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BIRD-FORESTRY RELATIONSHIPS IN CANADA: LITERATURE REVIEW AND SYNTHESIS OF MANAGEMENT RECOMMENDATIONS

TECHNICAL BULLETIN NO. 892
DECEMBER 2004

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PRESIDENT'S NOTE

Birds fill important ecological roles and are widely enjoyed by millions of individuals who watch, feed, photograph, and sometimes hunt them. Canada's extensive forests provide habitats for approximately 220 bird species, some of which are not found in other portions of North America. Canada's forests, which have been referred to as a "veritable neotropical migrant factory," represent the core breeding range for many birds.

However, over the last 30 years, concerns have arisen that some landbird species in Canada and the U.S. are declining. Fully 100 species are now on a Partners in Flight Watch List due to perceived threats to their habitat, declining populations, small population sizes, or limited distribution. In response to these concerns, voluntary partnerships such as Partners in Flight and the North American Bird Conservation Initiative have arisen and have generated management plans (e.g., Partners in Flight physiographic region plans, North American Landbird Conservation Plan, Framework for Landbird Conservation in Canada), assigned conservation priorities to species, and fostered conservation actions that will help address declines of high-priority species as well as "keep common species common".

In addition to providing habitat for birds, Canada's forests also provide wood products and economic benefits to society. Garnering these benefits, however, requires the use of silvicultural practices that temporarily alter forest and landscape structure. Thus, the recent North American Landbird Conservation Plan identified forestry activities as a priority conservation issue for the Partners in Flight northern forest avifaunal biome. If managers are to provide both wood products and habitat for birds, they need sound information with which to develop forestry practices that are sustainable, ecologically based, and scientifically advanced.

This Technical Bulletin seeks to provide such information for Canada. The authors reviewed more than 100 research-oriented publications to summarize and assess bird response to forest management practices at different scales. They note that, as with any management activity, habitat for some species is enhanced temporarily while habitat for others is diminished. At the stand scale, short-term effects of forestry practices on pre-harvest bird communities are often proportional to the extent of the harvest operation. Forest fragmentation per se does not appear to be a serious issue in Canada's commercial forest areas, but may be where forests are interspersed with other land uses. Existing information about edge effects is conflicting, and such effects likely vary by bird species and locale.

The forest industry has made very important contributions to research on the relationship between birds and forestry in Canada. There have, however, been few landscape-scale studies of birds to date, which is a key information need. More information is also needed about bird productivity and its relationship with forestry practices, and how to better emulate natural disturbances with silvicultural practices. In a review of the documents used in this assessment, the authors found that at least 60% of the studies benefited from industry contributions. More than 40% received either direct or indirect financial contributions. Many others received support through providing access to data, providing logistical support, use of field supplies and facilities, providing advice, and even conducting harvesting or other forest management operations in support of an experimental design. It is clear that many of the studies upon which this report is based could not have been undertaken successfully without the significant contributions made by the forest industry.

Ronald A. Yeske

December 2004

MOT DU PRÉSIDENT

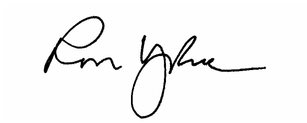
Les oiseaux remplissent un rôle écologique important et ils représentent un attrait pour des millions d'individus qui prennent plaisir à les observer, les nourrir, les photographier et parfois les chasser. Les vastes forêts canadiennes procurent des habitats pour environ 220 espèces d'oiseaux, parmi lesquelles certaines ne se retrouvent nulle part ailleurs en Amérique du Nord. Les forêts canadiennes, identifiées comme étant un « véritable espace de migration néo tropicale», constituent le cœur de la zone de nidification pour plusieurs oiseaux.

Cependant, depuis les 30 dernières années, on se préoccupe de plus en plus du déclin de certaines espèces d'oiseaux terrestres au Canada et aux États-Unis. Une centaine d'espèces sont actuellement sur la liste de Partenaires d'envol car on s'est aperçu que leur habitat est menacé, que les populations sont en déclin, qu'elles sont de petites tailles ou que leur distribution est limitée. En réponse à ces préoccupations, des partenariats volontaires tels que Partenaires d'envol et l'Initiative de conservation des oiseaux de l'Amérique du Nord ont vu le jour et ont généré des plans de gestion (par exemple, les plans régionaux physiographiques de Partenaires d'envol, le Plan de conservation des oiseaux terrestres de l'Amérique du Nord, le Plan cadre pour la conservation des oiseaux terrestres au Canada). Grâce à ces partenariats, on a établi des priorités de conservation pour les espèces et on a financé des actions de conservation visant deux objectifs : s'attaquer aux espèces dont le déclin constitue une priorité élevée et maintenir le caractère « commun » des espèces communes.

En plus de fournir un habitat aux oiseaux, les forêts canadiennes procurent aussi des produits du bois et des bénéfices économiques à la société. Toutefois, afin d'accumuler ces bénéfices, il est nécessaire d'utiliser des pratiques de sylviculture qui ont pour effet de modifier temporairement la structure de la forêt et du paysage. Par conséquent, le récent Plan de conservation des oiseaux terrestres de l'Amérique du Nord a identifié les activités forestières comme étant un enjeu de conservation prioritaire pour le biome avifaunique de la forêt nordique de Partenaires d'envol. Si les gestionnaires doivent fournir simultanément des produits du bois et des habitats pour les oiseaux, ils ont besoin d'information juste avec laquelle ils seront en mesure de développer des pratiques forestières durables, écologiques et à l'avant garde de la science.

Ce bulletin technique cherche à fournir ce type d'information pour le Canada. Les auteurs ont revu plus de 100 publications de recherche afin de synthétiser et d'évaluer la réponse des oiseaux face aux pratiques de gestion forestière à différentes échelles. Comme pour toute activité de gestion, les auteurs ont noté que l'habitat de certaines espèces est favorisé temporairement au détriment de celui d'autres espèces. À l'échelle du peuplement, les effets à court terme des pratiques forestières sur les communautés d'oiseaux observés avant la récolte sont souvent proportionnels à l'ampleur de l'opération d'exploitation. La fragmentation de la forêt proprement dite ne semble pas constituer un enjeu sérieux pour les zones de forêts commerciales au Canada, mais elle peut l'être dans les endroits où les forêts sont parsemées à travers les autres utilisations du sol. L'information existante traitant des effets de lisière est contradictoire. Ces effets sont susceptibles de varier selon les espèces d'oiseaux et l'emplacement.

L'industrie forestière a grandement contribué aux recherches visant à déterminer la relation entre les oiseaux et la foresterie au Canada. Toutefois, jusqu'à maintenant, il y a peu d'étude sur les oiseaux à l'échelle du paysage, malgré que cette information soit primordiale. Il est également nécessaire d'obtenir plus d'information sur la productivité des oiseaux et la relation qui existe entre la productivité et les pratiques forestières. On se doit enfin de savoir comment améliorer la simulation des perturbations naturelles dans les pratiques de sylviculture. Lors de la revue de la documentation utilisée dans le cadre de cette évaluation, les auteurs ont trouvé qu'au moins 60% des études ont bénéficié des contributions de l'industrie. Plus de 40% ont reçu des contributions financières directes ou indirectes. Plusieurs autres études ont reçu du soutien sous forme d'accès aux données, de logistique, d'utilisation du matériel et des installations sur le terrain, de conseils et même d'activités d'exploitation ou autres opérations de gestion forestière réalisées en guise d'appui à un design expérimental. Il s'avère incontestable que plusieurs études sur lesquelles ce rapport se fonde n'auraient pu être réalisées avec succès sans les contributions significatives de l'industrie forestière.



Ronald A. Yeske

Décembre 2004

BIRD-FORESTRY RELATIONSHIPS IN CANADA: LITERATURE REVIEW AND SYNTHESIS OF MANAGEMENT RECOMMENDATIONS

TECHNICAL BULLETIN NO. 892
DECEMBER 2004

ABSTRACT

This document presents a review of the influences of forest management on birds in Canada. The review draws primarily (but not exclusively) on Canadian literature for two reasons; first, and most importantly, is that the communities of birds and responses of birds to forest management are logically more likely to be similar within a geographic region or forest type. The second reason is to highlight the contributions of Canadian research to the present state of knowledge, and as a corollary, to identify topics and issues about which Canadian research is needed. The primary focus of this review is songbirds, although information on raptors has been included as well.

The objectives of this review are to:

- describe studies of bird-forestry relationships from Canada's Bird Conservation Regions (BCRs);
- describe existing knowledge of the effects of forest management on birds and bird habitat;
- synthesize management recommendations; and
- identify future research needs.

Well over 100 research-oriented publications were reviewed. Findings from those studies were combined with information from over 200 other documents to provide assessments of bird response to forest management practices at different spatial scales.

At the stand scale, the effects of practices (primarily associated with harvesting) lead to the broad conclusion that short-term effects on pre-harvest communities are in general proportional to the extent of harvest operations. Of course, there are many caveats to this broad assertion. For example, retention of residual structure may play an important role in ameliorating post-harvest effects on some species; the removal of overstory vegetation provides important habitat for bird species associated with early successional habitats; and many effects are likely analogous to those which occur following natural disturbances. Also, it is important to consider that differing silvicultural objectives are best met with specific harvest systems, and so substitution of a severe (from a bird effects perspective) harvest system with a more benign one is not always possible.

At a broader scale, specific spatial aspects of effects were reviewed, including forest fragmentation, edge effects, connectivity, and landscape-scale response. The literature suggests that forest fragmentation per se is not a serious issue in Canada's commercial forest areas, although it may be in areas where forests are interspersed with agricultural and urban lands. The amount of habitat available is more important than its spatial arrangement. The literature provides a confusing picture of the importance of edge effects (primarily nest predation) in largely forested areas. Convincing studies indicate that edge effects can be important factors in bird ecology, and just as convincing studies indicate the opposite. We argue that site-specific knowledge is needed to assess the importance of edge effects in any area, given that generalizations seem elusive. The weight of the relatively sparse evidence suggests that connectivity is not a serious issue in Canada's commercially managed forests, although it is best to draw conclusions on a species-by-species basis. There have not been many studies on landscape-scale response of birds to forest management, although those that exist provide significant insight into the importance of managing forests with a view broader than at the stand scale.

The document concludes with a review of general principles of forest management influences on birds and an identification of research needs. We contend that the most important among the substantial research needs identified are

- comparisons of response to forest management with natural disturbances;
- productivity-based assessments; and
- landscape-scale assessments.

KEYWORDS

avian communities, avian populations, bird communities, Bird Conservation Regions, bird populations, Canada, forest management, forestry practices, forest products industry, forest structure, forest age, natural disturbance, productivity research, timber harvest

RELATED NCASI PUBLICATIONS

Technical Bulletin No. 822 (February 2001). *Accommodating birds in managed forests of North America: A review of bird-forestry relationships.*

RELATION ENTRE LES OPÉRATIONS FORESTIÈRES ET LES OISEAUX DU CANADA: REVUE DE LITTÉRATURE ET SYNTHÈSE DES RECOMMANDATIONS DE GESTION

BULLETIN TECHNIQUE NO. 892
DÉCEMBRE 2004

RÉSUMÉ

Ce document présente une revue de l'influence de la gestion forestière sur les oiseaux du Canada. Pour cette revue, on a puisé dans la littérature canadienne principalement (sans que ce soit exclusif) pour les deux raisons suivantes : d'abord et avant tout, les communautés d'oiseaux et les réponses des oiseaux face à la gestion forestière sont, selon toute logique, susceptibles d'être similaires dans une même région géographique ou dans un même type de forêt; en second lieu, on souhaite mettre l'accent sur la contribution de la recherche canadienne à l'état actuel des connaissances et comme corollaire, on souhaite identifier les sujets et enjeux qui nécessitent des efforts de recherche au Canada. Cette revue se concentre sur les oiseaux chanteurs mais des informations sur les rapaces ont également été incluses.

Les objectifs de cette revue sont de:

- décrire les études sur les relations entre les oiseaux et la foresterie selon les régions de conservation des oiseaux du Canada (RCO);
- décrire la connaissance actuelle des effets de la gestion forestière sur les oiseaux et leur habitat;
- faire la synthèse des recommandations de gestion et;
- identifier les besoins de recherche futurs.

Plus de 100 publications de recherche ont été revues. Les conclusions de ces recherches ont été associées avec les informations de 200 autres documents afin de permettre d'évaluer la réponse des oiseaux face aux pratiques de gestion forestière pour différentes échelles spatiales.

À l'échelle du peuplement, les effets des pratiques (principalement associées à l'exploitation) mènent à la conclusion générale suivante : les effets court terme sur les communautés avant l'exploitation sont généralement proportionnels à l'ampleur des opérations d'exploitation. Évidemment, cette affirmation générale s'accompagne de plusieurs réserves. Par exemple, le maintien des structures résiduelles peut jouer un rôle important dans l'amélioration des effets suivant l'exploitation pour certaines espèces; l'enlèvement de la végétation de l'étage dominant procure un habitat important pour les espèces d'oiseaux associées aux successions précédentes d'habitats et plusieurs effets sont susceptibles d'être analogues à ceux qui suivent des perturbations naturelles. Également, il est important de noter que des objectifs de sylviculture différents sont habituellement atteints grâce à des systèmes de récolte spécifiques. Par conséquent, la substitution d'un système de récolte agressif (du point de vue des effets sur les oiseaux) par un système moins perturbateur n'est pas toujours possible.

À une échelle plus large, les aspects spatiaux spécifiques des effets ont été revus, soit la fragmentation de la forêt, les effets de lisière, la connectivité et la réponse à l'échelle du peuplement. La littérature suggère que la fragmentation de la forêt proprement dite ne constitue pas un enjeu sérieux pour les zones de forêts commerciales au Canada, mais elle peut l'être dans les endroits où les forêts sont parsemées à travers les terres agricoles et urbaines. La quantité d'habitats disponibles est plus importante que l'arrangement spatial de ces habitats. La littérature donne un portrait contradictoire de l'importance des effets de lisière (principalement la prédation des nids) dans les zones où la forêt

occupe une superficie considérable. Des études convaincantes indiquent que les effets de lisière peuvent être d'importants facteurs pour ce qui concerne l'écologie des oiseaux et des études tout aussi convaincantes indiquent exactement le contraire. Nous affirmons qu'une connaissance propre à des sites spécifiques est nécessaire pour évaluer l'importance des effets de lisière pour une zone donnée, puisqu'il semble que la généralisation soit incertaine. Étant donné que peu d'études permettent de conclure autrement, il semble que la connectivité ne constitue pas un enjeu significatif dans les forêts canadiennes gérées commercialement. Il est toutefois préférable de tirer des conclusions espèce par espèce. Il y a peu d'études, à l'échelle du paysage, qui portent sur la réponse des oiseaux face à la gestion forestière. Cependant, les études qui existent donnent, quant à elles, une bonne idée de l'importance d'une gestion à plus large échelle des forêts plutôt qu'à l'échelle du simple peuplement forestier.

Ce document se termine par une revue des principes généraux reliés à l'influence de la gestion forestière sur les oiseaux ainsi que par l'identification des besoins de recherche. Nous prétendons que parmi les besoins de recherche identifiés, les plus importants sont les suivants :

- comparaisons de réponse face à la gestion forestière avec des perturbations naturelles;
- évaluations basées sur la productivité; et
- évaluations à l'échelle du paysage.

MOTS CLÉS

communautés aviaires, populations aviaires, communautés d'oiseaux, Régions de conservation des oiseaux, populations d'oiseaux, Canada, gestion forestière, pratiques forestières, industrie des produits de la forêt, structure forestière, âge de la forêt, perturbation naturelle, recherche sur la productivité, récolte du bois

AUTRES PUBLICATIONS DE NCASI DANS CE DOMAINE

Bulletin technique no. 822 (Février 2001). *Accommodating birds in managed forests of North America: A review of bird-forestry relationships.*

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1.0 INTRODUCTION

Of Canada's total land area (approximately 9.2 million square kilometres), about 45%, or 4.2 million square kilometres, is forested (Natural Resources Canada 2000). These forests play a tremendously important role in providing habitat for breeding birds. Canada's boreal forests alone are estimated to support over 200 species of landbirds and provide habitat for between one and three billion individual breeding birds (Blancher 2003). Over the last couple of decades there has been much concern expressed about continental declines in bird populations (Terborgh 1989; Hagan and Johnston 1992; Peterjohn et al. 1995; Dunn et al. 1999; Rich et al. 2004) underscoring the need to understand and manage the response of birds to forest management. In order to manage the responses, and in particular to mitigate those which have potential for deleterious consequences, forest planning and operational practices should be based on scientific knowledge and the documented responses of birds to forest management activities.

Given the diversity of this country's forests, the response of birds to forest management is complex. Some species, particularly habitat generalists, are resilient to habitat changes (Merrill et al. 1998; Morissette et al. 2002; Boulet et al. 2003; Simon et al. 2003), whereas habitat specialists can be more sensitive (Hagan et al. 1996; Schmiegelow and Mönkkönen 2002; Kirk 2003). While Canada's forest types and bird conservation regions or BCRs (see Section 3.1) have bird species in common, they also have different assemblages of bird communities. The response of a given bird species or community to its habitat and to forest management is not always consistent across forest types or BCRs. As an example of the variation across communities, Erskine (1977) listed 19 bird species which vary either in habitat preference or density over parts of their range in boreal Canada. The topic of nest predation by forest edges provides an example of variation in response to forest management practices; while some studies have found no evidence of nest predation in relation to clearcut edges (Hartley and Hunter 1998), others have provided very convincing evidence (Manolis et al. 2000) that effects do exist.

It is clear that the relationship between birds and forest management is complex, and from the synthesis of information that follows, it is also clear that there are key relationships that are not well understood, and that the understanding of bird-forestry relationships varies across Canada's forest types. What are forest managers to do with this disparate knowledge? First of all, it is clear that developing management practices and understanding effects based on regionally-appropriate knowledge is important. However, it is not acceptable to, as Welsh (1988) discussed, use the rationale of "we don't know enough" as an excuse for inaction in circumstances where specific knowledge is not available. Although species may react differently in different parts of Canada, there are also many similarities. Therefore, it is important to take stock of the knowledge which does exist in order to formulate appropriate management practices and predicted responses to them, or extrapolate using the most reasonable information. So a synthesis of available information is required in order to provide forest managers with a set of information upon which to base their management actions. The need for such a synthesis is the main rationale for this undertaking.

In this document we have drawn primarily (but not exclusively) on literature based on Canadian research and observations. We have done so for two reasons; first, and most importantly, is that the communities of birds and responses of birds to forest management are logically more likely to be similar within a geographic region, forest type, or BCR. We have, therefore, not relied heavily on literature from Fennoscandia and much of the United States. Although Canada and Fennoscandia share a broad forest type (the boreal forest), the bird communities within them are significantly different in both species composition (Haila and Järvinen 1990; Schmiegelow and Mönkkönen 2002) and evolutionary ecology (Mönkkönen and Welsh 1994), and so we have used literature from northern Europe sparingly, and mostly for reference to broad ecological concepts. We have, however, as discussed in Section 3.1, drawn from U.S. studies in proximal portions of Canadian BCRs to contribute to this review.

The second reason for focusing on Canadian research is to highlight the contributions of Canadian research to the present state of knowledge, and as a corollary, to identify topics and issues about which Canadian research is needed.

Most of the literature on bird responses to forest management deals with songbirds, and so they are the primary focus of this review. Information on raptors has also been included, although a comprehensive review of the raptor literature was not attempted. The review does not deal with waterfowl, shorebirds, or tetraonids (grouse).

In this review we have attempted to differentiate bird responses to forest management, to the extent possible, based on the country's BCRs and forest regions, different forest management practices, and the spatial and temporal aspects of forest management activities. Through the report we have attempted to draw out from the literature topics of most relevance to the practical aspects of forest management, and we have attempted to identify topics most in need of further research.

The objectives of this review are

- to describe the studies of bird-forestry relationships from Canada's BCRs;
- to describe existing knowledge on the effects of forest management on birds and bird habitat;
- to synthesize management recommendations; and
- to identify future research needs.

The bulk of this document is a synthesis of research results, as presented in Section 3. This is intended to be of use to forest managers and to a broader audience interested in the relationships between birds and forest management. The synthesis of management recommendations as presented in Section 4 has the forest manager specifically in mind. It is hoped that this section can stand on its own and provide both broad and specific suggestions which forest managers will find of use in contemplating methods to take bird responses to forest management into account in both strategic and operational planning. Section 5 identifies research needs, and Section 6 presents conclusions.

1.1 Methods

This project is primarily a literature review, and as such the methods used were straightforward. We canvassed the literature on research and management directions related to bird response to forest management. Literature was obtained at local university libraries, on the Internet, from colleagues, and from our own personal libraries. The literature was reviewed more or less systematically with the topics which each publication addressed recorded along with notes from the publication.

2.0 STUDIES OF BIRD RESPONSES TO FORESTRY PRACTICES

2.1 Studies in Different Bird Conservation Regions

The concept of developing ecological units based on bird conservation needs and dynamics emerged in the late 1990s through the efforts of the North American Bird Conservation Initiative (United States North American Bird Conservation Initiative Committee 2000). Bird conservation regions are ecologically defined units with similar bird communities, and habitats and conservation issues; they are based on the hierarchical framework of nested ecological units identified by the Commission for Environmental Cooperation (Commission for Environmental Cooperation 1997).

The purpose of BCRs is to "systematically and scientifically apportion the United States and North America into conservation units; facilitate a regional approach to bird conservation; facilitate communication among bird conservation initiatives; and promote new or expanded partnerships" (United States North American Bird Conservation Initiative 2000).

Using BCRs as the geographic basis upon which to investigate the relationship of birds to forest management and identify related research needs, therefore, is consistent with the foreseen role of BCRs.

Within Canada there are 12 BCRs (Figure 2.1). Note that the numbering of BCRs begins in western Alaska and proceeds southerly and southeasterly across Canada, the United States and Mexico, so the numbering of Canadian BCRs does not begin with number 1.

3 – Arctic Plains and Mountains

4 – Northwestern Interior Forest

5 – Northern Pacific Rainforest

6 – Boreal Taiga Plains

7 – Taiga Shield and Hudson Plains

8 – Boreal Softwood Shield

9 – Great Basin

10 – Northern Rockies

11 – Prairie Potholes

12 – Boreal Hardwood Transition

13 – Lower Great Lakes/ St. Lawrence Plain

14 – Atlantic Northern Forest

Of these BCRs, four are entirely within Canada (Nos. 3, 6, 7, and 8), all but two (Nos. 3 and 11) have forested components (although the forest area of No 7 is minimal), and industrial forest management activities occur in most (Nos. 4, 5, 6, 8, 9, 10, 12, and 14).

The boundaries of many Canadian BCRs extend into the United States. Some extend quite far into the U.S.; the Northwestern Interior Forest BCR (# 4) extends well into western Alaska; the Great Basin BCR (# 9) exists mostly in the U.S., extending south to southern Nevada; and the Northern Pacific Rainforest BCR(# 5) extends south to northern California.

Because most Canadian BCRs extend into the United States, we used literature from shared BCRs to contribute to this review. The extent of use of research from United States was tempered by our assessments of how relevant the literature was, based on the forest management practices investigated and the ecological relevance to Canada. For example, we did not use literature from Nevada, even though much of the state is in a BCR which extends into southern British Columbia. However, we did use a considerable amount of literature from New England, Washington, Oregon, and Minnesota because we felt the forest practices and bird ecologies there were very similar to those in the Canadian portions of the shared BCRs. Our bias however, was clearly to explore investigations taking place in Canada.

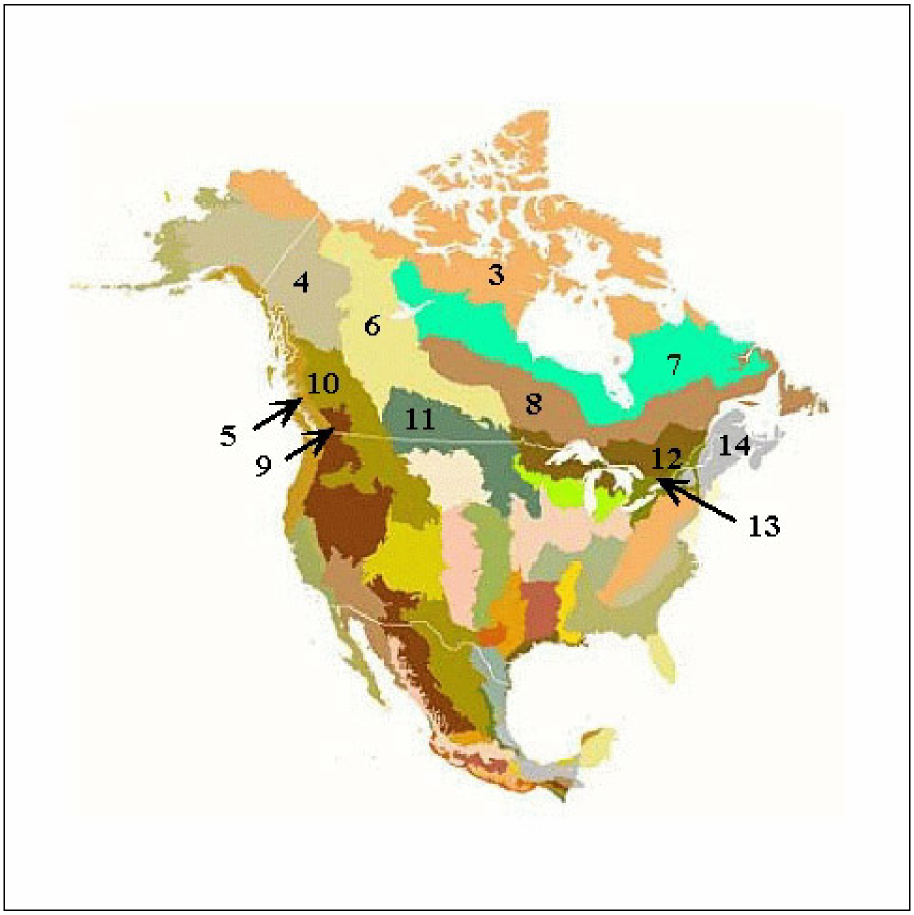

Figure 2.1 North American Bird Conservation Regions [Figure adapted from the Internet site of the North American Bird Conservation Initiative (http://www.bsc-eoc.org/international/bcrmain.html).]

We consulted well over 300 publications in the preparation of this review, of which 138 were research-oriented and reported on work from one or more Canadian BCRs. Figure 2.2 shows the distribution of the research publications relative to Canadian BCRs. Not included in the 138 publications are those which addressed bird response to forest management in general, those which provided context for discussions, and those which provided only management direction. The total number of the publications in Figure 2.2 exceeds 138 because some studies took place in more than one BCR.

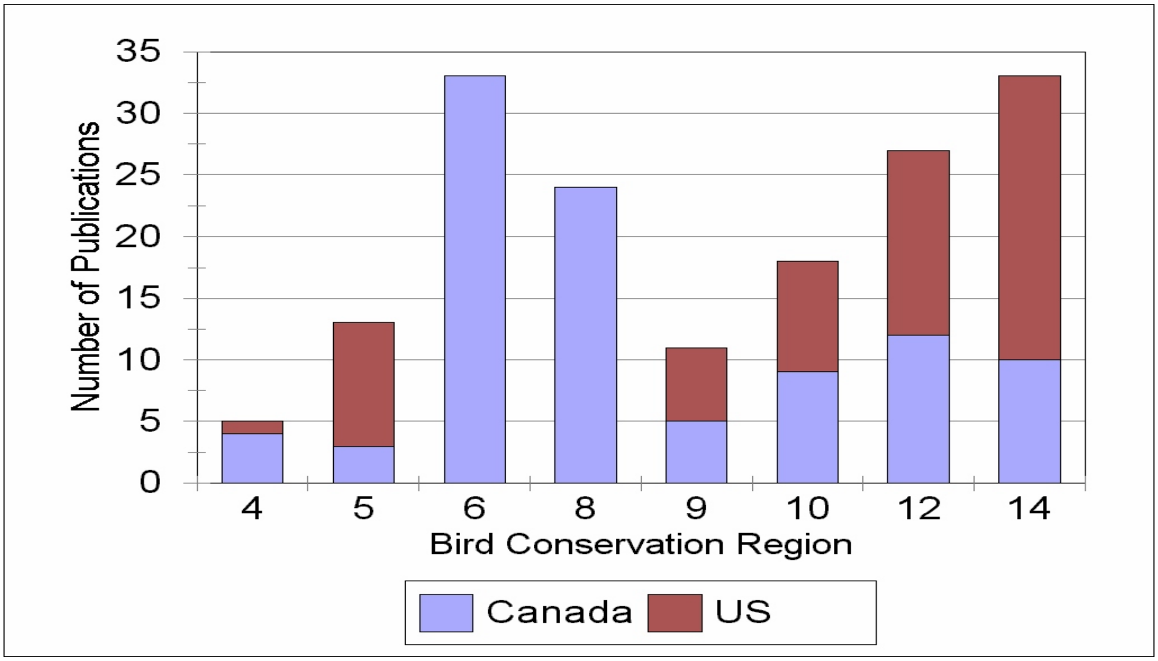

Figure 2.2 Distribution of the Research Publications Consulted in the Preparation of This Review

Figure 2.2 shows that BCRs 6 and 14 had the most publications. All the publications from BCRs 6 and 8 were from Canada (because those BCRs are entirely within Canada). A couple of points about Figure 2.2 are striking. First, the extent of work being undertaken in BCR 6 is notable, particularly because it is entirely within Canada. Second, there was a disproportionately heavy reliance in our efforts on work from the United States for BCRs 5 and 14. This is not in itself bad, but it is interesting to note that there seems to be a disproportionate amount of work from the United States relative to their total area. BCR 5 is the Pacific Northwest where there has been considerable interest in management of those forests in the United States for some time, at least partly because of old-growth management issues. BCR 14 includes Maine and northern New England; there has been a considerable amount of forest management research in Maine as its forests are very intensively managed compared to other states in the northeast. Figure 2.2 does not include citations from BCRs 3, 7, 11, or 13 as there is little or no commercial forestry carried out in those regions.

2.2 Studies Examining Specific Practices

Many of the studies we consulted related to specific management practices. While reviewing each publication, significant observations or discussions related to a series of topics were identified and recorded. In many instances a single publication provided insights on more than one topic, resulting in a greater number of observations than the number of publications. Figure 2.3 shows the frequency with which topics related to management activities were addressed in the publications we reviewed. Clearcutting was by far the most frequent topic. In general, publications that examined harvest-related effects or issues (clearcutting, partial cutting, salvage logging, thinning) were more numerous than those that dealt with post-harvest silvicultural activities. In fact, we found fewer than a dozen publications that provided substantial commentary on the effect of site preparation and vegetation management on forest birds. This could reflect researchers' opinions that the response of birds to forest harvest is more significant, or it could be that aspects of management related to forest regeneration were dealt with in publications that incorporated broader aspects of landscape responses to forest management.

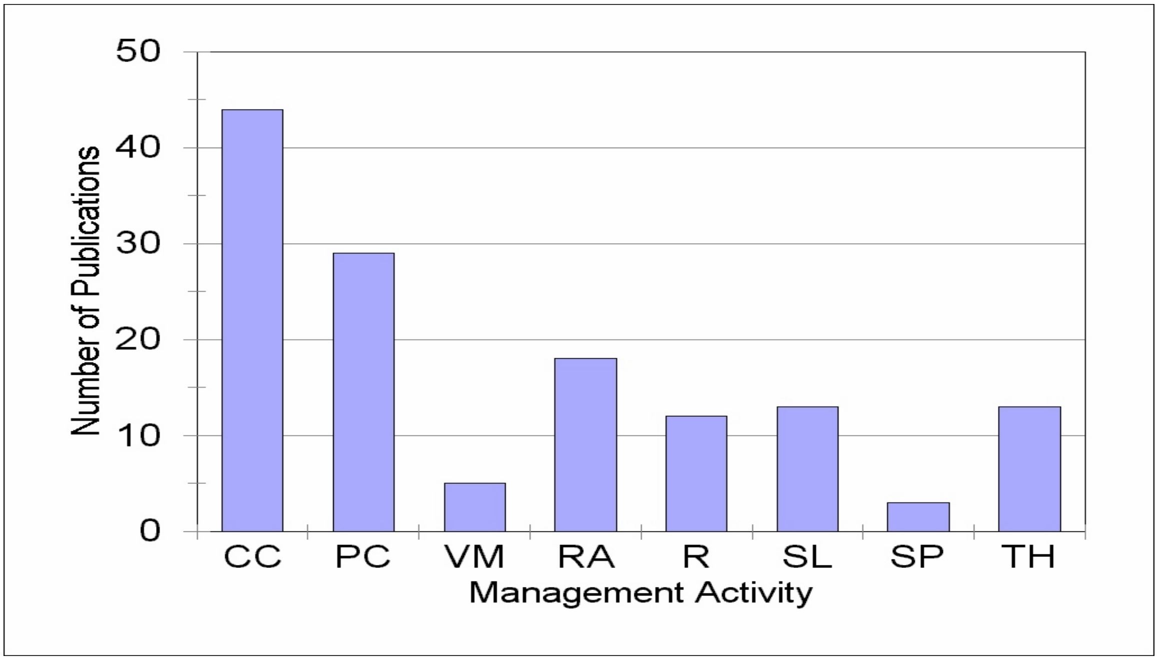

Figure 2.3 The Frequency with Which Topics of Various Management Activities Were Addressed in Publications Consulted in the Preparation of This Review [CC – clearcutting; PC – partial cutting, VM – vegetation management, RA – riparian area management, R – residuals, SL – salvage logging, SP – site preparation, TH – thinning]

2.3 Studies Examining Spatial Aspects of Bird Response

Most of the examinations of bird response to specific forest management activities shown in Figure 2.3 are directed at the stand or local scale. There is, as is discussed in more detail in Section 3, considerable interest in some specific topics related to bird response to the spatial configuration of stands and landscapes. Figure 2.4 shows the frequency with which publications addressed forest fragmentation, connectivity, edge effects (i.e., nest predation and parasitism), and broad spatial issues. There was much overlap in the topics, particularly among the first three. It was rare, for example, for a publication to discuss connectivity in the absence of further reference to forest fragmentation and so there is considerable redundance in the frequency with which these topics were addressed. Fragmentation could be portrayed as the context in which discussions of connectivity and edge effects occurred, but in some cases fragmentation was addressed without specific reference to connectivity or edge effects, and so it stands on its own as a topic of interest in addition to providing context for other spatial topics.

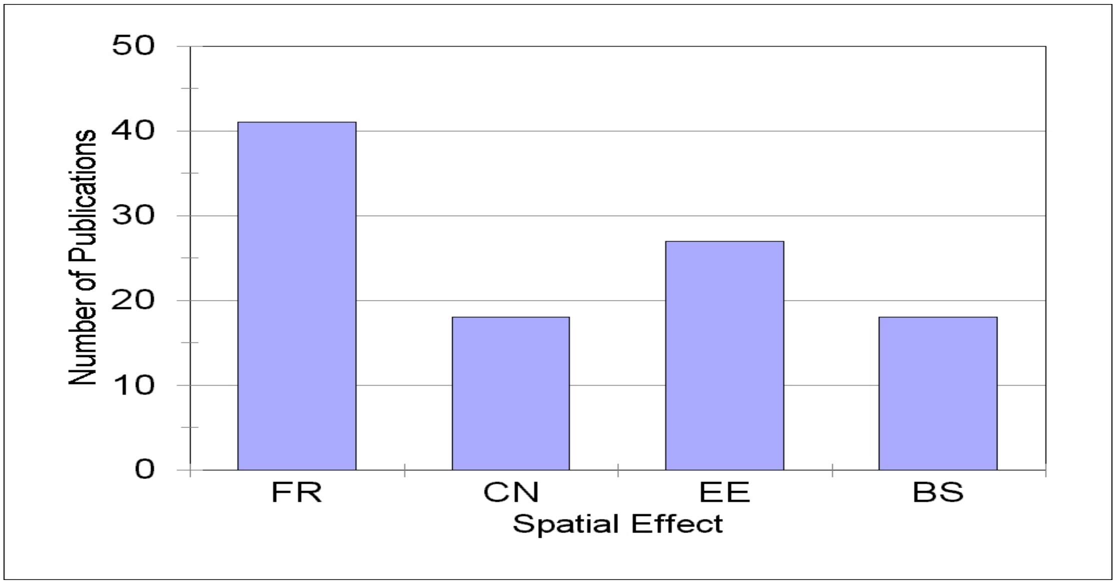

Figure 2.4 The Frequency with Which Specific Topics Related to Spatial Effects of Forest Management Were Addressed in Publications Consulted in This Review [FR – forest fragmentation, CN – connectivity, EE – edge effects; BS – broad spatial aspects (e.g., landscape scale forest composition)]

There was also some overlap between topics related to spatial effects and those which address specific management practices. For example, several studies of bird use of riparian areas also examined their potential role in providing connectivity between unharvested portions of the forest, and several studies of clearcutting provided input on the role that clearcut harvests have in altering the spatial configuration of the forest landscape.

Although we reviewed many publications that provided commentary on the topics of connectivity and on edge effects, the same is not the case for broad spatial aspects. This is a more difficult topic to address through field work, but as is discussed in Section 3.2.4, some very significant studies have taken place. Studies which have addressed this topic have involved, for the most part, significant amounts of effort and statistical design and analysis. On the other hand, there have been many studies on edge effects because the methods can be straightforward and the effort can be modest.

2.4 Studies Examining Specific Birds or Bird Communities

Fifty-two of the research publications we reviewed provided comments on the response of individual species of birds or groups of birds to forest management. The species which were discussed the most included ovenbird (because of its affinity for old forests and because it is relatively common and therefore easier to study), black-backed and three-toed woodpeckers, (because of their affinity for burned forests and because they are potentially threatened by specific practices) and pileated woodpeckers (because of their use of snags, coarse woody debris, and old forests). Many publications discussed the effects on guilds of birds; however, the guilds were defined differently in different publications so trends are somewhat difficult to discern. Many publications provided commentary on guilds defined by migratory groups, with neotropical migrants and resident birds being the subject of considerable concern. Other publications defined guilds based on nesting strategies (e.g., cavity nesters, canopy nesters, shrub nesters, ground nesters), foraging behaviour (e.g., ground foragers, aerial salliers), and food habits (e.g., insectivores, seed eaters).

Twenty-eight publications were (at least in part) attempts to characterize bird communities in specific areas or forest types. There was considerable overlap between this set of publications and the 52 discussed above. Thirty-six publications dealt specifically (i.e., they were identified in the titles of the publications) with individual species or groups of birds. The species and groups identified in these publications follow.

- neotropical migrants
- warblers
- black-throated blue warbler
- American redstart
- hooded warbler
- ovenbird
- Kirtland's warbler
- woodpeckers
- black-backed woodpecker
- three-toed woodpecker
- pileated woodpecker
- red-breasted nuthatch
- raptors
- boreal owl
- long-eared owl
- great gray owl
- hawk owl
- northern goshawk
- red-shouldered hawk
- osprey

3.0 BIRD RESPONSES TO FOREST MANAGEMENT

3.1 Responses Associated with Specific Management Practices

3.1.1 *Clearcut Harvest Systems*

Clearcut harvest systems remain the most common method of forest harvesting in Canada (Canadian Council of Forest Ministers 2003). There are many variations of clearcut harvesting, including patch cutting, strip cutting, seed tree cutting, cutting with partial retention, variable retention etc. (Mathews 1989) and there remains much terminological confusion regarding the gradation between clearcutting and other methods of harvesting. Nonetheless, to avoid what Smith (1986) referred to as the "semantic morass" surrounding the term, we will not attempt to define it too precisely and simply recognize that for the most part, it involves the removal of all or most trees within a harvest block in a single cut. In most of the works we cite, the authors have described the clearcuts which provided a basis for their investigations, and where appropriate we have noted relevant aspects of the clearcut operations.

Clearcut harvest systems give rise to a host of responses from bird populations. The most basic effects relate to the removal of forest trees which provided habitat for birds, replacing them with early-successional habitats. In general, bird communities mirror the successional stages of plant communities (Martin 1960; Crawford and Titterington 1979; Welsh 1987; Helle and Mönkkönen 1990; DeGraaf 1991; Kirk et al. 1996). Therefore, when forests are clearcut, there is usually a dramatic change in the structure of the bird community occupying the site. Table 3.1 provides a summary of several studies which have compared species abundance and/or composition in clearcut harvest areas and unharvested forests. Many, although not all, of the studies were short-term investigations based on comparing information gathered pre- and post-harvest. As the boreal and Acadian forests (mostly BCRs # 6, 8, and 14) are those in which clearcutting is most common, most studies regarding bird community structure post-harvest have taken place there.

Table 3.1 Summary of Selected Studies That Have Compared Species Abundance and/or Composition in Clearcuts and Unharvested Forests

Study	Location / Forest Type(s) / BCR	Brief Description	Response of Richness / Density	Response of Individual Species / Guilds	Notes/Summary
Kirk et al. (1996)[a]	Central Saskatchewan Boreal Forest (aspen dominated) BCR #6	As part of a comprehensive analysis of bird-habitat affiliations, data previously collected were reanalyzed and reported upon in this paper. Forest data were divided into four age classes ranging from very young (< 9 years) to old (80 years).	• Not addressed	Upper canopy gleaners and foragers were absent from, or occurred at low abundance in early successional stands. Low canopy and bark gleaners were most abundant in old stands. Ground foragers were most abundant in young stands. 4 species (black-throated green warbler, brown creeper, golden-crowned kinglet and evening grosbeak) occurred only in old stands and 19 were most abundant there. 19 species occurred exclusively in young or very young stands.	Discriminant analysis recognized four groups of birds based on relation to stand age: very early successional species, early successional species, mature forest species, and old forest.
Imbeau et al. (1999)	Quebec Boreal Forest (back spruce dominated) BCR #8	Study was intended to compare bird communities originating from fire vs. those originating from logging. Sampled 140 stations from 3 post-logging and 4 post-fire development stages. Sizes of cutovers not provided. Height of regenerating black spruce trees were used to define successional stage.	There was no association between species richness and development stages. The density was higher after clearcutting than before for some old stands.	Guilds more common in youngest clearcut class compared to old forests: ground and low nesters, neotropical migrants. Guilds more common in oldest forest compared to clearcuts: midstory canopy nesters, cavity nesters, residents (which were never found in clearcuts) Many differences in abundances of individual species between young clearcut and older habitats.	• The differences in bird communities between post-fire and post-harvest were more pronounced in young forests. • This study took place over a single field season only; the results should be interpreted in light of this.
Welsh (1987)	Ontario Boreal Forest (mixedwoods) BCR #8	• Examined 6 uncut stands (57 – 200 yrs) and 12 clearcut stands (1-33 years) over a single field season. • Cutblock size is not provided.	• Bird density was lowest 1 year after harvest, but highest 5 years after. • No. of species lowest 1 year after harvest (5), but by 5 years it was high (27).	• Early successional species include white-throated sparrow, chestnut-sided warbler, mourning warbler, and alder flycatcher. • Late successional species include Acadian flycatcher, golden-crowned kinglet, ovenbird, and bay-breasted warbler	• There was no clear relationship between density and stand age except that youngest plot had lowest number of birds. • Only example results provided. • The author described a clear pattern in which early successional species are most common after cuts, and late succession species in old forest. • Some species were present at all ages.

(Continued on next page. See note at end of table.)

Table 3.1 Continued

Study	Location / Forest Type(s) / BCR	Brief Description	Response of Richness / Density	Response of Individual Species / Guilds	Notes/Summary
Lance and Phinney (2001)	British Columbia Montane Forest (coniferous forest) BCR # 10	• Study reports primarily on bird responses to partial retention harvesting, but includes some clearcuts with no retention and mature forest. • 3 field seasons beginning 2 years after logging. • 2 clearcut blocks of 54 and 71 ha	Mature forest had greater species richness and higher density than clearcuts.	11 species (foliage gleaners, aerial salliers and bark gleaners) were significantly most abundant in mature forested sites including boreal chickadee, sharp-shinned hawk, varied thrush, magnolia warbler, and winter wren. 4 species were significantly most abundant in clearcuts: common snipe, song sparrow, rufous hummingbird and Lincoln's sparrow.	Very distinct niche separation amongst mature forest and clearcut species.
Derleth et al. (1989)	Maine Acadian Forest (conifer, hardwood, and mixed forests) BCR #14	• Study looked at avian response to small-scale habitat disturbance over 4 field seasons. • Clearcuts were 1-8 ha. • Cuts were 0-8 yrs old at the time of surveys.	• More species were observed in cuts (43) than controls (33) in hardwood forests and mixed growth forests (46 vs. 35). • There was no difference in diversity indices for cuts vs. controls in any forest type.	• 6 species were significantly more abundant in conifer cuts than conifer control; 2 species were more abundant in control (red-breasted nuthatch, Cape May warbler). • 7 species were significantly more abundant in hardwood cuts than hardwood control; 0 species more abundant in control. • 5 species were significantly more abundant in mixed growth cuts than mixed growth control; 0 species were more abundant in control. • Species more abundant in cuts than control in all forest types: common yellowthroat and white-throated sparrow.	• "Most species seem to either benefit or be unaffected by the creation of small openings". • 18 species more were common in cuts; 2 species were more common in control.

(Continued on next page. See note at end of table.)

Table 3.1 Continued

Study	Location / Forest Type(s) / BCR	Brief Description	Response of Richness / Density	Response of Individual Species / Guilds	Notes/Summary
Freedman et al. (1981)	Nova Scotia Boreal Hardwood Transition (aspen forests) BCR # 14	• Study compared bird densities in "operational clearcuts" (3 plots), strip cuts (2 plots), thinned plots (1 plot), and control areas (3 plots). • Clearcut plots were 3.4-4.1 ha. • Various-sized plots were used based on the configuration of sample areas. • The time since harvest is not provided, but vegetation characteristics of plots are.	26 species were used in the analysis. Average # species by treatment: control – 12.3; clear cut - 8.3; thinned – 7; strip cut – 11.5. • Average density (pairs/km^2): control – 663; clear cut – 588 thinned – 550; strip-cuts – 525.	Early successional species were most common in clearcuts. 9 species were most common in clearcuts including: ruby-throated hummingbird, chestnut-sided warbler, common yellowthroat, white-throated sparrow, and song sparrow. Abundant control plot species not in clearcuts were least flycatcher, hermit thrush, solitary vireo, red-eyed vireo, black-and-white-warbler, northern parula warbler, black-throated green warbler, ovenbird, and American redstart.	There were "few differences in the total density or richness of breeding birds…affected by several forestry practices including clearcutting…" There were "marked species changes with obligate forest birds being replaced by early –successional species on the clearcuts." Study took place over a single field season only; the results should be interpreted in light of this.
Hagan and Grove (1999a)	Maine Acadian Forest (different types) BCR # 14	• Surveyed many different forest stands and categorized them into 9 "superclasses" based on species composition and age. One of the superclasses was "clearcut" – less than 5 years old. • 4 field seasons	• Greatest diversity was in regenerating habitat (6-20 yrs) with residuals; least was in clearcuts. • Although clearcuts had the lowest diversity, 12 species had their highest abundances there. • Regenerating habitats (not with residuals) had the most species with highest abundance (15); clearcuts had 12, and the three mature habitats averaged 7.	• Species with highest specificity for early successional habitats: American goldfinch, common raven, great crested flycatcher, ruby-throated hummingbird, Tennessee warbler • Species with highest specificity for late successional habitats: black-billed cuckoo, blackpoll warbler, spruce grouse, sharp-shinned hawk, three-toed woodpecker, white-breasted nuthatch, wood thrush.	• Neotropical migrants were more abundant in young forest than in old; authors noted that several species of neotropical migrants are species of concern in the region and they seem to benefit from cutting.

(Continued on next page. See note at end of table.)

Table 3.1 Continued

Study	Location / Forest Type(s) / BCR	Brief Description	Response of Richness / Density	Response of Individual Species / Guilds	Notes/Summary
Johnson and Freedman (2002)	New Brunswick Acadian Forest (different types) BCR #14	• Study compared reference forests to plantations of various ages, including some < 5 yrs and recently planted. • All plantations were clearcut, site prepared, planted to seedlings and herbicided. • 2 field seasons. • Clearcuts ranged from 10.0 – 14.1 ha	• All plantations < 5 yrs all had low species diversity and richness compared to older plantations and reference forests • Youngest plantation had the lowest bird density; density in plantations generally increased to about 15 yrs old. • Bird density of reference forest was greater than young plantations, but less than older (13 – 21 yr) plantations.	• Community in young plantations was dominated by ground-nesting species, particularly common yellowthroat, Lincoln's sparrow, song sparrow and white-throated sparrow. • Canopy nesting birds were more prominent in older stands. • Cavity-nesting birds only occurred almost entirely in reference forest.	• "…16 species that bred in reference forest were not observed in plantations including species that prefer or require mature habitat"
Webb et al. (1977)	New York Acadian Forest (tolerant hardwoods) BRC #14	• Study assessed the effects of logging on birds in areas with various amounts of forest harvested. • 10 field seasons. • Harvests took place from 3-10 years prior to beginning of field work. • Unmerchantable trees were not harvested. • Harvest area was not provided. • Analyses were conducted on 26 of 56 species recorded.	• Total no. species observed in 100% clearcut area: 45; no. in natural area: 37 • 100% clearcut area had significantly higher index of diversity than natural (uncut) area.	• 6 of 26 analysed species showed increased abundance with logging: American redstart, chestnut-sided warbler, rose-breasted grosbeak, white-throated sparrow, black-and-white warbler, and veery. • 5 of 26 analysed species showed a decline in population with increasing intensity of logging: ovenbird, black-throated green warbler, blackburnian warbler, winter wren and least flycatcher.	• Changes in bird community were apparent, but not as drastic as found in other studies – perhaps this has to do with the duration of this study and the length of time since logging. • The author stresses the lack of strong effect of logging: "The fauna of the unlogged area is not supplanted by a different fauna on the logged areas"; "No species is so sensitive to habitat disturbance that it is 'driven out' by logging".

[a] Kirk et al. (1996) reports on an analysis of data initially collected by Terrestrial and Aquatic Environmental Managers Ltd. (1988).

3.1.1.1 *Effects on Diversity and Density*

Most studies of bird response to clearcut harvest systems noted an immediate decline in bird species diversity following clearcutting (Kendeigh 1947; Freedman et al. 1981; Welsh 1987, 1999; Lance and Phinney 2001; Johnson and Freedman 2002) although Webb et al. (1977) and Derleth et al. (1989), whose studies are discussed below, noted the opposite. However, most studies also noted that the depression in species diversity following harvest is short-lived and that within a few years, species diversity increased markedly. For example, in an extensive study of bird habitat use in Maine, Hagan et al. (1997) found clearcuts less than five years old had the lowest bird species diversity of 9 habitat "superclasses" they identified but, regenerating clearcuts (6-20 years old) had the second highest (regenerating habitats with residuals had the highest). Similarly in boreal Ontario, Welsh (1987) noted that clearcut sites had the lowest species diversity of a range of sites he examined ranging in age from one year (recent clearcut) to 220 years, but a five-year old site had the highest diversity. In a comparison of bird species in plantations and natural forest in New Brunswick, Johnson and Freedman (2002) found that although young plantations (i.e., recent clearcuts) had the lowest diversity, by the time they reached 13-21 years, their diversity was similar to that found in reference forests age 45 years and older. DeGraaf (1991) writing about bird assemblages in hardwood forests in New England, described a pattern in which although bird species diversity is low the year after clearcutting, it doubles in each of the second and third years, and then levels off gradually.

Bird density following clearcutting likely shows a similar pattern to diversity, although few studies have monitored bird density over a sufficiently long period of time to make an assessment, or sampled stands of a sufficient variety of ages to provide insight on this. Several studies, as described in Table 3.1, have found less dense populations after clearcutting than before. Of the studies which have described chronological changes in density, Welsh (1987) found that the highest density of the sites he surveyed occurred in a five-year-old stand (although it contained some mature coniferous and deciduous trees following cutting), and data presented by Johnson and Freedman (2002) showed a steady increase in bird densities associated with a chronological progression of plantation ages, to the point where bird densities in plantations of 13, 15, and 21 years exceeded those reached by each of five reference (natural) stands age 45 years and older.

Changes in diversity and density, although interesting, are not always significant, nor are increases necessarily desirable in an ecological context (Hagan et al. 1997; Welsh and Healy 1993). Creating habitats that support more bird species or more birds is not a meaningful goal in most situations when considering forest management effects or objectives. Increasing diversity is not a good thing if it means sacrificing species which occur in situations associated with less diverse or uncommon communities. Relatively young forests support diverse bird communities, including some species (e.g., golden-winged warbler, chestnut-sided warbler, Harris's sparrow) that are of high continental importance (Rich et al. 2004). However, there also is considerable concern associated with many species associated with older or less common habitats (Thompson et al. 1993; Imbeau et al. 1999; Thompson et al. 1999; Hobson and Bayne 2000b; Kirk and Hobson 2001; Cumming and Diamond 2002; Drapeau et al. 2002; Schmiegelow and Mönkkönen 2002). More important than high diversity or high populations on a harvest block or stand basis are considerations of clearcut harvesting effects on bird communities and individual species considering their relative abundance at a landscape scale, and relative to natural disturbances. This topic is discussed in more detail in Sections 3.1.4.3 and 3.2.4.

3.1.1.2 *Changes in Community Structure*

Not surprisingly, most studies of the effects of clearcut harvesting on bird communities have noted that the communities changed from old-forest associated guilds (e.g., canopy nesters, cavity nesters, canopy gleaners) to guilds associated with open habitats (e.g., ground and shrub nesters, ground foragers). In the boreal forest, species commonly associated with recently clearcut areas include common yellowthroat, alder flycatcher, song sparrow, white-throated sparrow, Lincoln's sparrow, and Le Conte's sparrow. These species are also commonly mentioned in studies in the Acadian forest; others include chestnut-sided warbler, American redstart, and ruby-throated hummingbird. (Many other species in both boreal and Acadian forest studies are noted as well, but those above tended to be documented consistently across studies).

Although most studies noted dramatic changes in the structure of bird communities, this is not universally the case. In one of the most comprehensive studies of this nature, Webb et al. (1977) examined changes in bird communities over 10 field seasons in tolerant hardwood forests in New York. The authors vehemently noted the lack of a strong effect of logging and declared that "[t]he fauna of the unlogged area is not supplanted by a different fauna on the logged areas". They examined changes in bird communities in areas which had experienced several levels of cutting, up to 100% clearcut. Although results revealed differences in relative abundance over the course of their study, 25 of the 26 species for which they had sufficient data to conduct detailed analyses occurred on both the natural area (control) and in the 100% clearcut area. However, two factors regarding their study likely had a strong effect on their conclusions. First was the timing of their assessment: the logging operations extended over seven years, and the bird censuses took place over a ten-year period beginning after the logging operations ceased, so that the clearcuts were likely well regenerated in at least some areas. As described above, bird communities change rapidly in the years following harvesting, so their assessment should be viewed as broader than one referring to the immediate effects of clearcutting. Second, the authors noted that the clearcut areas did not result in the removal of all trees, but rather only merchantable trees were taken (9-11m^2/ha of basal area remained). As described in Section 3.1.1.3, the retention of residual trees can have a strong effect on the bird community present following clearcutting. These factors undoubtedly strongly influenced the bird species they observed.

Also in the Acadian forest, Derleth et al. (1989) similarly concluded that most species of birds seem to be either unaffected or to benefit from harvesting. However, the cutblocks they examined were small (1 – 8 ha) and the cuts were up to 8 years old at the time of surveys.

3.1.1.3 *Amelioration of Changes by Retaining Residual Structure*

In previous literature reviews both Wedeles and Van Damme (1995) and Schieck and Song (2002) concluded that the retention of residual trees and patches following clearcutting can have a significant effect on bird community composition in cutovers. Table 3.2 provides a summary of several recent studies which have examined the effects of retaining residual trees in clearcut harvest areas. Summarizing the studies, it is reasonable to conclude that sites with retained residuals provide habitat for more species than do sites without residuals, and some bird species more commonly associated with forest cover are likely to be found post-harvest in sites with residuals. Sites where forest residuals are maintained also tend to contain more individual birds than do sites without.

Individually, and more so collectively, the results of the studies raise some questions, however. Although it is clear that residuals provide habitat for more species, it is not apparent what levels of residuals are optimum in various forest types. The studies in Table 3.2 examined levels of residual retention varying from 2 – 40%, and of patches up to 5 ha in size. As Lance and Phinney (2001) pointed out, information on the relationships between bird community response and the amount, size, shape and dispersion patterns would assist greatly in identifying practical targets.

Several studies also noted that although bird species associated with forest cover are present in harvest areas with residuals, no studies have been conducted on the productivity of those species. The habitat provided by residual retention may not be as extensive nor in most cases of the same quality (in terms of microhabitat) as is complete forest cover, so it may be that these sites provide lower-quality habitats for the species which use them. Van Horne (1983) pointed out that density can be a very misleading indicator of habitat quality, and noted that just because a site supports a seemingly dense population does not necessarily imply that it is truly productive. These sites may be ecological traps as described by Thompson (2004), who discussed differences between poor and superior-quality habitats. Therefore, it seems that the most important research need associated with residuals is obtaining estimates of productivity of the forest species which use them.

Although the maintenance of residual retention in harvest areas may be useful in dampening the immediate effects of clearcutting on some species of forest birds and emulating stand-level aspects of natural disturbances, not all forest bird species are accommodated by the maintenance of residuals. Schmiegelow and Hannon (1999) called their use into question because they seem not to provide productive habitat for vulnerable species, even with levels of retention of up to 40% as studied by Tittler et al. (2001). Schmiegelow and Hannon (1999) implied that it may be better to trade off forest trees and areas used for residual retention for use as part of contiguous forest blocks. The result would be lower levels of retention in less area harvested, leaving more area unharvested.

Most of the research conducted on the effectiveness of maintaining residual trees or patches to provide forest bird habitat has taken place in western Canada. Two additional studies from western Canada not included in Table 3.2 — Seip and Parker (1997) and Steventon et al. (1998)— also found that bird communities in harvest areas with residuals were more similar to mature forest than to those in clearcuts. There is a geographical gap in research of this nature, therefore, as no studies (of which we are aware) have taken place in central or eastern Canada. (The study of Merrill et al. [1998], however, was undertaken in northern Minnesota). Although no studies of residual retention in clearcuts have taken place in the East, the study of Webb et al. (1977) from New York found that partial harvest blocks contain bird communities similar to unharvested forest. Also, Crawford and Titterington (1979) working in Maine found that variables related to mature trees were correlated with the presence of forest birds in recently clearcut stands. The results of these studies could be taken as evidence that findings from the West are likely to apply in the East.

Clearcut harvest systems which include the retention of trees and patches in harvest blocks provide habitat for animals other than birds (Steventon et al. 1998). Working in central Alberta, Tittler and Hannon (2000) hypothesized that green-tree retention and the provision of habitat for murid rodents (rats, mice, and voles), red squirrels, and nest predating birds may lead to high rates of nest predation in cutblocks with residual retention. They tested this hypothesis using artificial nests placed in forested stands adjacent to cutblocks and in residual clumps and found no effect on nest predation.

Table 3.2 Summary of Selected Studies That Have Examined the Effects of Retaining Live Residual Trees or Patches in Clearcuts

Study	Location / Forest Type(s) / BCR	Brief Description	Key Results	Summary/Conclusions
Schieck and Hobson (2000)	Central Alberta Boreal Forest (mixedwood) BCR #6	• Surveyed disturbance blocks 2, 15, 30, and 60 years old of both fire and harvest origin with varying amounts of residuals (including some areas with no residuals). • Disturbance blocks contained 1 – 3000 trees in patches.	• Bird communities associated with large residual patches (> 100 trees) 2 years post-disturbance included species associated with both open areas and old forest. At 2 years post-disturbance, bird communities from large residual patches were more similar to those from old forest than were bird communities from small patches. • By 15 and 30 years, the differences between large and small patches had decreased due to bird communities from small patches becoming more similar to those from old forests over time.	• Best strategy is to retain a mix of patch sizes over a forest. • Productivity assessments are needed to quantify the real value of retention patches. • Retention patches cannot compensate for extensive tracts of old forest in harvested landscapes.
Schieck et al. (2000)	Central Alberta Boreal Forest (mixedwoods) BCR #6	• Amalgamated data used by Norton and Hannon (1997) and two previously unpublished studies. • 70 harvest blocks included in the analysis. • Percent canopy trees retained ranged from 2 – 40%. • Compared harvest plots with old growth control areas. • Study conducted "at the level of individual plots" rather than whole cutblock. Cutblocks 21-28 ha.	Variation in bird communities among harvest areas was correlated with the variation in the type and amount of residual materials. Plots in harvest blocks with few large trees or snags contained bird species associated with open forest, and shrubby habitats. As the amount of residual trees and snags increased, bird species associated with mature and old boreal forest became more common and birds associated with open country and shrubby areas became less common.	• Residual retention is effective in providing habitat for mature forest birds in cutblocks. • It may not be desirable to retain standing trees in all cutblocks as this is inconsistent with the natural disturbance regime. To match the natural disturbance pattern, managers need to create some blocks with no residuals, some with blocks with scattered residuals, and other cutblocks with loose or dense clumps.
Tittler et al. (2001)	Central Alberta Boreal Forest (Mixedwood) BCR #6	• This study extended the results and analysis of (Norton and Hannon 1997) by examining sites 3 years post-harvest. • Harvest blocks varying in size from 10 – 35 ha and retention from 10 – 40% (10 – 133/ha trees) were compared with unharvested controls.	• More species (10 of 27 analyzed) were negatively affected by logging than were positively affected (3) • The abundance of 8 species was positively correlated with post-harvest basal area up to 3 years post harvest, as was total songbird abundance and total abundance of generalist species. • The abundance of 3 species was negatively correlated with post-harvest basal area as was the total abundance of "cutblock" species. For "forest" species, retention of > 46% of basal area would be required to maintain them in cutblocks.	• The size of individual trees, not just the number is important in determining bird species response to retention. • More study is required to determine appropriate levels of tree retention. • Tree retention in harvest blocks is not sufficient to retain forest birds in harvested landscapes; managers should also maintain unharvested reserves.

(Continued on next page.)

Table 3.2 Continued

Study	Location / Forest Type(s) / BCR	Brief Description	Key Results	Summary/Conclusions
Lance and Phinney (2001)	British Columbia Montane Forest (Coniferous forest) BCR # 10	• This study reports the results of bird transects in six forest blocks, 2 each of clearcut with little/no retention, partial retention (patches 2 – 5 ha in size and scattered individual trees), and mature forest (control). • 2 clearcut blocks were 54 and 71 ha	• Retention blocks and mature forest had more bird species and more individual birds than the clearcuts. • Retention blocks contains bird species that were absent from clearcuts, other species that were absent from the forest, and other species that were absent from both other site types.	• The retention sites were "at the very least acceptable habitat for most of the members of the bird community". • Information on productivity (nesting and survival) is required to better quantify the effects. • Information on optimum amount, size, shape, and dispersion pattern is also needed.
Merrill et al. (1998)	Northern Minnesota Boreal Hardwood Transition (aspen forest) BCR # 12	• Examined 20 clearcuts with residuals and 20 clearcuts without. • Residuals were arranged in patches. • Conducted bird surveys inside residual patches, outside residual patches, in stands without residuals, and in the forest edge adjacent to the clearcuts. • Cutblocks averaged 14.6 ha (S.D. = 3.5) Patch size and tree species composition were not selection criteria, but were continuous variables.	Species with affinity for mature deciduous forest were associated with residual patches. Tree nesters and ground nesters were associated with residual patches. Species with affinity for open disturbed communities were associated with clearcuts with no residuals. Shrub nesters were associated with clearcuts with no residuals. Ground nesters were associated with clearcuts that have residual patches.	The cumulative effect of small residual patches over a forest can represent a valuable contribution to forest-bird diversity and populations. Productivity (nest monitoring) assessments are needed to quantify the impact of residual patches on bird populations.

Most of the studies cited above focused on retention of live residual trees and patches; however, much attention has also been devoted to describing the importance of maintaining snags and coarse woody debris in managed forests (Evans and Connor 1979; Hunter 1990; Thompson et al. 1993; Hagan and Grove 1999b; and many others). In fact, it is probably an axiom of informed forest management in Canada today that snags and coarse woody debris are recognized as valuable components of forest ecosystems and that efforts should be made to preserve them at least to some extent during forest management operations. Because the topic has been well explored and is likely familiar to most forest managers, we will not go into much detail here.

Snags and coarse woody debris are most often associated with old forests and burnt forests (Hunter 1990; Hutto 1995; Hejl et al. 1995; Hagan and Grove 1999b; Bunnell 1999b; Schieck and Song 2002; and many others); considerable commentary has been devoted in the literature to describing their importance and advocating their retention. Species noted as being at risk due to loss of snags are those which rely on tree cavities for nesting, woodpeckers and other insectivorous birds which prey on the insect communities associated with decaying wood, and birds which use snags for perches from which to hunt. (As noted in Section 3.1.3, considerable attention has been devoted to assessing the use of burnt trees by black-backed woodpeckers and three-toed woodpeckers.) Morissette et al. (2002) argued that a decline in snag abundance may be more detrimental for resident birds than migrants. They found statistically significant declines in several species of insectivorous birds in salvaged compared to unsalvaged burns, and that salvaging eliminated some resident species (bark-probing insectivores). They attributed these effects to a loss of available food. They noted that this may not be an issue during the breeding season when prey are not limiting, but that it could be an issue for year-round residents which rely on woodboring insects as an important winter prey. Imbeau et al. (2001), in their assessment of threats to boreal birds, believed that snag use for foraging was a lifestyle characteristic which increased the threat level because of snag loss during normal harvesting and post-fire salvage operations. Schmiegelow and Mönkkönen (2002) similarly noted that resident birds which rely on old forests and post-burn sites are at disproportionate risk compared to other species because of their reliance on dead and decaying wood for foraging. Evans and Conner (1979) provided an extensive list of snag utilization by birds of the northeastern United States; most of the species they note are resident birds which may be directly affected by inadequate snag management. Flemming et al. (1999) found that pileated woodpeckers use decaying wood for foraging and noted that forest management practices which reduce the availability of snags and woody debris would impact negatively on abundance of this species. Bull and Meslow (1977) in Oregon and Ontario Ministry of Natural Resources (1996) in Ontario noted likewise.

Several authors have noted that snags play an important role for raptors as nesting sites, and /or perching sites from which to hunt. Some have directly described, and others have implied, that destruction of snags may impact local populations (hawk owl – Duncan and Harris 1997; Hobson and Schieck 1999; Niemi and Hanowski 1997; great gray owl – Duncan 1997; Niemi and Hanowski; barred owls – Hannon 2000; boreal owl – Niemi and Hanowski; American kestrel – Hejl et al. 1995; and osprey – Penak 1983; Niemi and Hanowski 1997).

3.1.2 *Partial Harvesting*

3.1.2.1 *Selection Harvesting*

Compared to the number of studies which have examined the effects of clearcutting, relatively few studies in Canadian BCRs have examined the effects of selection harvesting (intended either for stand improvement or timber production) per se on birds. However, several authors have extrapolated likely effects on birds based on the amount of canopy retained and the habitat preferences of species and guilds.

Selection harvesting increases vertical diversity in closed forest stands because the canopy openings create an environment suitable for regenerating trees while still maintaining a mature canopy (Smith 1986; Mathews 1989). Hunter (1990) states "[t]o manage a forest stand for vertical diversity one should implement the kind of fine-scale uneven-aged management that produces uneven-height forests; in other words, selection harvesting." Wedeles and Van Damme (1995) noted that the presence of well developed vegetation layers and a more complex habitat structure results in higher within-stand bird species diversity in many cases than exists in stands managed using even-aged systems. They drew upon the discussions of Crawford and Titterington (1979), Temple et al. (1979), DeGraaf et al. (1993), and Thompson et al. (1993) (all of which are from U.S. portions of Canadian BCRs) to note that, as a result of selection harvesting, bird species associated with the forest canopy will likely remain, although there would be fewer mature trees and the upper canopy might not support as many birds; the canopies of low and midstory trees would support more low canopy species; and some ground species (such as sparrows and juncos) might be found in small openings.

These general extrapolations compare reasonably well to the results of Jobes et al. (2004) who compared bird communities in recent selection harvest areas (1-5 years since harvest) to those found in older harvests (15-20 years) and to those of reference forests in the hardwood forests of Algonquin Park in central Ontario. They found that species diversity and richness did not differ between the three site types. Of the 22 species for which they had sufficient data to perform detailed analyses, none of the species found in the reference forest were absent from either the recent or old treatment areas. However, the abundance of some species changed. Ovenbirds (a mature forest species) were significantly less abundant on logged stands than in the unharvested reference forest, whereas chestnut-sided warblers, white-throated sparrows, and mourning warblers (which are generally associated with more open or scrubby habitats) were all more common in recent treatment areas than in the reference forests.

Flaspohler et al. (2002) compared bird communities in selectively logged stands of various ages (up to 29 years post-harvest) in Michigan's Upper Peninsula. They found bird species richness highest in recently logged stands and lowest in stands with longer time since logging. Twelve species associated with the more open and shrubby conditions in recently harvested stands were not recorded in stands harvested longer ago (although some were recorded very few times). Two species, the black-throated green warbler and the ovenbird, were found more frequently in older harvest areas. They attributed this to these species' affinity for mature forests.

In the previously described study by Webb et al. (1977) which took place in New York, one of the harvest treatments compared to a natural area was a 25% canopy removal. Although the cut was a diameter limit rather than a true selection harvest, the results are likely relevant here. They found that all of the species in the reference forest for which they had sufficient data to analyse were also found in the 25% removal area. Two species of "undisturbed forest"—the wood thrush and blackburnian warbler—were much less common ($p < 0.01$) in the harvested area than in the natural area.

Medin and Booth (1989) compared the responses of songbirds to single-tree selection logging in coniferous forests in west-central Idaho. Similar to the above, they found relative stability in the bird community following selection harvest, although some species associated with more open habitats (e.g., chipping sparrow) increased following logging, and others associated with closed forests (red breasted nuthatch, brown creeper) decreased.

One of the research needs identified in the earlier discussion on retaining residual trees is to investigate differences in bird productivity between treatment and control sites. An informative study of this nature was conducted on ovenbirds and black-throated blue warblers in New Brunswick. Bourque and Villard (2001) monitored nests for up to three seasons of these two species in uncut and selection cut areas in two different landscapes, one which they categorized as intensively harvested, and another as moderately harvested. They found strikingly different results for the two species. While black-throated blue warblers responded positively to the treatment, both in terms of density and reproductive success, ovenbird densities and reproductive performance were markedly lower in the selection cuts. Ovenbird territory density, pairing success, and fledging success per territory were lower in the selection cut than in the uncut plots. The authors speculated that the effect may have been caused by increased shrubbiness which resulted from canopy openings. Shrub cover may have created suboptimal foraging and nesting microhabitats as the dense understory may reduce the quantity, quality, or accessibility of leaf litter. The authors pointed out that Burke and Nol (1998) found that both leaf litter depth and biomass of litter invertebrates where significantly higher within ovenbird territories than at random locations. This study not only identifies the detrimental effects of selection harvesting on a forest-associated species, but also highlights the importance of obtaining productivity information to facilitate more informed assessments of effects on species.

Another study which attempted to examine the effects of selection harvesting on bird productivity was that of Naylor et al. (2004). They examined the effects of various levels of selection harvesting on nesting activity and productivity on red-shouldered hawks in central Ontario. Although nest success was not influenced by any of the independent variables included in the analysis, they found that the area of, and proximity to, heavy cuts (selection or shelterwood cuts with a residual basal area of 14 – 16 m^2/ha) had a significant negative impact on activity status (whether or not a nesting area was active). Of these two variables, proximity of harvest was the more influential.

Of the species found more frequently in older stands, most attention has been paid to ovenbirds (Bourque and Villard 2001; Flaspohler et al. 2002; Jobes et al. 2004). Jobes et al. (2004) noted that this species has been identified by others as responding to landscape- and site-level habitat modifications through reductions in abundance. Although some studies which have contributed to, or have been undertaken in response to, concern regarding ovenbird sensitivity to forest management (including effects of fragmentation) have taken place in Canadian BCRs (e.g., Lambert and Hannon 2000; Bayne and Hobson 2002; Mazerolle and Hobson 2003) many others have not (e.g., Gibbs and Faaborg 1990; Van Horn et al. 1995). Nonetheless, this species does stand out as a good indicator of forest management effects for mature forest-associated birds.

Although Naylor et al. (2004) made a distinction between the level of harvesting within the selection system, no other studies we examined did. Wedeles and Van Damme (1995) pointed out that the continuum of tree removal from single-tree selection to group selection could be expected to produce a continuum of effects. In group selection harvests, the removal of a group of neighbouring trees lessens the continuity of vertical habitat diversity, but increases horizontal diversity. The larger openings produce more understory vegetation than do single-tree openings, and in the short-term, this would create more habitat for birds that depend on stand openings, but decrease habitat for canopy-using species (Crawford and Titterington 1979; Crawford and Frank 1987).

Although on one hand it is apparent that the effects of selection harvesting on forest bird species are much less than are those of even-aged systems, on the other hand, it is also apparent that the treatment is not completely benign, as consistently across a number of studies (albeit a rather small number), some species associated with mature forest have been negatively affected. Nonetheless, if an objective under consideration for forest management operations is the maintenance of existing bird communities, or minimization of immediate effects, the selection harvesting seems an obvious choice.

3.1.2.2 *Shelterwood Harvesting*

We found no studies on the response of birds to shelterwood harvesting per se, however, several authors (Crawford and Titterington 1979; Crawford and Frank 1987; DeGraaf 1987; Wedeles and Van Damme 1995) discussed likely effects based upon knowledge of forest changes after harvest and bird habitat preferences. The basis for discussing bird responses is that considerable vertical structure can remain throughout a shelterwood rotation.

Because part of the forest canopy is retained until the final cut, habitat is provided for overstory-dwelling species. However, it would be reasonable to expect that, following every canopy removal, habitat for fewer canopy-species would be provided and the abundance of this group of birds would decline. Regeneration beneath the overstory provides a degree of vertical diversity and habitat for birds that require understory vegetation. As the understory develops, habitat would be provided for shrub- and sapling-associated birds. Obviously when the canopy is removed following the final cut, it is likely that most canopy associated birds would disappear although some species may remain depending upon the development of the understory vegetation and the nature of the niche flexibility.

It is likely that the transition of bird communities from mature forest-associated to open-associated would be less abrupt than occurs with a clearcutting operation.

3.1.2.3 *Thinning*

Several authors have made inferential assessments about the likely response of bird communities to thinning (Crawford and Titterington 1979; DesGranges 1993; Hutto 1995). In general, the predicted responses include a decrease in the abundance of upper canopy birds, an increase in the abundance of shrub-sapling and lower canopy species, and a decline in abundance of cavity nesting species. These responses seem reasonable in discussions of commercial thinning operations (although adverse effects on cavity nesting species need not occur if measures are taken to preserve appropriate trees). Specific studies of the response of birds to thinning (Table 3.3) have provided more insight to these predictions.

Hagar et al. (1996) and Hayes et al. (2003) studied the effects of pre-commercial thinning in heavily stocked mid-age Douglas fir stands in Oregon. Both studies found that some crown-associated species decreased in abundance, while some shrub- and open-community species increased in abundance. In addition, both sets of authors suggested that thinning in these stands could create conditions that approximate those which bird species associated with old forests use (i.e., large, well-spaced trees, shrubby patches, and open canopies), and that they could therefore be made more attractive for birds typical of those habitats. With general concern about declines in the prevalence of western old forests (Kimmins 1997), such a strategy seems practical. This approach would be consistent with the findings of Bunnell (1999b) who concluded that there are no well-defined old-growth communities of birds in western forests, but that species thought of as old-growth obligates are attracted to key structural characteristics rather than to old stands per se. In a similar vein, Niemi et al. (1998) suggested that commercial thinning may to some extent simulate gap disturbances and provide similar habitat for birds. Likewise, Hayward (1997) suggested that thinning could be used to create conditions suitable for nesting structures for boreal owls. In contrast to these suggestions (particularly those of Bunnell [1999b]), Hutto (1995) warned that “new forestry” thinning practices may not be sound strategies for mitigating the effects of harvesting as they bypass normal successional stages and bring “unnatural” combinations of birds together. Hutto’s (1995) opinion, however, seems to be in the minority compared to those which advocate the use of thinning to simulate old growth conditions.

Easton and Martin (1998, 2002) investigated the response of bird communities to removal of deciduous competition from coniferous plantations in southern British Columbia. Although in their earlier (1998) study they did find some changes in the bird community, the differences between the thinned and unthinned areas were not striking. In that study, they found that nesting success in thinned sites was higher than in control sites. This finding is not well explained; however, they noted that nesting success in sites subjected to both thinning and herbicide treatments was very low and suggest that this was because the reduced cover in these sites made the nests prone to predation. The key finding from their two studies is that deciduous-associated birds did not seem to be dramatically affected by thinning. In the 1998 study, they suggest that this may have been due to vigorous sprouting of deciduous trees and bird use of remaining pockets of deciduous vegetation. In the 2002 study, which examined bird nest site selection, they found that birds compensated for the general decrease in deciduous vegetation by consistently selecting nesting sites with much heavier deciduous cover than typically present in the sites. Although it seems the birds were able to cope with the changes induced by the thinning, the treatments examined suggest some unthinned areas should be left to provide more complex bird habitat.

Thompson et al. (1999) presented a discussion which supports the suggestions made by Easton and Martin (1998, 2002). In their study of avian communities in mature balsam fir forests in Newfoundland, bird species richness was found to be higher in 40-year-old stands compared to 60- and 80-year-old stands, and no species reached peak abundance in 60-year-old stands. They attributed these findings largely to trends in deciduous tree and shrub density, which were lowest in the 60-year-old stands and argue that bird species richness in the relatively simple fir-dominated forests of Newfoundland is related to the availability of deciduous vegetation. They noted that pre-commercial thinning is a common practice in Newfoundland and suggested that most or all of the deciduous component present in fir stands should be maintained during thinning operations.

Christian et al. (1996) investigated the response of the bird community to strip thinning in young aspen stands in northern Minnesota. Although thinning reduced the presence of mid-successional bird species, they suggested that it could play a role in alleviating declines of several shrub-affiliated birds by increasing the breeding habitat available.

Table 3.3 Summary of Several Studies Which Have Examined the Response of Bird Communities to Thinning

Study	Location / Forest Type(s) / BCR	Brief Description	Key Results	Summary/Conclusions
Hagar et al. (1996)	Northwest Oregon Pacific Rainforest (Douglas fir dominated) BCR #5	• Compared bird communities in 8 thinned (ave. 360 trees/ha) and 8 unthinned and stands (ave. 495 trees/ha) in Douglas fir stands. • Two study areas:- one in the northern Oregon Coast Range, and one in the central Oregon Coast Range. • Stands were 40-55 years old. • Stand size ranged from 65 – 510 ha	• Bird species richness was not related to thinning. • 6 species were consistently associated with thinned stands in the two study areas: hairy woodpecker, red-breasted nuthatch, Hamond's flycatcher, warbling vireo, dark-eyed junco, and evening grosbeak. • Only one species was consistently associated with unthinned stands: pacific-slope flycatcher. • Several species associated with unthinned stands were found in either of the two study areas.	• The authors suggest that the thinning created habitat characteristics of old stands and this increased their attractiveness for some species. • The authors identify density ranges associated with different bird species and communities.
Hayes et al. (2003)	Northwest Oregon Pacific Rainforest (Douglas fir dominated) BCR #5	• Examined the effects of two thinning treatments (moderate: 247-321 trees/ha remaining; and heavy : 148-210 trees/ha remaining) in 35 to 45 year-old Douglas fir stands and compared these to control (no thinning) stands. • Stand size ranged from 65–100 acres. • Original stand densities not provided. • 12 stands total (8 treatment, 4 control).	• Of 22 species analyzed, 9 decreased significantly in thinnings relative to control and 8 increased significantly. • Of the 9 species which decreased, Pacific-slope flycatcher, Hutton's vireo, and brown creeper decreased more in heavily thinned stands than in moderately thinned ones. • Of the 8 species that increased, dark-eyed junco and hairy woodpecker increased more in heavily thinned stands than in moderately thinned ones.	• The authors suggest that thinning may be a good tool for accelerating the development of late-successional forest conditions. • The authors note that because neither thinned nor unthinned plots provided optimal habitat for all species, there is a need to retain some of each type on the landscape.
Easton and Martin (1998)	Southern British Columbia Interior Cedar-Hemlock Forest BCR #10	• Examined effects on bird communities of herbicide and manual thinning of deciduous trees in 11 to 22 year-old conifer plantations. • Hardwood volume reduced 90-96% by treatments. • 3 treatments of each kind and control. • Nest success also monitored.	• Thinned area had fewer species than control. • No differences were found in bird abundance between thinned and control areas. • Thinned areas lost golden-crowned kinglets and gained song sparrows. • Nesting success was higher in thinned (46%) areas than control (23%). • The same 10 species dominated each community. • There were no strong changes in populations of various guilds as defined by migratory, feeding, or nesting strategies.	• The authors suggest that vigorous sprouting of deciduous trees may have ameliorated any negative impacts associated with thinning. • The authors suggest leaving pockets of untreated vegetation to reduce potential negative impact.

(Continued on next page.)

Table 3.3 Continued

Study	Location / Forest Type(s) / BCR	Brief Description	Key Results	Summary/Conclusions
Easton and Martin (2002)	Southern British Columbia Interior Cedar-Hemlock Forest BCR #10	• Examined effects on bird nesting site selection of herbicide and manual thinning of deciduous trees in 11 to 22 year-old conifer plantations. • Stand size ranged from 22–47 ha. • Hardwood volume reduced 90-96% by treatments. • 3 treatments of each kind and control. • Nest site selection examined by characterizing the vegetation surrounding bird nests.	• Nest patches were positively correlated with the amount of remaining deciduous vegetation. • Birds consistently selected nest patches with more deciduous vegetation than typical of the sites.	• Birds appeared to compensate for alterations in stand habitat by finding patches of untreated or recovered vegetation in which to nest. • The authors suggest that nest patches similar in composition and structure to naturally regenerated areas – stands with significant deciduous and some coniferous vegetation– may provide more songbird species with opportunities for nesting.
Christian et al. (1996)	Northern Minnesota Boreal Hardwood Transition (aspen forest) BRC #12	• Examined effects on bird community of strip thinning in aspen stands. • All stands were 9-11 years old when thinned. • Examined 3 recently thinned (1-2 yrs) stands (16-38 ha), 2 stands thinned 7-11 years earlier (30 and 64 ha respectively) , unthinned sapling stands, and reference stands. • Seared strips were approx. 2.4 m wide with 1.2 m "leave" strips.	• More individuals were observed in the sapling-sized reference than thinned stands, but this difference was not apparent in comparison of pole-sized reference and thinned stands. • 8 species were observed in sapling-size reference but not thinned stands. • 1 species observed in sapling size thinned but not reference stands. • More long-distance migrants and omnivores were observed in sapling sized reference than sapling-sized thinned stands.	• Thinning led to a decrease in bird numbers primarily through effects on species that select midsuccesional deciduous or mixed-coniferous forests. • Opening of the canopy in thinned stands resulted in an increase in shrubs and provided more breeding area for birds associated with early-successional habitats. • The authors note than many shrub-affiliated species have declined regionally and nationally and suggest that thinning may be used to assist these species.
Freedman et al. (1981)	Nova Scotia Acadian Forest (aspen forests) BCR # 14	• Compared bird densities in "operational clearcuts" (3 plots), strip cuts (2 plots), thinned plots (1 plot), and control areas (3 plots). • Thinned plot was 1.8 ha and was 45% residual basal area (460 stems/ha)	Density of birds in the thinned plot was close to those of control plots, but there were fewer species in the thinned plot (7) compared to the controls (ave. 12.3). 3 species associated with open conditions (chestnut-sided warbler, mourning warbler, and common yellowthroat) were present in thinned plots, but not in the control areas. 4 species which were relatively abundant in control areas were not found in the thinned plot (ovenbird, black-throated green warbler, solitary vireo and hermit thrush).	• The thinned plot had an "intermediate mixture of birds" compared to the contrast between the clearcuts and the control plots. • This study had a simple design, and the use of only one thinned plot suggests caution in interpreting its results.

3.1.3 *Additional Harvesting Considerations*

3.1.3.1 *Fire and Salvage Logging*

The topic of salvage logging is most appropriate for forests which often (in an ecological sense) experience stand-replacing fires. In Canada this would apply to much of the southern and central boreal forest which experiences fire rotation periods of approximately 20-150 years (Heinselman 1981), the conifer-dominated portions of the Acadian Forest, which experiences fire rotation times of approximately 150 years (Wein and Moore 1977, 1979), and the forests of southern British Columbia interior which have fire rotation times of 10-200 years (Bunnell 1995) (parts or all of BCRs 4, 6, 8, 9, 10, 12, and 14). However, almost all of the literature related to Canadian BCRs on this topic is from the boreal forest and the Rocky Mountains.

Burned forests have a unique assemblage of species, very different from that which was present prior to fire, and very different from that which occurs following timber harvest (Apfelbaum and Haney 1981; Hejl 1994; Hutto 1995; Hobson and Schieck 1999; Imbeau et al. 1999; Schieck and Hobson 2000; Imbeau et al. 2001; Morissette et al. 2002). Burned sites contain a mix of species associated with early-successional communities (e.g., American kestrel, American robin) and some species which are commonly associated with mature forests (e.g., brown creeper, winter wren) (Table 3.4). The reason for this is rather obvious – these habitats contain elements associated with both open areas and closed-canopy forests. Much sunlight reaches the ground (due to the lack of a canopy) and so grasses, forbs, and shrubs usually dominated floristically, while the killed trees provide snags and much downed woody debris which is characteristic of mature forests. In addition, the density and recently burned condition of snags, and the frequent interspersion of residual patches of live trees provide conditions which are important for birds (Bunnell 1999b; Schieck and Hobson 2000; Schieck and Song 2002).

Standing dead trees are attractive for birds for several reasons. Morissette et al. (2002) noted that standing dead trees may increase the availability of conifer seeds, harbour large numbers of insect larvae, and may attract other insects as well (e.g., parasitic wasps [Hutto 1995]). They also provide abundant perches for insectivorous birds (Hutto 1995; Haggstrom and Kelleyhouse 1996; Morissette et al. 2002) and raptors (Haggstrom and Kelleyhouse 1996; Duncan 1997; Niemi and Hanowski 1997; Duncan and Harris 1997), and provide snags suitable for nest excavation by cavity nesters (Hunter 1990; Rotenberry et al. 1995; Hejl et al. 1995; Imbeau et al. 1999; Drapeau et al. 2002). Burned forests are thought to be particularly important for insectivorous species, primarily woodpeckers, but also warblers and other songbirds (Amman and Ryan 1991; Hutto 1995; Nappi et al. 2003).

Of the species strongly associated with burnt areas, considerable recent interest has centered on black-backed and three-toed woodpeckers. All the studies summarized in Table 3.4 except for Morrisette et al. (2002) found these species to be strongly associated with burned forest. In the Morrisette et al. study, both species were found only in burnt forests but were not included in the authors' analyses (nor therefore in Table 3.4) because of low detection rates. (Apfelbaum and Haney [1981] actually refer to the black-backed-three-toed woodpecker as it was sometimes referred to, but provide the scientific name for black-backed woodpecker.)

In his seminal works on life histories of North American birds, Bent (1964) described the propensity for Arctic three-toed and American three-toed woodpeckers, as they were then called, to be found in burned areas. Bock and Bock (1974) suggested that these species evolved in close association with burned forest. Hutto (1995) states that "..it would be difficult to find a forest-bird species more restricted to a single vegetation cover type in the northern Rockies than the black-backed woodpecker is to early post-fire conditions". Other recent studies also noted the heavy use by these species of burned forests (Schieck and Hobson 2000; Imbeau et al. 2001; Hoyt and Hannon 2002; Nappi et al.

2003). The increased availability of wood-boring and bark beetles explains their abundance in this habitat type (Murphy and Lehnhausen 1998; Hoyt and Hannon 2002; Nappi et al. 2003). In comparing bird presence in fires of different ages, Hoyt and Hannon (2002) found that black-backed woodpeckers were present in equal numbers in 3- and 8-year-old burns, but declined in numbers between 8 and 16 years post-fire. Three-toed woodpeckers decreased significantly between 3 and 8 years post-fire. They attribute these abundance patterns to niche partitioning between the two species. Three-toed woodpeckers feed primarily on bark beetles which are present only for a short period post-fire while black-backed woodpeckers feed primarily on wood-boring beetles which remain in the standing dead trees for a longer period post-burn. Nappi et al. (2003) examined black-backed woodpecker use after a large fire in the boreal forest at the Quebec-Ontario border. They found that the woodpeckers tended to select large snags and portions of snags that contained high densities of wood-boring insects.

The very heavy reliance of these woodpeckers on burned forests has caused concern about the effect of salvage logging. Hejl et al. (1995), Hutto (1995), Imbeau et al. (1999), and Nappi et al. (2003) all expressed concern that fire suppression in combination with the practice of salvage logging has the potential to have significant detrimental effects on these species. Imbeau et al. (2001) ranked both black-backed and three-toed woodpeckers among the species most threatened by forestry practices in eastern Canada and Fennoscandia largely because of their reliance on burned forests and their decreasing supply. Nappi et al. (2003) and Nappi et al. (2004) pointed out recent modifications to Quebec legislation provide incentives to increase salvage logging on public lands. In other provinces too, stumpage rates are considerably lower for burned wood and forest products companies are often directed to or given incentives to conduct salvage harvests in burned areas before the wood becomes too deteriorated by bark beetles to use for timber.

Several of the authors cited above call for a balanced approach to salvage logging which recognizes the importance that burned forest play as bird habitat. The most extensive recommendations come from Hutto (1995).

- Some areas should be set aside within large burns and should remain unsalvaged (Hutto 1995; Morissette et al. 2002).
- Avoid salvaging areas of burned forests adjacent to unburned forests (as the burned forest is good foraging habitat for birds which do not nest there) (Morissette et al. 2002).
- Consider burning forests after partial harvests have been conducted (Hutto 1995).
- In areas where burned habitat is rare, do not conduct salvage harvests (Hutto 1995; Nappi et al. 2003).
- Leave good quality snags within salvage areas (Hutto 1995; Nappi et al. 2003).
- Delay salvaging where possible so that the important immediate post-burn ecological values can persist (Nappi et al. 2004).
- Retain fire as an ecological force in forested landscapes (Hejl et al. 1995; Hutto 1995; Hoyt and Hannon 2002).

Nappi et al. (2004) pointed out that many questions related to the ecology of burnt stands to the question of "how much should be left, where and how?" are unknown. They advocate a precautionary approach in dealing with salvage logging, and that strategies be developed to assess the role of burnt forest at both stand and landscape scales. Nappi et al. (2004) also noted that it is not appropriate to rely on northern (i.e., beyond the current range of commercial forestry) areas to supply burnt forest habitat as ecological communities vary along north-south gradients, and so it is important to maintain burnt habitat across the range of forests to ensure appropriate biodiversity conservation.

Finally, we note that our discussion here has focused on salvage logging after fires, but salvage logging occurs after other disturbance events too (i.e., insect infestations and windthrow). We are aware of no studies investigating the response of birds to salvaging areas subject to these disturbances, but in general, it seems reasonable that the concerns expressed above would apply to these areas too.

Table 3.4 Species Associated with Post-Burn Conditions in Several Studies

Study and Location	Species	Notes
Hutto (1995) Northern Rocky Mountains, U.S.A	mountain bluebird[a], hairy woodpecker[a], three-toed woodpecker[a], black-backed woodpecker[a], olive-sided flycatcher[a], dusky flycatcher[a], Clark's nutcracker[a], chipping sparrow[a], white-crowned sparrow[a], brown-headed cowbird[a], Cassin's finch[a], red crossbill[a], common raven[a], calliope hummingbird[b], common nighthawk[b], northern flicker[b], Steller's jay[b], orange-crowned warbler[b], chipping sparrow[b], American robin[c], yellow-rumped warbler[c], dark-eyed junco[c]	Species listed are those with stronger affiliations with burned forests than other cover types. [a] – species with the strongest affiliation toward early-successional burned forest (< 10 years) amongst 15 habitat types. [b] – species with the strongest affiliation toward mid-successional burned forest (10–40 years). [c] – species detected in both early- and mid-successional burned forest 100% of the time.
Hobson and Schieck (1995) North-central/ Northeastern Alberta	American kestrel, hairy woodpecker, three-toed woodpecker, black-backed woodpecker, brown creeper, winter wren, yellow-rumped warbler	Species listed are those with highest indices of density in forests which were 1 year post-burn, compared to those which were 14 and 28 years post-burn.
Imbeau et al. (1999) Southern Quebec	cedar waxwing, hermit thrush American kestrel[a], three-toed woodpecker[a], black-backed woodpecker[a], tree swallow[a], eastern bluebird[a], Wilson's warbler[a]	Of 20 species analyzed, the first two listed were significantly more abundant in recent burns (vegetation < 2 m) than in any of 6 other vegetation classes. [a] – species which were too rare to include in overall analyses, but which occurred only in young burned stands.
Schieck and Hobson (2000) North-central/ Northeastern Alberta	barred owl, hairy woodpecker, three-toed woodpecker, black-backed woodpecker, northern flicker, gray jay, brown creeper, mountain bluebird, white-throated sparrow	Species listed are those which had the highest indices of density in stands which were 2 years post-fire compared to older post-fire stands and post-harvest stands. Stands had various amounts of residual trees and clumps.

(Continued on next page.)

Table 3.4 Continued

Study and Location	Species	Notes
Morissette et al. (2002) North-central Saskatchewan	yellow-rumped warbler[a], dark-eyed junco[b], olive-sided flycatcher[b], American robin[b], western wood pewee[b], winter wren[b], white-throated sparrow[c], brown creeper[c], house wren[c], chesnut-sided warbler[c], chipping sparrow[c],	Species listed are those which had significant (p< 0.5) % indicator values highest in burned forests (3 yrs post-burn) compared to unburned and salvaged forest. [a] – comparison of burned, unburned and salvaged mixedwood forests [b] – comparison of burned, unburned and salvaged jack pine forests [c] – comparison of burned, unburned and salvaged aspen forests
Apfelbaum and Haney (1981) Northern Minnesota	olive-sided flycatcher, black-backed woodpecker, gray-cheeked thrush, purple finch, American robin, dark-eyed junco, Swainson's thrush, white-throated sparrow	Species listed are those which were found in the year following a fire in a jack pine black spruce stand and which were not found there the previous year (the one before the fire).

3.1.3.2 *Old Forests*

The value of old forests and concerns over the diminishing amount of old forests across Canada has received a great deal of attention over the last several decades. Nowacki and Trianosky (1993) published a list of 749 literature citations related to old-growth forests in eastern North America (the eastern U.S. and southeastern Canada), and undoubtedly hundreds more have been published in the decade since. In 2001 the Canadian Forest Service organized a national symposium on "the old-growth issue" in Canada, resulting in a supplementary issue of the journal *Environmental Reviews* (Mosseler et al. 2003). A wide variety of ecological functions have been attributed to old forests, including providing unique habitat for wildlife, acting as reservoirs of genetic diversity, regulating water flows, maintaining biogeochemical cycles, and sequestering carbon (Hunter 1990; Maser 1990; Kimmins 1997; and many others). The ecological values of old forests which are most frequently cited for forest birds include the capacity to support large numbers of species, the provision of habitat for unique species, and the ability to support a high abundance of individuals, although these traits may not exist to the same extent for all old forests in Canada (Bunnell 1999b; Hobson and Bayne 2000b).

No definition of old growth is all-encompassing, although it is generally recognized as being beyond, or well beyond, the onset of economic forest rotation age. The structural characteristics of old-growth stands have been briefly summarized by Mosseler et al. (2003) who suggested that they be considered in developing an index of "old-growthness" for defining old growth forests. The attributes include

- uneven- or multi-aged stand structure, or several identifiable age cohorts;
- average age of dominant species approaching half the maximum longevity for species;
- some old trees at or close to their maximum longevity;
- presence of standing dead or dying trees in various states of decay;

- fallen coarse woody debris in various states of decay; and
- natural regeneration of dominant tree species within canopy gaps or on decaying logs.

Several studies have examined bird communities across a variety of forest ages and found evidence of high species richness, high abundance, and species which are either unique to old forests, or which are more common in old forests than in younger forests (Table 3.5). This has led many authors (Thompson et al. 1993; Imbeau et al. 1999; Hagan and Grove 1999a; Thompson et al. 1999; Hobson and Bayne 2000b; Kirk and Hobson 2001; Cumming and Diamond 2002; Drapeau et al. 2002; Schmiegelow and Mönkkönen 2002) to express concerns regarding age class truncation (i.e., harvesting the forest so that little area remains in older growth stages). We note that few of these studies have made reference to "normal" amounts of old-growth (i.e., pre fire-suppression, or in consideration of a range of natural variability); however, given continental declines in populations of some species with affinities for old-growth characteristics, the concerns seem valid.

Bunnell (1999b) noted that not all of the features of bird communities in old forests exist consistently. He emphasized the lack of uniqueness of old forests in his review of studies which have examined old growth forests in the Pacific Northwest, citing that only three of the seven studies (which included twelve analyses) actually found differences in species richness related to old forests, and that the percent of species shared between old forests and young forests exceeded 67% in most cases. Similarly, Thompson et al. (1999) noted that bird communities in young balsam fir forests (40–60 years old) in Newfoundland were similar to those in old (> 80 years) forests. Schieck et al. (1995) noted that the results of their investigation of bird use of aspen forests in Saskatchewan differed markedly from those of Westworth and Telfer (1993) who examined similar forests in Alberta. (Westworth and Telfer [1993] found that richness and abundance of birds were higher in 15-year-old forests than in 80-year-old forests, but Schieck et al. [1995] found that old forests contained more bird species than young forests.) In the black spruce forests of the Abitibi region of Quebec and Ontario, Drapeau et al. (2002) found that old forests do not have the same importance for the distribution of birds associated with dead wood that has been suggested by other studies.

Of course it is not surprising that the avian features of old forests are different across Canada's forests, as the old forests themselves are very different. On the Pacific coast, trees in old forests can be in excess of 1,000 years (Kimmins 1997), while in Newfoundland forests older than 80 years are considered old growth (Thompson et al. 1999), and in the Great Lakes-St. Lawrence forest, tolerant hardwoods beyond about 150 years are considered old growth and can persist on some sites for longer than 500 years (Uhlig et al. 2001). As Bunnell (1999b) pointed out, birds (and other animals) don't know when they are in old forests; their dependence or use of old forests relates to the presence of structural characteristics, such as those identified above by Mosseler et al. (2003). The authors of most of the studies cited in Table 3.5 make the same or similar points.

This hypothesis, relating to the affinity of species to structural characteristics rather than stand age, has led several authors to propose that it should be possible to create old forests' characteristics in forests which themselves are not old-growth. Bunnell (1999b) noted the retention of residual forest and structure in harvested areas maintains many species assumed to be late-successional associates. (Similar results were found by studies described in Section 3.1.1.3 and in Table 3.2.) Hagar et al. (1996) found several "old-growth" bird species consistently were more abundant in thinned versus unthinned stands leading them to suggest thinning as a means of approximating old-growth conditions. Hayes et al. (2003) suggested similarly. The suggestion for management of snags and downed woody debris, particularly in selection harvesting systems (e.g., Woodley and Forbes 1997; Hagan and Grove 1999b), has a similar intent. Killing trees to provide snags has been suggested by Hagan et al. (1997).

Although some practices can hasten the development of old-growth features, stand age will remain an issue, as Bunnell (1999b) pointed out. Large live trees and snags are a function of age, even if their advancement can be encouraged by thinning and girdling. Old trees with rough bark are required for shelter and foraging for many resident species during the winter, and the development of cavities suitable for nesting comes with age. Thus, although it may be that old growth characteristics can be induced to some extent, suitable age-related conditions need be present even for this. This and broader concerns related to age-class truncation and structure have led many authors to advocate retention of large areas of old forests (Evans and Conner 1979; Schieck and Hobson 2000; Imbeau et al. 2001; Cumming and Diamond 2002; Kirk 2003) or to extend or maximize rotation ages (Evans and Conner 1979; Kirk et al. 1996; Hagan et al. 1997; Hobson and Schieck 1999; Imbeau et al. 1999).

Table 3.5 Key Results Related to Bird Communities in Old Forests from Several Studies Which (to varying extents) Examined or Summarized Bird Communities in Relation to Forest Age[1]

Study	Location / BCR	Forest Type	Key Results
Welsh (1987)	Ontario BCR #8	Boreal Forest (mixedwoods)	• Several species were strongly associated with late successional stands (50-300 yrs).
Telfer (1993)	Prairie Provinces BRC#s 6 & 8	Boreal Forests	• The percent of bird species associated with mature (51-150 yrs) and old forests (150 + yrs) exceeds the percent of land area associated with old forest (assuming a 50-year fire cycle).
Hejl et al. (1995)[3]	U.S. Rocky Mountains BCRs # 9 & 10	Various	• 15 species were significantly more abundant in old growth than in other age classes in at least one of the four reviewed. • Woodpeckers, nuthatches, and thrushes were more abundant in old growth in general.
Schieck et al. (1995)	East-Central Alberta BCR #6	Boreal Mixedwoods (aspen stands)	• Species richness was highest in old (120 + years) stands compared to young (23-26 years) and mature (51-63 years) stands. • Two-thirds of the 57 species examined had their highest abundance in old forest.
Bunnell (1999b)[4]	Pacific Northwest BCR #5	Various	• Old growth stands had significantly highest species richness in parts of 2 of 7 studies and highest abundance in parts of 3 of 5 studies.
Hagan and Grove (1999a)	Northern Maine BCR # 14	Acadian Forest	• Most resident species had maximum abundance in mature softwoods than any other "superclass"; mature forests were also important for long distance migrants.

(Continued on next page. See notes at end of table.)

Table 3.5 Continued

Study	Location / BCR	Forest Type	Key Results
Thompson et al. (1999)	Newfoundland BCR #8	Boreal Forest (fir stands)	• There was a gradient of increasing abundance of some species with stand age that may be related to abundance of large diameter trees or dead trees • Two species (gray-cheeked thrush and black-backed woodpecker) found only or predominantly in old forests.
Imbeau et al. (2001) and Imbeau et al. (1999)	Quebec BCR #8	Boreal Forest (spruce-dominated)	• Three-toed woodpecker and black-backed woodpecker were the species most restricted to old-growth forests or recent burns.
Hobson and Bayne (2000b)	Central Saskatchewan BCR #6	Boreal Mixedwoods (aspen stands)	• High species richness in old forests (caused by increases in number of cavity nesting species and number of canopy nesting species) • Most abundant ground nesting bird (oven-bird) was most abundant in mature forest.
Kirk and Hobson (2001)	North-Central Saskatchewan BCR #6	Boreal Forest (jack pine stands)	• Several neotropical migrants were strongly associated with overmature stands containing a mix of jack pine, white spruce and white birch. These species included Cape May warbler, bay breasted warbler and Tennessee warbler.
Cumming and Diamond (2002)	Central Saskatchewan BRC #6	Boreal (mixedwoods)	Species richness was highest in oldest forests. Many species were not detected young forests, but no species were not detected in the oldest (> 140 yrs). • Several species were significantly more abundant in mature and old forests than in other age classes.
Schmiegelow and Mönkkönen (2002)	Canada[2]	Boreal	"Old forest specialists account for almost one-third of all birds breeding in older boreal forests." • 42% of resident species are old forest specialists

[1]Old forest, or old-growth forests were defined variously by the authors cited in this table. For most, the definition related to being older than the age at which commercial harvest generally occurs.
[2] This paper summarized bird distributions across the boreal forest, so all boreal BCRs are included.
[3]The authors summarized the results of four studies from the western United States (Peterson 1982; Mannan and Meslow 1984; Mannan and Siegel 1988; Hejl and Woods 1991).
[4]The author summarized the results of seven studies from the Pacific Northwest (Raphael 1984; Anthony et al. 1984; Manuwal and Huff 1987; Manuwal 1991; Nelson 1988; Carey et al. 1991; Lundquist and Mariani 1991)) All of these studies reported on species richness, all except Anthony et al. (1984) and Nelson (1988) reported on abundance.

3.1.3.3 *Riparian Buffers*

Riparian buffers are areas that remain unharvested around watercourses or wetlands during harvest activities. In forest management, provincial and federal regulatory requirements to provide riparian buffers have been developed largely to protect water quality from runoff and sedimentation from proximal harvesting operations (e.g., Ontario Ministry of Natural Resources 1998; New Brunswick Natural Resources and Energy 1999) and were not originally designed nor intended to provide riparian corridors for terrestrial wildlife. The required width of these buffers is variable across the country (range from 3–150 m) and applied on the basis of waterbody type and, in some instances, slope. Ecological considerations for the values inherent in the terrestrial portion of the riparian buffer have generally not been a factor when determining appropriate buffer widths. However, riparian habitats are widely recognized as being rich ecological zones, often containing an abundance of wildlife species well beyond their areal representation on the landscape (Stauffer and Best 1980; Hunter 1990; Bunnell 1999b). For birds, the high value of riparian ecosystems is explained by several factors, including the production of large numbers of insects and other invertebrates which are available as prey; and the presence of a variety of habitats and micro-habitats resulting from the transition from upland to aquatic zones; (Thomas et al. 1979 ; Stauffer and Best 1980; Bull and Skovlin 1982; LaRue et al. 1995; and others).

Studies of bird response to riparian buffers in a forest management context in Canada have examined three aspects of the interrelation: a) nest predation associated with the edge between riparian buffers and adjacent harvest areas (Boulet and Darveau 2000; Boulet et al. 2003); b) the role of riparian buffers in providing connectivity between unharvested forest areas (Machtans et al. 1996; Schmiegelow et al. 1997; Robichaud et al. 2002); and c) the role of riparian buffers in providing breeding habitat for forest birds (Johnson and Brown 1990; LaRue et al. 1995; Hagar 1999). Although the topics are related, (some studies, for example Pearson and Manuwal [2001], Whitaker and Montevecchi [1999] have examined more than one aspect), the effects are largely distinct and so are often considered independently. In this section, we focus on the role and suitability of riparian buffers for providing breeding habitat. The relation between buffers and nest predation is covered in Section 3.2.2, and the role of buffers in providing connectivity is covered in Section 3.2.3.

Table 3.6 summarizes several studies that have examined the relationship between breeding bird habitat and riparian buffers. Most studies of this sort have, at least in part, attempted to address the issue of buffer width, and to identify the width, or range of widths, which can provide suitable habitat for forest birds. Some individual studies (e.g., Darveau et al. 1995; Hagar 1999), and a synthesis across studies (Table 3.6) lead to the conclusion that as buffer width increases, species composition within the buffer becomes more similar to unlogged sites. However, this relationship is not linear. Rather, the most significant gains in species richness are made early on the curve. Narrow buffers (generally < 20 m) provide habitat mostly for "ubiquitous" species (Darveau et al. 1995; Whitaker and Montevecchi 1999) with non-specific habitat requirements (e.g., yellow-rumped warbler, fox sparrow), but not for most forest-dwelling species. A range of widths from about 40 to 100 m (on each side of a waterbody) has been identified as adequate for protecting forest species (Table 3.6). (The number of studies conducted of this sort is not sufficient to determine any trends or consensus in different forest regions or BCRs.) However, at least one study (Whitaker and Montevecchi 1999) has noted that even very wide strips (> 100 m) may not be sufficient to provide habitat for interior species, leading the authors to note that provision of forest bird habitat may not be a suitable mandate for riparian buffer strips. Others have also noted that separate conservation strategies should be employed for forest birds, and that reliance on buffer strips to provide interior habitat is not an efficient use of reserved forest land (because of the linear shape of riparian buffers), and perhaps inappropriate from a conservation perspective as some species may be limited or prefer upland habitats rather than riparian ones (Schmiegelow and Hannon 1999; Lambert and Hannon 2000; Potvin and Bertrand 2004). Shapes other than rectangles (the approximate shape of most riparian buffers) which have high edge-to-interior ratios are likely also better from an economic perspective as less total land is required to preserve the same amount of interior space with square or circular reserves. Some authors (Schmiegelow and Hannon 1999; Potvin and Bertrand 2004) have suggested or implied that it may be worthwhile to forgo riparian buffers in some instances and use the "banked" unharvested land to contribute to the development of large reserves. We note however, that there are regulatory requirements for the use of riparian buffers for the protection of water quality in most circumstances in Canadian jurisdictions and that these requirements would obviously need to be respected when strategies accommodating songbird habitat are being considered.

Another aspect of the discussion regarding the provision of interior forest habitat by riparian buffers has a mathematical component. If, say, a 50-m reserve is required for riparian reserves for water quality protection (as is the case in Ontario for lands with slopes of 16–30% (Ontario Ministry of Natural Resources [1988]) and 120 m is sufficient to provide for interior forest bird habitat, then the incremental width of providing interior forest habitat is 70 m (120 minus 50). It is then the area required for the incremental 70 m width which should be used in any trade-off considerations, rather than 120 m total width of the reserve.

Johnson and Brown (1990) and Potvin and Bertrand (2004) noted that some harvesting within riparian reserves may not degrade any role in providing bird habitat. Indeed, Potvin and Bertrand (2004) suggested that the use of selection cuts and partial harvests in reserves may be used to simulate old forest conditions and increase the attractiveness of buffers for some bird species which use habitat features associated with old forests.

Finally, several authors (Darveau et al. 1995; Whitaker and Montevecchi 1999; Pearson and Manuwal 2001) have noted that the propensity of riparian buffer strips to suffer from windthrow may decrease their value in providing habitat for forest birds.

Table 3.6 Summary of Several Studies Which Have Examined the Bird Communities in Riparian Buffers

Study	Location / Forest Type(s) / BCR	Brief Description	Key Results	Summary/Conclusions
Hagar (1999)	Western Oregon Pacific Rainforest (conifer dominated) BCR #5	• Compared bird communities in buffers with a gradient of widths from 0–75 m to control stands. • Sites were along 1st to 3rd order streams dominated by mature conifers. • Proximal stands were clearcut.	• Neither bird species richness nor total abundance was related to buffer width. • Species richness was higher in buffers vs. controls. • 12 species were observed more in buffer areas. • 8 species were observed more in unlogged sites. • Abundance of 6 species, primarily forest-dwelling, was positively related to buffer width. • Abundance of 5 species (all open-associated) was negatively related to buffer width.	• As buffer width increased, the species composition and relative abundance of birds in the buffers became more similar to that in unlogged sites; however, even the widest strips did not support all the species found in unlogged sties. • Some interior forest species may have been absent from buffers because of an avoidance of edge, or the area available may not be sufficient to support their territories. • "Buffers > 40 m wide are likely to support bird communities more similar to those in unlogged riparian sites than are narrower buffers.".
Johnson and Brown (1990)	Eastern Maine Acadian Forest (conifer-dominated mixedwoods) BCR #5	• Compared bird communities in an 1800 m long buffer strip adjacent to a lake to those of a nearby control site along a similar lake. • Buffer strip width varied between 70 and 100 m. • Proximal stands were clearcut. • Stands in the buffer strip were subject to selective harvesting, categorized into three levels of intensity.	Bird species diversity was greater in undisturbed forest. Densities of the following guilds were higher in the undisturbed forest: cavity nesters, foliage nesters, and ground foragers. 11 species (mostly forest-associated, and cavity nesters) nested in the undisturbed lakeshore but not in the buffer strip. 3 species (open and shrub-associated) nested in the buffer strip but not in the forest. "Many birds associated with edges or early- successional vegetation were attracted to the buffer strip." Blackburnian warbler showed the greatest negative response to increased levels of harvesting within the buffer strip.	• The authors support a previous recommendations that riparian buffers be 75 m wide with no cutting within the first 25 m of the strip and that further harvesting should not remove more than 50% of the canopy cover in one rotation. • If management is intended to provide habitat for species sensitive to disturbance, harvest within the buffer strip should be minimal. • Because of a lack of replicates in this study, its results should be interpreted cautiously.

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Table 3.6 Continued

Study	Location / Forest Type(s) / BCR	Brief Description	Key Results	Summary/Conclusions
Pearson and Manuwal (2001)	Western Washington Pacific Rainforest (conifer dominated) BCR #5	• Examined bird response to narrow (7–23 m) and wide (21–48 m) buffers; compared to preharvest conditions and control sites. • Sites were along 2nd and 3rd order steams with a coniferous canopy and a deciduous component. • Stands were 2nd growth 45-65 years old. • Proximal stands were clearcut.	Species turnover rate was highest in narrow buffers. Detections of resident species and species associated with conifer trees and shrubs in forested habitats declined in narrow buffers. Detections of interior forest species and riparian forest species declined in both buffer treatments. Detections of short-distance migrants, and species associated with shrubs and open habitats increased in buffers. Abundance of riparian-associated birds was correlated to berry-producing shrubs or the number of deciduous trees. Regression analysis indicated that buffers of 46-65 m would retain interior species.	Post-harvest changes in riparian bird community are likely explained by a) elongated shape of buffers; b) a decline in available conifer as deciduous trees and shrubs dominate sites close to water; c) changes in microhabitat in riparian zones caused by proximal logging; and d) changes in the upland habitat and its bird community which spill over into the riparian zones. Buffers of 45 m are recommended to retain pre-logging community.
Lambert and Hannon (2000)	Central Alberta Boreal Forest (mixedwoods) BCR #6	• Compared the response of ovenbirds in pre- and post-harvest buffers of buffers of 20 m, 100 m, and 200 m along 3 lakes to a control site. • Proximal stands were clearcut, up to 5% of standing timber was retained in small scattered clumps.	Ovenbirds were not found in any of the 20 m buffers. Ovenbird numbers in 100 m and 200 m buffers were conserved. The mean territory size decreased in 100 m and 200 m buffers after harvest. Territories in 200 m buffers narrowed, and territories in 100 m buffers shifted lakeward. Proportion of mated males in the 100 m and 200 m buffers combined did not change as a result of harvesting.	• 100 m buffers are adequate to support ovenbirds; however, designing buffers solely for ovenbirds is impractical. • Exclusive reliance on buffers to preserve interior species is inappropriate because some species may be limited or prefer upland habitats. • The lack of a decrease in pairing success is inconsistent with previously observed “crowding effect” documented by Hagan et al. (1996); possibly the unharvested forest ameliorated short-term disturbance effects on pairing success.

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Table 3.6 Continued

Darveau et al. (1995)	Southern Quebec Southern Boreal Forest (fir-dominated mixedwoods) BCR #8	Compared bird communities in buffers of 20, 40, and 60 m to those in 20 m thinned buffer and unharvested control. Sites were along rivers 5–15 m wide, with < 30 % slope, and an alder fringe 1–7 m wide. Stands were fir-dominated > 50 yrs old with < 25% dead trees. Proximal stands were clearcut.	Treatments did not affect overall species richness. No. of territories of forest-dwelling species was lower in the buffers than in the control, with the lowest in the 20 m thinned buffer. "Ubiquitous" species were most common in 20 thinned strips and least common in the control. Bird populations declined for three years following harvesting (the extent of the study).	20 m strips are suitable as habitat for ubiquitous species, but not for forest dwelling species. 60 m strips can support avifauna similar to that of a large forest tract. Crowding effect, as described in (Hagan et al. 1996), may have created difficulties in interpreting results of changes in bird numbers.
Whitaker and Montevecchi (1999)	Western Newfoundland Boreal Forest BCR #8	• Compared bird communities in buffers 20–50 m wide along streams and lakes to those in control areas. • Streams were 4-15 m wide, lakes ranged from 2–200 ha. • Proximal stands were 3-5 yr. old clearcuts.	• Total number of birds observed in buffer strips was greater than in controls because of the greater abundance of birds in the open-edge and ubiquitous guilds; counts of other guilds were similar between buffer strips and controls. • There was no differences in species richness between buffers and controls. • There was a weak positive relationship between the total number of birds observed in buffer strips and buffer width. • There was no difference in counts of riparian species between buffer strips and controls and there was no relationship between strip width and counts of riparian species. • Buffer width was not a significant factor influencing numbers of interior forest birds and accounted for little of the observed variation in the counts.	• Buffer widths of > 20 m may be beneficial to forest generalists; in this study buffer strips 20–50 m wide were used by a relatively diverse array of species from a variety of guilds. • Wide buffers are likely not required to protect riparian species as they restrict their activity to nearshore riparian vegetation. • Even very wide strips (> 100 m) may not be sufficient to provide habitat for interior forest species, so it may be best not to attempt to provide habitat for them through the use of buffers, but rather to develop separate conservation strategies.

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Table 3.6 Continued

Potvin and Bertrand (2004)	Southern Quebec Southern Boreal Forest/Boreal Transition (fir/spruce/birch dominated) BCRs #8 & 12	Compared the response of birds (and other wildlife) to 51-125 m wide riparian strips and 52-132 m upland strips surround by harvest blocks to residual blocks and control sites. Riparian strips had small streams (< 3 m wide) in the middle. Proximal stands were harvested, with 24-39% of area left in residual strips and patches. Forest in strips was black spruce-dominated mixedwoods.	• The percent occurrence of 13 bird species was analysed. • There was a higher probability of occurrence of 4 species in riparian strips (white-throated sparrow, hermit thrush, black-backed woodpecker and dark-eyed junco), compared to control and a lower probability of occurrence for two species (Nashville warbler and bay-breasted warbler) in the riparian strips than in the control. The difference in the bay-breasted warbler abundance was most striking.	• Blocks larger than 50 ha are likely needed for area-sensitive species such as bay-breasted warbler; they suggest 1 km^2 as a minimum size. • The authors suggest converting some of the standard 20 m wide riparian buffer strips to large blocks to provide high quality habitat, even if it means increasing the size of clearcuts. • The authors also suggest the possibility of use of selection cuts and partial harvests in buffer zones to create old forest conditions.

3.1.4.3 *Comparison of Harvesting and Natural Disturbances*

Many studies of the response of birds to forest management have focused on comparisons between harvested and unharvested forest areas with discussions of the effects based on an implicit notion that these two conditions represent the suite of possible forest states. This is obviously not the case, given that all of Canada's forests are, to varying extents, disturbance driven. Given that forest management in Canada is rapidly adopting the ideal that forest management should attempt to emulate natural disturbances to the extent possible, useful studies are those which focus on comparing harvested and naturally disturbed forests.

For the boreal forest, most attention has been focused on fire as the agent of disturbance, and as noted in Section 3.1.3.1, burnt forests have a unique assemblage of bird species, very different from those which occur following timber harvest. The two most relevant studies on this topic in the boreal forest have been carried out by Hobson and Schieck (1999) and Schieck and Hobson (2000). In the two studies, the authors examined bird communities in forests with comparable time-since-harvest and time-since-fire. In the earlier of the two studies, clearcuts and burned areas were compared and the maximum time-since-disturbance was 30 years; in the later study the comparison was between burned areas which had residual trees and patches of different sizes, and comparable harvest areas; the maximum time-since-disturbance was 60 years. Both studies found striking differences in species composition in the more recently disturbed areas, with mature forest- and snag-associated species such as black-backed woodpecker, three-toed woodpecker, and brown creeper common in the burned areas and open- and shrub-associated species much more common in the harvested areas, although harvested areas with large patches of residuals (up to 3000 trees) were more similar to old forests than were those with small residual patches. Both studies found that the initial marked difference between the harvested and burned forest areas diminished over time. This was attributed to the snags falling down and the development of forest cover in both disturbance types. However, both studies also found that even in the oldest aged stands they compared, there remained significant differences in species composition between the naturally disturbed and harvested stands. In both studies this was attributed largely to the higher shrub density in the post-harvest stands and differences in the vertical layers and structure of vegetation. Schieck and Hobson (2000) concluded with a note that even though large residual patches provided habitat for more old species initially, patches of all sizes retained old forest species even at mid- and late-rotation age. Therefore, they advised retaining patches of variable sizes depending on whether managers wish to promote old forest bird communities during early or late rotation.

For tolerant hardwood forests, the most applicable study is that of Jobes et al. (2004) who, as noted in Section 3.1.2.1, compared bird communities in areas selectively harvested up to 20 years previously with those of reference forests subject only to natural disturbances. They found that species diversity and richness did not differ between the harvested and natural areas but that the abundance of some mature forest species was greater on the natural areas, and some shrub- and open-affiliated species were more common in the harvested areas. The study of Webb et al. (1977), which is discussed in detail in Section 3.1.1.1, also compared harvests in tolerant hardwood forests to control areas and had similar findings.

At a landscape scale, the studies of Drapeau et al. (2000) and Zimmerling (2004), discussed in detail in Section 3.2.4, have compared bird communities in natural boreal landscapes (subject primarily to natural disturbances) to landscapes in which forest management was the primary agent of change. The results of the two studies differed markedly. Whereas Drapeau et al. found very significant differences, Zimmerling for the most part did not. The contrast between the two studies relates in part to the forest types which regenerated post-harvest. In northwestern Quebec, where Drapeau et al. worked, the natural mixedwood forest was replaced by a forest with a much higher deciduous component, whereas in the portions of Ontario's boreal forest studied by Zimmerling, the post-harvest forest was more similar to the post-fire forest (except for one site ecoregion in which there were striking differences in the bird communities post-fire and post-harvest).

Many authors have noted that forest management differs markedly from fire, or other natural agents of disturbance (e.g., Bunnell 1995; Hutto 1995; Rotenberry et al. 1995; Niemi et al. 1998; Schieck and Hobson 2000, Drapeau et al. 2002 and many others); others have noted that animals perceive their environments differently from the way in which humans do (e.g. McCullough 1996; Fahrig 1999; Bunnell 1999b). Marrying these notions, two key questions arise:

Do forest birds perceive the differences between a managed landscape and a landscape subject to natural disturbances in such a way as to lead to important differences in the manner in which they respond to them?

If they do perceive differences, what are the key aspects of managed landscapes which cause differences in the manner in which birds respond?

Neither of these two questions is simple to deal with, and of them, the second is the more challenging to address. Furthermore, although the questions are posed of forest birds in general, it is virtually certain that the answer will be different for different species and groups of birds.

Given that forest management in Canada is moving toward the emulation of natural disturbances as a result of both mandatory (e.g., Ontario's Crown Forest Sustainability Act), and voluntary (e.g., certification standards) initiatives, we believe these two questions are among the most important research topics related to the integration of forest and wildlife management.

3.2 Spatial Aspects of Effects

Changes in landscape patterns created by forest management have been the subject of a considerable amount of research and literature. At the stand and forest scales, interest has focused on differences in nest predation and nest parasitism along forest edges, between stands or patches of different size, and between habitats created by forest management (e.g., recently clearcut areas vs. remnant forest). Of these two mechanisms (predation and nest parasitism) most attention in Canada's managed forests has focused on predation because of the general lack of evidence of significant nest parasitism. At intermediate scales, some research has been conducted on connectivity gaps and the possible barriers to bird movement caused by discontinuities in habitat created by forest management. At the broadest scale, and integrating both predation and connectivity with aspects of habitat configuration, much attention has been focused on potential fragmentation effects. These three topics–edge-related predation, connectivity, and fragmentation–are discussed in this section.

3.2.1 *Forest Fragmentation*

Forest fragmentation occurs when a contiguous forest is broken into discontiguous tracts. This may result from a variety of activities on the landscape including forest management, oil and gas development, agriculture, or urban development. In the last 20 years or so many scientific studies have explored the concepts and effects associated with forest fragmentation. Many important works have contributed to the development of fragmentation theory (e.g., MacArthur and Wilson 1967; Harris 1984; Andrén 1994; and others). The collection of papers in Rochelle et al. (1999) were very useful in providing direction and contemporary ideas related to the concept and we have made extensive use of them in this review.

Concern regarding habitat fragmentation has its roots in island biogeography theory (MacArthur and Wilson 1963, 1967) which has as its core the notion that biodiversity on islands is affected because of their isolation from other terrestrial habitats. The theory contends that the number of species that islands contain is related to their size and their distance from other islands, and that islands suffer high species turnover because of local extinctions and recolonizations. Metapopulation concepts, first described by Levins (1970) address the way groups of subpopulations interact in patchy or discontiguous habitats, and have also contributed strongly to thinking about fragmentation issues (McCullough 1996; Schmiegelow et al. 1997; Bunnell 1999b).

Although initial studies of forest fragmentation effects on songbirds appeared consistent with the theory of island biogeography (Freemark and Merriam 1986), these studies were conducted in landscapes in which forest fragments were isolated in agricultural landscapes. For managed forest landscapes, the analogy of a "hostile sea" separating habitat patches does not hold (Bunnell 1999b; Schmiegelow and Hannon 1999) since the intervening landscapes (i.e., harvested areas) are not as inhospitable as are agricultural lands, and therefore mature forest patches do not function as true islands.

Many authors (Fahrig 1997, 1999; Bunnell 1999a, 1999b; Schmiegelow and Hannon 1999; With 1999; Haila 2002) believe that fragmentation has served as a catchall for a variety of concerns associated with forest habitat and that the concept in its true form is not very relevant in managed forest environments (but see Manolis et al. 2000, 2002) and discussions of their work in Section 3.2.2). They note that it is reasonable to expect a population to fluctuate more or less in proportion to habitat availability, and that fragmentation effects occur when a population declines to a greater extent than does its habitat. Andrén (1994) reviewed over 30 studies and found that where the proportion of suitable habitat in the landscape remains at or above 30%, population declines are generally in proportion to the amount of habitat lost. Fahrig (1997) arrived at a similar estimate using simulation analyses; she suggested that when breeding habitat covers more than 20% of the landscape, "survival is virtually ensured" no matter how fragmented the habitat is.

Bunnell (1999a) describes several forms of habitat modification which are often lumped together with fragmentation concerns including loss of old forest habitat, changes in patch size, and changes in amount of edge. Key in this list is habitat loss. Habitat loss is not fragmentation per se, but these two manners of habitat degradation often co-occur and lead to the misrepresentation of concerns regarding habitat loss as concerns regarding fragmentation (Bunnell 1999a, 1999b; Schmiegelow and Hannon 1999; Norton et al. 2000; Fahrig 1999). Bunnell (1999a) refers to fragmentation as a "panchreston" which means "a proposed explanation intended to address a complex problem by trying to account for all possible contingencies but typically proving to be too broadly conceived and therefore oversimplified to be of any practical use." Haila (2002) refers to it as "conceptually ambiguous" at least partly because of the confounding interrelation between habitat loss and habitat fragmentation. Most authors agree that habitat loss is by far the more serious issue for terrestrial wildlife, including forest birds (Fahrig 1997; Schmiegelow et al. 1997; Bunnell 1999a, 1999b; Fahrig 1999; Trzcinski et al. 1999; Schmiegelow and Mönkkönen 2002; Fahrig 1999; Drapeau et al. 2000). Although the difference may seem semantic, it is much more if concern about fragmentation leads to management efforts to reconfigure rather than conserve habitat. Fahrig (1999) noted that "[v]ery little benefit will accrue to most species of concern through manipulations or judicious planning of habitat configuration.…Emphasis on habitat configuration appears largely misguided if the objective is species conservation." Furthermore, Bunnell (1999b) emphasizes that if spatial arrangement of habitat is less important than total amount, that permits greater operational flexibility and allows forest managers to exploit the advantages of zoning of forest practices.

Trzcinski et al. (1999) noted that the negative findings related to forest fragmentation that many studies purport to have found because of fragmentation, have really been due to habitat loss. They cite the theoretical work of Fahrig (1998) who identified very limiting conditions under which fragmentation is likely to affect a population's viability.

The average between-generation movement distance of organisms is approximately 1-3 times the expected nearest distance between breeding sites.
The breeding habitat of the organism covers < 20% of the landscape.
The habitat is not ephemeral.
The organism has high breeding site fidelity.
The mortality rate in the nonbreeding habitat areas is much higher than the mortality rate in breeding areas.

Few studies have examined the effects of fragmentation independent of the effects of habitat loss in forested landscapes. McGarigal and McComb (1995) compared the effects of forest cover and fragmentation on bird species abundance in western Oregon. They sampled vegetation and birds in 30 landscapes which varied in forest cover from 0.7 to 100%. Using measures of configuration that were independent of forest amount, they found that "with the exception of a few edge species", bird species' abundances were more strongly associated with habitat area than with configuration (i.e., fragmentation). Working in landscapes with forest cover ranging from 2.5% to 55% in southern Ontario and southern Quebec, Trzcinski et al. (1999) found that the probability of presence/absence was correlated with forest cover for all 31 bird species they studied; for 25 of these, the relationship was statistically significant. On the other hand, fragmentation was a significant predicator for only six species (and for two of these the relationship was positive). Drapeau et al. (2000) assessed characteristics of the songbird community across three distinct landscape types in the Abitibi region of northwestern Quebec and found patterns of bird community composition were related to several landscape composition variables, but not to configuration variables. Schmiegelow et al. (1997) manipulated a boreal landscape in central Alberta so as to isolate patches of various sizes from areas of contiguous forest. They did find evidence of fragmentation effects (e.g., several species were less abundant in isolated and connected fragments than in controls); however, they conclude that the magnitudes were small "given the extent of our manipulations."

One reason that fragmentation may not present a dire issue in much of Canada's forest relates to the forests' naturally patchy nature. Cotterill and Hannon (1999) noted that this may have led species inhabiting forest patches to be resilient to edge effects, and the same may be true for broader fragmentation effects. Bunnell (1999a) noted that many patchy environments are very diverse and productive, and that concern about fragmentation has diverted attention from the important contribution that patchiness makes in supporting species richness. Hobson and Bayne (2000a) cited examples of circumstances in which interspersion of habitats at a local scale is related to bird species richness; likewise, McGarigal and McComb (1999), who analyzed landscape variables in a manner which allowed them to determine the independent influence of key characteristics, noted that most of the species associated with late-seral forests in western Oregon are associated with their fragmented distribution.

It appears that the weight of evidence, both conceptual and empirical, is on the side of fragmentation per se not being a serious issue for songbirds in managed forest landscapes. There are some caveats, however. First and foremost, the conclusion that fragmentation is not a serious detrimental force, should not be taken to imply that the effects, primarily habitat loss, frequently confused with fragmentation are not important concerns. Second, although the empirical evidence strongly suggests that habitat loss is by far more important, there may be species for which fragmentation is a concern. Some edge species studied by McGarigal and McComb (1995) did show negative fragmentation effects, as did also four of the species studied by Trzcinski et al. (1999). Of the effects that Schmiegelow et al. (1997) did find, they found them most pronounced in neotropical migrants and resident birds. They noted that neotropical migrants in the boreal forest tend to be habitat specialists and this may compromise their ability to adjust to rapid changes in landscape configuration. They also caution that their results were short-term, and that estimates of abundance, upon which they rested their conclusions, may not provide a reliable indicator of habitat quality (Van Horne 1983).

Fahrig (1999) offered the following conclusions regarding fragmentation in continuous forests:

Habitat loss has a much greater effect on population persistence than changes in habitat configuration.
Population survival may show a threshold response to habitat loss.
Conservation efforts should focus primarily on habitat conservation and restoration. Alteration of habitat configuration cannot compensate for habitat loss.
Patch-scale data such as patch size or patch isolation cannot provide evidence for landscape-scale fragmentation effects. Such effects can only be observed through landscape scale studies.
The term "fragmentation" should not be used if habitat loss is the main factor being considered. Focus on "fragmentation effects" leads to the erroneous conclusion that negative effects of habitat loss can be compensated by alteration of habitat configuration.

3.2.2 *Edge Effects*

Table 3.7 provides an overview of several studies that have examined the phenomenon of nest predation and the possible links between forest management and predation effects on the nests of forest birds. Nest predation and nest parasitism have been shown to be serious detrimental influences on forest birds in landscapes in which forest patches exist within an agricultural matrix (e.g., Gates and Gysel 1978; Wilcove 1985; Yahner and Scott 1988; Robinson et al. 1995). The factors contributing to higher nest predation along forest edges and inside forest patches identified by these and other studies include

higher densities of prey along edges, which attract higher predator densities and higher levels of predatory foraging;
habitats adjacent to forests acting as a source of predators which forage into the adjoining forests;
habitat edges used as travel corridors by predators, increasing the opportunistic finding of birds nests; and
agricultural landscapes supporting more generalist predators than forest landscapes, causing increases in predator populations.

A key question is whether or not these same dynamics and resultant effects exist in landscapes in which forests predominate and in which forest management is the primary land use. Boulet and Darveau (2000) summarized the hypotheses invoked by other researchers to suggest why edge-related effects would not occur in managed forest landscapes in which clearcutting is the dominant agent of change.

- Clearcut areas are ephemeral and so permanent changes in predator or prey populations or dynamics associated with them would not exist.
- Forest-clearcut edges are more abrupt than are edges in forest-agricultural matrices, making them less attractive for nesting birds and subsequently to predators.
- The abundance of generalist predators is lower in a mosaic of forest and clearcuts than in a forest-agriculture mosaic.
- Generalist predators are less common in forest environments than in agricultural environments.

In addition to these reasons, Cotterill and Hannon (1999) noted that natural edges at a variety of scales are common in the boreal forest because of its disturbance-driven dynamics. They cited the suggestions of Noss (1991) and Andrén (1995) that edge effects may not occur in patchy environments because species that inhabit them have adapted to a heterogeneous environments and the creation of more edge in an already patchy environment may not lead to negative effects.

Many of the studies we examined for this review found no edge-related nest predation effect (Table 3.8). However, evidence does exist that edge effects do occur. Fenske-Crawford and Niemi (1997) found strong evidence of an edge effect as did Manolis et al. (2000) who reported on two studies (one with artificial nests and one based on monitoring natural nests) in northern Minnesota. (The 2000 study was expanded upon in Manolis et al. [2002]). In a comprehensive analysis, Manolis et al. (2000) reviewed 26 analyses of edge and fragmentation effects reported upon in 11 previously published studies (some of which are included in Tables 3.7 and 3.8) and some of Manolis's unpublished data. The studies they analyzed were all from the northern and northeastern United States, including several studies located within the U.S. portion of Canadian BCRs. They were critical of the design of several studies (e.g., some had considerable pseudoreplication) and of the statistical techniques and power of many of the analyses employed. Of the 26 analyses they reviewed, 13 found edge effects, 12 did not, and one showed greater nest predation rates in unfragmented versus fragmented areas. However, when they excluded analyses of low or moderate statistical power, most (68-93%, depending on the statistical power to detected change) of the remaining studies showed edge effects of some sort. This led them to conclude that strong evidence does exist for clearcut-edge effects in the northeastern United States.

Others have also conducted meta-analyses to search for broad answers to the edge effect question. Hartley and Hunter (1998) examined the results of 33 analyses undertaken in 13 studies of edge effects in forested landscapes. All the studies analyzed were from the United States and many were from areas south of Canadian BCRs. There was some overlap in the studies analyzed by Hartley and Hunter (1998) and those analyzed by Manolis et al. (2000). Hartley and Hunter (1998) were not as critical of the statistical techniques employed as were Manolis et al. (2000). Hartley and Hunter (1998) found that elevated nest predation rates near edges were detected in only 3 of the 13 studies they reviewed. Andrén (1995) also examined a series of fragmentation and edge studies. The studies he examined were mostly from the temperate United Stands and boreal Scandinavia. All nine studies he examined from forest-dominated landscapes showed no edge effects while 18 of 20 studies he examined from forest-farmland landscapes did show edge effects.

In a synopsis primarily based on studies from agricultural regions, Paton (1994) suggested that edge effects usually occur within 50 m of forest edges. Kremsater and Bunnell (1999) assessed nine studies from a variety of landscapes and agreed with Paton's (1994) assessment. However, Manolis et al. (2000, 2002) disagreed vehemently with the concept of a 50-m boundary on effects and cite evidence from forest-dominated landscapes in the northeastern United States that suggests that edge effects can occur up to and perhaps beyond 300 m into contiguous forests. Burke and Nol (2000) also found evidence that the edge effect extends beyond 50 m.

There is evidence that some of the reasons cited above explaining why edge effects do not occur in forested environments may not be universally true. For example, King et al. 1998) found higher densities of eastern chipmunks and red squirrels near clearcut borders than in the interior. Bider (1968) also found evidence of increased squirrel and chipmunk activity at ecotones. Red squirrels were found to be very important nest predators in several studies (Tewksbury et al. 1998; Sieving and Willson 1998; Song and Hannon 1999; Boulet et al. 2003). Boulet et al. (2000) suggested that red squirrels may be compacted into forest edges following the removal of their proximal habitat during clearcut operations, thereby increasing predation in edges. Manolis et al. (2002) suggested that the high densities of murids often found in clearcuts may lead to "spillover" predation in forest edges.

Several studies have examined the relative nest predation rates in harvested and unharvested forests (Table 3.7). Some of these studies have compared predation in riparian buffer zones and the adjacent clearcut areas, others have made comparisons between clearcut areas and unharvested forests, and others have examined partial cuts or cuts with residual retention. Studies that have found higher rates of nest predation in forested patches (Rudnicky and Hunter 1993; Hanski et al. 1996; Darveau et al. 1997), although not examining edge effects per se, contribute to the notion that some sort of dynamics do occur which make forest areas more attractive to predators and/or more susceptible to nest predation and therefore lend credence to arguments that negative edge effects do exist in forested environments.

None of the studies summarized in Table 3.7 reported higher rates of nest predation in clearcut or harvested areas compared to unharvested areas. So it seems clear that nesting habitats located adjacent to clearcut stands are not a major focus of predator activity. This is reinforced by the findings of Tittler and Hannon (2000) who found no difference in predation rates between clearcuts with different levels of residual retention. Since the retention of residuals is a management practice based on emulating natural disturbance as a means of enhancing habitat suitability in regenerating forests, a comparison of predation levels between harvested areas and areas subjected to natural disturbances may be more appropriate in terms of developing sustainable forest management approaches rather than (or in addition to) comparisons of harvest to no harvest; however, we are aware of no such investigations. Few studies have investigated edge effects for even up to 5 years post harvest (Table 3.7) and so the question of how long effects exist (if indeed they do) remains relatively unexplored.

What is to be made of this contradictory evidence regarding edge effects? Unfortunately, it seems the answer is not clear. Although most evidence suggests that edge effects are not significant in Canadian managed forests, there is some evidence to the contrary. While the studies included in the three compilations discussed above included some Canadian BCRs, not a lot of studies have been undertaken in Canadian forests. In the boreal mixedwoods of Alberta, Cotterill and Hannon (1999), Song and Hannon (1999), and Tittler and Hannon (2000) found no evidence of edge effects, and Ibarzabal and Desrochers (2001) found no evidence of edge effects in the southern boreal forest of Quebec. However, as noted above, studies which have found higher nest predation in forests abutting clearcuts contribute to the credibility of positive edge effect arguments. Burke and Nol (2000) did find some evidence of edge effects in Ontario, but most of their study sites were south of the area in which forest management is prevalent. In the rest of Canada, evidence regarding edge effects comes from studies in the northeastern U.S. portions of Canadian BCRs and there, although several studies have suggested a lack of edge effects, the persuasive analysis of Manolis et al. (2000) providing evidence to the contrary must be taken into account.

Although it seems a call for research is appropriate, given the lack of definitive resolution on this issue compared to the number of studies undertaken, it is clear that management of the forests will obviously not wait for resolution. This is likely an issue for which local and regional specific knowledge is required. As Welsh (1987) noted, there is no substitution for local knowledge. Given the importance of the local predator community in influencing nest survival rates (King et al. 1998; Cotterill and Hannon 1999; Boulet et al. 2003), local approaches taking into account predator (primarily red squirrel) abundance may be of use. Some have suggested using larger cuts to ameliorate edge effects, as the edge:area ratio is lowered when the same amount of forest is cut using a large cut compared to several small cuts (King et al. 1996; Manolis et al. 2002).

Although the issue of edge-related nest predation may await a definitive conclusion, the topic of cowbird parasitism is clearer. Studies in the managed forests of Canadian BCRs which have examined nest parasitism (usually in the context of examining other fragmentation or edge-related issues) have found no evidence that nest parasitism exists at anything more than very minor levels (Kremsater and Bunnell 1999; Schmiegelow and Hannon 1999; Bourque and Villard 2001; Ibarzabal and Desrochers 2001; Drapeau et al. 2000).

Table 3.7 Summary of Selected Studies That Have Examined the Effects of Nest Predation

Study	Location/Forest Type(s)/BCR	Brief Description	Key Results	Summary/Conclusions
Cotterill and Hannon (1999)	Central Alberta Boreal Forest (mixedwood) BCR #6	• Compared nest predation in 11 leave patches (ave. 40 ha) and in 11 control blocks • Proximal stands were subjected to first pass in a two-pass harvesting system. • Used artificial nests placed on the ground and in shrubs. • Examined predation 1 year and 5 years after logging.	• Clearcutting did not significantly affect predation rates on ground or shrub nests. • There was no edge-related increase in nest predation. • Murids were most common predator of ground nests; although murids and red squirrels were important predators of shrub nests, the predator in many instances could not be determined. • Generalist predators commonly associated with agricultural areas were not detected.	• The authors note that the statistical power to detect differences among treatments was low. • "There appears to be no evidence for short-term negative edge effects in this forest at the current level of fragmentation." (Approx. 14% of the study area was fragmented by clearcutting).
Song and Hannon (1999)	Central Alberta Boreal Forest (mixedwood) BCR #6	• Compared nest predation in aspen stands adjacent to a) white spruce stands, b) clearcuts; c) seismic lines and in the interior of aspen stands. • Used artificial nests – both shrub and ground. 2 field seasons. Clearcuts were 1-2 yrs since harvest.	For ground nests, there was no effect of edge type on predation in either of the 2 years of the study. For shrub nests, the results were variable. Predation rate was higher on shrub nests than on ground nests. There was no edge effect at aspen/clearcut edges.	Annual variation in patterns of predation was explained by patterns of red squirrel activity. • "Clearcuts and aspen forests next to clearcuts are unlikely to provide favourable habitat for nest predators." • The authors conclude that it does not appear that anthropogenic activity causes an increased incidence of nest predation at forest edges relative to natural edges and the forest interior.
Tittler and Hannon (2000)	Central Alberta Boreal Forest (mixedwood) BCR #6	• Examined nest predation in cutblocks with three levels of residual retention, and in forest adjacent to cutblocks. • Used artificial nests. • 1 field season. • 3 years after logging.	The level of retention did not affect predation rate in the adjacent forests, nor did it affect within-cutblock predation rate.	• The authors conclude that vegetation is not a good predictor of nest predation in this area. • The authors concur with earlier studies that cutblocks do not provide habitat that increased potential predator abundance, nor did they facilitate movement of predators along forest edges, nor does amount of residual retained influence predation.
Boulet et al. (2003)	Southern Quebec Southern boreal forest (black spruce – dominated mixedwoods) BCR #8	• Compared nest predation in five 60-m wide riparian strips and in five 60-m wide non-riparian strips to five control sites. • Proximal stands were clearcut. • Used artificial nests placed on the ground and in trees. • 2 field seasons. • 1-2 years after logging. • A concurrent nest predator survey was conducted.	Proportion of depredated nests did not differ among treatments or nest heights. Most common predators were red squirrels and gray jays.	• The authors do not believe that logging modified the community of nest predators, as has been found in forest-agricultural areas, or that short-term crowding increased nest predation.

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Table 3.7 Continued

Study	Location/Forest Type(s)/BCR	Brief Description	Key Results	Summary/Conclusions
Darveau et al. (1997)	Southern Quebec Southern boreal forest (fir-dominated mixedwoods) BCR #8	Investigated nest predation in 25 riparian buffers of 20, 40, and 60 m and 20 m (thinned) to control strips (> 300 m) and 15 clearcuts subjected to different regeneration practices (planting with chemical and mechanical weeding, and natural regeneration without vegetation control). Riparian sites were along rivers 5–15 m wide, with < 30 % slope, and an alder fringe 1–7 m wide. • Thinning removed 33% of trees (the largest). • Stands abutting riparian strips were clearcut. • Used artificial nests placed on ground and in trees (only ground used in clearcuts). 4 field seasons. 3-5 years since harvest at start of study.	• For riparian buffers, the risk of predation was lowest in 20 m intact strips, intermediate in 20 m thinned and control strips, and highest in 40 m and 60 m strips. • Nests in unmanaged clearcuts had 3–10 times lower probability of predation than those in control riparian strips. • There was no difference in predation between clearcut treatments, although nests experienced high predation the first year after weeding. • Predators in riparian strips included red squirrel (39% of predated eggs), small mammals (22%), birds (14%), woodchuck (14%), and weasel, raccoon, snowshoe hare, and porcupine (10% combined)– a greater variety of predators than other similar studies have found.	• A major finding was the much lower rate of ground nest predation in naturally regenerated clearcuts than in control forest strips. The authors suggest the much higher density of squirrels in riparian strips contributed strongly to this result. • The authors caution that the comparison between clearcuts had limited statistical power due to low sample size. • The authors suggest that the 20 m and control strips were less attractive to predators than were the 40 and 60 m strips, explaining the higher predation in the intermediate width strips. • The authors conclude that "[w]e have no evidence that forest management alone can lead to an increase in nest predation", but they note that forest management in combination with other activities may affect nest predation.
Ibarzabal and Desrochers (2001)	Southern Quebec Southern boreal forest (fir-spruce) BCR #8	• Examined predation of bait stations (similar to artificial nests) in forests placed 0, 30, 60, 90, and 120 m from open areas created by recent clearcuts and power lines. • Clearcut stands were < 5 yrs old; power lines had vegetation < 1 m. • Bait stations were placed on the ground and in trees. • 2 field seasons	• There was no relation between predation and distance to edge. • Predation rates were more than twice as high for ground stations compared to tree stations. • Predators included red squirrels, murids, mustelids, and birds (although total number of instances [25] in which predators were identified was low).	• Major finding is the lack of edge effect.

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Table 3.7 Continued

Study	Location/Forest Type(s)/BCR	Brief Description	Key Results	Summary/Conclusion
Steventon et al. (1999)	Central British Columbia Costal-Interior Transition (western-hemlock dominated) BCR #10	• Examined predation rates in four site types: 30% ba removal, 60% ba removal, clearcut, and uncut. • Used artificial nests placed on the ground (in 1993), and 5 years later (using same plots) used artificial nests placed in shrubs. Harvest conducted < 2 years prior.	• In 1993, only 6% of nests were depredated–very low compared to other studies. • There was no evidence of a treatment effect in 1993. • In the 1998 shrub experiment, there was little evidence to indicate predation rate differed substantially by treatment. • In the 1998 shrub nest experiment, there was no evidence that 30% removal was different from uncut forest; however, results were equivocal for 60% removal.	• The low predation rate in 1993 was likely related to low predator populations. • "Relative to the uncut forest, our data show no increase in depredation of artificial nests after 30% ba removal…With the variability we observed, however, we cannot rule out an increased risk of predation with 60% removal, relative to uncut forest or clearcuts."
Tewksbury et al. (1998)	Western Montana Interface of Montane forest and farmland (cottonwood – aspen) BCR # 10	• This study compared bird productivity in a highly fragmented agricultural landscape with one dominated by forests. • 16 sites were monitored and the fate of over 1,900 real nests was determined. • 2 field seasons. • Study sites averaged 12 ha.	Nest predation was higher in forested, less fragmented landscapes. Predation rate was not affected by distance to edge, or patch size.	• The authors attribute the higher predation in forested landscapes to the much higher red squirrel density there. • The result of increased predation in forested landscapes is contrary to other studies in mixed landscapes. The authors suggest that the agricultural environment did not lead to increased attractiveness to predators (relative to the loss of forest predators) which occurs in other agricultural settings.
Fenske-Crawford and Niemi (1997)	Northern Minnesota Boreal -Hardwood Transition (aspen mixedwoods) BCR #12	• Examined predation along edges and up to 100 m into interior in 5 medium-age and older forests abutting 2- to 4-year-old aspen (hard edges), and in 5 medium-age and older forest abutting 13-19-year-old aspen forest (soft edges). • Predation recorded by motion-sensitive cameras. • Used artificial ground nests. 1 field season.	Predation was greatest at the edges of both hard and soft boundaries. Predation was higher at soft edges than at hard edges. Eight mammalian species of predators identified.	• The authors hypothesize that increased predation at edges is because of increased predatory activity there perhaps because of increased cover, or because of their use as travel routes. • The authors suggest that the higher predation at soft edges may be related to the variety of predators which preyed on the nests.

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Table 3.7 Continued

Study	Location/Forest Type(s)/BCR	Brief Description	Key Results	Summary/Conclusion
Hanski et al. (1996)	Northern Minnesota Boreal-Hardwood Transition (Mixedwoods) BCR #12	• Investigated relationship between bird predation and several vegetation parameters (and distance to edge) in two locations in northern Minnesota. • Monitored fates of real nests detected by careful searches in forests and open areas. • Open areas which abutted forests included clearcuts, young forest, (time since disturbance not provided) power line rights-of-way, and small bogs. • Surrounding landscape was mostly forested. 1 field season.	• No evidence of edge effect was found in either forest or open habitats. • Nest predation was lower in open habitats than in forests.	• Proximity of nest to edge had no effect on nesting success. • The authors suggest that lower predator densities in open areas explained the difference in predation rates between habitats.

Manolis et al. (2000)	Northern Minnesota
	
	Boreal Hardwood Transition
	
	BCR #12
		• Conducted two studies: natural nest study and artificial nest study
		• Natural nest study
		  • Examined predation of nests in forest tracts relative to vegetation and habitat variables and distance to edge.
		  • Proximal stands were clearcut.
		  • Stands were 3-18 yrs old.
		  • 3 field seasons.
		• Artificial nest study
		  • As part of 3 different experiments, artificial nests were placed at the clearcut edges and a variety of distances into the forest ranging from 0-300 m.
		  • Stands were 3-18 years old.
		  • 2 field seasons.
			In the natural nest study, mortality rates were greater at edges than in forest interior for ground nesting birds (most of which were ovenbirds); distance to edge was the best predicator nest success in logistic regressions.
			In the natural nest study, distance to clearcut edge was not a predictor of nest success for two most common arboreal nesters, but authors note low statistical power for this determination.
			In the artificial nest study, predation rates were greater at edges than in the forest interior.
				• The authors supplemented the analysis of their experiments with an examination of previous studies of edge effects. They noted that many studies had low statistical power and conclude that edge effect is important for many studies in forested environments. (See text for more discussion.)

(Continued on next page.)

Table 3.7 Continued

Study	Location / Forest Type(s) / BCR	Brief Description	Key Results	Summary/Conclusions
Burke and Nol (2000)	Central and Southern Ontario Great Lakes-St. Lawrence Forest (tolerant hardwood dominated) BCRs # 12 & 13	• Compared the reproductive success of forest birds at two contiguous forests with 40 forest fragments • Reproductive success gauged through nest monitoring. • Measured nest predation and cowbird parasitism. • Studied five species: ovenbird, wood thrush, rose-breasted grosbeak, red-eyed vireo, and veery. • Sampled one year at most sites, but up to 4 years at some.	• There was no significant effect of local forest cover or fragment size on predation rates for any species except ovenbird, for which predation rate declined with increases in the amount of woodlot core area. • Nests of two species (rose-breasted grosbeak and veery) were more likely to be depredated when < 100 m from edge than nests in forest interior.	• All fragments were in an agricultural-urban setting and not in a managed forest environment, but the study is useful here because of the inclusion of two large (> 10,000 ha) areas of continuous forest. • "For all species, the general trend in our study area was for nest success and number of young fledged from successful nests to be highest in continuous forest, and within fragmented habitats, for large fragments to be more successful than small fragments."
King et al. (1996)	New Hampshire Acadian Forest (tolerant hardwood dominated) BRC #14	• Examined reproductive success of ovenbirds in relation to distance from edge from small (2.1–5 ha) clearcuts. • Examined from clearcut border to 400 m into the forest interior. • Monitored real nests, and examined several aspects of productivity. 2 field seasons Clearcuts <= 6 years old.	• There was no difference between edge (< 200 m from edge) and interior (201-400m) in the distribution of ovenbird nests and territories or in the ability of males to attract mates. • Indicators of nest survival were lower in edge areas compared to interior areas for one of the study's two years. • Indicators which did not show an edge-related effect included proportion of pairs fledging young, number of young fledged per pair, and fledgling weight.	• Although the results seem somewhat equivocal, the authors attach greater significance to the indicators which did not show an edge effect than to those that suggested one may exist. • The authors suggest that even if productivity is lower within 200 m from an edge, the net effect on ovenbird populations in this landscape is ameliorated somewhat by the small scale of silvicultural operations, the proportion of mature forest in the region, and the tendency of ovenbirds to renest after initial nest failure.

(Continued on next page.)

Table 3.7 Continued

Study	Location/Forest Type(s)/BCR	Brief Description	Key Results	Summary/Conclusions
Rudnicky and Hunter (1993)	Maine Acadian Forest (spruce-fir mixedwood) BCR #14	• Compared nest predation in forest and in abutting clearcuts. • Forest patches ranged from 9–203 ha; many patches were buffer strips between clearcuts. • The landscape was mostly forested (88%). • Used artificial nests. 2 field seasons. 3 to 10 years post-cut.	Forest nests experienced significantly higher predation than did clearcut nests. There was no relation between predation and distance to edge. Generally, neither clearcut size nor forest size affected predation rates.	• The lack of edge effect is similar to other studies in forested environments, but the higher predation rate in forests is not. • The authors note that although the landscape was dominated by forests, the forest tracts also could be considered fragmented by roads, waterbodies and clearcuts.
Small and Hunter (1988)	Maine Acadian Forest (red oak-white pine dominated) BCR #14	• Examined predation on artificial nests in 8 forest fragments of 20–1040 ha. • Although nests were placed in forest fragments, the surrounding area was mostly forested (66-85% based on 3 km radius). • Fragments were surrounded by fields, power lines, roads and bodies of water. • 2 field seasons.	• Predation rate was negatively correlated with the size of the fragment. • Edge:area ratio and distance to edge were not related to predation rate.	• These results support those found in more agricultural areas showing that size of forest tract is important in predicting the rate of nest predation. • "Our results imply that all birds nesting on the ground in small forests, not just those nesting near the edge will be affected by the large predation rates. Furthermore fragmentation influences predation rates in landscapes where forests are dominant."

Table 3.8 Summary of Results of Predation Investigations Described in Table 3.7

Study	Edge Effect	Nest Type	Relative Predation	
			Level	**Comparison**
Small and Hunter (1988)	No	Artificial		
Rudnicky and Hunter (1993)	No	Artificial	higher	forest patches vs. clearcuts
Hanski et al. (1996)	No	Real	higher	forests vs. open areas
King et al. (1996)	No[1]	Real		
Darveau et al. (1997)		Artificial	higher higher	riparian buffers vs. clearcuts wide buffers (40 & 60 m) vs. narrow buffers (20 m)
Fenske-Crawford and Niemi (1997)	Yes	Artificial	higher	along edges of soft contrast vs. edges of hard contrast
Tewksbury et al. (1998)	No	Real	higher	forested landscapes vs. agricultural landscapes
Cotterill and Hannon (1999)	No	Artificial	same	clearcuts and leave patches
Song and Hannon (1999)	No[2]	Artificial	same	clearcuts and forest
Steventon et al. (1999)		Artificial	same[3]	partial cut and forest
Manolis et al. (2000)	Yes[4]	Both		
Burke and Nol (2000)	Yes[5]	Real		
Tittler and Hannon (2000)		Artificial	same same	Within-cuts with variable levels of retention between clearcuts with variable retention and along forest edge
Ibarzabal and Desrochers (2001)	No	Artificial		
Boulet et al. (2003)		Artificial	same	buffer strips and forest

[1] – There was indication of an edge effect in some bird productivity indicators in one of the two years of the study.
[2] – There was no edge effect for ground nests; for shrub nests, the results were equivocal.
[3] – There was no difference between forest and 30% ba removal; results were equivocal for 60% ba removal vs. forests.
[4] – Two separate studies were reported on in this paper (one tracking fate of natural nests, and the other using artificial nests); they both reported edge effects.
[5] – Edge effect existed for two of five species examined.

Table 3.8 identifies a distinction between studies based on monitoring real nests, and those which used artificial nests. Artificial nests were usually baited with quail eggs (or those of a similar species), or clay or plasticine eggs. There has been criticism of the use of artificial nests (e.g., Haskell [1995]) based on the fact that predators may not respond to them in the same manner as they do to real nests with real eggs, nor do researchers necessarily place them in the same spots that natural nests may be. We were unable to detect any trend in the existence or lack of existence of edge effects based on nest type.

3.2.3 *Connectivity*

One of the issues raised as a concern relating to the interactions between forest management and birds is connectivity. The concern is that habitats, or portions of forest which have been "disconnected" by harvesting will be unavailable for use by some species because of their inability or disinclination to cross harvested areas. Bunnell (1999b) noted that "[c]onnectivity exists when organisms can move freely among separate patches of habitat. If organisms cannot move freely the patches and subpopulations they host are disconnected and isolated." Implicit in this definition is that connectivity has both a structural component (i.e., habitats are physically connected) and a functional component (i.e., the species or populations of interest can use the physical connection provided) (Merriam 1991; With 1999). Therefore, connectivity should be viewed from the perspective of individual species. While one species may view a landscape as connected, another less mobile, or more reclusive species may not. With this in mind, it may seem counterintuitive that connectivity would be a concern for songbirds, many of which migrate thousands of miles between their summer and winter abodes. However, as Desrochers and Hannon (1997) pointed out, most songbirds migrate at night and move through habitats in day when they may be vulnerable to predation in open habitats. Desrochers and Hannon (1997) cited several studies which found that woodland birds respond strongly to predation risk outside the cover of forests. At the scale it is discussed here, the main associated with connectivity is avoidance of demographic isolation. At broader scales, issues of genetic isolation may apply, but there are not likely relevant at the scale of forest management operations.

Recognizing the potential effects of fragmentation on wildlife, Noss and Harris (1986) and many others have advocated the use of corridors to provide connectivity. For forest birds, the potential role of riparian or upland buffers in providing connectivity has been cited by many (Whitaker and Montevecchi 1999; Pearson and Manuwal 2001; Imbeau and Desrochers 2002; Potvin and Bertrand 2004), even though there has not been an extensive amount of work on this in Canada's forests.

In Canada, a small number of studies have examined the topic of connectivity and forest birds. These studies have been of two types: studies examining the role of riparian buffers in providing connectivity, and studies examining the willingness of birds to cross gaps. Of course, these topics are related in a number of ways, not the least of which is that a bird that is unwilling to cross forest gaps may have a greater propensity to use buffers as travel corridors.

Machtans et al. (1996) found riparian buffer strips may act as movement corridors for dispersing juveniles in Alberta's boreal mixedwood zone. However, the results of their study were not unequivocal—only one of two study sites yielded this result and the two sites differed in their configurations, making interpretation difficult (Machtans et al. 1996). In a follow-up to the Machtans et al. (1996) study at the same sites, Robichaud et al. (2002) found that riparian buffer strips acted as movement corridors for adult and juvenile birds; however, the effect decreased with time since harvest of the adjoining forest. In the same area, Hannon and Schmiegelow (2002) followed up on an earlier experiment reported upon by Schmiegelow et al. (1997). They found that the presence of corridors facilitated travel of some resident species to connected forest patches, but that the effect was not consistent. They concluded that "corridors had limited utility for most species, at least over the short term." Both Hannon and Schmiegelow (2002) and Robichaud et al. (2002) opined that the role of corridors in facilitating travel will decrease as the abutting harvested forest grows. Therefore, from this limited amount of studies, it seems corridors do at least play a small role in facilitating travel by some songbirds, but the role may be relatively short-lived. The duration of the role likely depends on individual species and the species' propensity for crossing gaps.

St. Clair et al. (1998) compared the willingness of four resident species (black-capped chickadee, white-breasted nuthatch, hairy woodpecker, and downy woodpecker) to travel in three habitats (continuous forest, corridors < 10 m wide, and gaps in forest cover of 25–200 m) in response to broadcast chickadee mobbing calls. They found that chickadees were as likely to use corridors as to travel in continuous forest, but the other species were not. The authors suggest that corridor width may have limited the birds' willingness to use them. All the species avoided gaps, but chickadees and downy woodpeckers appeared to be braver than the other two species, crossing gaps more frequently.

In another study published in the same paper, St. Clair et al. (1998) examined the willingness of chickadees to cross gaps or take detours through forested areas which had various levels of inconvenience for travel. They found that the distance birds were willing to travel in the open increased as detours became less efficient, but that a threshold existed, as the birds were apparently not willing to travel across gaps greater than 50 m when they had a choice of detouring under forest cover.

Desrochers and Hannon (1997) conducted a similar gap-crossing assessment of five woodlands species (black-capped chickadee, red-breasted nuthatch, golden-crowned kinglet, yellow warbler, and red-eyed vireo). They found that the species differed greatly in their propensity to cross gaps in response to playback calls; however, all species were more reluctant to cross open areas than to travel through woodland. They conclude that woodland corridors do facilitate movements, although more so for some species than others. They use their results to speculate that maintaining connections among forest fragments may be important to facilitating songbird dispersal.

As part of Hannon and Schmiegelow's (2002) corridor study, they compared the abundance of several species of birds in isolated patches, in connected patches, and in reference forests. They found generally lower abundance in isolated patches and concluded from this that gaps in forest cover created by recent clearcutting appeared to reduce the probability of reaching isolated forest patches for some forest birds, especially residents.

It seems, therefore, that some evidence exists that woodland birds use corridors, although the results of empirical studies (Machtans et al. 1996; Schmiegelow et al. 1997; Robichaud et al. 2002; Hannon and Schmiegelow 2002) are equivocal. We note, however, that all these studies took place in one region in central Alberta. Comparable studies from other Canadian BCRs are lacking, and so broader conclusions must be tentative. Moreover, there is evidence that forest gaps caused by clearcutting inhibit some species of birds from crossing them, and possibly from using otherwise suitable isolated habitat.

Bunnell (1999b) pointed out that evidence of use of corridors in forested environments does not necessarily suffice to support arguments of their importance. With (1999) made a similar point and used the ability of northern spotted owls to traverse open areas during juvenile breeding dispersal to demonstrate that habitat specialists do not necessarily require corridors to locate suitable breeding habitat. With (1999) suggested that the jury is still out on the utility of corridors, and notes that the debate may not be resolved in general because it depends on the organism being considered. The results of the gap-crossing experiments discussed above support this point. With (1999) conducted an analysis of various theoretical landscape designs to examine the importance of connectivity for theoretical species of various gap-crossing abilities. Largely from this, she concluded that habitat corridors may not be strictly necessary to achieve connectivity. However, given the rudimentary state of our understanding of the requirements of individual forest bird species, this inference is premature for them, and also underscores the necessity of an organism-centered perspective when considering connectivity.

Opinion on the importance of corridors is mixed. Bunnell (1999b) reviewed publications providing empirical information on the use of corridors (for mammals and birds), and concluded "while evidence for movement within corridors is accumulating for agricultural and urban landscapes, extrapolating findings and conclusions to managed forests is questionable (Small and Hunter 1988; Lindenmayer 1994). We lack evidence of the efficacy of corridors in managed forests." While on the one hand there is relatively little evidence that lack of connectivity is a threat in managed forest landscapes (Bunnell 1999b) and empirical evidence of the utility of corridors by forest birds is equivocal, there is nonetheless some evidence that forest birds are inhibited from crossing gaps. Most authors advocated the maintenance of connectivity at least as a precautionary approach (Noss and Harris 1986; Hunter 1996; With 1999). However, Hannon and Schmiegelow (2002) suggested it may be better to relocate some buffer strips so that they can contribute to increasing the size of protected old forest, rather than reserving them in case they have a connectivity function.

A managed forest designed to approximate natural disturbances would have features that provide for connectivity. Tittler and Hannon (2000) noted that residual trees and clumps of trees may serve as stepping stones for dispersal of forest birds. Linear patches of unharvested forest such as those which occur along wetter areas following fires may also facilitate bird travel. In addition, the provision of riparian buffers and the seeming decrease in the resistance of birds to cross open areas as a harvested forest area matures, suggest that practices based on the approximation of natural disturbances will likely provide for connectivity for songbirds.

3.2.4 *Landscape-scale Response*

As described earlier (Sections 3.2.1–3.2.3), considerable attention has been focused on several aspects of bird response to issues of the spatial arrangement of stands resulting from forest management. The experimental work on fragmentation, connectivity, and nest predation described previously has been undertaken at local or stand scales, and then, logically, the implications of possible responses (or lack of response) have been discussed with reference to forest landscapes. At a broader scale, there has been some interest in the potential response of birds to reconfigured landscapes as a whole, rather than the pieces of landscapes. In general, these studies have undertaken bird surveys over broad areas and characterized, according to a series of spatial metrics, the landscapes surrounding the survey points. From this, the studies have examined whether there are relationships between spatial landscape metrics and variations in bird communities over the landscape. The most comprehensive of these was undertaken by Drapeau et al. (2000) and is discussed in considerable detail below.

Drapeau et al. (2000) characterized the landscape in the Abitibi region of northwestern Quebec as either natural (mainly affected by fire and insect outbreaks), preindustrial (where logging and agriculture have been occurring since the 1930s), and industrial (characterized by industrial timber activities in the last 20 years). They found a striking gradient of changes from a natural-disturbance-driven landbase in terms of forest composition across these landscapes in which the deciduous forest component increased in both the pre-industrial and industrial forests, and mixedwood forest decreased to almost the exact same extent (Table 3.9).

There were other significant differences too: the proportion of mature forest was nearly twice as high in the natural landscape than in the pre-industrial and industrial landscapes and there was an increase in patchiness of forest mosaics from the natural to the pre-industrial landscape.

Table 3.9 Percent of Area of Deciduous, Mixed Wood, and Coniferous Forest Types in Natural, Pre-Industrial, and Industrial Landscapes in the Area Examined by Drapeau et al. 2000 (Abitibi Region of Quebec)

	Percent of Area		
Forest Type	**Natural**	**Industrial**	**Pre-Industrial**
Deciduous	16.5	37.4	66.7
Mixedwood	65.2	39.9	16.5
Coniferous	18.3	22.7	16.8
Total	100	100	100

Not surprisingly, there were major differences in the bird communities among these landscapes. The natural forest was characterized by a more homogenous bird community strongly associated with the coniferous component, and generalist species were more abundant in the pre-industrial landscape than in either of the other two. The mean number of mature forest species and individuals diminished significantly from the natural to the pre-industrial forest, and there were fewer species and individuals associated with early-successional forests than in either of the other two. Statistical analysis revealed that conversion of the mature forest from mixedwood to deciduous across the landscapes (as reflected in the proportional composition of deciduous, mixedwood, and coniferous forest types) was the main factor responsible for differences in abundance patterns of mature forest bird across landscapes. The authors conclude that mature forest birds are truly influenced by landscape-scale change. Further analysis revealed that the contribution of landscape context variables in explaining variation in the bird communities was equivalent to that of local habitat variables, and so the bird community landscape mosaics "appear to be more than the sum of forest types and are in their own right an important component for songbirds. Hence, predictions of the regional consequences of forest management on wildlife based solely on local scale models are likely to be misleading." The authors suggested that changes in composition of nearby habitats following logging may be more critical for birds than changes in configuration of remnant mature forest patches. They concluded with the following dire statement: "For bird communities, this conversion of mature forests from mixedwood to deciduous cover may jeopardize their ecological integrity, notably through collapses of regional populations of bird species associated with mixed and coniferous mature forests. Hence, even though management practices may show some similarities with natural disturbances…under current practices, it appears unlikely that managed forests can adequately substitute for natural forests in the boreal mixedwood zone".

Although Hobson and Bayne (2000a) did not include landscape-level variables in their study, their analysis of bird richness and abundance in relation to stand-level variables led them to articulate similar concerns about "unmixing the mixedwoods" as those expressed by Drapeau et al. (2000). They found higher species richness and abundance in mixedwood stands compared to pure forest stands of four tree species. This led them to express concern regarding the lack of efforts to foster mixed stands rather than single-species stands, and the potential implications of this at the landscape level.

Hagan and Meehan (2002) examined landscape and stand-level variables and their relation to the presence/absence of songbirds in a managed forest landscape in north central Maine. For 17 of the 20 species they analyzed, variation in presence/absence was better explained by stand-level variables than by landscape variables; for only two species were landscape parameters the better predictor of presence/absence (for one species, neither stand nor landscape variables predicted presence/absence.) Landscape-level variables did emerge as significant for some species, when combined with stand-level variables, but on the whole, stand-level variables were the more important predictors.

The results of Hagan and Meehan (2002) seem at odds with those of Drapeau et al. (2000); however, as Hagan and Meehan point out, their study was examining a mosaic of "differently suitable" habitat, whereas Drapeau et al.'s took place in a landscape with more contrast. In other words, there was considerably less variation in the landscapes examined by Hagan and Meehan (2002) than those examined by Drapeau et al. (2000). In addition, Hagan and Mehan's study was examining presence/absence of individual species, whereas the Drapeau et al. study was examining species richness.

Drolet et al. (1999) analyzed the presence/absence of 14 forest bird species in relation to landscape variables in the southern boreal forest of Quebec. The occurrence of three species was significantly correlated to landscape structure, and four to combined measures of the landscape. Fewer landscape variables were included in the analysis of this study than in either of the two discussed above. Although the relationships were statistically significant, they had relatively low predictive power. Nonetheless, the authors argue that the landscape-level effects of logging are not trivial for songbirds because the effects are likely additive to other sources of decline.

Zimmerling (2004) reported on the interim results of a landscape-scale assessment in boreal Ontario; bird communities were compared in large landscapes (approx. 100 km^2) in which harvesting was the main disturbance to those in which fire was the main disturbance. In one ecoregion (of six examined) they found significant differences in species composition. This was attributed to the fact that harvested areas were regenerated to aspen there, whereas burned areas regenerated to jack pine. For other ecoregions, where there were not landscape-scale differences in the regenerated forests, there were few differences in the bird communities; bird species richness was the same in these landscapes, and less than 10% of the 159 bird species recorded were found to be influenced by the type of disturbance. The differences which did exist were attributed partly to the relative difference in abundance of snags as a result of the disturbances. While this assessment provides much encouragement that forest management attempts to emulate natural disturbances can be benign for forest birds, the results from the one ecoregion in which there were significant differences lends support to the concerns expressed by Drapeau et al. (2000) and Hobson and Bayne (2000a).

These landscape-level effects relate to landscape composition and habitat loss rather than fragmentation. As noted in Section 3.2.1, the current thinking is that habitat loss is by far a more important concern than is forest fragmentation in managed forests. These studies, particularly Drapeau et al. (2000), suggest that the response of birds to habitat modification at the landscape scale cannot simply be assumed to be the sum of stand-level responses. Niemi et al. (1998) cited several studies from northern Europe which led them to the same conclusion. For forest managers in some landscapes, the implications of this assessment may be very significant. It is likely not sufficient to implement stand-level practices such as providing residual trees in cutovers or leaving areas of burned trees unsalvaged in attempts to ameliorate or manage the effects of forest management on birds. The implications of altering the overall composition of the forest may be more than the additive cutblock effects. This may call for the use of cumulative effects assessment in predicting the responses of bird communities to forest management over large scales (such as the forest management unit) and in identifying objectives for bird communities. Similarly, the use of stand-based habitat supply models to predict the outcomes of management scenarios may need to be reexamined as they are based on stand-level relations; although they are clearly necessary tools, they are not by themselves sufficient to deal with estimation of broad area effects. In other words, it is likely that the effects of forest management on song birds over large areas cannot be estimated by summing the predicted stand-level effects.

The assessment of Zimmerling (2004) lends support to this notion as well. Its positive results support the notions of emulating natural disturbances, not just at the stand level but also at the landscape scale, and that the emulation should not focus just on disturbance patterns, but on successional pathways in regenerating the forest. Landscape management approaches to the conservation of biodiversity and forest habitat are further discussed in Section 4.3.

3.3 Temporal Aspects of Bird Responses

Most of the studies we have examined, by virtue of their short durations, have investigated short-term aspects of bird response to forest management. These are best exemplified by studies of bird response to clearcutting (e.g., Freedman et al. 1981; Lance and Phinney 2001) but also exist in studies of bird use of riparian buffers (e.g., Johnson and Brown 1990; Machtans et al. 1996), edge effects (e.g., Rudnicky and Hunter 1993), and other topics as well. Although short-term responses are interesting both for some operational and theoretical reasons, what is of most concern to forest managers are long-term responses. For example, while it may be interesting (and expected) that the bird community changes markedly after a site is clearcut, the more important potential response relates to long-term changes or trends which result from the nature of the regenerated forest over a broad area. If a site is managed so that it returns to a state similar to that in which it was prior to the harvest, the short-term response may be relatively unimportant; however, if for example, many similar sites are changed from one forest type to another, then the broader consequences become more important.

A simple context for considering this is shown in Figure 3.1. Short-term effects over a limited space are of relatively little interest. If, however, the practices occur widely and the response is long-lasting or leads to a long-term change in the forest (moving, in Figure 3.1, from the lower left hand portion of the graph to the upper right hand portion), the response of the bird community becomes of increasing interest and importance.

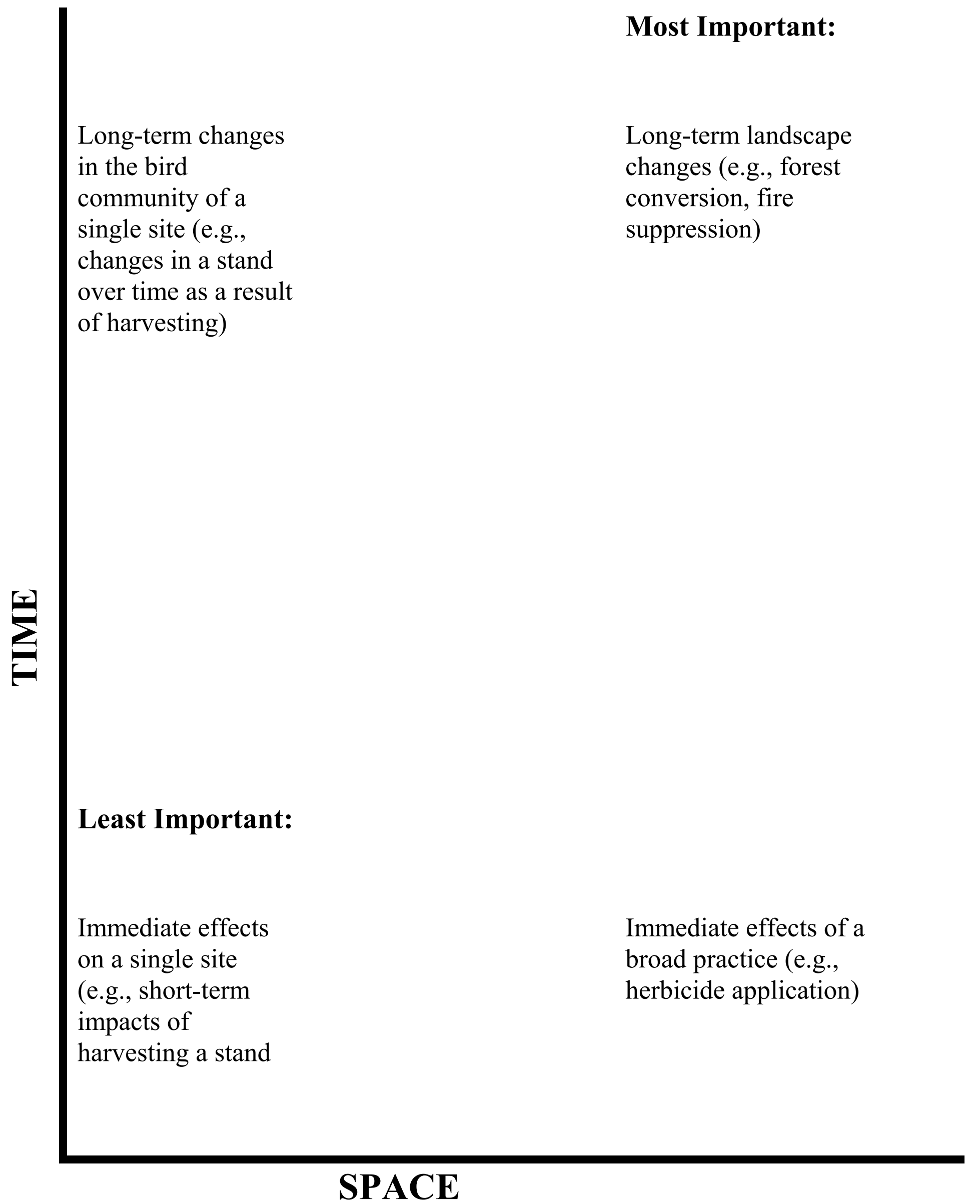

Figure 3.1 Depiction of Changes to Bird Response to Forest Management in Space and Time

Most studies have been in the lower left hand portion of the Figure 3.1, yet many extrapolate or present hypotheses of resulting changes in the upper right hand portion.

Of the issues we reviewed, the study of Drapeau et al. (2000), who examined long-term implications of landscape-level changes in forest composition, best exemplifies the upper-right hand portion of Figure 3.1. Concerns about truncation of the forest age-class distribution as expressed by Hagan and Grove (1999a), Cumming and Diamond (2002), and Schmiegelow and Mönkkönen (2002), and others would also fit. Addressing these potential effects will be a challenge for forest managers since they require a long-term review of broad management strategies, not just modifications to silvicultural or harvesting practices.

There is room for debate in assessing the gravity of these two potentially serious effects. At least one other study (Hagan and Meehan 2002) has suggested that the findings of Drapeau et al. (2000) may not apply at the species level (although Hobson and Bayne [2000a] concur with Drapeau et al.). Furthermore, the concerns expressed by Drapeau et al. and Hobson and Bayne are in reference to one particular type of forest (boreal mixedwoods). Although McGarigal and McComb (1995) found a relationship between bird response to landscape variables in the Pacific Northwest, similar studies in other Canadian BCRs are lacking. More research on this important topic is called for.

4.0 MANAGEMENT RECOMMENDATIONS

Many of the papers reviewed did not make specific management recommendations. However, specific concerns related to the potential effects of forest management activities on forest birds can often be addressed through the application of forest planning and operational approaches that could minimize effects based on these concerns. Furthermore, recommendations were not specifically made to address concerns on a BCR or regional basis, but were made with reference to specific forest practices, forest types, bird species, or scale-related issues.

There are a number of general principles or concepts that can be considered when developing management strategies to minimize the potential for adverse effects of forestry on birds or to benefit bird populations. These concepts are found frequently in the literature, and may not be specific to a particular region or bird species, but provide important concepts for consideration when developing management strategies related to forest birds.

In general, the numbered elements in Sections 4.1 – 4.3 begin with those which we believe are the most important. However, we caution not to attribute too much importance to their relative ranking. Issues likely vary according to landscape context, geographic region, management regime, bird species being considered, etc.

4.1 Summaries of General Principles

Managing forest landscapes to minimize the effects of forestry on birds is compatible with a sustainable approach to forest management.

The development of a strategy to conserve forest biodiversity will also conserve forest birds. This requires maintaining variability in the forest, at multiple scales, in terms of tree species composition, seral classes, landscape patterns and availability of structural habitat elements. Since birds have variable habitat requirements, they respond differently to different forest practices. A landscape design concept that embraces different harvest and silvicultural techniques and various intensities of management activities will promote the maintenance of variability in the forest, which in turn will provide different habitats for various species of birds. Of course, different harvesting and regeneration methods are used for different legitimate silvicultural purposes. It is obviously not practical to trade off silvicultural regimes to favour wildlife habitat considerations without due consideration of effects in obtaining silvicultural objectives. In general, managed forest landscapes sustain highly diverse and productive bird populations. However, individual species or communities with affinities for older forest and related structural habitat elements, post-fire habitats or non-disturbed forest areas, may require special management strategies.

Several authors concluded that many species would benefit from forest management, in particular species with affinities for early-successional forests (Welsh and Lougheed 1996; Hagan et al. 1997; Imbeau et al. 1999). However, operational practices cannot be relied upon to maintain all habitats; in particular large patches of old forest and early-successional, post-fire habitats are becoming scarce in Canada's forests (Schmiegelow and Mönkkönen 2002). Therefore, management scenarios should ensure these habitats are available in future forests to maintain species associated with them.

Management strategies cannot be developed to manage for all the species, in all places, at all times.

Welsh (1988) and Hejl et al. (1995) both noted that management decisions to benefit one species may not benefit others. The key to providing habitat for multiple species of birds is to use planning and operational practices that maintain a diverse forest mosaic and habitat availability over time. This can be achieved through the development of a coarse- and fine-filter approach to the conservation of biodiversity. A coarse-filter approach that provides habitat variability in terms of forest patterns, composition, and residual structures can ensure a range of habitats and seral classes are available (Hunter 1993). Fine-filter approaches can be based on the use of indicator or focal species (Hannon and McCallum 2004) which are associated with rare or special habitats, species at risk or species with high regional or BCR management priorities (Rich et al. 2004).

Don't do the same thing everywhere. Variability is the key; management strategies should endeavor to maintain the heterogeneity of forest landscapes.

As noted by Bunnell (1999b), "no single approach is sufficient" to maintain habitat for all species of birds. Forest managers should attempt to maintain variability at both the landscape and stand levels. For instance, use a variety of harvest systems, and apply a range of silvicultural practices at the stand level to promote heterogeneity. (Here again, the need to recognize the fit of management techniques to appropriate silvicultural and economic objectives is obvious).

Landscape-level issues are at least as important as stand-level.

Rotenbery et al. (1995), recommended that management decisions be made first at a landscape scale and secondly at a small scale. Likewise, Drapeau et al. (2000) concluded that greater attention should be paid to landscape-scale changes in forest cover (species composition, amount of mixedwood, older forest seral classes) and their impacts on birds in managed boreal forests. To address these issues, some provinces in Canada have now developed landscape-level forest management guidelines (British Columbia Ministry of Forests 1995; Ontario Ministry of Natural Resources 2001). Andison (2003) provides an excellent overview of concepts and challenges related to forest planning and landscape design concepts.

The amount of habitat available is more important that the spatial arrangement of it.

As previously noted, many researchers (see Section 3.2.1) have suggested that birds will fluctuate more or less in proportion to the amount of suitable habitat available. Fragmentation effects occur when population decreases are greater than changes in habitat availability (Fahrig 1999; Bunnell 1999b; Schmiegelow and Hannon 1999). The question of how much habitat is enough, and threshold responses to habitat amount (if and when they occur) continues to be an important issue and one that is not readily answered.

The availability of habitat structural elements (snags, coarse woody debris, complex understory vegetation, diseased or decaying trees, canopy cover) appears to be more important that stand age.

Bunnell (1999b) suggests that vertebrates perceive habitat in terms of the availability of habitat elements rather than habitat age. Although habitat structural elements are generally a function of stand age (large live trees, snags, fallen woody material), harvest and silvicultural practices can be adapted to maintain these elements in regenerating stands (see Sections 3.1 and 3.1.2.3).

Birds don't always respond to the same things in the same way in all places. There are regional and site differences and managers may need localized information or further research to develop effective strategies.

Welsh (1987) cautioned that patterns of succession and related habitat structure, and bird habitat preferences and requirements may change from "place to place." Just because a species is associated with a specific habitat type in one location, it is not necessarily the same elsewhere. This emphasizes the importance of site-specific knowledge when developing management strategies for bird conservation. Where possible, forest managers should obtain or collect localized information on bird-habitat associations prior to developing management strategies. This can best be accomplished through research and monitoring programs in partnership with industry, government, and non-government agencies.

There will always be trade-offs; what you do for one species may not be beneficial for other bird or wildlife species.

Rotenbury et al. (1995) cautioned that one silvicultural practice would favor some birds at the expense of others (also see Section 3.1). This principle relates to the previous one and further reinforces the notion that management practices should be varied across the landscape in order to maintain forest diversity. There are a number of ways to address this issue: use a coarse- and fine-filter approach to conserving biodiversity; promote habitat variability; balance trade-offs across the landscape; and employ forest planning models to predict habitat availability under different management scenarios into the future.

Special consideration should be given to the management of habitat for rare, threatened, or endangered species and species known to be declining across a broad region.

Priority should be given to species listed by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) or high-priority species listed in the North American Landbird Conservation Plan developed by Partners in Flight (Rich et al. 2004). The conservation of forest birds, especially habitats for rare, threatened or endangered species (RTEs), is an important element of a sustainable approach to forest management.

Management strategies designed to achieve sustainable forest management must involve trade-offs between the ecological, economic, and social values of the forest. The optimal solution for one element of sustainable forest management may not be optimal for the other elements.

The predicted outcome of management strategies and forest-level strategic plans must be evaluated in terms of the effects on the social, economic, and ecological components of the forest. Values associated with these three elements of sustainable forest management vary among different resource managers, government, and non-government organizations and individuals. Sustainability, in terms of the integration of all these elements, involves coming to terms with trade-offs between values arising from our choices of management actions, or finding win-win solutions if possible to address the needs and values of current and future generations (Adamowicz and Burton 2003).

There is a need to be cognizant of (potential) differences in short-term versus long-term effects of forest management strategies on birds.

As discussed in Section 3.3, most of the research reviewed examined short-term rather than long-term effects. Rotenberry (1995) notes that cumulative effects may be more pronounced on common bird species in the long term; however, short-term effects may be greatest on uncommon species whose declines go unnoticed due to lack of data or research on these species. Currently, short- and long-term effects of management practices on birds are likely best addressed through strategies designed to conserve forest biodiversity. However, forest managers, governments, and researchers should work together to develop adaptive management and monitoring frameworks to reduce the risk and uncertainty associated with forest management over the long term, and develop alternative planning and operational approaches to more effectively manage potential adverse effects of forest management on birds in the future.

4.2 Stand-Level Management Recommendations

4.2.1 *Recommendations Related to Clearcut Harvest Systems*

Clearcut harvest systems can be modified to provide retention of residual forest (single trees and patches) and snags and coarse woody debris as a means of minimizing effects on birds and other wildlife. A review of variable retention strategies (also described as wildlife tree retention, green tree retention, maintenance of residual) for ameliorating the effects of clearcuts on birds is described in Section 3.1.1.3. Based on our review of the literature, we offer the following suggestions.

Maintain residual forest as individual trees or in patches. The residuals should include both live trees (to provide future snags in regenerating forests) and dead (snags) or dying trees (to provide habitat elements similar to old stands or natural disturbances).

The snags and trees retained should be variable in diameter, representative of the species found in the harvested area prior to logging and have different stages of decay. Ensure that large trees, both dead and alive, are retained.

Maintain a mixture of large and small patches, both within and between harvest areas.

4. Consider whether trade-offs between levels of retention and harvest area are important in some circumstances (for example, consider whether it is more desirable to retain a high amount of post-harvest in-block residuals, or harvest a smaller area with fewer residuals).

The amount of residual forest (e.g., number of residual trees/ha) to maintain continues to be an important question. An overview is provided in the discussion and Table 3.2 in Section 3.1.1.3.

4.2.2 *Recommendations Related to Partial Harvest (Selection, Shelterwood)*

Few specific management recommendations have been made regarding the amount of forest to remove (or retain) to foster bird habitat in partial harvest systems. Partial harvest systems can help promote habitat variability and may provide an excellent alternative when developing strategies where harvest intensities and the level of residual forest could be varied to assist with trade-offs required to manage timber and non-timber values (Jobes et al. 2004).

4.2.3 *Recommendations Related to Salvage Logging*

The harvest of trees and snags remaining in a burn after fire affects the quality of habitat for many species of wildlife. Birds, including cavity nesting species and songbirds, are adapted to and most abundant in habitat conditions that result from natural disturbances.

In recognition of the importance of burned forest areas for birds, Hutto (1995) and others make the following recommendations for salvage logging.

Set aside areas within large burns that will remain unsalvaged.

In areas where burned habitat is rare, do not conduct salvage harvests.

Leave good-quality snags within salvage areas.

Delay salvaging where possible so that the important immediate post-burn ecological values can persist (Nappi et al. 2004).

4.2.4 *Recommendations Related to Thinning*

As indicated in Section 3.1.2.3, very little research has been conducted on the response of forest birds to thinning of forest stands in Canada. Scientists have most often predicted expected outcomes of thinning operations based on bird habitat requirements, and changes in species composition and the availability of structural habitat elements in the stand post thinning. Based on our review, we offer the following recommendations.

- Adapt thinning practices where possible so snags, dying trees and deciduous species are maintained.
- Promote habitat variability by providing thinned and unthinned stands on the forest landscape.

4.2.5 *Recommendations Related to Riparian Buffers*

The requirement to maintain riparian buffers during harvest activities is widespread in Canada, and is principally in place to protect water resources from adverse effects due to sedimentation and runoff. The utility of these areas for providing bird habitat is related to structure of the riparian forest, character of adjacent habitats, and buffer width, with species composition becoming more similar to unharvested areas as buffer width increases (Table 3.6). In many regions in Canada, management activities are not permitted in riparian zones, mainly due to concerns for water quality; however, several studies suggested that partial harvest activities might be beneficial to some species of birds (Johnson and Brown 1990) and in fact hasten development of old forest conditions (Potvin and Bertrand 2004).

Forest managers could consider the following criteria when designing riparian buffers to optimize habitat values for birds:

- the habitat requirements of forest birds, particularly any of local or regional concern;
- the potential of conducting partial harvesting within riparian reserves;
- existing requirements for buffer width related to water quality protection;
- the existence of other opportunities for providing interior habitat;
- connectivity of forest habitats at a landscape scale;
- opportunities to maintain riparian habitats as part of network of representative ecosystems; and
- instances where riparian buffers could be large enough (i.e., considered as leave blocks) to provide habitat for interior forest-associted species.

A caveat to the desirability of managing riparian buffers for birds comes from some authors (Schmiegelow and Hannon 1999; Potvin and Bertrand 2004) who have suggested or implied that it may be worthwhile to forgo riparian buffers in some instances and use the “banked” unharvested land to contribute to the development of large reserves. However, as noted earlier, there are regulatory requirements for the use of riparian buffers for the protection of water quality in most circumstances in Canadian jurisdictions and that these requirements would obviously need to be respected when strategies accommodating songbird habitat are being considered.

4.3 Landscape-Level Management Recommendations

Landscape-level issues can be addressed primarily through forest planning approaches. The development of a landscape design concept that incorporates stand-level operational practices (as outlined above) with strategies designed to maintain a diverse forest mosaic similar to that found in natural forest landscapes is likely the best way to minimize the potential effects of forestry on forest birds. This includes the maintenance of species composition, age class, and the forest patterns and structure generally associated with forests derived from natural processes. Planning approaches developed to best approximate natural forest conditions for birds will also benefit other wildlife species.

Maintain areas of old forest or late-successional habitat across managed landscapes.

Forest managers should include the maintenance of old forest habitats at a landscape scale as a management objective since all species do not necessarily benefit from practices designed to retain stand-level habitat structural elements (Evans and Conner 1979; Schieck and Hobson 2000; Schieck et al. 2000; and many others). The optimal or required size of these areas remains a question; some studies indicate “extensive tracts” are needed but do not quantify what that means on an areal basis (Schieck and Hobson 2000; Schmiegelow and Mönkkönen 2002). Other studies have suggested that rotation periods be lengthened to provide more old forest habitat and enable successional processes to proceed especially in boreal mixedwood forests (Kirk et al. 1996; Drapeau et al. 2002).

Explore alternative management strategies that maintain forest species composition similar to that of the natural forest. Specific concerns relate to the maintenance of mixedwood forest ecosystems or uneven-aged forests.

Changes in the composition and amount of mixedwood forest habitat in the boreal forest has been raised as a critical issue by several studies (Drapeau et al. 2000; Hobson and Bayne 2000b). Of particular concern is the “unmixing” of the forest due to the importance of this forest type for many species of birds. This concern relates primarily to the decreased availability of the conifer component in mixedwoods due to selective logging, the conversion of mixedwood stands to hardwoods following harvest, and a decrease in the availability of older mixedwood and conifer stand. To mitigate these effects, Drapeau et al. (2000) recommended maintenance of large tracts of natural mixedwood stands. Additional strategies to maintain the coniferous component in mixedwoods could be employed, including softwood understory protection strategies and underplanting of softwood in aspen stands and mixedwood stands.

Where possible, maintain habitats derived from fire events or insect /disease infestations.

As discussed in Section 3.1.3.1, salvage logging can have negative effects on habitat specialists associated with these naturally disturbed sites. The maintenance of these areas, wherever possible, should be promoted since the habitat resulting from these events cannot be achieved through harvest practices.

Develop management scenarios that promote habitat variability at a landscape scale.

As indicated previously in this report, the maintenance of habitat diversity is critical in order to provide suitable habitat for forest birds. Forest management plans with management scenarios that integrate stand- and landscape-level strategies for the maintenance of biodiversity should be developed to ensure continued variability in forest composition, patterns, and age class structures.

Explore opportunities to manage the forest age class structure and species composition so they more closely resemble that of a natural forest.

Management practices that consider natural processes attempt to maintain forest species composition and age class structure that are more similar to a natural forest where feasible. The feasibility of incorporating these strategies into forest management planning and regulatory frameworks is reliant on many factors and must be balanced in order to achieve sustainability objectives.

Maintain benchmark, non-harvest areas or superior quality habitats (special sites).

In addition to the maintenance of older forest habitats, many studies suggest that non-harvested or protected areas and special habitat sites be maintained within managed forest landscapes. Thompson (2004) concludes that superior quality habitats are disproportionately more important to wildlife than are other habitats, and species that occupy preferred habitats are more fit than those in less optimal habitats which may act as sinks.

5.0 RESEARCH NEEDS AND CONTRIBUTIONS

5.1 Research Needs

Many research-oriented publications conclude with a call for more research to address the issues they have identified or were unable to resolve. This section attempts to synthesize such information with research needs that have become apparent from this literature review.

5.1.1 *Comparisons of Responses to Forest Management with Responses to Natural Disturbances*

As noted in Section 3.1.4.3, given the momentum in Canada to adopt forest management paradigms based on emulating natural disturbances, key research issues are those which investigate differences between forest bird responses to natural disturbances and landscapes which result from attempts to emulate such landscapes.

5.1.2 *Productivity-Based Assessments*

Many of the studies we reviewed based their assessments on bird surveys and counts of birds in habitats that were variously affected by forest management. Several authors, most notably Van Horne (1983) and Thompson (2004), have warned that density can be a misleading indicator of habitat quality and of the productivity of the animals using the habitat. The classic example of this, for forest birds, is that male ovenbirds in small forest patches have been found to be less likely to be paired than those in large forest tracts (Hagan et al. 1996). Studies based solely on surveys of singing birds would not detect this important finding. Although many authors of assessments based on abundance warn of the shortcomings of basing conclusions on studies of the type they have written, abundance-based assessments remain more common than productivity-based ones. This is, of course, because it is much easier to gather abundance data than productivity data. Yet, some studies based on productivity have been undertaken (e.g., Burke and Nol 2000; Bourque and Villard 2001) and are able to state their findings much more unequivocally than those based on indicators of density alone. Additional productivity-based assessments therefore would be more useful in answering questions regarding bird responses to forest management.

5.1.3 *Landscape-Scale Assessments*

Studies addressing the broad-scale response of birds to forest management are at least of comparable value to those which focus on stand-level response. Recent studies of this sort (Drapeau et al. 2000; Hagan and Meehan 2002; Zimmerling 2004) have provided insight into the effects of landscape-scale manipulation which is the sum of forest management activities. These studies are valuable in answering key questions in forest bird ecology such as the following.

1. What is the response of birds to broad scale attempts to emulate natural disturbances (Zimmerling 2004)?

What is the response of birds to landscape-scale changes in forest composition (Drapeau et al. 2000)?

To our knowledge, only a few studies of this sort have been completed; while they are difficult and likely expensive to undertake, they are the most valuable in terms of identifying substantial issues and answers regarding the interaction of forest birds and forest management.

5.1.4 *Long-Term Studies*

Most of the studies we reviewed were less than three years in duration. Studies of this sort are confounded by external influences on bird populations, temporal complications (such as the concussion response of birds to forest harvesting identified by Hagan et al. [1996]), and random events. Short-term studies are much more likely to make errors of both Type I (concluding that an effect existed when in fact it didn't) and Type II (concluding that an effect did not exist, when in fact it did). Short-term studies are not fully able to detect subtle yet important responses of birds to habitat changes, nor are they able to fully assess the effects and effectiveness of alternative forest management approaches to mitigate potential effects. They also cannot detect the amelioration or exacerbation of effects over time as the forest changes. As with broad-scale studies, long-term ones are expensive, and may not lend themselves to the academic environment in which much research is conducted or a government environment which suffers from annual uncertainties in funding. Carefully designed research can sometimes use chronosequencing as an approximation for the passage of time in studying responses and may for some types of research provide opportunities to deal with the difficulty in conducting long-term research. A more practical approach to undertaking long-term studies may lie in adaptive management partnerships between researchers, government, and forest management companies.

5.1.5 *Old Forests*

Many publications we reviewed expressed concerns regarding the effects on songbirds of a decline in availability of old forests as a result of forest management activities (Thompson et al. 1993; Imbeau et al. 1999; Hagan and Grove 1999a; Thompson et al. 1999; Hobson and Bayne 2000b; Kirk and Hobson 2001; Cumming and Diamond 2002; Drapeau et al. 2002; Schmiegelow and Mönkkönen 2002). This concern was expressed most strongly for the boreal forest. Although attempts to emulate natural disturbance regimes are taking age-class distribution into account (e.g., Ontario Ministry of Natural Resources [2001]), the approach is not yet universal and questions remain about how much old forest is "sufficient" for a variety of reasons. There are suggestions regarding the simulation of old forest conditions using silvicultural techniques such as thinning, but these seem more appropriate for temperate forests and the forests of the Pacific Northwest. We believe there is a need for research on the effects of loss of old forest habitats on forest birds at the landscape scale, the extent of old forest required to ensure landscape-scale persistence of healthy forest bird populations, and silvicultural approaches to simulating old growth conditions in boreal forests.

5.1.6 *Neotropical Migrants*

Several studies have found or suggested that neotropical migrants may be more susceptible to habitat changes caused by forest management than are other migratory guilds (Hutto 1995; Easton and Martin 1998; Bourque and Villard 2001; Kirk and Hobson 2001), although this view is not universally held (Hagan and Grove 1999a). There is evidence that many neotropical migrants are declining (Terborgh 1989; Hagan and Johnston 1992; Rich et al. 2004). Blancher (2003) noted that almost a third of the neotropical migrants which breed in the boreal forest for which Breeding Bird Survey[1] data are available, are exhibiting significant declines in at least a portion of their Canadian

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[1] The Breeding Bird Survey is a continent-wide volunteer-based bird survey effort which facilitates tracking of bird populations at a variety of scales. It is coordinated by the Patuxent Wildlife Research Centre in the United States and the National Wildlife Research Centre in Canada (http://www.pwrc.usgs.gov/bbs/index.html.)

range. Although much attention has focused on the loss of tropical forests as the primary reason for these declines, Sherry and Holmes (1993) argued that migratory populations are limited simultaneously in summer and winter by a dynamic equilibrium between fecundity (which occurs in the summer) and mortality (which occurs mostly in the winter). Given the declines in populations of neotropical migrants and their reliance upon Canada's forests, particularly the boreal forest (Blancher 2003), we believe it is important to direct research toward addressing implications that forest management may be playing a role in their decline, and if it is, identifying the mechanisms involved.

5.1.7 *Rare Species*

Many of the reports we reviewed did not include rare species in their analyses because insufficient observations of these species were available to use as a basis for statistical analyses. For example, Jobes et al. (2004) excluded 34 of the 52 species they identified in their assessment of bird response to selection logging; Schmiegelow and Hannon (1999) excluded 21 of the 58 species they identified from their analyses of fragmentation effects; Hobson and Bayne (2000b) excluded 30 of the 87 species they identified from their consideration of the effects of "unmixing the mixedwoods"; Webb et al. (1977) excluded 32 of the 58 species for which they collected data on the assessment of the effects of harvesting on forest birds; and Thompson et al. (1999) excluded 10 of the 42 species for which they collected information from their analyses of the effects of forest management on birds in old balsam fir forests. In some cases, the rare species were birds clearly associated with non-forest habitat; however, many were true forest species. Several authors have noted that rare species may be sensitive to changes in habitat, which may be one of the reasons for their rarity (Noon et al. 1979; Rotenberry et al. 1995; Hagan and Meehan 2002). Exclusion of these species from conclusions regarding the response of birds to forest management may be a significant oversight. There may be several ways to investigate the response of rare species to forest management.

1. Undertake specific field assessments based on rare species. These are likely to be difficult and expensive because of the species' rarity, however.
2. Undertake meta-analyses using data from studies which have been unable to analyze rare species themselves because of their paucity of data.
3. Simulate the response of rare species based on their habitat affiliations or guild associations. Work of this sort is described, but not reported upon in detail by Hannon (2000).

5.1.8 *Responses at the Northern Extent of Forest Management*

Forest management in Canada is moving northward in response to increasing demand for forest products and improvements in technology which make harvesting less productive forests economically feasible. We found many studies from the boreal BCRs # 6 and #8. Those from BCR #6 were dominated by assessments from central Alberta and central Saskatchewan, and those from BCR #8 had strong representation from Quebec's southern boreal forest. We found few publications from BCR #4, the most northerly BCR in which forest management is presently occurring. Other than several studies from the Abitibi region in Quebec we found relatively little research from areas close to the northern extent of forestry in Canada. There is a need for studies of bird responses to forest management from these northern areas to address knowledge gaps and provide greater understanding of these less productive and perhaps more sensitive ecosystems.

5.1.9 *Residuals*

Section 3.1.1.3 discusses the role of residual trees and patches in ameliorating some of the effects of harvesting on forest birds. Through the use of this approach, several questions have arisen for which research seems appropriate. These issues include identification of key (threshold) amounts of residuals required to provide habitat for forest birds and whether residual trees and patches are truly productive habitats.

5.1.10 *Ecology of the Importance of Burnt Stands*

It is clear that burnt stands are vital for some bird species (See Section 3.1.3.1), and many authors have made recommendations regarding their retention. However, key questions regarding how much should be left and in what spatial arrangements should be addressed.

5.1.11 *Thresholds*

Manipulative studies have generally been directed at answering questions regarding whether certain management practices have positive or deleterious effects on birds. However, there is very little literature on thresholds or acceptable variation in targets. Although we have a strong sense that, for example, leaving residuals in clearcut harvest areas is beneficial for forest birds, we do not know how much is enough. How much residual is required for a given level of forest bird activity? How much variation is there by BCR or forest region? Similarly, we do not know how much coarse woody debris should be left on a site to elicit desired responses from the bird community or selected species, although there is a general sense that more is better. We also do not know, for example, what thinning objectives (i.e., remaining stand densities) are sufficient to provide old forest structures for various songbirds. Identification of stand-level thresholds are likely more amenable to research, but landscape-level thresholds, such as the amount of "core" forest required to support viable populations of sensitive species, are extremely important in designing overall management strategies.

5.1.12 *Habitat Affiliations*

Most species-based reviews end with calls for basic research on habitat affiliations, which in some ways seem inevitable. As several of the papers reviewed here have pointed out (most notably Welsh [1988]), incomplete knowledge is not an excuse for inaction; approaches such as mimicking natural disturbances offer sound direction even in the face of incomplete knowledge. We believe that the most obvious habitat affiliations of most forest birds are understood. For example, black-backed woodpeckers are known to be burnt forest specialists. The next level of understanding, and that which is missing for many species, concerns the secondary habitat choices. Again, using black-backed woodpeckers as an example, the appropriate question would be to what extent can they (do they) rely upon or use other forest types in the absence of burnt forests. Thompson (2004) emphasized the importance of superior quality habitats for wildlife species. The identification of superior or preferred habitats relative to acceptable or other used habitats is an important topic of research, particularly for species such as black-backed woodpeckers and interior-associated species.

5.2 Industry Contributions to Research

There are several roles the forest industry can play in research efforts of the kinds identified in this review. Most obvious is the provision of direct financial support to researchers, but several other roles are also possible (e.g., gathering and provision of data, assistance with field logistics, etc.). We attempted to examine the extent to which the forest industry has supported research on birds by reviewing the "Acknowledgments" sections included in the literature we assembled for this review.

In conducting this review, we drew upon, to varying extents, over 300 journal articles, research reports, papers in conference proceedings, theses, books, etc. Of these documents, many were not used in this assessment of industry contributions. The reasons for not using documents included the following: the research was not done in Canada; books are generally based on syntheses of information and so their acknowledgments generally do not reference all the sources of information used; and many documents (> 30) did not include acknowledgments.

After identifying those documents not suitable for use, 151 were available for the assessment. We read the "Acknowledgments" sections of these documents and identified the role that forest industry played in providing assistance. For this analysis, we identified the following types of industry contribution:

- indirect financial support through a collaborative agency (e.g., the Sustainable Forest Management Network, NSERC Research Partnerships Program);
- direct financial support;
- conducting harvesting or other forest management operations in support of an experimental design;
- providing access to privately owned forest lands; and
- providing other types of assistance (e.g., provision of data, assistance with logistics, loan of field supplies, use of facilities, provision of advice, etc.).

Of the 151 documents reviewed, indirect financial support was acknowledged by 37, direct financial support by 28, conducting operations in support of research by 12, providing access to private land by 6, and provision of other types of assistance by 27. Fifty-seven documents did not make reference to any type of industry contribution in their acknowledgments. There were 110 references to industry assistance in 90 documents (some recognized more than one manner of assistance from the forest industry). In sum, 60% (90/151 of the documents used in this analysis recognized industry assistance.

Upon closer review of the 151 documents used in this assessment, a case can be made for excluding quite a few more. Some of the documents are based on research from southern Ontario, or other places in Canada where commercial forest management is not prevalent; other documents are theoretical in nature, or are syntheses or meta-analyses based on previously-published research; others were based in protected areas; and others are best characterized as bird-survey or habitat characterization work. Although it is possible that industry may have supported efforts such as these, because they are not directly related to experimental work in "the working forest", they are not a obvious opportunities for industry participation.

Somewhat subjectively, we identified 33 studies that could be eliminated from consideration for reasons such as those described above. When those studies are not included in the analysis, 76% (90/118) of the documents used in the more restricted analysis recognized industry assistance.

The support of the forest industry seems very important for research related to bird-forestry relations. From this simple analysis it seems that at least 60% of research-related documents published based on Canadian efforts have benefited from industry assistance. Financial support was provided to 65 of the151 (43%) studies included in the broader assessment review and 65 of the 118 (55%) studies used in the more restricted assessment. (Some of the 37 studies that received indirect financial support and 28 studies that received direct financial support acknowledged both indirect and direct funding support).

Of course this analysis is very subjective and open to criticism. A point can be made that it would be very difficult to carry out many of the experimental studies used in writing this report without some sort of assistance from industry, and so it is not surprising that that a high proportion of studies benefited from industry assistance. Several other caveats should also be recognized.

- There is no standard format for "Acknowledgments" sections, and so some types of contributions may have gone unmentioned in the documents we reviewed.
- Virtually all of the "Acknowledgments" sections included thanks to individuals for various types of support; it may be that some of the acknowledged individuals worked for a forest products company industry and were acting on its behalf, and this would have escaped our analysis.

For some research efforts, assistance may not have been sought from the forest industry and so the lack of recognition in the "Acknowledgments" section should not be taken to infer a negative response to a request for assistance.

One final observation relates to the provision of financial support. This analysis showed that research based in Alberta benefited most from industry financial support. Although we did not originally intend to compare support for research across provinces, the level of support achieved for work in Alberta is notable. Of the 37 studies that received indirect financial contributions, 15 were for research conducted in Alberta. Of the 28 studies which benefited from direct financial support from forest products companies, 18 were for research conducted in Alberta.

6.0 CONCLUSIONS

Forest management influences birds in many ways. At the stand level, the short-term effects on pre-harvest bird communities increase with the amount of harvest, so that, in general, selection harvesting has least impact and clearcutting has most. Of course there are many caveats to this broad assertion. For example, retention of residual structure may play an important role in ameliorating post-harvest effects on some species; the removal of overstory vegetation provides important habitat for bird species associated with early successional habitats; and many effects are likely analogous to those which occur following natural disturbances. Also, it is important to consider that differing silvicultural objectives are best met with specific harvest systems, and so substitution of a severe (from a bird-effects perspective) harvest system with a more benign one is not always possible.

At the landscape level, the paradigm of emulating natural disturbances, to the extent possible, offers some reassurance that effects on birds caused by forest management will be similar to those which occur naturally, although there are many differences between a naturally disturbed forest area and one which has been subjected to harvesting. Given that stand-scale management of forests is embedded within broader landscape-level management which dictates or includes harvest area and volume targets, silvicultural strategies, and regeneration objectives, landscape-scale decisions regarding forest management are likely to have broader impacts, even though stand-scale operations can be very important at a local level.

In Section 4.1 we identified general principles of forest management influences on birds. They provide the key lessons learned from this review, and taken together could provide the basis of a strategy for incorporating considerations regarding effects on birds into forest management.

Not surprisingly, this review identified a number of important research needs (see Section 5.1). Strong cases can be made for pursuing each of the research topics there, and we believe all are important. It is difficult and subjective to assert why some research needs are more important than others. Moreover, several of the research needs overlap considerably. Nonetheless, based on the advantages of resolving the issues associated with the needs, we believe these are the topics most in need of exploration:

- comparisons of response to forest management with natural disturbances;
- productivity-based assessments; and
- landscape-scale assessments.

There are obviously many important aspects of effects of forest management on birds that are not well known or quantified. Nonetheless, we believe that a lack of detailed knowledge is not a basis for inaction. The philosophy of attempting to emulate natural disturbances, even with its considerable uncertainties, provides a coarse filter upon which species- and habitat-specific fine filters can be added based upon the availability of more detailed knowledge of the requirements of individual species.

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APPENDIX A

SCIENTIFIC NAMES OF ANIMALS MENTIONED IN THIS REPORT

Common Name	Scientific Name
Birds:	
Acadian flycatcher	Empidonax virescens
alder flycatcher	Empidonax alnorum
American goldfinch	Carduelis tristis
American kestrel	Falco sparverius
American redstart	Setophaga ruticilla
American robin	Turdus migratorius
barred owl	Strix varia
bay-breasted warbler	Dendroica castanea
blackpoll warbler	Dendroica striata
black-and-white warbler	Mniotilta varia
blackburnian warbler	Dendroica fusca
black-backed woodpecker	Picoides arcticus
black-billed cuckoo	Coccyzus erythropthalmus
black-capped chickadee	Parus atricapillus
black-throated blue warbler	Dendroica caerulescens
black-throated green warbler	Dendroica virens
boreal chickadee	Parus hudsonicus
boreal owl	Aegolius funereus
brown creeper	Certhia americana
brown-headed cowbird	Molothrus ater
calliope hummingbird	Stellula calliope
Cape May warbler	Dendroica tigrina
Cassin’s finch	Carpodacus cassinii
cedar waxwing	Bombycilla cedrorum
chipping sparrow	Spizella passerina
chestnut-sided warbler	Dendroica pensylvanica
Clark’s nutcracker	Nucifraga columbiana
common nighthawk	Chordeiles minor
common raven	Corvus coras
common snipe	Gallinago gallinago
common yellowthroat	Geothlypis trichas
dark-eyed junco	Junco hyemalis
downy woodpecker	Picoides pubescens
dusky flycatcher	Empidonax oberholseri
eastern bluebird	Sialia sialis
eastern wood pewee	Contopus virens
evening grosbeak	Coccothraustes vespertinus
fox sparrow	Passerella iliaca

Common Name	Scientific Name
golden-crowned kinglet	Regulus satrapa
gray-cheeked thrush	Catharus minimus
gray jay	Perisoreus canadensis
great crested flycatcher	Myiarchus crinitus
great gray owl	Strix nebulosa
hairy woodpecker	Picoides villosus
Hamond’s flycatcher	Empidonax hammondii
hermit thrush	Catharus guttatus
hooded warbler	Wilsonia citrina
house wren	Troglodytes aedon
Hutton’s vireo	Vireo huttoni
Kirtland’s warbler	Dendroica kirtlandii
least flycatcher	Empidonax minimus
Le Conte’s sparrow	Ammodramus leconteii
Lincoln’s sparrow	Melospiza lincolnii
long-eared owl	Asio otus
magnolia warbler	Dendroica magnolia
mountain bluebird	Sialia currucoides
mourning warbler	Oporornis philadelphia
Nashville warbler	Vermivora furicapilla
northern flicker	Colaptes auratus
northern goshawk	Accipiter gentilis
northern hawk owl	Surnia ulula
olive-sided flycatcher	Contopus borealis
orange-crowned warbler	Vermivora celata
osprey	Pandion haliaetus
ovenbird	Seiurus aurocapillus
pacific-slope flycatcher	Empidonax difficillis
pileated woodpecker	Dryocopus pileatus
purple finch	Carpodacus purpureus
red-breasted nuthatch	Sitta canadensis
red crossbill	Loxia curvirostra
red-eyed vireo	Vireo olivaceus
red-shouldered hawk	Buteo lineatus
rose-breasted grosbeak	Pheucticus ludovicianus
ruby-throated hummingbird	Archilochus colubris
rufous hummingbird	Selasphorus rufus
sharp-shinned hawk	Accipter striatus
solitary vireo	Vireo solitarius
song sparrow	Melospiza melodia
spotted owl	Strix occidentalis
spruce grouse	Dendragapus canadensis
Steller’s jay	Cyanocitta stelleri
Swainson’s thrush	Catharus ustulatus
Tennessee warbler	Vermivora peregrina
three-toed woodpecker	Picoides tridactylus

Common Name	Scientific Name
tree swallow	Tachycineta bicolor
varied thrush	Ixoreus naevius
veery	Catharus fuscenscens
warbling vireo	Vireo gilvus
western wood pewee	Contopus sordidulus
white-breasted nuthatch	Sitta carolinensis
white-throated sparrow	Zonotrichia albicollis
Wilson's warbler	Wilsonia pusilla
winter wren	Troglodtytes troglodytes
wood thrush	Hylocichla mustelina
yellow-rumped warbler	Dendroica coronata
yellow warbler	Dendroica petechia
Mammals:	
eastern chipmunk	Tamia striatus
raccoon	Procyon lotor
red squirrel	Tamiasciurus hudonicus
snowshoe hare	Lepus americanus
weasel	Mustela sp.
Woodchuck	Marmota monax
Trees:	
balsam fir	Abies balsamea
black spruce	Picea mariana
Douglas fir	Pseudotsuga menziesii
eastern white pine	Pinus strobus
jack pine	Pinus banksiana
red oak	Quercus rubra
trembling aspen	Populus tremuloides
western hemlock	Tseuga heterophylla
white spruce	Picea glauca
white birch	Betula papyrifera