



Identifying rare species of songbirds in managed forests: application of an ecoregional template to a boreal mixedwood system

S.J. Hannon^{a,*}, S.E. Cotterill^b, F.K.A. Schmiegelow^c

^a*Department of Biological Sciences, University of Alberta, Edmonton, Alta., Canada T6G 2E9*

^b*Department of Sustainable Resource Development, Edmonton, Alta., Canada T5K 2M4*

^c*Department of Renewable Resources, University of Alberta, Edmonton, Alta., Canada T6G 2E9*

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Abstract

Foresters are under increasing national and global pressure to demonstrate that forestry activities are ecologically sustainable. One aspect of this is maintenance of current biodiversity on forest management areas. This is problematic where rare species are concerned, due to a paucity of information on which to base management decisions, and potential difficulties in monitoring such species. Generally, species with narrow geographic distribution and high habitat specificity are rare and are most at risk due to habitat change. We present a method of identifying rare species found in commercial habitat types that may be at risk due to forestry activities. We also introduce the concept of temporal rarity into a systematic classification system. We then apply this system to data on songbirds from the boreal mixedwood ecoregion in Alberta, Canada. We identified an initial list of 33 species that were rare based on a rank abundance plot. We then removed species from the list whose geographic ranges within the ecoregion were peripheral and that were more abundant in non-commercial habitat types. We added species that were abundant in our year of sampling but were rare in most other years and flagged species that were irruptive or hard to detect. Finally, we evaluated the conservation priority of the remaining 18 species using three criteria: (1) those that were specialists on habitats that will be reduced or altered by forestry, (2) those already listed as sensitive, and (3) those with restricted continental ranges that overlapped substantially with the focal ecoregion.

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1. Introduction

Forestry is a rapidly expanding global industry and most forest ecosystems have been altered by forestry activities (Bryant et al., 1997). While many studies

have raised concerns about the ecological sustainability of traditional forestry operations (e.g. Niemi et al., 1998), global markets for forest products are increasingly being influenced by consumer demand for 'green' wood products (Ozanne and Vlosky, 1997). Hence, many forest companies have embraced the concept of ecologically based sustainable forestry through ecosystem management, which emphasises the maintenance of ecological processes and biota in combination with fibre removal (Maser, 1990;

* Corresponding author. Tel.: +1-780-492-7544;

fax: +1-780-492-9234.

E-mail address: sue.hannon@ualberta.ca (S.J. Hannon).

Grumbine, 1994). One approach to ecosystem management is to attempt, using forest practices, to emulate the patterns and structures of natural disturbances, such as fire (i.e. a coarse-filter approach, sensu Hunter, 1990). This assumes that the associated habitats and their biota will also be maintained. This approach, however, may be too coarse to conserve species with very specific habitat requirements, such as many rare species.

Rarity can take many forms (Harper, 1981; Rabinowitz, 1981). For example, species may be rare in space because they have highly specific requirements for habitats, inhabit areas with low carrying capacity, are held at low numbers by predators or pathogens or have poor dispersal abilities. Alternatively, they may be temporally rare due to periodic reductions in critical resources or catastrophic stochastic events. The plethora of causes and patterns of rarity makes it difficult for managers to determine which rare species they should be concerned about. In addition, often little is known about the habitat requirements of rare species. Most ecological studies emphasise common species (Kunin and Gaston, 1993) and some rare species are highly variable temporally, making them difficult to sample and to model habitat associations (Helle and Mönkkönen, 1998; Carlson and Schmiegelow, 2002; Queheillalt et al., 2002).

Rabinowitz (1981) created a useful framework to classify rare species based on their geographic range, habitat specificity and local population size. Species with high habitat specificity, narrow geographic range and sparse local populations may be very susceptible to anthropogenic change and hence are of high management concern (Arita et al., 1990). Additionally, species that exhibit high temporal variability and/or that track changes in food supply over spatial scales greater than those relevant to forest managers, may also be susceptible to habitat changes but are difficult to monitor. In this paper, we incorporate the element of temporal rarity into Rabinowitz's framework to produce a template for identifying rare passerine bird species in forests with commercial value. Our focus is to identify rare species susceptible to changes in their habitat caused by forestry and for which forest companies have a high responsibility and ability to conserve through habitat management. We explore application of this template in a case study of boreal mixedwood forest in northern Alberta.

2. Identifying rare passerine species in commercial forests

Our approach was to develop a decision tree (Fig. 1) that filtered data on avian species abundance, distribution, habitat specificity, temporal variability and detectability. This allowed us to systematically identify rare species in commercial forest types and to determine those most suitable as management targets. We then applied this template to bird communities in the boreal mixedwood ecoregion in Alberta.

2.1. Step 1. Determine which species are rare within a forest management area

Defining species rarity is often done arbitrarily (e.g. by expert opinion (Rabinowitz et al., 1986) or by deciding that half (e.g. Arita et al., 1990) or a quarter (e.g. Gaston, 1997) of the species list is rare). A more consistent and quantitative method for assessing rarity would be helpful to practitioners. Most explorative studies in community ecology begin with construction of a rank abundance plot (Whittaker, 1965). For many communities in temperate and boreal regions these plots have a lognormal distribution (Preston, 1948)

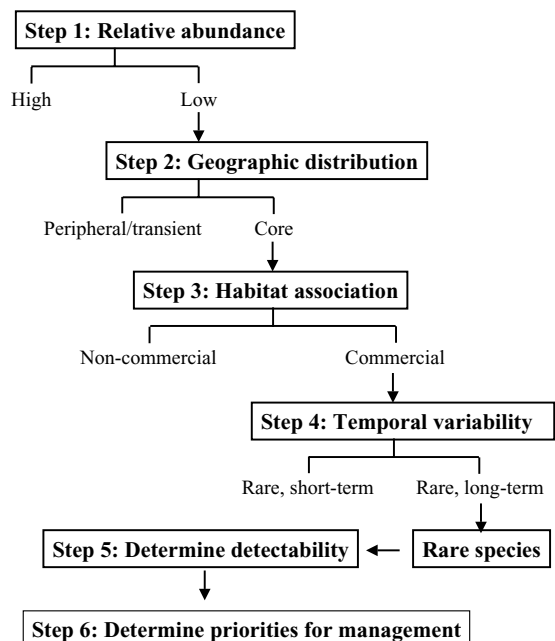


Fig. 1. A flowchart to identify rare species of management concern at the scale of forestry operations.

(i.e. a few species are dominant numerically, many species have low abundances). Examination of such plots should indicate an appropriate cut-off point for rarity. Relative abundances are often negatively correlated with body mass (and territory size) of the organisms (Arita et al., 1990; Dobson et al., 1995) and hence relative abundances should be corrected in some way by body size.

2.2. Step 2. Determine geographic distribution and remove peripheral species

Geographic distribution can be defined as the extent of occurrence (i.e. the area encompassed by the outermost limit of the range) or the area of occupancy (only those areas where the species is found) (Gaston, 1997). For many species, the extent of occurrence can be readily determined using field guides, but the actual area of occupancy may be unknown. We suggest using extent of occurrence at two spatial scales: the continental distribution and the distribution overlapping the ecoregion (as per Strong and Leggat, 1981) in the province or state in which the forest management area of interest is contained. The former scale defines whether a species is widely or narrowly distributed. The latter scale indicates how important the ecoregion is in supporting the continental population and hence the level of responsibility for management of their habitat by forestry companies within that ecoregion.

Transient species not regularly recorded in the ecoregion should be removed. Other species may be rare in a certain region because they are at the edge of their geographic range (so-called diffusive rarity, Schoener, 1987). Such peripheral populations may be of conservation interest due to their genetic diversity (Lesica and Allendorf, 1995), and can form the leading edge for geographic expansions or shifts in range due to factors such as climate change. Hence, we advocate only removing peripheral species if their geographic range has very low overlap with the ecoregion where forestry occurs.

2.3. Step 3. Remove species that are rare in commercial forest, but whose primary occurrence is in non-commercial habitats

Species may occur at low densities in marginal habitat, while being more abundant in adjacent, pre-

ferred habitats (Kluyver and Tinbergen, 1953). Furthermore, species found in a wide variety of habitats are unlikely to be habitat specialists, and hence are not as vulnerable to local extinction (Rabinowitz, 1981). If data do not exist to estimate abundances in non-commercial forest types, then field guides, species accounts, or studies on species in different areas of the ecoregion could be used to assess this subjectively.

2.4. Step 4. Identify species that are rare in some years but abundant in others

Many avian species show high temporal variability in abundance (Helle and Mönkkönen, 1998). These include irruptive species that specialize on certain resources, such as outbreaks of insect populations (e.g. spruce budworm, *Choristoneura fumiferana*) or seed crops (Benkman, 1987), and resident species that suffer periodic population declines due to extremely cold winters or lack of food (e.g. Desrochers et al., 1988). Hence, low numbers of these species in short-term surveys may not be indicative of overall temporal and spatial rarity and vice versa. In addition, the factors driving this temporal variation occur on spatial scales much larger than most forest management units, making the conservation status of these species difficult to assess. For species exhibiting high temporal and spatial variation (i.e. irruptives), it is difficult to attribute low local numbers to changes in local habitats caused by forestry activities. However, we note that such attributes can also mask declines, and that broader-scale evaluations are necessary. Long-term data sets can be used to assess temporal variability, but if these do not exist, then field guides or species accounts can be used to identify irruptive species. We advocate removing species from the rare species list that are rare infrequently and adding species that might have been common in the sampling year, but are frequently rare.

2.5. Step 5. Identify species that may be difficult to detect with standard sampling methods

Some species may be classified as rare due to sampling artefacts. For example, abundances of species that aggregate spatially are often underestimated (Wright, 1991). Other species may produce songs of

high frequency that are difficult to hear (Borrer and Gunn, 1985) and/or have high sound attenuation in forested habitats (Schieck, 1997). Finally, species that breed earlier or later than most other species in an area may not be sampled adequately by conventional breeding bird surveys. The difficulty in including these species in management planning is two-fold: first, determining whether they are rare or not, and second, measuring a response to management activities using conventional sampling methods. As a precaution, these species should be maintained on the rare species list, with the caveat that appropriate sampling techniques should be developed for them.

2.6. Step 6. Determine priorities for management

Once rare species relevant to forest management have been determined, they must be prioritized for fine-filter management (Hunter, 1990). Species with the following characteristics should receive highest priority: (1) those that are specialists on habitats that will be reduced or altered by forestry, (2) those already listed as sensitive or “at risk”, and (3) those with restricted continental ranges that overlap substantially with the ecoregion where forestry activities are taking place. These latter species should receive high priority for habitat management by forestry companies operating within the ecoregion.

3. Case study: bird community in the boreal mixedwood forest of Alberta

We now apply the conceptual framework developed in the preceding section to identify rare songbird species in commercial forests of north-central and north-eastern Alberta. We first classify species' rarity through systematic evaluation then organize species by geographic distribution, habitat specificity and temporal and regional rarity.

3.1. Study area

The province of Alberta contains the majority of the boreal mixedwood forest in western Canada (Strong, 1992). A natural disturbance regime of fire and insect outbreaks has created a heterogeneous landscape of different forest types of various ages, interspersed with

wetland habitats. Pure and mixed stands of trembling aspen (*Populus tremuloides* Michx.), balsam poplar (*P. balsamifera* L.), and white spruce (*Picea glauca* (Moench)) dominate upland areas, with lesser amounts of white birch (*Betula papyrifera* Marsh.) and balsam fir (*Abies balsamea*). Jack pine (*Pinus banksiana* Lamb.) occurs on drier sites, and black spruce (*P. mariana* (Mill.) BSP) and tamarack (*Larix laricina* (Du Roi) K. Koch) are found on wetter sites.

Currently, over 95% of the coniferous volume and 73% of the deciduous volume of commercial species in the boreal mixedwood region has been allocated to forestry companies under Forest Management Agreements with the Alberta government (Alberta Environmental Protection, 1996). The primary method of harvest is clearcut logging in a two or three pass system. The prioritisation of older forests for harvest combined with short rotation periods (40–70 years) will result in a significant reduction in the amount and distribution of older forests in future landscapes. Old (>100 years) aspen-dominated forests are structurally unique compared with younger stands and support higher species richness than younger forest (Stelfox, 1995). Several bird species occur at their highest abundances in older forest (Schieck et al., 1995), thus, loss of old-growth is of conservation concern. Hence, in this paper we focus on post-rotation age (>80 years) commercial forest types.

3.2. Songbird community

We have been studying the responses of the bird community to forestry in the region since 1992 (reviewed in Schmiegelow and Hannon, 1999). In this paper, we focus on passerine songbirds, which typically hold small territories and are easily censused using auditory and visual assessment techniques. Our focus on passerines does not imply that other taxal groups are of less importance for conservation. We simply do not have a comparable dataset for non-passerines in this region. The passerine community across all habitat types within the boreal mixedwood ecoregion of Alberta consists of 87 species, of which 48% are neotropical migrants, 37% are short-distance migrants and 15% are residents (derived from Gutsell et al., 2000).

We include data from four, multi-year, large-scale research programs that examined bird communities in

Table 1
Sources, locations and survey methods of studies used in this paper

Source	Location (latitude/longitude)	Survey method
1. Hannon (1999)	54°55'N/111°55'W 55°25'N/111°55'W	Point counts ^a
2. Schmiegelow et al. (1997), Schmiegelow (unpublished data)	55°15'N/113°35'W	Point counts ^a
3. Tittler et al. (2001)	55°20'N/113°27'W	Point counts ^a
4. Hannon et al. (2002)	55°07'N/113°43'W 55°08'N/111°45'W 55°23'N/113°38'W	Spot mapping ^b

^a Five minute, 50 m fixed-radius point counts; three synchronous rounds between 26 May and 9 July 1997. We used 50 m radius to avoid biasing rare species towards those with soft or high-pitched calls. Relative abundance of each species calculated as average number detected over three rounds, weighted by evidence of breeding activity (Schmiegelow et al., 1997).

^b Six rounds of spot mapping from 26 May to 30 June 1997 on 400 m × 125 m grids spanning the riparian zone and riparian forest at eight lakes (four grids per lake) (Hannon et al., 2002).

the boreal mixedwood ecoregion in north-central and north-eastern Alberta (Table 1, Fig. 2). These studies ran simultaneously during the summer of 1997 and we sampled both commercial (>80-year-old aspen (246 point count stations), jack pine (59 stations), white spruce (14 stations) and mixedwood stands (aspen–pine 44 stations; aspen–spruce 34 stations)) and non-commercial habitats (clearcuts <5 years (48 stations), clearcuts 15 years (24 stations), burns <5 years (23 stations), black spruce/tamarack bogs (24 stations) and riparian areas (32 grids)). Our data are relevant

to two scales: (1) the stand or local scale (~10–100 ha) and (2) the forest management unit scale (~10⁵ to 10⁶ ha). Most decisions regarding forestry planning in commercial forests are made at these spatial extents.

3.3. Step 1. Determine which species are regionally rare

In our study areas, 57 species were detected at 397 stations in commercial cover types only (Appendix A),

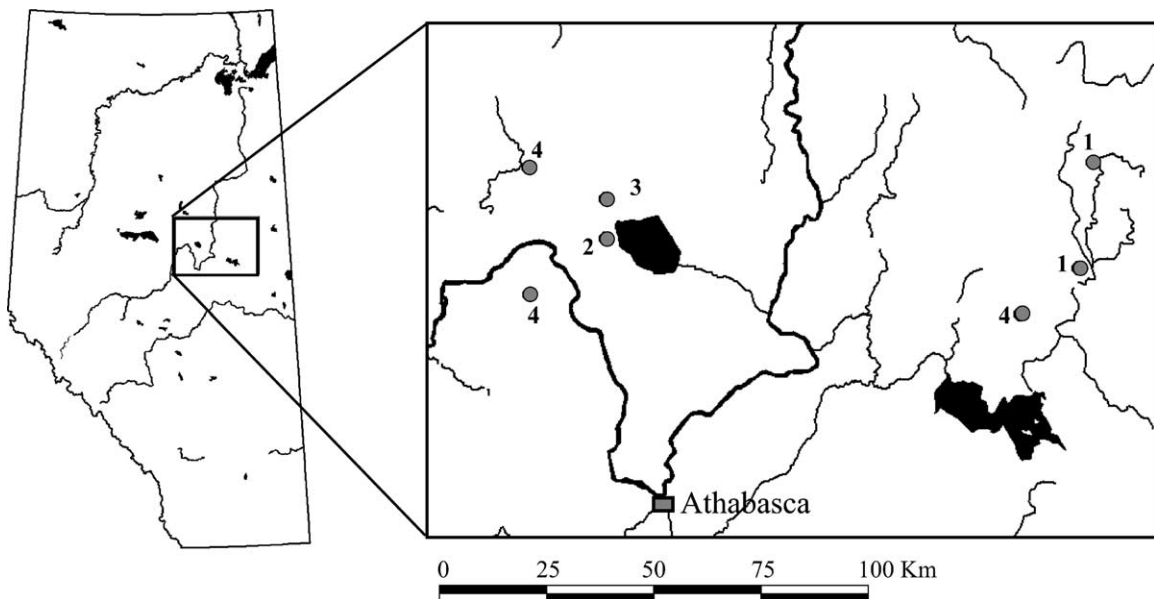


Fig. 2. Location of the study sites in Alberta. Numbers refer to the studies listed in Table 1.

however we removed five species of corvids (Gray Jay (*Perisoreus canadensis*), Blue Jay (*Cyanocitta cristata*), Black-billed Magpie (*Pica pica*), American crow (*Corvus brachyrhynchos*) and Common Raven (*C. corax*) and the tree swallow (*Tachycineta bicolor*) from the analysis because they were not adequately sampled using our techniques (Schmiegelow et al., 1997). We did not scale our data for body mass or

territory size, since our analysis included only passerine species, which had territories and body masses of fairly similar size. We constructed and examined a rank abundance plot (Fig. 3) and classified any species with an abundance $\leq 1\%$ of the total number of individuals in the community as “rare”. As a result, we designated 33 species as regionally rare (Fig. 4) and 18 as regionally abundant.

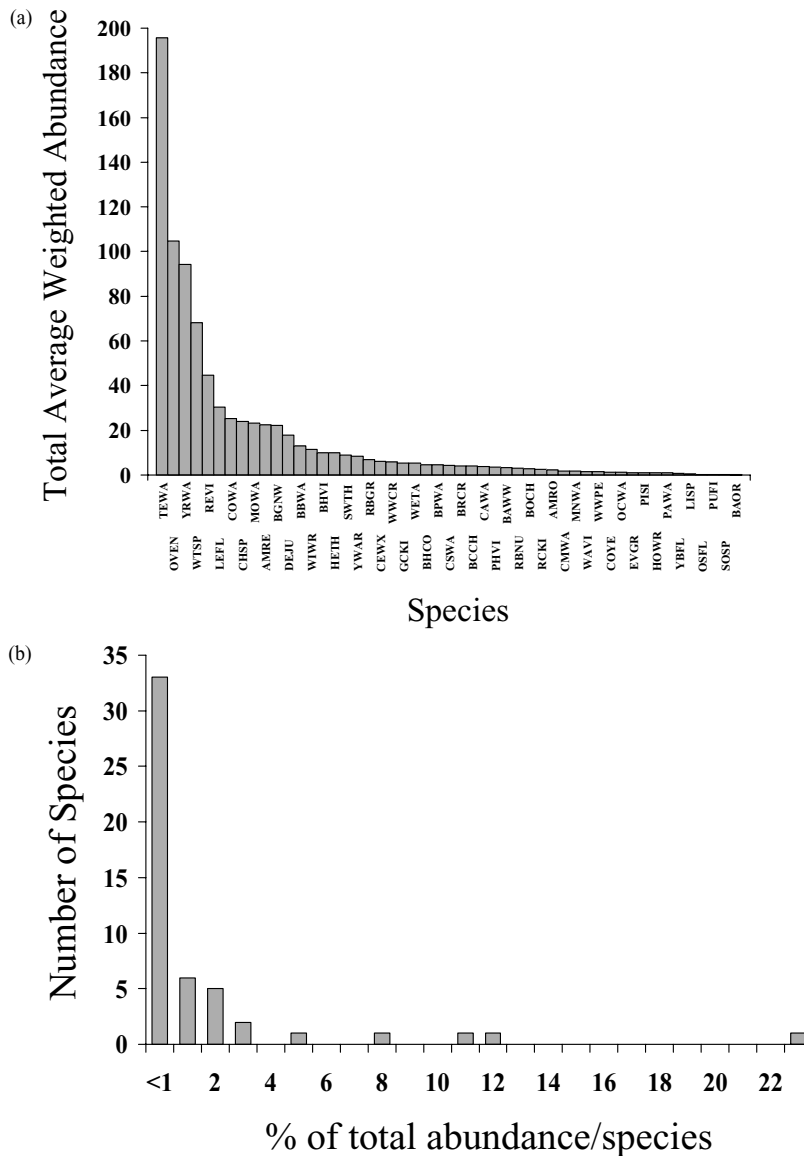


Fig. 3. Rank abundance plot (a) and plot of % of total abundance represented by each species (b) for all species observed in commercial stands in 1997.

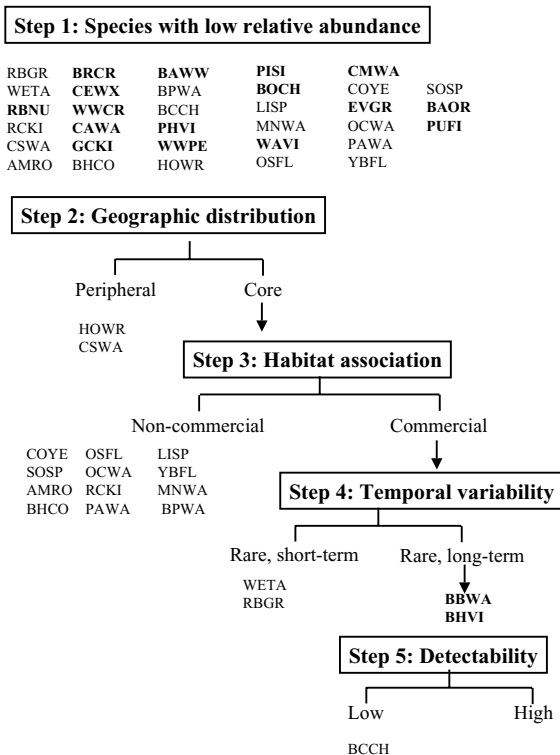


Fig. 4. A flowchart showing the 33 species initially categorized as rare and a list of species removed at each stage of the analysis (species to the left of the chart). Species in bold indicate those remaining on the rare species list after all filters were applied.

3.4. Step 2. Categorize geographic distribution and remove peripheral species

We categorized the extent of North American breeding distributions of all species using range maps in Robbins et al. (1983). We assigned species to four groups based on the area of their range, using species with the smallest (Connecticut Warbler, scored as 1) and largest (Chipping Sparrow, scored as 4) ranges as a basis of comparison (Appendix A). Species were divided into those with a wide North American range (3, 4) and those with a narrow geographic range (1, 2), consistent with Rabinowitz's scheme for rarity (Table 2). At the ecoregion level, we used range maps from a provincial field guide (Fisher and Acorn, 1998) to determine what percentage of the boreal mixedwood ecoregion in Alberta (Strong and Leggat, 1981) was covered by the distribution of each species. Overlap was coded as follows: 1, <25%; 2, 25–49%; 3, 50–99%; 4,

complete overlap (Appendix A). We also consulted distribution/abundance maps from the Breeding Bird Survey (BBS) to determine core areas of the breeding range (<http://www.mbr-pwrc.usgs.gov/bbs/bbs.html>).

From the list of 33 rare species, two species had overlap indices with the boreal mixedwood of 1 or less: the Chestnut-sided Warbler and the House Wren (Appendix A). The Chestnut-sided Warbler is restricted to a tiny area in the north-eastern portion of the province and the core of its range occurs much further east in Ontario, Quebec and the Great Lake States according to BBS distribution maps. The House Wren's distribution overlaps with the extreme southern part of the boreal mixedwood. It is very common to the south and west of the boreal mixedwood, in the parkland, southern fringe of the boreal forest and the southern part of the province, according to BBS maps. We considered these species peripheral within the boreal mixedwood ecoregion in Alberta, and they were removed from the list of rare species (Fig. 4).

3.5. Step 3. Remove species that are rare in commercial forest, but whose primary habitat is in non-commercial habitats

We used two approaches to identify non-commercial forest species: (1) we compared the relative abundances of regionally rare species in commercial versus non-commercial cover types we sampled; and (2) for habitats we did not sample we used data from Kirk et al. (1996), a study that focussed on habitat affinities of birds in the northern and western boreal forest of Canada. Using data from Study 4, we compared the number territories per hectare for each species in the riparian zone with that in the adjacent upland forest. Data from studies 1–3 were used to identify species that were rare in commercial cover types but more abundant in clearcuts, burns and black spruce/tamarack forest. Common Yellowthroat and Lincoln's Sparrow were more abundant in riparian areas (Table 3) and in early successional habitats (clearcuts and burns) (Table 4) than older forest stands. Song Sparrows were more abundant in riparian areas (Table 3), and Ruby-crowned Kinglet was most abundant in black spruce/tamarack forests (Table 4). These four species were removed from the rare species list. We removed an additional eight species (American Robin, Brown-headed Cowbird, Blackpoll Warbler, Magnolia Warbler,

Table 2
Classification of passerine species observed in commercial forest types in the boreal mixedwood of Alberta^a

Geographic distribution	Wide		Narrow	
Habitat specificity	Generalists or non-forest species	Forest species	Generalists or non-forest species	Forest species
Regionally and Temporally rare	HOWR ^b	RCKI ^c	PAWA ^c	CSWA ^b
	LISP ^c	BHVI^d	YBFL ^c	BPWA ^c
	COYE ^c	BAWW	MNWA ^c	BBWA^d
	SOSP ^c	BRCR	WWPE	CAWA
	AMRO ^c	GCKI	PHVI	CMWA
	BHCO ^c	BOCH		
	OSFL ^c	WAVI		
	OCWA ^c	RBNU		
	BAOR			
Regionally rare and Temporally abundant	CEWX^c	WWCR^e		PISI^c
		EVGR^c		PUFI^c
Regionally abundant and Temporally rare				WETA ^f
				RBGR ^f
Regionally abundant and Temporally abundant	WTSP	SWTH	LEFL	BGNW
	REVI	OVEN	MOWA	WIWR
	CHSP	YRWA	COWA	
	DEJU	AMRE	TEWA	
	YWAR	HETH		
	BCCH^g			

^a Species in bold are the remaining rare species after applying all of the filters in Fig. 1. Species codes defined in Appendix A.

^b Species removed because of geographic distribution.

^c Species removed because they are abundant in non-forested habitats or in non-commercial forest types.

^d Species common in 1997 but rare in 3 or 4 of 6 years.

^e Irruptive species.

^f Species removed because they were abundant in the majority of years on the same sites.

^g Species was rare in our sample, but was hard to detect and is very common elsewhere in the province.

Olive-sided Flycatcher, Orange-crowned Warbler, Palm Warbler, Yellow-bellied Flycatcher) that were primarily associated with habitats other than our commercial cover types based on Kirk et al. (1996) (Fig. 4).

3.6. Step 4. Identify species that are rare in some years but abundant in others

Some species may have been rare in 1997, but abundant in other years or vice versa. To identify

these species, we examined relative abundances in each year from 1993 to 1998 from Study 2 (the only site where we had long-term data; $n = 85$ point count stations) and reclassified species as rare using the 1% cut-off rule (step 1). Western Tanager was abundant in 4 of 6 years and Rose-breasted Grosbeak was abundant in 5 of 6 years, hence we reclassified them as regionally abundant but temporally rare in Table 2. All other rare species were rare in all 6 years, except Brown Creeper, which was only abundant in 1 of

Table 3

Density of territories (number/ha) in riparian shrub zone and adjacent deciduous upland forest for species with significantly more territories in the riparian zone^a

Species	Number of riparian territories	Number of upland territories	Z	P
Common Yellowthroat	16.00	0.25	-2.82	0.005
Lincoln's Sparrow	22.00	1.00	-4.40	<0.001
Song Sparrow	31.00	1.00	-4.36	<0.001

^a Z and P values from Wilcoxon matched pairs signed ranks test.

Table 4

Post-hoc comparisons^a of species that were more abundant in non-commercial than commercial cover types using a Kruskal–Wallis test

Species	χ^2	d.f.	P	Habit type ^b				
				CC1	CC2	Burn	BST	Comm
Common Yellowthroat	127.91	8	<0.001	a	a	b	b	b
Lincoln's Sparrow	128.65	8	<0.001	a	b	bc	bc	c
Ruby-crowned Kinglet	83.30	8	<0.001	b	b	b	a	b

^a Change in letter denotes significant differences between habitats; a: habitat(s) with highest abundance; b or c: habitats with lowest abundance; Kruskal–Wallis test followed by a post-hoc simultaneous test procedure for non-parametric, unplanned multiple comparisons on significant results (Sokal and Rohlf, 1981). White spruce was not included in post-hoc comparison due to unequal sample size.

^b CC1: recent clearcut; CC2: 15-year clearcut; burn; BST: black spruce/tamarack; Comm: commercial cover types (aspen, jack pine, white spruce, mixed aspen–pine, mixed aspen spruce). Commercial cover types were tested separately, but results are combined here since the relationship of interest is the comparison of non-commercial vs. commercial cover types. Due to the varying number of point count stations per habitat, a random sample of 23 stations (number of stations in the burn) was generated for each of the four non-commercial and five commercial cover types, except for white spruce, which only had 14 stations.

6 years. Hence, these species remained as rare. Of species classified as abundant in 1997, Swainson's Thrush, Tennessee Warbler and Winter Wren were abundant in 5 of 6 years and all the others except two were abundant in all 6 years: hence, we kept these species as abundant in Table 2. Blue-headed Vireo and Bay-breasted Warbler, classified as abundant in 1997, were actually rare in 3 of 6 and 4 of 6 years, respectively. Hence we reclassified them as regionally and temporally rare in Table 2.

Cedar Waxwing, White-winged Crossbill, Evening Grosbeak, Pine Siskin and Purple Finch are irruptive (Ehrlich et al., 1988). Fall and winter population densities of these species are affected by the availability of seed crops, subsequently affecting breeding population size. Although these species were not common in any of the 6 years we censused, they do have a possibility of becoming common in years with high seed crops. Hence, we classified these species as being regionally rare but temporally abundant (Table 2).

3.7. Step 5. Identify species that may be difficult to detect with standard sampling methods

By using a 50 m radius for our point counts, we hoped that species with low aural detectability would be adequately sampled. However, of the species that we classified as regionally rare, Black-and-white Warbler, Bay-breasted Warbler, Cape May Warbler, Golden-crowned Kinglet, Cedar Waxwing and Brown

Creeper may have been difficult to detect because their songs are of high frequency (Borror and Gunn, 1985; Ingold and Galati, 1997; Baptista and Krebs, 2000). Philadelphia Vireo could have been confused with the more abundant Red-eyed Vireo, which has a similar song. Cedar Waxwings breed late in the season in aggregations, hence our point counts may have underestimated their abundance. Boreal Chickadees lack an advertising song and are fairly quiet during the breeding season (Ficken et al., 1996). We left these species on the list, with the caveat that they may have been undersampled. The Black-capped Chickadee is an early breeder and would not have been singing at peak rate when our surveys were conducted, hence we likely underestimated its abundance. Although appearing rare in our study area, it is one of the most common songbirds in Alberta (Semenchuk, 1992), hence we removed it from the list of rare species.

3.8. Step 6. Determine priorities for management

Under short rotation forest management, mature and old forest will become increasingly scarce. Of the remaining rare species on our list, nine are mature or old forest specialists, found primarily in forest >80-year-old and at very low frequencies in younger regenerating stands (Schieck et al., 1995; Schmiegelow and Mönkkönen, 2002): Bay-breasted Warbler, Canada Warbler, Cape May Warbler, Brown Creeper, Golden-crowned Kinglet, White-winged Crossbill, Pine Siskin, Boreal Chickadee and Red-breasted

Table 5
Final list of rare species ordered by conservation concern from high to low^{*}

Species	Forest species	Old forest specialists	Sensitive or status undetermined ^a	Local responsibility ^b
Bay-breasted Warbler	*	*	*	3.0
Canada Warbler	*	*	*	4.0
Cape May Warbler	*	*	*	4.0
Brown Creeper	*	*	*	1.0
Golden-crowned Kinglet	*	*		1.33
White-winged Crossbill	*	*		1.33
Pine Siskin	*	*		2.0
Boreal Chickadee	*	*		1.33
Red-breasted Nuthatch	*	*		1.33
Purple Finch	*		*	2.0
Black-and-white Warbler	*			1.33
Warbling Vireo	*			1.33
Evening Grosbeak	*			1.33
Blue-headed Vireo	*			1.33
Philadelphia Vireo				4.0
Western Wood-Pewee				2.0
Baltimore Oriole				0.5
Cedar Waxwing				1.33

^a From Alberta Sustainable Resource Development (2001) or declining on BBS routes.

^b From Appendix A.

* Indicates type of species.

Nuthatch. Hence, we ranked these nine species of high conservation concern in areas managed for timber (Table 5). Bay-breasted Warbler, Canada Warbler, Cape May Warbler and Purple Finch were listed as “sensitive” at the general status level in Alberta (Alberta Sustainable Resource Development, 2001), primarily due to their reliance on older forest or because of declines in abundance on BBS routes in Alberta. Brown Creeper is currently listed as status “undetermined”, due to a lack of data. The other species are not considered at risk.

We created an index of local responsibility by dividing the score for ecoregion overlap by the score for North American range (Appendix A). For example, Canada Warbler has a restricted North American distribution (1) but completely overlaps the boreal mixedwood ecoregion (4), giving a maximum responsibility index of 4. Four of the rare species had responsibility scores of 3 or 4 for the boreal mixedwood: Bay-breasted Warbler, Canada Warbler, Cape May Warbler and Philadelphia Vireo (Table 5). Based on our three criteria (specialists on habitats altered by forestry, sensitive species, and those with restricted continental ranges that overlapped substantially with

the focal ecoregion), we ranked Bay-breasted Warbler, Canada Warbler, Cape May Warbler and Brown Creeper as rare species of the highest conservation concern. Abundance of Purple Finch is declining on BBS routes in Alberta, although route coverage of its range in the boreal mixed-wood is sparse. We flag this species and old forest species (Golden-crowned Kinglet, White-winged Crossbill, Pine Siskin, Boreal Chickadee and Red-breasted Nuthatch) as species of next highest conservation concern.

The remaining species we rank as lower conservation concerns for the following reasons. None of them is considered sensitive or at risk in Alberta. Of the remaining four forest species (Black-and-white Warbler, Warbling Vireo, Evening Grosbeak, Blue-headed Vireo), all have ranges that completely overlap the boreal mixedwood, however they also have broad continental distribution and hence lower responsibility for the boreal mixedwood. Hence, we consider them of moderate conservation concern. Cedar Waxwing, Baltimore Oriole, Western Wood-Pewee and Philadelphia Vireo might be of lesser conservation concern in commercial forest, as they appear to be habitat generalists (Witmer et al., 1997;

Rising and Flood, 1998; Moskoff and Robinson, 1996; Bemis and Rising, 1999), that breed in riparian areas and early successional habitats, as well as forest (Table 2). In addition, the Baltimore Oriole has a very large geographic range and only a 25% overlap with the boreal mixedwood, hence the Alberta responsibility is only 0.5.

4. Conclusions

Using our template, we reduced an initial list of 33 rare species to 18 rare species and further refined that list to highlight 10 species of high conservation concern and 4 of moderate conservation concern for forest managers in commercial forest in the Alberta boreal mixedwood. This method could be applied in any jurisdiction and for any group of organisms where reasonable data exist on geographic range and habitat associations. Of our 14 species of high to moderate conservation concern, four are irruptive species (Table 2). We recognize that these species have wide fluctuations in abundance and/or respond to variations in food supply or other extrinsic factors over a wide spatial extent. These species are difficult to monitor because they operate over temporal and spatial extents that are longer and larger than those typically used by forest managers. Special attention should be paid to determining appropriate sampling methods and scale of management for these species. They should probably be monitored and managed by provincial and federal government agencies in concert with local companies. Our final list may also include some species that we think are rare, but may have been undersampled by our techniques. Sampling schemes that account for potential biases in detectability should be developed (e.g. Green and Young, 1993; Link et al., 1994; Mönkkönen and Aspi, 1998; Queheillalt et al., 2002) and used in monitoring.

In order to manage habitat for rare species of conservation concern, we must determine their fine-

scale habitat preferences. More intensive and longer-term work should be directed at defining specific habitat associations of these species. Spatial and temporal variability of rare species hampers the development of habitat association models, particularly if models are based on short-term data. In a follow up paper, we will explore the sensitivity of models to increasing sampling intensity and duration, and to alternative analytical techniques. In the interim, large reserves of habitats targeted by forestry activities, in our case older forests, should be maintained on managed landscapes as a precaution against loss of rare species.

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Appendix A

Average weighted abundance observed in 1997 at point count stations in commercial forest cover types. Species are listed in order of decreasing abundance, with initial list of rare species in bold.

Species	Scientific name	Code	Abundance ^a	% of total abundance	North American distribution	Overlap with boreal mixedwood	Alberta responsibility
Tennessee Warbler	<i>Vermivora peregrina</i>	TEWA	197	23.23	2	4	2.00
Ovenbird	<i>Seiurus aurocapillus</i>	OVEN	105	12.38	3	4	1.33
Yellow-rumped Warbler	<i>Dendroica coronata</i>	YRWA	95	11.20	4	4	1.00
White-throated Sparrow	<i>Zonotrichia albicollis</i>	WTSP	69	8.14	3	4	1.33
Red-eyed Vireo	<i>Vireo olivaceus</i>	REVI	45	5.31	4	4	1.00
Least Flycatcher	<i>Empidonax minimus</i>	LEFL	31	3.65	2	4	2.00
Connecticut Warbler	<i>Oporornis agilis</i>	COWA	26	3.07	1	3	3.00
Chipping Sparrow	<i>Spizella passerina</i>	CHSP	24	2.83	4	4	1.00
Mourning Warbler	<i>Oporornis philadelphia</i>	MOWA	24	2.83	4	4	1.00
American Redstart	<i>Setophaga ruticilla</i>	AMRE	23	2.71	3	4	1.33
Black-throated Green Warbler	<i>Dendroica virens</i>	BGNW	23	2.71	2	4	2.00
Dark-eyed Junco	<i>Junco hyemalis</i>	DEJU	18	2.12	4	4	1.00
Bay-breasted Warbler	<i>Dendroica castanea</i>	BBWA	13	1.53	1	3	3.00
Winter Wren	<i>Troglodytes troglodytes</i>	WIWR	12	1.41	2	4	2.00
Blue-headed Vireo	<i>Vireo solitarius</i>	BHVI	10	1.18	3	4	1.33
Hermit Thrush	<i>Catharus guttatus</i>	HETH	10	1.18	3	4	1.33
Swainson's Thrush	<i>Catharus ustulatus</i>	SWTH	9	1.06	3	4	1.33
Yellow Warbler	<i>Dendroica petechia</i>	YWAR	9	1.06	4	4	1.00
Rose-breasted Grosbeak	<i>Pheucticus ludovicianus</i>	RBGR	7	0.83	2	4	2.00
Cedar Waxwing	<i>Bombycilla cedrorum</i>	CEWX	7	0.83	3	4	1.33
White-winged Crossbill	<i>Loxia leucoptera</i>	WWCR	6	0.71	3	4	1.33
Golden-crowned Kinglet	<i>Regulus satrapa</i>	GCKI	6	0.71	3	4	1.33
Western Tanager	<i>Piranga ludovicianus</i>	WETA	6	0.71	2	4	2.00
Brown-headed Cowbird	<i>Molothrus ater</i>	BHCO	5	0.59	4	4	1.00
Blackpoll Warbler	<i>Dendroica striata</i>	BPWA	5	0.59	2	4	2.00
Chestnut-sided Warbler	<i>Dendroica pensylvanica</i>	CSWA	5	0.59	1	1	1.00
Brown Creeper	<i>Certhia americana</i>	BRCR	5	0.59	3	4	1.33
Black-capped Chickadee	<i>Poecile atricapillus</i>	BCCH	4	0.47	4	4	1.00
Canada Warbler	<i>Wilsonia canadensis</i>	CAWA	4	0.47	1	4	4.00
Philadelphia Vireo	<i>Vireo philadelphicus</i>	PHVI	4	0.47	1	4	4.00
Black-and-white Warbler	<i>Mniotilta varia</i>	BAWW	4	0.47	3	4	1.33
Red-breasted Nuthatch	<i>Sitta canadensis</i>	RBNU	4	0.47	3	4	1.33
Boreal Chickadee	<i>Poecile hudsonicus</i>	BOCH	3	0.35	3	4	1.33
Ruby-crowned Kinglet	<i>Regulus calendula</i>	RCKI	3	0.35	3	4	1.33
American Robin	<i>Turdus migratorius</i>	AMRO	3	0.35	4	4	1.00
Cape May Warbler	<i>Dendroica tigrina</i>	CMWA	2	0.24	1	4	4.00
Magnolia Warbler	<i>Dendroica magnolia</i>	MNWA	2	0.24	1	4	4.00
Warbling Vireo	<i>Vireo gilvus</i>	WAVI	2	0.24	3	4	1.33
Western Wood-Pewee	<i>Contopus sordidulus</i>	WWPE	2	0.24	2	4	2.00
Common Yellowthroat	<i>Geothlypis trichas</i>	COYE	2	0.24	4	4	1.00
Orange-crowned Warbler	<i>Vermivora cecilia</i>	OCWA	2	0.24	4	4	1.00
Evening Grosbeak	<i>Coccothraustes vespertinus</i>	EVGR	2	0.24	3	4	1.33
Pine Siskin	<i>Carduelis pinus</i>	PISI	2	0.24	2	4	2.00
House Wren	<i>Troglodytes aedon</i>	HOWR	1	0.12	4	1	0.25
Palm Warbler	<i>Dendroica palmarum</i>	PAWA	1	0.12	1	4	4.00
Yellow-bellied Flycatcher	<i>Empidonax flaviventris</i>	YBFL	1	0.12	1	4	4.00
Lincoln's Sparrow	<i>Melospiza lincolnii</i>	LISP	1	0.12	3	4	1.33

Appendix A. (Continued)

Species	Scientific name	Code	Abundance ^a	% of total abundance	North American distribution	Overlap with boreal mixedwood	Alberta responsibility
Olive-sided Flycatcher	<i>Contopus borealis</i>	OSFL	1	0.12	3	4	1.33
Purple Finch	<i>Carpodacus purpureus</i>	PUFI	1	0.12	2	4	2.00
Song Sparrow	<i>Melospiza melodia</i>	SOSP	1	0.12	3	4	1.33
Baltimore Oriole	<i>Icterus galbula</i>	BAOR	1	0.12	4	2	0.50

^a Average weighted abundance for all commercial sites combined, rounded up; 50 m radius point counts used.

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