Forest birds and forest management in Ontario: Status, management, and policy

by Ian D. Thompson[1], James A. Baker[2], Susan J. Hannon[3], Robert S. Rempel[4] and Kandyd J. Szuba[5]

ABSTRACT

This paper presents a summary of presentations and discussions at a 3-day workshop on research and management of forest birds in Ontario forests. While many forest birds in Ontario do not appear to be negatively affected over the long term by forest management, some species were noted as declining using Breeding Bird Atlas data and more research is required to understand the causes, some of which may well be related to habitat change on the wintering grounds. For example, the aerial foragers as a group have declined significantly during the past 20 years. Recent research suggests landscape convergence between managed and fire-origin stands for bird species over time, but negative effects were suggested for boreal chickadee (*Poecile hudsonsicus*), brown creeper (*Certhia familiaris*), and some cavity-users, although there is no evidence of declines in these species from the current atlas data. This inconsistency needs to be evaluated. In Carolinian forests, even small-scale tree harvesting in this already highly fragmented landscape can have deleterious effects on breeding success for some species, such as wood thrush (*Hylocichla mustelina*) and rose-breasted grosbeak (*Pheucticus ludovicianus*). New modelling techniques and meta-analyses seem to hold considerable promise as tools to help managers understand key habitats, species that require special attention, and as predictive models of forest management effects. A large number of recommendations to improve the management of forest birds are provided and as is a suggested research agenda to improve our understanding of key factors affecting birds in managed forests.

Key words: forest birds, forest management, boreal forest, Great Lakes–St. Lawrence forest, Carolinian forest, indicators, modelling, cavity nester, spruce budworm, forest policy, Ontario

RÉSUMÉ

Cet article présente un sommaire des exposés et des discussions qui ont eu lieu lors d'un atelier de trois jours sur la recherche et la gestion des oiseaux des forêts de l'Ontario. Même s'il apparaît que l'aménagement forestier en Ontario ne semble pas affecté négativement à long terme les oiseaux forestiers, certaines espèces se sont avérées être en déclin selon les données de l'Atlas des oiseaux nicheurs et de plus amples recherches sont requises pour en comprendre les causes, certaines pouvant bien être reliées aux modifications de l'habitat dans les aires d'hivernage. Par exemple, les oiseaux se nourrissant en vol en tant que groupe ont connu un déclin significatif au cours des 20 dernières années. Des recherches récentes laissent entendre une convergence des écosystèmes entre les peuplements aménagés et ceux issus de feux de forêt au niveau des espèces aviaires au cours du temps, mais des effets négatifs seraient apparus dans le cas de la mésange à tête brune (*Poecile hudsonsicus*), du grimpereau brun (*Certhia familiaris*) et de certains utilisateurs de cavités, même s'il n'y a pas d'indication d'un déclin à partir des données actuelles de l'atlas. Cette divergence doit être étudiée. Dans les forêts caroliniennes, même les petites coupes de bois dans ce milieu déjà très fragmenté peuvent entraîner des effets néfastes au niveau du succès de l'appariement chez certaines espèces, comme la grive des bois (*Hylocichla mustelina*) et le cardinal à poitrine rose (*Pheucticus ludovicianus*). De nouvelles techniques de modélisation et de meta-analyses semblent très prometteuses en tant qu'outils pour aider les aménagistes à visualiser les principaux habitats, à identifier les espèces qui nécessitent une attention spéciale et à agir comme des modèles de prédiction des effets de l'aménagement forestier. Nous présentons plusieurs recommandations pour améliorer la gestion des oiseaux forestiers ainsi qu'un agenda de recherches destinées à améliorer notre compréhension des facteurs clés affectant les oiseaux dans les forêts aménagées.

Mots clés : oiseaux forestiers, aménagement forestier, forêt boréale, forêt des Grands Lacs et du Saint-Laurent, forêt carolinienne, indicateurs, modélisation, nicheur, tordeuse des bourgeons de l'épinette, politiques forestières, Ontario

[1]Canadian Forest Service 1219 Queen St. East, Sault Ste. Marie, Ontario P6A 2E5. E-mail: Ian.Thompson@NRCan-RNCan.gc.ca
[2]Ontario Ministry of Natural Resources, Applied Research and Development Branch, 1 Stone Road , Guelph, Ontario N1G 4Y2.
[3]Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6G 2E9.
[4]Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, 955 Oliver Road, Thunder Bay, Ontario P7B 5E1.
[5]Domtar Inc., Forest Products Group, 100 Old Nairn Road, Nairn Centre, Ontario P0M 2L0.

Introduction

Forest birds, especially migrants, have become a conservation concern globally and in Canada because of broad-scale declines in numbers of many species and the difficulty in assigning specific causes for the observed declines (e.g., Terbourgh 1989, Stutchbury 2007). While there are many reasons that birds may be declining, habitat loss globally is one of the most significant causes. While population effects may be occurring to many forest birds on the wintering grounds, Canada is the breeding ground of many neo-tropical migrant species, so loss of habitat here may have an enhanced effect on population stability. Many other bird species remain in Canada throughout the year, as residents, and if these species are declining, then habitat loss may be a key cause. Numerous researchers have suggested that forest birds can be used as indicators of sustainable forest management, owing to their relative ease to census and the wide variety of habitats selected among species (Welsh 1981, McLaren *et al.* 1998, Venier and Pearce 2004, Rempel 2007).

The late 1990s and early 2000s saw a large number of forest bird research projects done in Ontario and considerable work completed elsewhere with applicability to Ontario's forests. This work was funded by various agencies, especially the Sustainable Forest Management Network, Forest Ecosystem Science Cooperative, Forestry Research Partnership, and Ontario Living Legacy Trust, and enabled many relevant studies on the long-term effects of forest management on birds in boreal and Great Lakes–St. Lawrence forests. In addition, the second edition of the Ontario Breeding Birds Atlas (Cadman *et al.* 2007) was completed in late 2007, 20 years after the first edition. While much of this research has been published, is published in this issue, or will be published in other journals, the work has not been drawn together into a cohesive format where it can be used by forest managers. This paper presents a summary of the results from a workshop (in Sault Ste. Marie, April, 2008) with recommendations for management, monitoring, and future research.

Forest Bird Status

Changes in distribution and abundance

Change in bird status and causation of change are of great interest to land managers in Ontario. One source of data on change in distribution and abundance of birds in Ontario is the 2 Ontario breeding bird atlases (Cadman *et al.* 1987, 2007). The recent Ontario Breeding Bird Atlas project (OBBA; Cadman *et al.* 2007) was an extensive mapping effort, and comparison to the previous atlas provided a status update over 20 years. Blancher (2008) integrated results of the OBBA and other relevant data to identify changes in abundance of forest birds between atlas surveys (Fig. 1).

Changes during the 20-year interval were ranked as: Large Declines (<-50%), Moderate Declines (-50 to -25%), Stable (-25 to 33%), Moderate Increases (33 to 100%), or Large Increases (>100%). Ontario forest birds were generally stable or increasing between the 2 atlas periods (Blancher 2008). More declines were apparent among Boreal Hardwood Transition (Bird Conservation Region [BCR] 12) species (17% large declines, 20% moderate declines) than among birds in the Boreal Softwood Shield (BCR 8; 2%, 11%). However, all aerial foragers (swallows, kingbirds, flycatchers, goatsuckers) were found to be declining, and this assessment was consistent between roadside breeding bird surveys and the OBBA point counts. Several common boreal species have also declined, including: northern goshawk (*Accipiter gentilis*), Tennessee warbler (*Vermivora peregrina*), purple finch (*Carpodacus purpureus*), and ruby-crowned kinglet (*Regulus calendula*). Blancher reported that average reliability of status assessments was relatively poor in BCR 8, reflecting less survey coverage in the north. Great Lakes–St. Lawrence forest species in decline include: brown thrasher (*Toxostoma rufum*), scarlet tanager (*Piranga olivacea*), whip-poor-will (*Caprimulgus vociferus*), rose-breasted grosbeak (*Pheucticus ludovicianus*), and gray catbird (*Dumetella carolinensis*), among others.

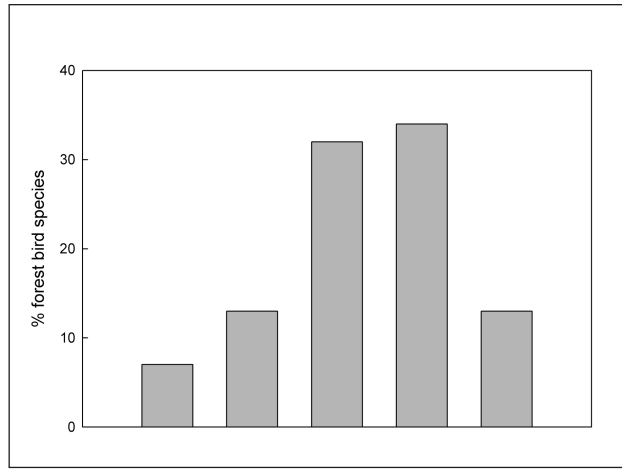

Fig. 1. Percent change of 135 forest birds in Ontario between 1987 and 2007 from Blancher (2008).

Assessment of alternative monitoring programs

In Ontario, many different bird monitoring programs have been established including large-scale, multi-species surveys such as the Breeding Bird Survey or the Ontario Breeding Bird Atlas, habitat specific surveys such as the Forest Bird Monitoring Program and the Marsh Monitoring Program, migration monitoring stations (e.g., Long Point Provincial Park, Thunder Cape), winter surveys such as Christmas Bird Counts or Project Feeder Watch, and various surveys for particular species groups such as aerial waterfowl surveys and nocturnal owl surveys. Francis *et al.* (2008) noted that all of these programs differ in their geographic coverage, sampling methods, sampling intervals, inherent biases, and the inferences that can be drawn from them. None presents a comprehensive picture of trends across all of Ontario. In evaluating which monitoring program is applicable to a particular monitoring or management need, Francis *et al.* (2008) suggested reflecting on such questions as: What is the need? Is the survey design adequate? Does the program contribute to priority management or conservation objectives? What are the risks/benefits associated with not undertaking the monitoring? Will the monitoring program increase our understanding of system processes and appropriate management actions? Environment Canada is currently reviewing 150 bird monitoring programs in Canada and an external panel will identify major gaps and provide direction for filling these gaps. Some of the points that should be considered in developing new monitoring programs include ensuring that monitoring is integrated with management, programs are coordinated for efficiency, that appropriate and sound statistical designs are used, and that data are well maintained, analyzed, and available. Additional questions and issues that should be considered in either designing or implementing a monitoring program include the appropriate geographical scale, required time scale, types of data, methods to improve assessment (e.g., based on just birds or multiple species), and replication versus duplication.

Modelling distribution and abundance

Field measurements of songbird abundance are expensive and difficult, so alternative methods of assessing conservation status and planning are also being explored. Duffe *et al.* (2008) used satellite-based remote sensing data with point-count data for habitat modelling. They developed artificial intelligence algorithms in the program MaxEnt to produce ecological niche models for various species (Fig. 2). This was projected over the entire landscape to obtain a prediction of the geographical distribution of each species for a given area. Duffe *et al.* (2008) focussed on modelling the predicted occurrence of priority Partners in Flight (PIF) species in 2 forest ecosystems (Eastern Boreal and Interior Douglas-Fir). Based on this predictive map, they outlined sample bird conservation plans based on area of potential habitat at various scales within the Bird Conservation Regions. An advantage of using satellite-based data is the ability to create standardized, high-resolution environmental variables over large extents that can be monitored and updated through time, regardless of land ownership issues (public/private) or political boundaries. The approach can integrate the true multi-stressor environment that exists in these active landscapes (e.g., forestry, wildfire, mining, climate change).

The Boreal Avian Modelling Project was initiated to help address the lack of synthesis of information on boreal bird

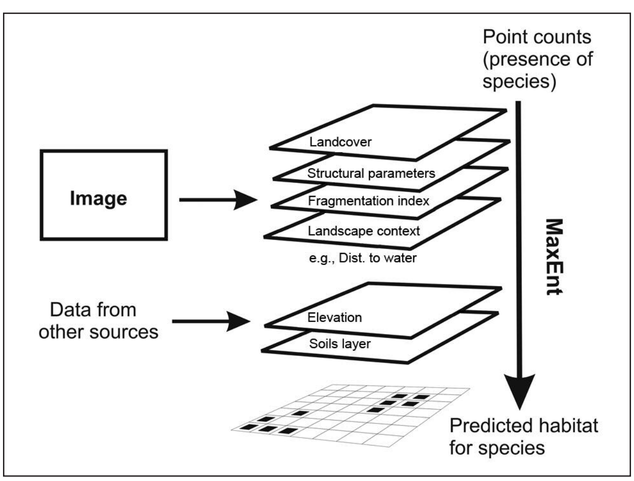

Fig. 2. Representation of the MaxEnt modelling process used by Duffe *et al.* (2008) to predict habitats used by forest birds.

distribution, abundance and habitat use across the boreal forest (Song 2008). The project has thus far assembled over a half million data points from over 33 000 point count stations, generously provided by 40 data contributors from more than 70 projects. Initial correlation and regression-tree models produced for the western boreal region (the first phase), and nationally, have provided good insight into appropriate climate covariates for use in further modelling efforts. The team is continuing to refine the habitat covariates, drawing from a suite of national coverages. Their modelling efforts have also highlighted the challenges of variation in sampling methods and study designs. Near-term efforts will focus on completion of national models of abundance, density and distribution, development of regional models relevant to the scale of forest tenures or management units, and the provision of information products directly relevant to the sound management of migratory bird populations in Canada.

Forest Birds and Forest Management

With the adoption of new technologies, forest management has changed on a continual basis since mechanized forest harvesting began in Ontario in the 1940s. Aside from improved harvesting techniques and equipment, management of the regeneration of forests has also changed. For example, planting and aerial seeding forest stands became common in the 1980s and herbicide use, the chemicals, and technologies have changed through time. Forest management has also changed policy objectives many times during this 60-year period, from sustained yield, to multiple use, to sustainable forest management, and most recently to the emulation of natural disturbances. Therefore, trying to discern the short- and long-term effects of forest management on populations of forest birds has been challenging and confounded and complicated by such an untidy "experiment" and because a full rotation—at least in boreal forests—is still incomplete. At the same time, ecologists have only relatively recently recognized that landscape structure and composition, rather than just stand structure and composition, also contributes to habitat selection by birds. Nevertheless, forest management has effects on forest age, structure, and plant species composition and hence the need to predict, to the best extent possible, the longer-term effects of forest management practices, to provide an indication of whether or not management is sustainable, and to determine mitigating actions if necessary. This information forms a key part of the adaptive management process that can be used to inform and improve forest management.

Nudds (2008), Venier (2008), and Zimmerling (2008), and a summary paper by Donnelly and Wedeles (2008) investigated possible broad-scale effects of forest management on boreal forest birds at stand and landscape scales. In each of the 3 field studies, comparisons were made between stands originating following wildfire and those originating after timber harvesting. Zimmerling (2008) took a broad survey approach, counting birds in stands across much of boreal Ontario in a range of age classes of burned and managed stands. He found that counts for 55% of bird species did not differ between fire-origin and managed-origin stands, that some species were most abundant in managed stands, and some were most abundant in burned stands for the same age class. For example, much higher numbers of cavity-nesting species were present in young burned stands than in managed stands that had fewer snags. Red-breasted nuthatches (*Sitta canadensis*) and brown creepers (*Certhia americana*) were most abundant in old fire-origin forests, but some species, such as bay-breasted warbler (*Dendroica castanea*) were most abundant in the oldest managed forests.

In the Pukaskwa Park area, Venier (2008) and Venier and Pearce (2007) also showed that there were broad similarities in bird species between a managed landscape and the unmanaged park, but with some clear differences. Five different species were most common for each of the 2 areas. In contrast to other studies reported at this workshop, in Venier's study, brown creepers were most abundant in the managed landscape, contrary to other recent studies in boreal forests (e.g., Drapeau *et al.* 2000, Zimmerling 2008). The stand associations observed for this species were consistent with other work, however, as she found the birds in old stands with large amounts of woody debris. Large numbers of declining trees in the managed landscape also likely supported the higher numbers of black-backed woodpeckers (*Picoides arcticus*) compared to in the old forest of the unmanaged landscape. Black-backed woodpecker density was low, however, in comparison to numbers of this species reported by Drapeau *et al.* (2008), from recently burned areas in Quebec. Among the variables Venier (2008) found most important in predicting occurrence of many bird species were forest structure, overstory floristics, landscape context, and understory floristics. Species in lowest abundance in the managed landscape vs. the park included bay-breasted warbler, black-throated green warbler (*Dendroica virens*), ovenbird (*Seiurus aurocapillus*), and red-eyed vireo (*Vireo olivaceous*). Nudds (2008) found little difference in patterns of avian species richness between fire origin (80- to 120-year-old forest) and managed landscapes (40- to 60-year-old forest) by stand age, type, or size. About 20 species was the maximum number found in any stand. Richness varied more among forest stand types than between the 2 landscapes of different origin and mean stand age. However, local richness was <50% of the regional richness, derived from Cadman *et al.* (1987), suggesting high inter-specific competition and functional redundancy among species. Little evidence was found to suggest that post-harvest stands differed from wildfire-origin stands in creating songbird habitats. The sometimes contradictory results among these studies in boreal forests illustrates the complexity of the ecological relationships between forests (composition, structure, origin) and forest songbirds across Ontario, and the difficulty of creating all habitat types by emulating natural disturbances in forest management. Do these apparent conflicting results simply reflect variation in emergent bird communities due to subtle variation in post-disturbance conditions and inter-specific competition, as suggested by Nudds (2008)? If so, then an expectation of creating all habitats by emulating natural disturbances via forest management may be unrealistic, especially at small scales.

Other recent research has focussed on stand level changes, looking at specific forest management issues and techniques in Ontario. Nol (2008) and Burke *et al.* (2008) studied the effects of various silvicultural practices on breeding birds in southern Ontario. Working in the Great Lakes–St. Lawrence forest of central Ontario, Nol (2008) assessed the effects of partial harvesting in hardwood stands on bird species richness, by comparing reference sites with no management for more than 30 years to stands harvested more recently using single-tree and group selection approaches. There was little difference in overall species richness associated with partial harvesting. However, compared to partially harvested sites, yellow-bellied sapsuckers (*Sphyrapicus varius*) were significantly more abundant and had greater fledging success on reference sites where declining trees and beech (*Fagus grandifolia*) trees were more abundant. Yellow-bellied sapsuckers are important as a keystone species in deciduous forests because they are cavity excavators whose cavities are used by many other species. The authors suggested that management should retain beech and dying trees to prevent a predicted severe reduction in the population of the yellow-bellied sapsucker in central Ontario, a region in which beech bark disease is contributing to the decline of this species. In southern Ontario forests, management and tree species losses to invasive alien diseases and/or insects has resulted in homogenization of forest stands, with fewer tree species, now particularly dominated by sugar maple (*Acer saccharum*). This change will likely have long-term implications for avian species diversity owing to reductions in preferred tree species for nesting and feeding.

Burke *et al.* (2008) assessed the effects of forestry in the Carolinian zone of southern Ontario, where forest fragmentation is significant and associated rates of nest predation and nest parasitism by cowbirds (*Molothrus ater*) are high. They found that wood thrushes (*Hylocichla mustelina*) responded positively to single tree selection but negatively to group-selection harvesting. Rose-breasted grosbeaks breeding in recently managed stands had a low rate of nest survival. Their main conclusions were that bird population density is not a reliable indicator of habitat quality, some stand management techniques can have negative effects on some bird species in fragmented Carolinian forests, and management must consider larger landscapes because no single stand, managed or unmanaged, supported the full suite of species that occurred in the larger landscape. Multiple conditions are required to maintain the full diversity of avian species. This was similar to the conclusion reached by Nudds (2008) in boreal forests. For managers, this implies that habitat supply across larger landscapes, as well as composition and structure within stands, must both be considered.

Nol (2008), Drapeau *et al.* (2008), and Burke *et al.* (2008) all observed that various cavity-nesters have different nesting preferences between dead or declining trees, among decay classes and sizes of these snags, and among tree species. Therefore, to provide for forest birds, managers must continue to maintain the diversity of tree species and stand types across the landscape, paying particular attention to provision of cavity trees and declining trees in a range of sizes and species.

In boreal forests, Drapeau *et al.* (2008) suspected that a general decrease in area of late seral-stage forests, which maintain the highest density of snags, may result in a decline in populations of many cavity-nesters, especially secondary cavity-nesters, which they found were all most abundant in old forests. Drapeau *et al.* (2008) found that primary cavity-nesters were most abundant in recent burns up to 2 years post-burning and that, within these burned stands, black-backed woodpeckers preferred stems >15 cm DBH. In Quebec, salvage logging of recently burned boreal forests is a conservation issue and one for which there are no guidelines. They also reported that three-toed woodpeckers (*Picoides tridactylus*) and boreal chickadees (*Poecile hudsonicus*) preferred large uncut forest remnants in managed landscapes. Drapeau *et al.* (2008) suggested that while snags are an important feeding substrate for woodpeckers in any aged forest, woodpeckers cannot be treated uniformly as a guild owing to differences in nesting requirements and feeding substrates, at stand and landscape scales.

Thompson *et al.* (2008) reported that responses of songbird species varied depending on type of post-harvest silviculture treatment and time since harvesting. They found that many species responded positively to regenerating planted forests, including bay-breasted warblers and Swainson's thrushes (*Catharus ustulatus*). Five of 8 old-growth-associated species had densities in older managed stands (30–50 years) that were similar to densities in the uncut control areas. Boreal chickadee, brown creeper, and Blackburnian warbler (*Dendroica fusca*) were old-forest bird species that were absent, or in very low numbers, in 30-50 year old regenerating stands. Planting and tending of stands reduced the deciduous component to a level such that several species preferred naturally regenerating logged stands because of a higher deciduous stem density, including least flycatcher (*Empidonax minimus*), ovenbird, Philadelphia vireo (*Vireo philadelphicus*), and hairy woodpecker (*Picoides villosus*). Landscape-level variables, especially total area treated, were important predictors for occurrence of several species, including Nashville warbler (*Vermivora ruficapilla*), red-eyed vireo, and hermit thrush (*Catharus guttatus*). A spatial predictive modelling scenario indicated that only a limited area of least flycatcher habitat would be available after 100 years, given the current rate of post-harvest silvicultural treatment. Therefore, a long-term view must be taken, in the management of second-growth stand composition, to ensure that some mixedwood stands that are dominated by deciduous trees remain to support species that prefer these stand types.

Riparian areas have long been protected from forest management in Ontario by using no-harvest or limited-harvest buffer zones. While riparian buffers may provide habitat for some species, these areas do not necessarily emulate natural disturbance patterns because fires often burn to shorelines. Holmes *et al.* (2008) have begun an experiment to examine effects of partial harvesting in buffer areas on boreal songbirds. While longer-term effects may yet occur, after 3 years, they found little effect on the bird community and no effect on use by spring and fall migrants, based on extensive mist-netting and point-count results.

Donnelly and Wedeles (2008) provided a summary of management recommendations for forest birds. They highlighted the importance of structural elements and heterogeneity at multiple scales, including among patch sizes, large-diameter trees, and snags. They also stressed the importance of adaptive management. Naylor (2008) reviewed a prescriptive approach to maintaining stick nests and the process used to update the Ontario forest management guidelines used to protect these stick nests. His work provided an innovative use of original data and scientific literature to assess the efficacy of guidelines for forest management around stick nests in Ontario. This adaptive assessment has led to a number of changes to the guidelines. For example, while expert opinion suggested a 1000-m buffer around great blue heron (*Ardea herodias*) colonies, research indicated that 300 m is sufficient to protect a colony. Naylor concluded that overly conservative prescriptions for protection may have economic and ecological implications.

Forest Birds and Spruce Budworm

Data from the National Forestry Database suggest that the spruce budworm provides an enormous, but temporally and spatially variable, food supply for birds (e.g., 52 million ha of moderate to severe defoliation in Canada in1975, but only 0.7 million ha in 2005). Attaining astonishing densities during outbreaks (e.g., 14 million mature larvae per hectare; Crawford and Jennings 1989), budworm larvae are found in the forest canopy, pupating on the lower branches, and spinning down on silken threads into lower strata, where they can become food for birds employing a variety of foraging strategies in multiple strata (canopy, mid-canopy, shrub layer, ground layer). Moderate to severe defoliation of new coniferous growth by the budworm is obvious as dry, red needles, and is easily mapped. Outbreaks have occurred during episodic periods, with the last major outbreak occurring during 30 years from 1966 to 1996, with a peak in 1980 and a decline to low levels since then (Fleming *et al.* 2000). The latter outbreak, which was actually a series of individual outbreaks across the province, eventually covered the entire range of spruces (*Picea* spp.) and balsam fir (*Abies balsamea*) in Ontario.

The literature suggests that some birds show consistent numerical responses to outbreaks ("the budworm specialists"), while other species may show a less pronounced response. Songbird responses were corroborated in a local-level analysis during an outbreak near Manitouwadge Ontario, in work done by Daniel Welsh (Canadian Wildlife Service) and reported by Venier *et al.* (2008). In that study, territory mapping over 5 years (1979–1983) on 18 plots in spruce–fir–aspen (*Populus tremuloides*) forest and measures of budworm density (1982, 1983) suggested a dramatic positive response by bay-breasted warbler, Cape May warbler (*Dendroica tigrina*), and Tennessee warbler. However, these species accounted for less than 30% of all bird territories on the plots, and other species appeared to show only partial responses to increasing budworm numbers, including winter wren (*Troglodytes troglodytes*), ovenbird, yellow-rumped warbler (*Dendroica coronata*), Blackburnian warbler, and Canada warbler (*Wilsonia canadensis*).

A link to spruce budworm populations had not previously been proposed to explain an apparent Canada-wide decline of the Canada warbler. Sleep *et al.* (2008) predicted that, if such a link exists, then there should be temporal and spatial coincidence of outbreaks and increased warbler detections. Further, the relationships should be similar in other known budworm associates (Bay-breasted warbler, Tennessee warbler, Cape May warbler), and the relationships should be stronger than for birds known to be diet generalists that also prefer mature forest and occur over a similar geographic range (Blackburnian warbler, black-throated blue warbler [*Dendroica caerulescens*], and black-throated green warbler). Regression analysis between National Forest Database variables on defoliation and Breeding Bird Survey data, assessed at the level of the province and the country, supported all of these predictions. This research highlights the importance of considering alternate hypotheses with respect to understanding changing bird numbers. In this case, changes in songbird populations may be explained by factors on the breeding range (i.e., food) not related to habitat supply.

Forest Bird Monitoring

Bayne *et al.* (2008) described the Alberta Biodiversity Monitoring Institute (ABMI) approach to monitoring biodiversity throughout the province of Alberta. The province is divided into a grid with sampling points 20 km apart that are sampled every 5 years, for up to 2500 species. ABMI has developed systems to report on changes in abundance or occurrence of species or groups with respect to a reference condition, "intactness," which represents the abundance of a species in relatively pristine landscapes (e.g., no roads or other large scale disturbances). Information is made available to researchers, managers, and the public depending on needs organised into an "information pyramid." At the base (level 1) are primary data on the landscape characteristics of a prescribed area (e.g., % forest cover, area), level 2 is the state of individual species, level 3 the state of specific guilds (e.g., old-growth specialists), level 4 the state of general guilds (e.g., forest specialists), level 5 is taxonomic indices (e.g., birds as a whole), and level 6 is a single composite biodiversity index. Preliminary analyses on the state of boreal birds produced an intactness score of 81, reflecting an increase in abundance of grassland, edge, and habitat generalist species, all species that benefit from human disturbances; an early warning that bird communities have departed from the reference condition (100). This approach can be used to choose a set of focal species for habitat suitability modelling.

Habitat suitability models are useful tools to predict the effects of various forest management scenarios, including no disturbance, on habitat supply for wildlife. Many of these models, including Ontario's Habitat Suitability Matrix model, contain suitability ratings based on expert opinion and data from the literature, supplemented with local empirical data where available. Few of these models, however, are validated for the region of concern using local data on bird abundances. Holmes *et al.* (2007, 2008) tested habitat suitability models for 22 forest bird species, chosen to represent a range of habitat requirements, by using bird monitoring data collected under Bird Studies Canada's Boreal Forest Bird Program. Species-specific habitat suitability models were used to assign suitability rankings for each forest type, and these were then compared to actual species' abundances obtained from the point count data. Their results showed that habitat suitability rank was a poor predictor of bird abundance and hence of habitat quality; the models tended to over-predict the presence of bird species, in particular for common species and habitat generalists. This result could be caused by low detection probabilities for species in the point count data, due to sampling design (single 5-minute point counts). To improve model prediction, researchers recommended that further field sampling, with 4 visits per point, should be conducted for at least 9 of the species studied including: hairy woodpecker, blue-headed vireo (*Vireo solitarius*), red-eyed vireo, red-breasted nuthatch, Swainson's thrush, hermit thrush, Tennessee warbler, Blackburnian warbler, and dark-eyed junco (*Junco hyemalis*).

Forestry alters a number of forest attributes on the landscape, including age class, interspersion of age classes, and the amount of coniferous and deciduous cover types (Drapeau *et al.* 2000, Hobson and Bayne 2000). Rempel (2007) and Rempel *et al.* (2008) used these 3 major attributes to form the axes of a graphic cube that defined the habitat needs of forest songbirds. These axes represented high to low edge density, homogeneous to heterogeneous forest matrix, hardwood- to softwood-dominated overstory, young to old stands, and open to closed canopy. Rempel further used these attributes to predict the abundance of 30 songbird species and then chose a subset of 13 focal species whose habitat requirements encompassed those of the full songbird community. Focal species were alder flycatcher (*Empidonax alnorum*), black-and-white warbler (*Mniotilta varia*), bay-breasted warbler, Blackburnian warbler, brown creeper, common yellowthroat (*Geothylpis trichas*), chestnut-sided warbler (*Dendroica pensylvanica*), least flycatcher, ovenbird, red-breasted nuthatch, red-eyed vireo, winter wren, and white-throated sparrow (*Zonotrichia albicolis*). Maintenance of the full range of the habitat conditions identified in Rempel's models is a coarse-filter strategy for managing forest biodiversity. Applications of models for these species include scenario analyses that predict outcomes of a range of forest management policies and practices.

Another approach to identifying species that could decline as a result of forestry activities is to identify forest cover thresholds for species sensitive to the loss of forest cover. A threshold is a level at which a small change in amount of forest cover can cause a very large change in the abundance of an organism. Few studies have evaluated whether thresholds exist. Three studies in New Brunswick (Guenette and Villard 2005, Betts *et al.* 2007, Poulin *et al.* 2008) found thresholds for Nashville warblers, ovenbirds, yellow-bellied flycatchers (*Empidonax flaviventris*), Blackburnian warblers, and brown creepers. A comparison between areas and methods used found little consistency in threshold levels or presence, indicating that thresholds may be an artefact of the technique used (Villard and Betts 2008). Further, a study in Alberta on winter resident birds found no evidence for strong threshold responses (Swift 2007, Hannon and Swift 2008). Hannon and Swift (2008) reviewed the evidence for threshold responses in forest birds and critically evaluated methods to detect thresholds. Overall, the review indicated that threshold responses may exist for some species but the exact conditions that result in the existence of a threshold is difficult to specify and cannot be extrapolated between regions or across spatial scales for the same species. Forest cover thresholds at small scales (e.g., around nest sites) may be higher than those at larger scales (territory or landscape) (Poulin *et al.* 2008) and fitness thresholds may be higher than occurrence or abundance thresholds. Instead of looking for thresholds, Hannon and Swift recommended that other approaches, such as the modelling approaches suggested above, should be employed to ensure sufficient habitat for forest songbirds.

Forest Policies and Practices

In Ontario, Forest Management Plans (FMPs) seek to balance objectives for wood supply, habitat, and other economic, ecological, and social values, but wood supply targets are often not met because reductions are necessary to meet non-timber objectives (Northwatch 2007). Baker *et al.* (2008) described opportunities and difficulties in providing bird habitat in Ontario FMPs, using the Spanish Forest (~1 million hectares) in the boreal to Great Lakes–St. Lawrence transition of northeastern Ontario as an example. The forest has been managed for a variety of forest products and services for over 100 years.

The 2005–2010 FMP contains objectives and indicators prescribed in Ontario's approved manuals to support conservation of biodiversity and sustainability of the Crown forest, including emulation of natural landscape patterns, forest structure and composition targets (including old growth), habitat provision and protection, and social and economic benefits (OMNR 1996, 2004).

Baker *et al.* (2008) described the current coarse- and fine-filter management hierarchy used in Ontario, noting that adjustments could be made to any aspect to enhance provisions for forest birds. The coarse filter prescribes that: (i) the supply of forest types and age classes follow closely the future trajectory expected under a natural disturbance regime (the natural benchmark), and (ii) harvested landscapes emulate natural landscape patterns, including size and distribution of disturbed patches, and the supply of residual trees and patches, and coarse woody debris (OMNR 2002).

Opportunities to provide for forest birds across the landscape within the coarse-filter approach include using a set of habitat suitability matrices (Holloway *et al.* 2004) to project habitat supply over the planning term of 100 years in the Strategic Forest Management Model (SFMM; Davis 1999). Challenges for implementation include concerns over the accuracy of the matrices (Holmes *et al.* 2007), assumptions of habitat quantity expected under a natural disturbance regime, accuracy of the forest resource inventory (Thompson *et al.* 2007), and tradeoffs with other competing values of the plan. Further, while habitat relationships have been evaluated at the stand level, population responses occur at the landscape level and have not been tested. A constraint of SFMM is that the natural disturbance regime is modelled as a deterministic fire return interval based on expected average values of key parameters. Fire disturbance simulations suggest return intervals are probabilistic, varying over time and space (Perera *et al.* 2004). Thus, SFMM likely underestimates the variation inherent in a naturally disturbed landscape, and its outcomes are likely conservative. Work is progressing on spatial planning models that will help to overcome some of these issues (e.g., Moore and Rouillard 2008, Rempel 2007, Rempel *et al.* 2007).

Existing fine-filter management for wildlife requires that (i) the needs of featured species are highlighted (e.g., marten [*Martes americana*], black bear [*Ursus americanus*], pileated woodpecker [*Dryocopus pileatus*], black-backed woodpecker, moose [*Alces alces*], deer [*Odocoileus virginana*], and others [*Otherus stuffii*]), and (ii) additional protection (areas of concern [AOCs]), through reserves and timing restrictions, is applied to sensitive sites such as shorelines, bald eagle [*Haliaeetus leucocephalus*], osprey [*Pandion haliaetus*], great blue heron [*Ardea herodias*], and hawk nests, and moose aquatic feeding areas. Company-specific standard operating procedures present other opportunities to provide for birds (e.g., avoid disturbing occupied songbird and grouse nests discovered during operations, minimize the area traversed by machinery, ensure retained trees are those with the greatest value to wildlife [e.g., existing cavities], report newly discovered stick nests and species at risk observations to OMNR).

Other challenges in providing for forest birds in an FMP include:

(i) explaining habitat objectives in terms understandable to the public;
(ii) additional habitat objectives increase the potential for conflict among competing objectives (e.g., young habitat vs. old; conifer vs. hardwood);
(iii) use of a natural benchmark may increase habitat for some species but cause habitat for others to decline, a trajectory possibly unacceptable to the public;
(iv) many fine-filter rules may result in an artificial landscape pattern dominated by uncut strips and circular reserves and could have cascading effects on other wildlife (e.g., shoreline buffers for water quality might affect habitat supply for beavers (*Castor canadensis*) and beaver pond associates, such as rusty blackbirds (*Euphagus carolinus*) and black ducks (*Anas rubripes*);
(v) marketability and difficult terrain may also result in greater retention than was planned, with unintended effects on landscape pattern.

Improving planning

In Ontario, a continuous improvement loop (plan, act, evaluate, adjust) is followed for forest management policy and planning, with varying degrees of rigour. Currently, a complete updating and consolidation of the forest management guidelines is underway, with a view to increasing effectiveness and efficiency. Issues concerning accuracy of aspatial habitat models (Holmes *et al.* 2007) are being addressed with development of new spatial models (Rempel 2007 and Rempel *et al.* 2008). Rempel *et al.* (2008) described a new approach for habitat planning that will: (i) define states characterizing the full range of habitat conditions on the landscape (the evaluative framework), (ii) identify a set of focal bird species, (iii) build and field-test spatially explicit habitat models, (iv) use a spatially explicit, process-based disturbance model ("BFOLDS" – the Boreal Forest Landscape Dynamics Simulator; Perera *et al.* 2004) to simulate and predict the range of natural variation of bird habitat supply over time, and (v) apply the bird habitat models to landscapes reflecting a variety of management scenarios or options, as simulated by the spatial model "Patchworks" (Moore and Rouillard 2008), so the likely effects of these management options can be understood.

Using this modelling process, Rempel *et al.* (2008) outlined how landscape signatures (spatial attributes or patterns) of simulated landscapes were assessed in scenario comparisons for the Lake Nipigon Forest in northwestern Ontario. Rempel *et al.* (2008) noted that Patchworks simulations suggested that levels of bird habitats predicted, in the absence of management, by BFOLDS were most likely to be provided on the landscape by: (i) a management scenario with no habitat-based spatial restrictions (i.e., fine-filter AOCs) on forest harvesting, or (ii) a scenario designed to emulate natural disturbance patterns through application of the appropriate guidelines (OMNR 2002). Rempel *et al.* (2008) concluded that a wide diversity of forest cover type, age, and age-class interspersion is needed to conserve songbird community diversity.

Current management concerns arising from the Migratory Birds Convention Act

Hughes (2008) and deVries (2008) addressed implications under the Migratory Birds Convention Act (MBCA) with respect to the potential mortality of forest birds and their young, during forest management activities, which have been raised by the public. The Act forbids "disturbance, destruction, or taking of the nests of migratory birds," and applies to all citizens and industries undertaking activities on Crown or private land. deVries noted its original intent was to control commercial egg collecting and market hunting of birds, both of which contributed significantly to population declines and even extinctions before the Act came into force in 1917. Hughes (2008) suggested that the Act had been successful in controlling active exploitation, but that the risk of accidental (incidental) destruction of nests and, hence, non-compliance is high.

deVries (2008) explained that the forest industry has attempted to comply with the MBCA through Forest Management Plans, Environmental Management Systems, and Sustainable Forest Management Systems. He suggested that the direct risk of mortality to birds from forest management is low because harvesting and thinning during May, June, and July affect only 0.04% of Canada's forest. By comparison, 11 times that area is burned by wildfire, in an average year. deVries added that forest harvesting provides a diversity of habitat types for birds in time and space in a controlled manner, much like fire does. Hughes (2008) concluded that the MBCA applies to any active nest or those with the potential for reuse, and every industry is required to comply. Under the law, Environment Canada's (EC) responsibility rests with the birds, not the habitat. EC is continuing discussions with the forest industry and others regarding potential modifications to the Act and regulations to permit activities such as forestry, which can result in accidental losses of bird nests, with the proviso of an overall benefit to bird populations. EC is assessing options for regulations, using guiding principles of population conservation, improved legal certainty, risk-based, and minimal regulatory burden.

Conclusions

Most forest bird species in Ontario are not declining, but there are some species that do show long-term declines. Populations may vary in response to food and habitat supply and so will vary over time, for example those correlated with insect outbreaks. Further, some species seem to prefer some areas of the boreal zone over others within Ontario, resulting in ecoregional differences in population density, possibly related to broad habitat conditions, for example. The recent and past breeding bird atlas (Cadman *et al.* 1987, 2007) data enabled a comparison of counts separated by 20 years. These data suggested that several individual forest species are declining, including the aerial foraging guild as a whole that has had a large decline throughout the province (Blancher 2008). The reasons for declines are not fully understood and there is limited knowledge of changes in habitat used during migration, wintering habitat, over-wintering success, migration mortality, or about the effects of climate change. The long-term downward trend in spruce budworm since the late 1980s may have had a negative effect on some declining species, such as Canada warbler (Sleep *et al.* 2008).

Most birds in Ontario seem to be unaffected by forest management over time and continue to persist across a broad managed landscape (Blancher 2008). However, some studies clearly suggested that, while convergence is occurring in bird communities between the oldest second-growth stands and older uncut forests in Ontario based on point counts, not all species occur in similar numbers in managed and unmanaged landscapes (Thompson *et al.* 2008, Zimmerling 2008). In cases where multiple causation of decline is possible (e.g., declining neotropical migrants), it is difficult to tease apart the contribution of forest management on the breeding grounds from other factors, such as wintering conditions, for any of these declines.

Research on harvesting and post-harvest silvicultural treatments indicated benefits for some species, no effect on most, but concerns about a few species depending on the silvicultural system (Burke *et al.* 2008, Nol 2008, Nudds 2008, Thompson *et al.* 2008, Venier 2008, Zimmerling 2008). In southern Ontario, where gap dynamics is important in renewing the forest, low impact logging that emulates this process by selecting individual trees has reduced effects on declining species such as wood thrush and rose-breasted grosbeak. Nevertheless, effects on productivity were seen (Nol 2008). Birds may select habitat at landscape (ca. 50–500 ha), stand ($\leq$50 ha), and/or site scales. Elements at each scale may be more or less important depending on the individual species, but if key elements are affected, then species associated with that element respond. For example, snags, mature and old-growth conifer-dominated forest, and large trees are habitat elements that have been generally reduced by forest management and for which there appears to have been effects on some species. In Carolinian and Great Lakes–St. Lawrence forests, concerns remain for several species over the effects of fragmentation, long-term reduction in stand heterogeneity, and too short return times between harvests (Burke *et al.* 2008). Further, several listed species, such as wood thrush, rose-breasted grosbeak, hooded warbler (*Wilsonia citrina*), and Acadian flycatcher (*Empidonax virescens*), will require careful management and more research to understand effects of disturbances.

In boreal forests, concerns about a few, mostly resident, species were observed across several studies including: some secondary cavity nesters, brown creeper, boreal chickadee, and black-backed woodpecker (Drapeau *et al.* 2008, Thompson *et al.* 2008, Zimmerling 2008). At the same time, no evidence was presented by Blancher (2008) that any of these species have declined during the 20 years between atlas surveys, and Venier and Pearce (2007) found that brown creepers were unaffected by forest management. These differences need to be reconciled. Lack of a decline detected from atlas data may be masked by relatively poor coverage from northern boreal areas, or that forest management effects are difficult to detect over large spatial and temporal scales. Alternatively, in many managed areas, it may be that sufficient old stands or stands with certain old-forest attributes remain to support populations (e.g., Venier and Pearce 2007), or that these studies did not sample the full range of stands occupied by these species.

Most work has indicated the need to develop better data on breeding success, demography, and absolute density for key individual species to enable population modelling. Estimates of bird abundance are most often of relative abundance from unrepeated point counts, rather than providing estimates of absolute abundance. However, we do not know if bird presence indicates that the bird is breeding and, if it is breeding, whether fledging will be successful. The work by Nol (2008) and Burke *et al.* (2008) clearly suggested that successful nesting and fledging is habitat dependent and that density (e.g., from point counts) may not reflect breeding success. Hence, at least for key species, better information may be essential to understanding species responses to habitat change in terms of long-term persistence.

Whether or not there is a need to alter forest practices to reduce threats to various bird species is unclear, owing to a lack of complete understanding of effects, and the fact that a full forest rotation has not yet been completed. Therefore, a precautionary and adaptive approach to forest management should be continued or adopted, especially for rare or declining species. For example, we need to test and falsify the idea that the "coarse-filter approach" to forest management is maintaining all bird species in time and space before embarking on individual species management programs (except for species of concern). Several authors suggested there is a need for better landscape-level species models for the key species of interest, such as those used as indicators in forest management, or identified as declining (e.g., (e.g., Holmes *et al.* 2008, Rempel 2008). For example, a test of the Ontario habitat matrix resulted in poor predictive capacity (false positive or negative) for several important species including boreal chickadee, suggesting that our understanding is poor, or that better modelling techniques are needed (Holmes *et al.* 2007, 2008).

Monitoring programs, using forest birds as the indicators, must be linked to forest management as a tool to assess long-term changes and sustainability. A monitoring program linked to forest management and supported by predictive models is important to provide data to an adaptive management framework. However, for this process to work well, improved habitat models are needed. Two general classes of models are used in habitat modelling currently: those that simulate future forest conditions, and those that assign habitat values to a set of forest conditions. In Ontario, future forest conditions are simulated using models like BFOLDS (a fire behaviour/succession model to simulate natural disturbance), SFMM (a non-spatial strategic model to evaluate forest management goal tradeoffs), and Patchworks (a goal-driven spatial harvest simulator with forest succession components). Models to assign habitat value to forest condition include the habitat matrix models (based largely on expert opinion), habitat suitability models (a mix of expert opinion and data), and regression type models (based exclusively on data relationships). Where information is lacking, but where decision support models are required, expert opinion is often used to develop the necessary models. Given the lack of data, initially such models are rarely tested to determine either accuracy or generality, but are nonetheless used for decision-making. Modelling requires an iterative approach supported by monitoring data over time.

Summary of management implications

Bird status

1) While management in boreal forests does not appear to be having long-term (50- 60-year) negative effects on most breeding bird populations, continued monitoring is essential to ensure that any effects can be determined and evaluated, and corrective management actions taken (and see 6. below).
2) Continued targeted evaluation of the status of listed species and species suspected in decline should be undertaken at regular intervals (e.g. 5 years).
3) Species noted in individual studies as possibly affected by forest management, but not shown to be declining from the breeding bird atlas data, need their population status assessed more accurately. These species include brown creeper, boreal chickadee, primary cavity nesters, and secondary cavity nesters.
4) Aerial foragers or other species with significant declines, as determined through analysis of atlas data, need to be closely monitored.
5) Bird population data in Canada needs to be supplemented with information from stop-over sites and the wintering grounds to more accurately assess trends in status.
6) Most results describe patterns of relative bird abundance; better data on absolute density and breeding success for selected species is essential to demonstrate effects of forest management, climate change, or other perturbations in forests and to assess habitat quality.

Forest management

1) Riparian areas should be managed under the emulation of natural disturbances paradigm, unless other considerations are paramount (e.g., social values). Within riparian areas it is important to: maintain natural heterogeneity in forest composition, age classes, and structure; maintain a range of sizes and shapes for buffers; state riparian and adjacent terrestrial management objectives explicitly in forest management plans; and link riparian management strategies to the overall landscape design.
2) It is difficult to generalise effects of forest management because these may vary by avian species and silvicultural technique. However, landscape context is important for many species. Further, birds use a wide variety of habitats, age classes, and forest structures, so it is important to manage for heterogeneity at multiple scales using natural patterns as guides.
3) In Great Lakes–St. Lawrence and Carolinian forests, fragmentation and landscape homogenization is a major concern shown to reduce avian diversity, density, and breeding success. In already highly fragmented landscapes, even selection harvesting increases negative effects on some bird species. Management objectives, and perhaps guidelines, should be established across large landscapes in southern Ontario to address these issues.
4) There is considerable evidence for convergence of bird communities in managed and burned boreal forest habitats over time, but concerns remain for several species such as primary and secondary cavity nesters, brown creepers, boreal chickadees, and aerial foragers as a guild. Habitat should be specifically planned and managed for these species and guilds to support their populations.
5) Large trees (>15 cm DBH), large declining trees, large woody debris, and large snags are important habitat elements, and management should maintain a range of types, sizes, and decay classes of snags and declining trees.
6) Burned forests are source habitats for some primary excavators, especially black-backed woodpeckers, and so not all burned forests should be salvage-logged.
7) Management should maintain the representative species mix and tree communities of the original forest across the landscape; this is especially an issue in Great Lakes–St. Lawrence and Carolinian forest types. Retrospective studies may be needed to determine a baseline condition.

8) New fine-filter direction for specific birds is needed only if existing coarse- and fine-filter direction is inadequate. For example, improved species-specific guidelines for stick-nesting species are available in Ontario, providing an example of an adaptive management approach.

Monitoring

1) Reliable evaluation of bird status will always require a mix of monitoring approaches because of their inherent strengths and biases. Some programs might target an individual species (rare species or an indicator), a group of similar species (e.g., waterfowl), or in a certain habitat type (e.g., riparian). Not all groups or species can be monitored effectively using a single technique.
2) Linking management to monitoring requires integration of predictive modelling into the planning process in an adaptive management context. Modelling, planning, and monitoring teams should meet early in the forest management planning cycle to gain a common understanding of management issues, survey design, implementation practices, and data needs.
3) To evaluate effects and effectiveness of management actions on bird populations, status assessment must include reserves and other reference areas that are not subjected to forest management. This is not additional, but integral to management needs.
4) Large-scale monitoring programs, such as the ABMI, are useful because they allow a large-scale assessment of changes in biodiversity. At a regional level, they can be used to test the predictions of scenario analyses. However, adequate sampling intensity of birds is essential to ensure that all species are detected.
5) Monitoring should be done against habitat models to understand data gaps.
6) Spatial heterogeneity of species occurrence among stands must be expected. Therefore, it is important to sample several stands in a given treatment.
7) Rare species, species that appear to be declining, and species with hypothesized threshold responses with large extents of forest cover, or those with steep declines in response to forest loss, should be targeted as focal species for monitoring.

Summary of research needs and data gaps

Bird status

1) For species where declines have been detected we need to understand the cause of the decline. For example, are declines related to breeding ground, wintering ground, or migration habitat changes, food supply, climate change, pollution, exploitation, or excessive mortality from disease, etc.?
2) Is the competition hypothesis an explanation for inconsistent species assemblages among forest stands?
3) How can reliability of status estimates in northern areas such as BCR 8 be cost-effectively improved?
4) How can we effectively monitor and model status of rare species?
5) What is the best way to monitor wetland and riparian species?
6) What are the best modelling techniques and data sources for producing predictive species distribution and abundance maps? How robust are these models, and can we separate ecological information and understanding from variance caused by multiple environmental factors?
7) Is it more cost-effective to sample many different sites, or to sample fewer sites many times? What is the optimal balance?
8) For a given species known to be in decline, are other members of the associated guild of species also declining, or is the decline specific to the species?
9) Are we missing declining species owing to large statistical variance and/or insufficient or ineffective sampling?

Forest management

1) How does dead wood contribute to bird nesting and foraging ecology?
2) Are selected indicator species suitable?
3) What differences exist between riparian areas in natural areas and managed forests over large scales?
4) How many and what quality of snags and/or declining trees are needed to maintain persistence in cavity-users, and what is the appropriate landscape-level context?
5) How important is gap dynamics, especially in the boreal forest, to maintaining avian diversity?
6) Do habitat thresholds exist for indicators and species in decline?
7) What are climate change effects likely to be on forest birds?
8) Does existing coarse-filter management maintain bird populations?

Monitoring

1) Is there a list of focal species common across Ontario forests?
2) Outputs of scenario modelling should be validated by monitoring forest birds before and after forestry activities to determine model validity.
3) Are current monitoring techniques delivering sufficiently robust data to suggest effects of forest management and for population modelling?

Habitat models

1) Models are often used in planning to make predictions concerning the sustainability of management options, but these planning predictions are seldom tested. To help assess validity of planning models, models should be tested by comparing the predictions to outcomes of forest management. Testing could begin now by looking at past predictions.
2) Improved habitat models are needed for planning. Models should consider spatial relationships and the possibility of habitat thresholds. Also, modelling platforms should be designed to better communicate results to planners and public audiences.
3) Modellers should consider systems (causal) models in addition to statistical (correlation) models. Such models facilitate exploration of causal relationships and conditions outside the current environmental domain (e.g., effects of climate change).
4) Some habitat variables (e.g., snag density) may be influenced so strongly by stochastic events and initial stand conditions that they are largely unpredictable through time. Therefore, caution should be used in predicting future conditions of such variables in the planning process.

5) In Ontario different habitat models are used in different administrative regions, but it may be better to use a standardised suite of predictive models throughout the province in the planning process.
6) Basing models on adequate sample sizes, over longer-term datasets, and from a reasonable geographic distribution would improve accuracy. This requires comprehensive and coherent habitat data (e.g., stand age and type) that would allow comparisons across regions.
7) Forest habitat models might be improved by expanding the use of remotely sensed data for inventorying habitat variables such as stand age, woody material, and soil types.
8) There is a need for an improved understanding (and prediction) of successional pathways, including differences between burns and managed forests.
9) Corrections for species detectability might improve models where absolute density rather than relative density is required.

Policy and planning

1) Defining habitat conditions or benchmarks for forest management plans is critical, independent of other drivers of avian populations. What other influences should be considered for birds unrelated to forestry or local habitat supplies (e.g., habitat change on wintering grounds, budworm effects, climate change)?
2) Partners in Flight plans for all BCRs are imminent. A policy response will be needed, especially if these conflict with the emulation of natural disturbances.
3) Clarification from government about how to comply with the MBCA in the context of forestry is evolving, but a variety of means has been used by managers to reduce the problem (e.g., operating practices, habitat supply modelling).

Acknowledgements

The Sault Ste. Marie workshop was funded by the Forest Ecosystem Science Cooperative, Sustainable Forest Management Network, and Ontario Ministry of Natural Resources. The Organizing Committee was: Ian Thompson (CFS), Jim Baker OMNR), Margaret Donnelly (SFMN), Robert Rempel (OMNR), Derrick Romaine (Abitibi- Bowater), Kandyd Szuba (Domtar), Dianne Miller (Forest Co-op), and Bob Watt (OMNR). Facilitation was provided by CFS personnel: Guy Smith, Jason Langis, and Stan Phippen. A helpful record of the proceedings was kept by Janet Jackson. Ken McIlwrick was kind enough to operate the computer and survived 2 (inevitable) technical failures during the program. Considerable local logistical help was provided by Dianne Miller (Forest Ecosystem Science Cooperative) and Catherine Rostron (SFMN). We also thank the workshop participants for 2 days of very fruitful and interesting discussions. Samantha Song (Environment Canada) and an unknown reviewer provided many helpful suggestions on the first draft of this manuscript.

References

Baker, J., G. Lucking and K. Szuba. 2008. Providing for bird habitat in forest management plans in Ontario – opportunities and difficulties. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.

Bayne, E. 2008. Development and application of biological integrity indices for reporting status and trends of biodiversity. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.

Betts, M.G., G.J. Forbes and A.W. Diamond. 2007. Thresholds in songbird occurrence in relation to landscape structure. Conservation Biology 21: 1046–1058.

Blancher, P.J. 2008. Status of Ontario's forest birds. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.

Burke, D., K. Elliot and S. Holmes. 2008. Impacts of partial harvesting on forest breeding birds in fragmented forests. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.

Cadman, M.D., P.J.F. Eagles and F.M Helleiner. 1987. Atlas of the breeding birds of Ontario. University of Waterloo Press, Waterloo, ON.

Cadman, M.D., D.A. Sutherland, G.G. Beck, D. Lepage and A.R. Couturier (eds.). 2007. Atlas of the Breeding Birds of Ontario, 2001–2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature. Toronto, ON.

Crawford, W.S. and D.T. Jennings. 1989. Predation by birds on spruce budworm *Choristoneura fumiferana*: functional, numerical, and total responses. Ecology 70: 152–163.

Davis, R. 1999. Strategic Forest Management Model Version 1.6 User Guide. Ont. Min. Nat. Res., Toronto, ON. 270 p.

deVries, A. 2008. Forest industry perspective on the Migratory Birds Convention Act: challenges and solutions. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.

Donnelly, M. and C. Wedeles. 2008. Birds and forest management: an overview of relationships and management approaches. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.

Drapeau, P., A. Leduc, J.-F. Giroux, J.-P. L. Savard, Y. Bergeron and W.L. Vickery. 2000. Landscape-scale disturbances and changes in bird communities of boreal mixed-wood forests. Ecological Monographs 70: 423–444.

Drapeau, P., A. Nappi, L. Imbeau, Y. Bergeron and A. Leduc. 2008. The importance of standing deadwood in the foraging and nesting ecology of birds in the boreal forest. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available a: http://www.forestco-op.ca/forest_birds_workshop.htm.

Duffe, J., R. Zimmerling, J. Paquette, J. Kennedy and K. Ziemba. 2008. Modelling bird habitat using satellite derived data for area-based habitat conservation plans. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.

Fleming, R.A., A.A. Hopkin and J.-N. Candau. 2000. Insect and disease disturbance regimes in Ontario's forests. *In* A.H. Perera, D.L. Euler and I.D. Thompson (eds.). Ecology of a managed terrestrial landscape: patterns and processes of forest landscapes in Ontario. pp. 141–162. UBC Press, Vancouver, BC.

Francis, C.M., P. Blancher and D. Phoenix. 2008. Bird monitoring programs in Ontario: what have we got and what do we need? Pre-

sentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.
Guenette, J.S. and M.-A.Villard. 2005. Thresholds in forest bird response to habitat alteration as quantitative targets for conservation. Conservation Biology 19: 1168–1180.
Hannon, S. and T. Swift. 2008. Forest cover thresholds in forest birds: implications for management. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.
Hobson, K.A. and E. Bayne. 2000. Breeding bird communities in boreal forest of western Canada: consequences of "unmixing" the mixedwoods. Condor 102: 759–769.
Holloway, G.L., B.J. Naylor and W.R. Watt (eds.). 2004. Habitat relationships of wildlife in Ontario. Revised Habitat Suitability Models for the Great Lakes–St. Lawrence and Boreal East Forests. Ontario Ministry of Natural Resources, Southern Science and Information Section and Northeast Science and Information, Joint Technical Report No. 1. 116 p.
Holmes, S.B., K. McIllwrick and D. Kreutswiser. 2008. Forest bird responses to partial cutting in riparian reserves in Ontario's boreal mixedwood forest. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.
Holmes, S.B., L.A. Venier, B.J. Naylor and R.J. Zimmerling. 2007. A test of Ontario's habitat suitability matrix as a forest management planning tool for forest birds. The Forestry Chronicle 83: 570–579.
Hughes, J. 2008. Development of a new regulatory approach for the management of incidental take of migratory birds. Presentation, Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network.
McLaren, M.A., I.D. Thompson and J.A. Baker. 1998. Selection of vertebrate wildlife indicators for monitoring sustainable forest management in Ontario. The Forestry Chronicle 74: 241–248.
Moore, T. and D. Rouillard. 2008. Patching together the future of forest modelling: Implementation of Patchworks in the 2009 Romeo Malette forest management plan. The Forestry Chronicle 84: 718–730.
Naylor, B. 2008. Effects of forest management on stick-nesting birds: new direction for mitigation in Ontario. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.
Nol, E. 2008. Partial harvesting impacts on forest breeding birds in forested landscapes. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.
Northwatch. 2007. Wood supply, wood flow, and licensing. Report by ArborVitae Environmental Services Ltd, and Fleming Forestry, for Northwatch. Available at http://www.web.ca/~nwatch/fmp/index.html.
Nudds, T. 2008. Pattern, process, and bird community assembly on boreal landscapes originating from fire and timber harvest. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.
[OMNR] Ontario Ministry of Natural Resources. 1996. Forest management planning manual for Ontario's Crown forests. Queen's Printer for Ontario, Toronto. Available at http://www.mnr.gov.on.ca.
_____. 2002. Forest management guide for natural disturbance pattern emulation, version 3.1. Queen's Printer for Ontario, Toronto. Available at http://www.mnr.gov.on.ca.
_____. 2004. Forest management planning manual for Ontario's Crown forests. Queen's Printer for Ontario, Toronto. Available at http://www.mnr.gov.on.ca.
Perera, A.H., D.G. Yemshanov, F. Schnekenburger, D.J. B. Baldwin, D. Boychuck and K. Weaver. 2004. Spatial simulation of broad-scale fire regimes as a tool for emulating natural fire disturbance. *In* A.H. Perera, L.J. Buse, and M.G. Weber (eds.). Emulating natural forest landscape disturbances: concepts and applications. pp. 112–122.Columbia University Press, New York.
Poulin, J.-F., M.-A. Villard, M. Edman, P.J. Goulet and A.-M. Eriksson. 2008. Thresholds in nesting habitat requirements of an old forest specialist, the brown creeper (*Certhia americana*), as conservation targets. Biological Conservation 141: 1129–1137.
Rempel, R.S. 2007. Selecting songbird species for biodiversity conservation assessment: response to forest cover amount and configuration. Avian Conservation and Ecology 2: 6 [online]. Available at http://www.ace-eco.org/vol2/iss1/art6.
Rempel, R.S. 2008. Developing a focal species bioassay for assessment of songbird conservation design strategies. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.
Rempel, R.S., J. Baker, P.C. Elkie, M.J. Gluck, J. Jackson, R.S. Krushnerik, T. Moore and A.H. Perera. 2007. Forest policy scenario analysis: sensitivity of forest songbirds to changes in mature forest cover amount, composition, and configuration. Avian Conservation and Ecology 2: 5 [online]. Available at http://www.ace-eco.org/vol2/iss1/art5/.
Rempel, R.S., J. Baker, P. Elkie, M. Gluck, J. Jackson, R. Kushneriuk, T. Moore and A.H. Perera. 2008. Development and evaluation of coarse-filter policy options for the conservation of forest songbird communities. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.
Sleep, D., M. Drever and K. Szuba. 2008. Linking the range-wide decline of a songbird to long term prey cycles: The case of the Canada warbler. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.
Song, S. 2008. Boreal avian bird modelling project. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.
Stutchbury, B.J.M. 2007. The silence of the songbirds. Harper Collins, Toronto, ON.
Swift, T.L. 2007. Relative effects of habitat cover versus configuration, and the existence of critical thresholds in ecology. PhD. Thesis, University of Alberta, Edmonton, AB.
Terbourgh, J. 1989. Where have all the birds gone? Princeton University Press. Princeton, NJ.
Thompson, I.D., C. Jastrebski, D. Corbett and G. Tink. 2008. Effects of post-harvest silviculture and stand age on boreal bird community structure. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.
Thompson, I.D., S. Maher, D. Rouillard, J. Fryxell and J. A. Baker. 2007. Accuracy of forest inventory mapping: some implications for boreal forest management Forest Ecology and Management 252: 208–221.

Venier, L. 2008. Forest birds as indicators of sustainable forest management. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.

Venier, L.A. and J.L. Pearce. 2004. Birds as indicators of sustainable forest management. The Forestry Chronicle 80: 61–66.

Venier, L.A. and J.L. Pearce. 2007. Boreal forest landbirds in relation to forest composition, structure, and landscape: implications for forest management. Canadian Journal of Forest Research 37: 1214–1226.

Venier, L., J. Pearce, D. Fillman, D. McNicol and D.A. Welsh. 2008. Boreal mixedwood bird community response to spruce budworm outbreak and succession. Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.

Villard, M.A. and M.G. Betts. 2008 (in press). *In* M.A. Villard and B.G. Jonsson. Setting Conservation Targets for Managed Forest Landscapes. Cambridge University Press, Cambridge, UK.

Welsh, D.A. 1981. Impact on bird populations of harvesting the boreal mixedwood forest. *In* R.D. Whitney and K.M. McClain (eds.). Boreal mixedwood symposium. pp. 155–167. Canadian Forest Service, COJFRAC proceedings 0-P-9.

Zimmerling, J.R. 2008. Do post-harvest forests emulate natural disturbance from the perspective of boreal landbirds? Presentation to Forest Birds Workshop, Sault Ste. Marie, ON. April 8–10, 2008. Forest Ecosystem Science Co-operative and Sustainable Forest Management Network. Available at http://www.forestco-op.ca/forest_birds_workshop.htm.