of disturbances in three contiguous landscapes: (1) a pre-industrial landscape where human settlement, logging activities and agriculture date back to the early 1930's, (2) an industrial timber managed landscape characterized by recent commercial harvesting (< 20 years) of the forest and (3) a natural mixed-wood boreal forest landscape that is mainly affected by fire and insect outbreak disturbances.

Landscape-scale patterns of bird community structure and composition were investigated over the entire forest mosaic, including all forest types rather than focusing on a single habitat type (e.g., mature forests). We used a stratified sampling design to cover the range of forest types in each landscape while accounting for the heterogeneity of forest mosaics (juxtaposition of forest types). In each landscape, sampling stations were grouped by line transects to maximize time spent sampling, minimize time traveling between sites and consider interstand heterogeneity of forest mosaics. From four to six stations were located along line transects 1.2 to 2.5 km long. Line transects were separated by at least 1 km. Distance between stations varied from 250 to 400 m ensuring independence between stations (Bibby et al. 1992). Each station was within a relatively homogeneous forest type. Overall, 459 sampling stations along 100 line transects provided extensive coverage of the study area.

Data on bird species occurrence and abundance were recorded over an unlimited distance around each station. Sampling stations were visited twice during the breeding season, once in the first half and once in the second half of June. A methodological study on the efficiency of the point count method in characterizing bird community species richness and composition at the scale of individual points (Drapeau et al. *in press*, a) was used to establish the sampling procedure. Features of vegetation structure and composition were quantified at each sampling station from mid-July to mid-August. At each station, five 10 X 10 m quadrats were located as follows: one at the center of the station and the others oriented in the cardinal compass directions 30 m from the center. In each quadrat, we measured and calculated 24 habitat variables. The composition and configuration of the landscape surrounding each sampling station was measured in concentric circles of increasing radii of 500 m and 1 km. Landscape composition was assessed by calculating within each circle the proportion of area occupied by each forest and non-forest habitat type. Landscape configuration was measured with four indices known to influence bird distribution ; habitat heterogeneity, edge sensitivity, and two measures of core habitat. For more details on methods used in this research see Drapeau et al. (*in press*, b).

## OVERALL PATTERNS

Total bird diversity index (gamma diversity) in forest mosaics of the three landscapes reached their highest values in human-disturbed landscapes (Table 1). Similar patterns were obtained for beta diversity whereas no significant difference was observed at the scale of alpha diversity. These results suggest that increases in total bird diversity (gamma diversity) in forest mosaics of both human-disturbed landscapes are mainly associated with the increased proportion of early-successional habitats created by logging (industrial landscape) and the abandonment of cultivated fields (pre-industrial landscape). Increases in the regional importance of early-successional habitats provided ecological opportunities for additional species that were less abundant in small forest openings (such as openings created by spruce budworm outbreaks) of the natural landscape. This increased the length of the bird community gradient and, hence, the species turnover rate (beta diversity) in both human-disturbed landscapes. Human disturbances in the composition and configuration of these forest mosaics did not, however, result in "species packing" of birds, so species diversity at the local scale (alpha diversity) did not increase (Table 1).

Table 1. Descriptive statistics and results of one-way ANOVA on comparisons of bird community structure parameters among the three landscapes and four forest types (deciduous, mixed-deciduous, mixed-coniferous, coniferous) of a boreal mixedwood forest in Abitibi, Quebec. Significant differences between landscapes are indicated by different letters.

| Community parameters | Pre-industrial n = 164 | | Industrial n = 169 | | Natural n = 126 | | F | Prob. | HSD Tukey's |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | | | |
| Alpha diversity[†] | 20.13 | 5.17 | 20.11 | 4.40 | 19.28 | 4.59 | 1.44 | 0.239 | A, A, A |
| Beta diversity[‡] | 2.61 | | 2.29 | | 1.88 | | | | |
| Gamma diversity[§] | 88 | 3.05 | 89 | 2.75 | 70 | 1.71 | | | |

[†] Alpha diversity refers to the mean number of species detected in a sampling station.
[‡] Beta diversity represents the turnover of species among sampling stations in each landscape. Details on how it is measured are specified in the methodology
[§] Gamma diversity refers to total species richness for the entire landscape. It is estimated following a Jacknife procedure (Heltshe and Forrester 1983), to control for differences in sample size among landscapes.

## BIRD COMMUNITY RESPONSE TO INCREASES OF EARLY-SUCCESSIONAL FOREST TYPES

Several studies have documented changes in bird communities at the stand level following forestry activities (Conner and Adkisson 1975; Morgan and Freedman 1986, Yahner 1986; Welsh 1987; Thompson et al. 1992). These studies have shown how the near complete removal of forest vegetation following clearcuts leads to a different set of bird species from those of mature forests. However, cumulative impacts of such forestry practices on bird communities at the landscape scale have been far less documented (Dobkin 1994; Hejl et al. 1995). Our study shows that stand-scale changes following timber activities produce important changes in forest cover of landscape mosaics and hence in the composition of bird communities at the landscape scale. Species adapted to early-successional forests become more abundant in preferential habitats in both industrial and pre-industrial landscapes (Fig.1). Our results thus support predictions that early-successional species will increase in managed forest landscapes (Raphael et al. 1988; Hagan et al. 1997).

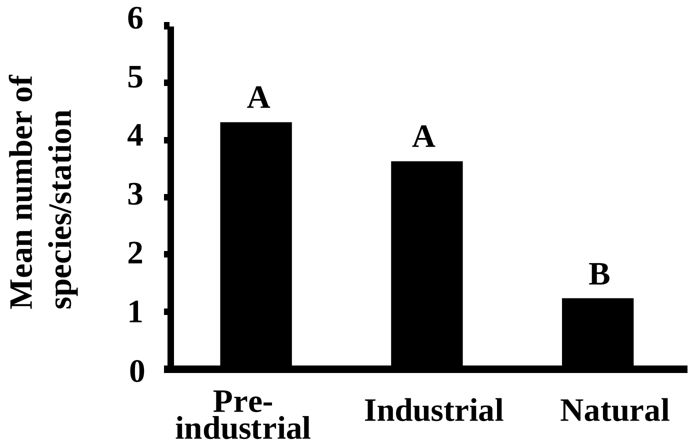


Figure 1. Changes in mean number early successional species per sampling station in Quebec's boreal mixed-wood forests. Comparisons were conducted using two-way ANOVA's with the three landscapes and four forest types (deciduous, mixed-deciduous, mixed-coniferous, coniferous). Means and standard deviations (±1 SD) of species richness were estimated on a subset of 127 sampling stations corresponding to early-seral habitats.

## BIRD RESPONSE TO CHANGES IN MATURE FORESTS

The mean number of mature forest bird species was significantly lower in the industrial and pre-industrial landscapes compared with the natural landscape (Fig. 2).

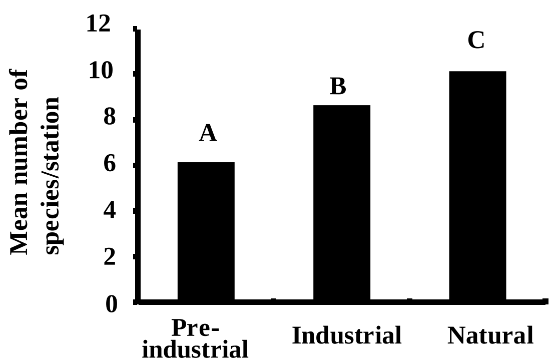


Figure 2. Changes in mean number of mature forest bird species in Quebec's boreal mixed-wood landscapes. Comparisons were conducted using two-way ANOVA's with the three landscapes and four forest types (deciduous, mixed-deciduous, mixed-coniferous, coniferous). Means of species richness were estimated on 221 stations in mature forests. Significant differences are indicated by different letters.

Important changes in bird species composition of mature forests also occurred across the three landscapes (Fig. 3).

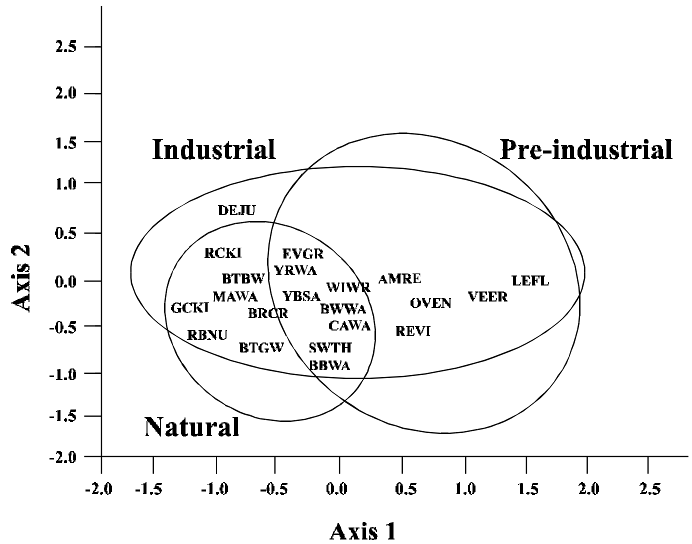


Figure 3. Ordination of the bird species on the first two axes of the CA of bird community data for the subset of 221 stations sampled in mature forest stands. For each landscape 67% concentration ellipses are presented. Only species significantly associated to each axis are presented. Abbreviations are: AMRE; American Redstart, BBWA; Bay-breasted Warbler, BRCR; Brown Creeper, BTBW; Black-throated Blue Warbler, BTGW; Black-throated Green Warbler, BWWA; Black-and-white Warbler, CAWA; Canada Warbler, DEJU; Dark-eyed Junco, EVGR; Evening Grosbeak, GCKI; Golden-crowned Kinglet, LEFL; Least Flycatcher, MAWA; Magnolia Warbler, OVEN; Ovenbird, RBNU; Red-breasted Nuthatch, RCKI; Ruby-crowned Kinglet, REVI; Red-Eyed Vireo, SWTH; Swainson's Thrush, VEER; Veery, WIWR; Winter Wren, YBSA; Yellow-bellied Sapsucker, YRWA; Yellow-rumped Warbler.

Boreal species became significantly less abundant from the natural to the pre-industrial landscape (Table 2).

Table 2. Frequency of occurrence of mature forest bird species and results of G tests comparing their distribution in the three landscapes in Abitibi, Quebec. Only species for which loadings on the CA ordination strongly contributed to structure the first two axes of the ordination diagram are presented. Species are listed from most significant differences in occurrence among landscapes to least different. Mature forests include deciduous, mixed and coniferous stands > 12 m with closed and open canopy.

| Species | Pre-industrial (N = 62) | Industrial (N = 66) | Natural (N = 93) | G values |
|---|---|---|---|---|
| Blackburnian Warbler | 9 | 17 | 56 | 24.93*** |
| Golden-crowned Kinglet | 12 | 35 | 66 | 22.51*** |
| Veery | 44 | 26 | 23 | 18.11*** |
| Black-throated Blue Warbler | 13 | 15 | 46 | 12.11** |
| Red-breasted Nuthatch | 10 | 24 | 44 | 11.56** |
| Dark-eyed Junco | 2 | 13 | 18 | 10.41** |
| Magnolia Warbler | 24 | 52 | 59 | 9.03* |
| Bay-breasted Warbler | 7 | 15 | 32 | 8.93* |
| Least Flycatcher | 25 | 21 | 16 | 7.78* |
| Black-throated Green Warbler | 11 | 19 | 39 | 7.49* |
| Ruby-crowned Kinglet | 20 | 37 | 58 | 7.39* |
| Yellow-rumped Warbler | 17 | 32 | 51 | 7.00* |
| Swainson's Thrush | 34 | 50 | 83 | 6.08* |
| Evening Grosbeak | 11 | 18 | 36 | 5.94 $^{NS}$ |
| Canada Warbler | 14 | 15 | 37 | 5.20 $^{NS}$ |
| Brown Creeper | 6 | 13 | 23 | 4.95 $^{NS}$ |
| Yellow-bellied Sapsucker | 26 | 45 | 58 | 4.46 $^{NS}$ |
| Winter Wren | 39 | 54 | 87 | 4.44 $^{NS}$ |
| Black-and-white Warbler | 40 | 43 | 43 | 3.35 $^{NS}$ |
| Ovenbird | 57 | 50 | 78 | 1.00 $^{NS}$ |
| American Redstart | 49 | 47 | 73 | 0.34 $^{NS}$ |

*$P$ < 0.05; **$P$ < 0.01; ***$P$ < 0.001; NS, not significant

This downward trend was in part consistent with the loss of mature forests that characterizes human-disturbed landscapes (Andrén 1994, Hagan et al. 1997). Conversion of mature forests from mixed-wood to deciduous across the three landscapes was, however, the main factor for the differences in abundance patterns of mature forest birds across landscapes (Fig. 4). Decreases in proportion of mixed-wood stands from the natural, to the industrial and the pre-industrial landscapes (Fig. 4) follows the same pattern as the reduction in mean number of mature forest species (Fig. 3). Species associated to mixed and coniferous forest cover such as blackburnian warbler, black-throated blue warbler, black-throated green warbler, red-breasted nuthatch, golden-crowned kinglet, and ruby-crowned kinglet became less abundant in mature forests of industrial and pre-industrial landscape mosaics while frequency of occurrence of species associated to deciduous forests such as veery and least flycatcher increased (Table 2).

Overall, significant declines in the frequency of occurrence of mature forest species outnumbered increases.

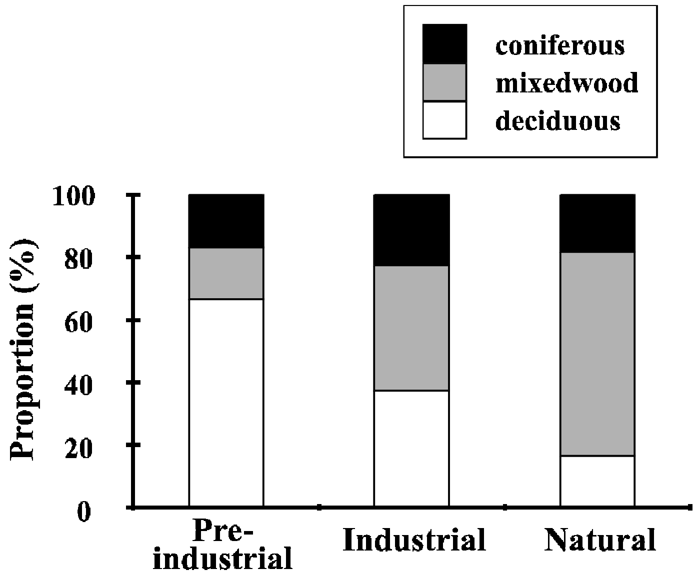


Figure 4. Proportion of mature forests dominated by a deciduous, mixed and coniferous cover in Quebec's mixed-wood boreal forest landscapes.

## MANAGEMENT IMPLICATIONS

Recent studies advocate that changes in the age-class distribution of stands in forest mosaics due to short timber rotation length in managed forests is one important long-term effect of forest management on boreal forest ecosystems and their wildlife (Cumming et al. 1994; Spies et al. 1994; Wallin et al. 1994; Gauthier et al. 1996). As shown by our results, increases in the proportion of early-successional habitats and decreases in mature and old-growth habitats influence landscape-scale patterns of wildlife populations and communities. Hence, the high regional abundance of bird species associated with early-successional habitats found in our industrial landscape could likely persist in managed forest landscapes. Likewise, short timber rotations in managed boreal mixed-wood landscapes may favor the dominance of a deciduous forest cover and result into large-scale changes in the species composition of mature forest bird communities. Projections of forest mosaic diversity based on a model of natural forest dynamics after fire in the boreal mixed-wood forest indicate that managed landscapes will become dominated by deciduous forest types if current silviculture practices are maintained (Gauthier et al. 1996). In addition, Carleton and McLellan (1994) have showed that post-fire stands mostly regenerated to coniferous forests and boreal mixed-woods whereas post-logged stands were almost entirely deciduous. They advocate the large-scale conversion from conifer to broadleaf forests that is currently underway in the boreal mixed-wood forest is in part related to impacts of forestry practices on vegetation regeneration.

In eastern boreal mixed-wood forests, short timber rotations (Spies et al. 1994; Gauthier et al. 1996) coupled with effects of industrial logging on vegetation regeneration (Carleton and McLellan 1994) should produce a greater proportion of deciduous forest cover than in unmanaged forests. We believe that this pattern will be prevalent in the next timber rotation. For bird communities, this conversion of mature forests from mixed-wood to deciduous cover may jeopardize their ecological integrity, notably through collapses of regional populations of bird species' associated with mixed and coniferous mature forests.

Changes in species composition of bird communities may be attenuated however, provided that current forestry practices are modified in managed forest landscapes. Approaches that are based on patterns and processes of natural ecosystem dynamics have recently been proposed as new models of silviculture that can conciliate cost-effective wood production with maintenance of biodiversity (Haila et al. 1994; Bergeron and Harvey 1997). In boreal mixed-wood forests, Bergeron and Harvey (1997) proposed combining several stand-level silvicultural treatments in order to favor the transition between forest types (deciduous, mixed-wood, coniferous) rather than the traditional cyclical rotation of similarly composed stands. At the landscape level, they urged forest managers to plan towards maintaining a proportion of deciduous, mixed-wood and coniferous forest types that is close to the proportion found in natural forest mosaics of the boreal mixed-wood forest. Guidelines on proportions of stand types to maintain for different rotation periods could be set with landscape-scale models of forest dynamics for different natural disturbance regimes (Gauthier et al. 1996, Bergeron et al. 1999).

## REFERENCES

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos 71: 355-366.

Anglestam. 1996. The ghost of forest past-natural disturbance regimes as a basis for reconstruction of biologically diverse forests in Europe. Pages 287-337 *in* R. M. DeGraaf and R. I. Miller, editors. Conservation of faunal diversity in forested landscapes. Chapman and Hall, New York, New York.

Bergeron, Y., and B. D. Harvey. 1997. Basing silviculture on natural ecosystem dynamics: an approach applied to the southern boreal mixed-wood forest of Québec. Forest Ecology and Management 92: 235-242.

Bergeron, Y., B. Harvey, A. Leduc and S. Gauthier. 1999. Forest management guidelines based on natural disturbance dynamics: Stand and forest level considerations. Forestry. Chronicle 75: 1-6.

Carleton, T. J., and P. McLellan. 1994. Woody vegetation responses to fire versus clear-cutting logging: A comparative survey in the central Canadian boreal forest. Ecoscience 1: 141-152.

Conner, R. N., and C. S. Adkisson. 1975. Effects of clearcutting on the diversity of breeding birds. Journal of Forestry 73: 781-785.

Cumming, S. G., P. J. Burton, S. Prahacs, and M. R. Garland. 1994. Potential conflicts between timber supply and habitat protection in the boreal mixed-wood of Alberta, Canada: a simulation study. Forest Ecology and Management 68: 281-302.

Drapeau. P., A. Leduc, and R. McNeil. *In press,* a. Refining the use of point counts at the scale of individual points in studies of bird-habitat relationships. Journal of Avian Biology.

Drapeau, P., A. Leduc, J.-F. Giroux, J.-P. Savard, Y. Bergeron and W.L. Vickery. *In press*, b. Landscape-scale disturbances and changes in bird communities of eastern North American boreal mixed-wood forests. Ecology.

Edenius, L. and J. Elmberg. 1996. Landscape level effects of modern forestry on bird communities in North Swedish boreal forests. Landscape Ecology 11: 325-338.

Enoksson, B., P. Anglestam, and K. Larsson. 1995. Deciduous forest and resident birds: the problem of fragmentation within coniferous forest landscape. Landscape Ecology 10: 267-275.

Franklin, J. F., and R.T. Forman. 1987. Creating landscape patterns by forest cutting: ecological consequences and principles. Landscape Ecology 1: 5-18.

Freedman, B., S. Woodley, and J. Loo. 1994. Forestry practices and biodiversity, with particular reference to the Maritime Provinces of eastern Canada. Environmental Review 2: 33-77.

Gauthier, S., A. Leduc, and Y. Bergeron. 1996. Forest dynamics modeling under natural fire cycles: a tool to define natural mosaic diversity for forest management. Environmental Monitoring and Assessment 39: 417-434.

Hagan, J. M., P. S. McKinley, A. L. Meehan, and S. L. Grove. 1997. Diversity and abundance of landbirds in a northeastern industrial forest. Journal of Wildlife Management 61: 718-735.

Haila, Y., I.K. Hanski, J. Niemelä, P. Punttila, S. Raivio, and H. Tukia. 1994. Forestry and the boreal fauna: matching management with natural forest dynamics. Annales Zoologici Fennici 31: 187-202.

Hansen, A. J., T. A. Spies, F. J. Swanson, and J. L. Ohmann. 1991. Conserving biodiversity in managed forests, lessons from natural forests. BioScience 41: 382-392.

Helle, P., and O. Järvinen. 1986. Population trends of North Finnish land birds in relation to their habitat selection and changes in forest structure. Oikos 46: 107-115.

Heltshe, J. F and N. E. Forrester. 1983. Estimating Species Richness using the Jacknife procedure. Biometrics 39: 1-11.

Hejl, S. J., R. L. Hutto, C. R. Preston, and D. M. Finch. 1995. Effects of silvicultural treatments in the Rocky mountains. Pages. 220-244 *in* T. E. Martin et D. M. Finch, editors.Ecology and Management of Neotropical migratory birds, A Synthesis and Review of Critical Issues. Oxford University Press. New York, New York.

Hunter, M. L. Jr. 1992. Paleoecology, landscape ecology, and conservation of Neotropical migrant passerines in boreal forests. Pages 511-523 *in* J.M. Hagan III and D.W. Johnston, editors. Ecology and conservation of Neotropical migrant landbirds. Smithsonian Institution Press, Washington.

McGarigal, K. and W. C. McComb. 1995. Relationships between landscape structure and breeding birds in the Oregon coast range. Ecological Monographs 65:235-260.

Morgan, K. and B. Freedman. 1986. Breeding bird communities in a hardwood forest succession in Nova Scotia. Canadian Field Naturalist 100: 506-519.

Noss, R. F. 1993. A conservation plan for the Oregon Coast Range: some preliminary suggestions. Natural Areas Journal 13: 276-290.

Schmiegelow, F. K. A., C. S. Machtans, and S. J. Hannon. 1997. Are boreal birds resilient to forest fragmentation? An experimental study of short-term community responses. Ecology 78: 1914-1932.

Spies, T. A., W. J. Ripple, and G. A. Bradshaw. 1994. Dynamics and pattern of a managed coniferous forest landscape in Oregon. Ecological Applications 4: 555-568.

Thompson, F. R., III.,G. R. Probst, and M. G. Raphael. 1995. Impacts of silviculture: overview and management recommendations. Pages 201-219 *in* T. E. Martin and D. M. Finch, editors. Ecology and Management of Neotropical migratory birds, A Synthesis and Review of Critical Issues. Oxford University Press. New York, New York.

Väisänen, R.A., O. Järvinen, and P. Rauhala. 1986. How are extensive, human-caused habitat alterations expressed on the scale of local bird populations in boreal forests? Ornis Scandinavica 17: 282-292.

Wallin, D. O., F. J. Swanson, and B. Marks. 1994. Landscape pattern response to changes in pattern generation rules: land-use legacies in forestry. Ecological Applications 4: 569-580.

Welsh, D. A. 1987. The influence of forest harvesting on mixed coniferous-deciduous boreal bird communities in Ontario, Canada. Acta oecologica 8: 247-252.

Yahner, R. H. 1986. Structure, seasonal dynamics and habitat relationships of avian communities in small even-aged forest stands. Wilson Bulletin 98: 61-82.