

The response of boreal forest songbird communities to fire and post-fire harvesting

J.L. Morissette, T.P. Cobb, R.M. Brigham, and P.C. James

Abstract: Post-fire timber harvesting (salvage logging) is becoming more prevalent as logging companies try to recover some of the economic losses caused by fire. Because salvaging is a relatively new practice and because of the common perception that burned areas are of little value to wildlife, few guidelines exist for salvaging operations. We surveyed birds in unburned and burned stands of jack pine (*Pinus banksiana* Lamb.), mixedwood, and trembling aspen (*Populus tremuloides* Michx.) to characterize the post-fire bird community in commercially important forest types. The effects of salvage logging were examined in mixedwood and jack pine. Using fixed-radius point counts, a total of 1430 individuals representing 51 species were detected during this study. Community analysis revealed that burned forests supported a distinct species assemblage of songbirds relative to unburned forests and that salvage logging significantly altered this community. An examination of guild composition showed that resident species, canopy and cavity nesters, and insectivores were the least likely to be detected in salvaged areas. Species less sensitive to salvage logging tended to be habitat generalists, omnivores, and species that nest on the ground or in shrubs. We suggest alternative management strategies that may help reduce the impact of salvage logging on the boreal forest songbird community.

Résumé : La récolte de bois après feu (coupe de récupération) devient plus en plus répandue car les compagnies forestières essaient de réduire les pertes économiques causées par le feu. Étant donné que la récupération est une pratique relativement nouvelle et que la perception populaire veut que les brûlis aient peu de valeur pour la faune, il existe peu de lignes directrices pour les opérations de récupération. Nous avons effectué des relevés d'oiseaux dans des peuplements non brûlés et des peuplements brûlés de pin gris (*Pinus banksiana* Lamb.), de bois mélangés et de peuplier faux-tremble (*Populus tremuloides* Michx.) en vue de caractériser les communautés d'oiseaux après feu dans les types forestiers d'importance commerciale. Les effets de la récupération ont été examinés dans des peuplements mélangés et des peuplements de pin gris. Dans l'ensemble des parcelles inventoriées selon la technique des dénombrements à rayon limité, nous avons détecté un total de 1430 individus représentant 51 espèces. L'analyse des communautés d'oiseaux chanteurs révèle que les brûlis supportent un assemblage distinct de celui des forêts non brûlées et que la coupe de récupération altère significativement cette communauté. L'examen de la composition des guildes a montré que les espèces résidentes, les nicheurs de la voûte forestière et les nicheurs de cavités et les insectivores ont les plus faibles probabilités d'être détectés dans les peuplements où le bois a été récupéré. Les espèces les moins sensibles à la coupe de récupération tendent à être des généralistes d'habitats, des espèces omnivores et des espèces qui nichent au sol ou dans les arbustes. Nous suggérons des stratégies alternatives d'aménagement qui pourraient aider à atténuer l'impact de la coupe de récupération sur les communautés d'oiseaux forestiers chanteurs.

[Traduit par la Rédaction]

Introduction

In light of increased forest harvesting pressure and the subsequent need for long-term sustainable forest management strategies, boreal forest ecosystems are receiving increased attention from ecologists (e.g., Beauchesne 1991; Stelfox 1995; Niemi et al. 1998). It has become a commonly

held belief among forest managers and researchers that the most sustainable forest management practices will be those that best emulate natural disturbance regimes (e.g., Attiwill 1994; Bunnell 1995; Hobson and Schieck 1999). Some of the most recent research in boreal ecosystems has involved comparing patterns in habitat and community structure created by natural disturbance (e.g., wildfire) to those created by forest harvesting (Hobson and Schieck 1999; Imbeau et al. 1999; Schieck and Hobson 2000).

Disturbances like fire are largely responsible for the broad range of stand age-classes that occur across the boreal forest landscape. The unpredictable nature of fire, in terms of timing, location, and intensity, maintains landscape heterogeneity by creating a variety of successional stages (Drapeau et al. 1999; Imbeau et al. 2001). Since bird communities vary among successional stages and forest types, the diversity of patches on the landscape also maintains songbird diversity (Westworth and Telfer 1993; Schieck et al. 1995; Kirk et al. 1996).

In a landscape where fire is the predominant disturbance, it is reasonable that many species, both plant and animal,

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have evolved to rely on the diversity of habitat types that fire generates. This is certainly true of insects such as wood boring beetles (e.g., Cerambycidae, Buprestidae) which are attracted in large numbers to burned areas (Evans 1966, 1972; Hutto 1995; Cobb 2001). Fire also creates habitat for specific birds; for example, black-backed woodpeckers (*Picoides arcticus*) are found in high densities in recent post-fire habitat (Blackford 1955; Hutto 1995; Murphy and Lehnhausen 1998), probably to capitalize on increased prey availability. In a study of Rocky Mountain bird communities, Hutto (1995) found that the distribution of several bird species was relatively restricted to early post-fire conditions. Bock and Lynch (1970) found that 28% of 32 regularly breeding species in the Sierra Nevada were found in burned plots only, while just 19% were unique to unburned forests. More recently, Hobson and Schieck (1999) and Imbeau et al. (1999) each reported a unique community assemblage of birds in burned boreal mixedwood and burned black spruce forests, respectively. Songbirds are appropriate to study when measuring the impact of various forest management strategies because their communities (*i*) include a variety of coexisting species with different ecologies, (*ii*) are sensitive to differences in vegetation structure and composition and changes in food availability, and (*iii*) are relatively easily surveyed (Martin 1995). Furthermore, the results for birds may represent a suitable index for the effects of forest management strategies on other organisms in the boreal forest such as insects and plants (O'Connell et al. 2000; Petersson et al. 1995).

In dry years, forest harvesting companies can incur substantial economic losses from damage to merchantable timber by wildfire. An attempt to recover these economic losses via post-fire harvesting of salvageable timber (hereafter salvage logging) is now common practice (Hutto 1995; Robinson and Zappieri 1999). Because salvaging is a relatively new practice, and because of the common perception that burned areas are of little value to wildlife, few ecologically oriented management guidelines exist for salvage logging operations.

Although a number of studies have examined the effect of disturbance due to wildfire on wildlife (e.g., Crête et al. 1995; Bunnell 1995; Pémoulié 1995; Apfelbaum and Haney 1981), few have described the impact of removing burned timber from this newly created habitat (but see Saab and Dudley 1998). Also, few studies (but see Hobson and Schieck 1999; Imbeau et al. 1999) have tested whether burned areas represent critical habitat for boreal forest songbirds, and none that we know of have focussed on different burned boreal forest types at the same time.

The objectives of this study were to characterize the songbird community in different burned boreal forest types and to determine the impact of salvage logging on the songbird community, ultimately facilitating better management decisions regarding salvage logging. Specifically, we set out to (*i*) characterize songbird communities in burned forest of three major forest types (aspen–spruce mixedwood, jack pine, aspen) and compare them with unburned forests of the same type in the same area; (*ii*) determine the effects of salvage logging on songbird abundance, species richness, and diversity in jack pine and mixedwood forests; and (*iii*) determine the effects of salvage logging on songbird community

assemblages by examining guild composition and relative abundance of individual species in jack pine and mixedwood forests.

We expected that certain species would use burned forest more, because they evolved with fire as a primary disturbance. We also predicted that certain functional groups of birds (guilds) would show greater sensitivity to fire and salvage logging than others. For example, we speculated that the increase in insect availability thought to occur post-fire (Evans 1972; Hutto 1995) should favour insectivores, while fire could also reduce understory heterogeneity and, in turn, decrease the number of shrub nesters. We expected that both salvaging and fire should favour groups of species that prefer early successional habitats but that each treatment would favour groups with different nesting and foraging requirements. Finally, we expected that the differences observed both at the species and guild levels could be detected using community analysis (ter Braak 1995; Hobson and Schieck 1999) allowing us to broadly examine the songbird community across different treatments and forest types.

Materials and methods

Study area

The study took place during the summer of 1998 in an area of burned forest hereafter referred to as the Hawk Fire (54°45'N, 108°13'W) north of Meadow Lake, Sask. (Fig. 1). The Hawk Fire burned during the summer of 1995 to a size of approximately 40 000 ha. After the fire, intensive salvage logging took place until the winter of 1997.

The ecoregion classification of the area is mid-boreal upland forest. The dominant tree species include jack pine (*Pinus banksiana* Lamb.) on sandy soils, and trembling aspen (*Populus tremuloides* Michx.) on loamy soils and south-facing slopes. Where moisture conditions permit, aspen is often found in combination with white spruce (*Picea glauca* (Moench) Voss) resulting in a forest type referred to as mixedwood. Black spruce (*Picea mariana* (Mill.) BSP) and tamarack (*Larix laricina* (Du Roi) K. Koch) occur in peatland and low areas (Acton et al. 1994).

Site selection

Within the boundary of the Hawk Fire, we sampled areas of mixedwood, aspen, and jack pine (Table 1) in each of three treatment categories: unburned, burned, and salvaged with the exception that no burned aspen stands in the Hawk Fire had been salvaged. However, to characterize the songbird community of burned forests, and because aspen is the primary species harvested in unburned stands, we compared burned and unburned aspen. Using forest inventory maps, we selected unburned, burned, and salvaged sites of each forest type with similar composition, age-classes, and stand densities. All sites were then randomly selected from within these categories. To keep burned and salvaged sites as similar as possible with respect to successional stages, we only sampled sites salvaged prior to winter 1996. Thus, at the time of surveys, burned sites were 3 years post-fire, while salvaged areas were 2 or 3 years post-salvage. We sampled all unsalvaged burned areas of mixedwood and jack pine meeting the selection criteria within the boundaries of the fire. Forest stands sampled ranged in area from 6 to 70 ha.

Table 1. Vegetation characteristics of each forest type and treatment.

Habitat type* (no. of sites)	% canopy	% DWM*	% vegetation	% litter	% bare ground	% grass	% moss	% lichen	Density of regenerating trees/ha
UMW (4)	50.0±9.8 [†]	39.0±11.0	24.8±8.0 [†]	52.5±21.1	0±0	0.5±0.7	17.0±16.1	0±0	0±0
BMW (7)	37.4±7	32.9±11.6	35.6±6.5	48.7±13.7	2.0±3.6	4.8±4.2	7.9±9.2	0±0	46±40
SMW (6)	0±0 [‡]	50.0±10 [‡]	27.9±13.7	34.1±10.6	20.0±12.2 [‡]	15.1±6.7 [‡]	3.2±4.2	0±0	95±42 [‡]
UJP (13)	38.3±7.8 [†]	24.6±9.6	27±9.1	22.7±10.7 [†]	0±0 [†]	0.99±1.6 [†]	44.1±13.1 [†]	4.8±12.1 [†]	0±0 [†]
BJP (12)	22.1±12.6	19.8±13.2	17.1±11.5	41.0±22.7	16.5±20.5	8.7±8.3	15.7±22.0	0.8±1.8	58±95
SJP (13)	0±0 [‡]	50.6±13.6 [‡]	13.6±6.8	44.1±13.7	23.4±17.0	16.6±9.8 [‡]	1.1±1.3 [‡]	0±0	24±43
UAS (12)	50.5±8.9 [†]	37±13	39.8±10.8	54.9±11.2	0±0	3.7±3.4	1.0±0.92 [†]	0±0	50±70 [†]
BAS (12)	37.1±16.1	43.5±13.2	33.0±14.2	57.2±14.7	0±0	3.4±1.6	7.5±9.2	0±0	124±146

Note: Values are means ± SDs.

*SMW, salvaged mixedwood; BMW, burned mixedwood; UMW, unburned mixedwood; SJP, salvaged jack pine; BJP, burned jack pine; UJP, unburned jack pine; BAS, burned aspen; UAS, unburned aspen; % DWM, percent down woody material.

[†]Significant difference between unburned and burned ($P < 0.05$, t test for samples with unequal variance).

[‡]Significant difference between burned and salvaged ($P < 0.05$, t test for samples with unequal variance).

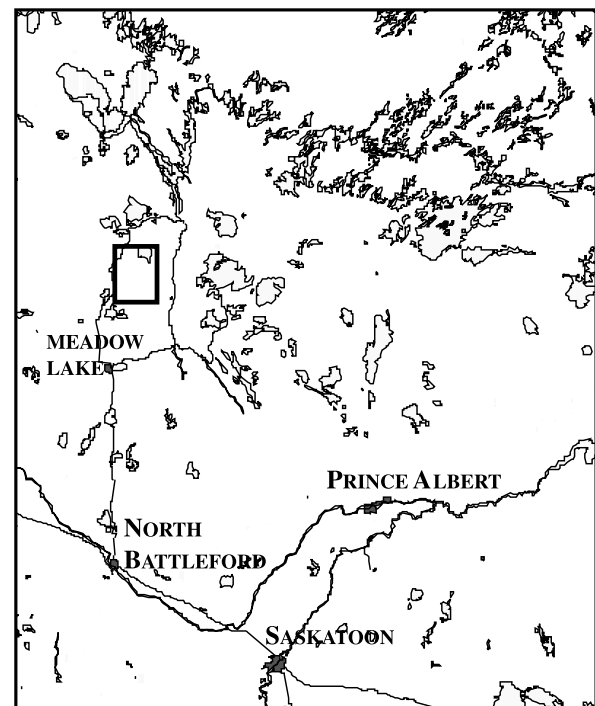
To establish which species normally occurred in a given forest type for this area, we included in our sampling protocol unburned stands of each forest type outside the fire boundary. Finally, to evaluate the impact of salvage logging, songbird communities were sampled in salvaged jack pine and mixedwood areas. Sites were located a minimum of 300 m apart to maximize independence. To reduce the variability caused by edge effects, the perimeter of each point count radius was located at least 50 m from any edge. Edge habitat was considered to be a change in tree species composition or a boundary between forest and either road or an area that had been logged.

Vegetation sampling

All vegetation measurements were taken within a 20 m radius plot centered on the point count site. Shrubs and regenerating trees were measured and counted in one 5 × 5 m plot at a random distance and direction from the point count site. Percent ground cover by litter, bare ground, moss, lichen, herbs, and grass was measured in three 1 × 1 m plots, also located a random distance and direction from the point count station. Percent downed woody material (DWM) and percent canopy cover were measured using a densitometer (Emlen 1967). This device is a vertical viewing tube, with a built-in mirror and level, used to increase the accuracy of estimates for canopy and ground cover (Emlen 1967). Both percent canopy cover and percent DWM for a station were measured every 5 m along radial transects within the vegetation plot until 50 points had been measured. For each habitat parameter, we calculated a mean value for each site. These values were then used to calculate an overall mean value for each habitat type. All vegetation measurements were conducted during a single visit to each site during July 1998.

Bird surveys

Bird surveys took place during the breeding season (28 May – 3 July 1998). To reduce bias, observers underwent a period of training prior to the surveys. All surveys were conducted beginning 30 min before sunrise and ending 4 h after sunrise (Bibby et al. 1992). We surveyed the bird community using 5-min, fixed radius (100 m) point counts (Ralph et al. 1995). Because of differences in detectability among bird species, this radius corresponded with the maximum recom-

Fig. 1. Location of study area near Meadow Lake, Saskatchewan.

mended radius for use within forests (Schieck 1997) and was also appropriate for sampling open habitat such as salvaged areas. For each count, an observer arrived at a predetermined station, and immediately began a 5-min counting period during which all species seen and (or) heard were recorded. A 5-min period was chosen because previous studies have shown that at least 85% of the species present are detected, thus maximizing the number of stations which can be visited in a given time (Ralph et al. 1995; Welsh 1995). Birds whose songs were not immediately recognized were recorded on tape or visually identified after the 5-min counting period ended. Each station was sampled twice during the breeding season (once early and once late) to account for differences in the timing of breeding by early and late-arriving migrants. Previous studies have shown that two visits to a station during the breeding season will detect at least 90% of the birds present (Petit et al. 1995) and may be pref-

erable to sampling a smaller number of stations more often (Ralph et al. 1995).

Statistical analyses

Comparisons of vegetation parameters were carried out among treatments for each forest type using *t* tests; unburned sites and salvaged sites were always compared independently to burned sites. For all analyses of point count data, we used the maximum number of individuals for each species recorded at a sampling station during the two counts. The strength of the affiliation of bird species with unburned, burned, or salvaged areas was tested using indicator species analysis (Dufrene and Legendre 1997). This method combines information on species abundance in a particular treatment and the faithfulness of occurrence of a species in that treatment resulting in an indicator value for each species. Indicator values were then tested for statistical significance using a Monte Carlo technique (McCune and Mefford 1997; PC-ORD version 3.01; 999 permutations). Comparisons of each species were carried out separately for each forest type. Species were then ranked in order of descending indicator value for each treatment (unburned, burned, and salvaged). Patterns of guild composition were then examined for groups of species showing the highest indicator values for a given treatment. Information about foraging, nesting, and migration guilds for the bird community in our study area was obtained from Erskine (1977), Smith (1993), and Sauer et al. (1999).

Community analysis was performed using detrended correspondence analysis (DCA) and detrended canonical correspondence analyses (DCCA; ter Braak and Smilauer 1998; Jongman et al. 1995). DCA is a nonlinear, indirect gradient analysis (no environmental variables), suitable for evaluating data with unimodal response models and data sets for which no explicit environmental variables were measured (ter Braak 1995). However, environmental variables were included in the analysis as passive variables to aid in the interpretation of the ordination (Hobson and Schieck 1999). To test for significant differences among treatment types, a bootstrap Monte Carlo test with 999 iterations was carried out in the DCCA with the treatment types coded as dummy variables (Halvorsen 1996).

Results

Vegetation sampling

The differences we found in vegetation composition among the treatments of each forest type (unburned, burned, salvaged) reflect the changes in vegetation structure that would intuitively be expected following a disturbance such as fire or salvage logging (Table 2). For instance, unburned sites tended to have the highest canopy cover, the greatest cover by litter and moss, and in the case of jack pine stands, the most lichens. Burned sites also had more regenerating trees. Regenerating aspen in particular were more than 1.5 m tall. Thus, in burned mixedwood and aspen sites, more regenerating trees also resulted in a more dense understorey layer than in unburned sites.

In general, burned sites had less canopy cover than unburned sites but had more canopy cover than sites that had been salvaged (Table 2). Burned sites also had greater percent cover by herbs and forbs, and in jack pine, by grass,

than unburned sites. Salvaged sites were similar to burned sites in percent cover by herbs and litter and had at least as many regenerating trees as unsalvaged sites. In jack pine sites, there was significantly reduced cover by moss in salvaged sites (Table 2). Salvaged sites had the most cover by grasses and percent DWM (Table 2).

Bird surveys

We sampled songbirds at a total of 79 sites and recorded 1430 individuals of 51 different species. Scientific names for each species and the mean maximum abundance per station are given in the Appendix (Table A1). Arbitrarily, for comparisons of treatments within forest types, only species recorded at least three times in a forest type are included in the analysis. Where forest types are treated simultaneously, species that occurred three times in total, over all forest types combined, are included. All other analyses included all songbird species detected.

Response of guilds and individual species

In all forest types, the songbird species we recorded typically occurred in both burned and unburned habitats (Tables 2, 3, and 4). However, based on relative abundance estimates, several species were found to be strongly associated with unburned forests. For example, northern waterthrush were strongly associated with unburned mixed wood sites, while blue-headed vireos and red-eyed vireos were strongly associated with unburned jack pine and mixedwood sites and ovenbirds were significant indicators of unburned aspen sites.

Many species were strongly, though not exclusively, associated with burned forests. For example, the olive-sided flycatcher, and western wood-pewee occurred most frequently in burned, unsalvaged areas in jack pine and aspen forest types (Tables 3 and 4). American robins and dark-eyed juncos both reached their highest abundance at jack pine burned sites (Table 3; Appendix). Likewise, brown creepers were more abundant in burned aspen forests than unburned aspen forests (Table 4).

Thirty-five of the species detected (66%) were never recorded in either jack pine or mixedwood salvaged areas (Appendix). Five species were recorded only in salvaged areas: Le Conte's sparrow, song sparrow, sharp-tailed sparrow, vesper sparrow, and Lincoln's sparrow (Table 3; Appendix). Other species such as the white-throated sparrow, clay-colored sparrow, and alder flycatcher were abundant in burned areas but were significantly more abundant in salvaged areas (Tables 2 and 3).

Indicator species analysis also provided insight into the aggregation of bird species among treatments within each forest type. Species are presented by descending percent indicator value for each treatment (Tables 2, 3, and 4). To highlight trends in the use of unburned, burned, and salvaged areas by different functional groups, each species is accompanied by its associated nesting, foraging, and migratory guild. Patterns of guild composition among groups are helpful for interpreting species associations with unburned, burned, or salvaged areas.

Salvaged sites were composed of habitat generalists and of species known to prefer early successional habitats and of habitat generalists (Smith 1993), while unburned sites favoured species known to prefer older forests. Burned sites

Table 2. Percent indicator values for species occurring in unburned, burned, and salvaged mixedwood forest.

Species	% indicator value			<i>p</i>	Guild*			
	Unburned	Burned	Salvaged		Migration	Nest site	Nest type	Foraging
Northern waterthrush	84	16	0	0.013	LD	G	O	FI
Winter wren	78	22	0	0.135	SD	G	CV	GI
Bay-breasted warbler	78	22	0	0.143	LD	C	O	GI
Red-eyed vireo	64	36	0	0.047	LD	C	O	FI
Magnolia warbler	64	36	0	0.176	LD	S	O	FI
Ovenbird	58	42	0	0.040	LD	G	O	GI
Red-breasted nuthatch	51	49	0	0.157	PR	C	CV	BI
Ruby-crowned kinglet	51	49	0	0.209	SD	C	O	FI
American robin	45	26	30	0.999	SD	S	O	GI
Yellow-rumped warbler	40	60	0	0.011	SD	C	O	FI
Gray jay	36	41	24	0.999	PR	C	O	OM
Tennessee warbler	30	70	0	0.161	LD	S	O	FI
Mourning warbler	16	9	75	0.020	LD	G	O	FI
White-throated sparrow	9	23	68	<0.001	SD	G	O	OM
Tree swallow	0	30	70	0.335	SD	C	CV	AI
Chipping sparrow	0	30	70	0.447	LD	S	O	OM
Dark-eyed junco	0	22	78	0.048	SD	G	O	OM
House wren	0	18	82	0.018	LD	C	CV	FI
Clay-colored sparrow	0	7	93	0.015	LD	S	O	OM

Note: Species are presented by descending percent indicator value for each treatment.

*LD, long distance; SD, short distance; PR, permanent resident; G, on ground; C, in large canopy tree; S, in shrubs, saplings, or understory trees; O, open cup; CV, cavity or hole; FI, foliage insectivore; BI, bark insectivore; GI, ground insectivore; OM, omnivore.

appeared to be intermediate in that generalists, species that prefer early successional habitats, and many species known to prefer mature forests were all abundant. For example, habitat and diet generalists, such as the white-throated sparrow, chipping sparrow, and dark-eyed junco (Tables 2 and 3; Smith 1993), were more common in burned and salvaged areas. In contrast, species more typical of habitats with a closed canopy, such as the ruby-crowned kinglet and winter wren, were equally abundant in burned and unburned mixedwood forests (Table 2).

Patterns of habitat use were also apparent among nesting guilds. In mixedwood and jack pine stands, 8 of 10 species which had their highest indicator values in salvaged areas were ground and shrub nesters. In burned and unburned sites, the three nest site guilds were more evenly distributed, although there were proportionally fewer ground nesters with their highest indicator value in these habitats (Tables 2, 3, and 4). Cavity nesters were excluded from salvaged areas entirely except for two species: the house wren and tree swallow (Tables 2 and 3).

A comparison of foraging guilds revealed that in jack pine, five of the six (83%) species having significantly higher indicator values in salvaged areas were omnivorous (Table 3). Likewise, in mixedwood, three of five species (66%) having a significantly higher indicator value in salvaged areas were omnivorous. Both burned and unburned forests clearly favoured insectivores (Tables 2, 3, and 4).

Finally, although all three migratory guilds (resident, short distance, long distance) were represented in burned and unburned forests, resident species (boreal chickadee, red-breasted nuthatch, brown creeper) were the least likely to be detected in salvaged areas. The black-backed woodpecker, three-toed woodpecker, and black-capped chickadee were also only de-

tected in burned forests but could not be formally included in the analysis because of low detection rates (Appendix).

Detrended correspondence analysis

The DCA provides an overall examination of the songbird communities with all habitats combined. The dispersion of site score values along the first DCA axis is best explained by habitat type (Fig. 2; gradient length: 4.3, eigenvalue (EV): 0.66) with unburned sites having the lowest values, burned sites having intermediate values, and salvaged sites having the highest values. Sites were ordered along the second axis according to forest type (Fig. 2; gradient length: 2.2, EV: 0.22) from fully deciduous at the lowest end to fully coniferous at the highest end. Axis 1 and axis 2 together explained 37 and 29% of the variance in species abundances, respectively. To assist in interpreting this analysis, we placed 80% confidence intervals around each treatment in each forest type (Fig. 3). Since sites that are close together in the ordination are most similar, our DCA results show that the disturbance by salvaging displaces the songbird community from its undisturbed condition more than fire. However, it should also be noted that fire intensity may play a role in the dispersal of the points. Areas that were more lightly burned tended to be more similar to unburned areas than areas that had burned at a higher intensity (J.L.M., personal observation).

We tested for statistical significance of the first DCA axis using a Monte Carlo test in DCCA with treatments and forest types coded as dummy variables and included as the only environmental variables (Schieck and Hobson 2000; ter Braak 1992). There was a statistical difference among treatments for all forest types except mixedwood. In mixedwood, there was no significant difference between burned and un-

Table 3. Percent indicator values for species occurring in unburned, burned, and salvaged jack pine forest.

Species	% indicator value			<i>p</i>	Guild*			
	Unburned	Burned	Salvaged		Migration	Nest site	Nest type	Foraging
Yellow-rumped warbler	60	34	0	0.002	SD	C	O	FI
Blue-headed vireo	57	7	0	0.001	SD	C	O	FI
Ovenbird	49	1	0	<0.001	LD	G	O	FI
Red-eyed vireo	38	0	0	0.005	LD	C	O	FI
Gray jay	34	22	1	0.106	PR	C	O	OM
Hermit thrush	33	36	0	0.045	SD	S	O	GI
Red-breasted nuthatch	22	26	0	0.131	PR	C	CV	BI
Chipping sparrow	14	36	16	0.134	LD	S	O	OM
Ruby-crowned kinglet	13	7	0	0.390	SD	C	O	FI
Boreal chickadee	6	15	0	0.243	PR	C	CV	BI
Connecticut warbler	2	6	0	0.545	LD	G	O	FI
Dark-eyed junco	1	46	12	0.005	SD	G	O	OM
Olive-sided flycatcher	1	35	0	0.010	LD	C	O	AI
American robin	0	45	1	<0.001	SD	S	O	GI
Western wood-pewee	0	25	0	0.024	LD	C	O	AI
Winter wren	0	25	0	0.022	SD	C	CV	FI-GI
White-throated sparrow	0	25	70	<0.001	SD	G	O	OM
Tree swallow	0	14	12	0.406	SD	C	CV	AI
Common yellowthroat	0	2	14	0.336	LD	S-G	O	FI
House wren	0	2	20	0.119	LD	C	CV	FI
Alder flycatcher	0	1	40	0.003	LD	S-G	O	AI
LeConte's sparrow	0	0	13	0.316	SD	G	O	OMI
Vesper sparrow	0	0	27	0.036	SD	S	O	OM
Song sparrow	0	0	27	0.029	SD	S	O	OM
Lincoln sparrow	0	0	40	0.003	LD	G	O	OM
Clay-colored sparrow	0	0	73	<0.001	LD	S	O	OM

Note: Species are presented by descending percent indicator value for each treatment.

*LD, long distance; SD, short distance; PR, permanent resident; G, on ground; C, in large canopy tree, S, in shrubs, saplings, or understory trees; O, open cup; CV, cavity or hole; FI, foliage insectivore; BI, bark insectivore; GI, ground insectivore; OM, omnivore.

burned site groupings, which is consistent with our results for the relative abundance of individual species. Results of the Monte Carlo test for all comparisons are presented in Table 5 including *F* statistics and *P* values.

The DCA also showed that salvaging creates a unique species assemblage of songbirds (Figs. 3a and 3b), although at the time we sampled, there was little difference in the communities found in salvaged mixedwood and salvaged jack pine areas (Table 5). When included on the DCA biplot, species that had their highest abundance in salvaged sites (white-throated sparrows, tree swallows, clay-colored sparrows) also had their predicted maximum abundance (centroid) within or near the confidence intervals for that treatment type (Fig. 4). Similarly, species that were abundant in both salvaged sites and burned sites had their centroid between or near confidence intervals for those habitat types (e.g., mourning warbler, alder flycatcher, house wren). Olive-sided flycatcher (Figs. 4b and 4c), chipping sparrow (Fig. 4a), American robin (Fig. 4a), and dark-eyed junco (Fig. 4a) are examples of species which had their predicted maximum abundance within the confidence intervals for burned forests.

Discussion

Responses of guilds and species

Patterns of songbird distribution among the different habi-

tats were consistent with data about specific habitat preferences (Smith 1993; Sauer et al. 1999; Erskine 1977) and differences in the vegetation parameters that we measured. For example, species typically associated with open, grassy habitats were most abundant in salvaged areas (e.g., clay-colored sparrow, vesper sparrow), which had the greatest percent cover by grass. Species associated with mature stands or requiring tree cover and foliage for nesting or foraging (e.g., ruby-crowned kinglet, red-eyed vireo) were most abundant in unburned areas.

In burned areas, the songbird community included both early successional species (e.g., white-throated sparrow; Crête et al. 1995; Imbeau et al. 1999) and species generally thought to prefer mature forests (e.g., boreal chickadee). In our study, the red-breasted nuthatch, which is generally thought to avoid burned areas (Raphael and White 1984; Bock and Lynch 1970), was equally abundant regardless of whether a habitat had been burned or not. This is likely, because not all tree crowns in our sites had been burned, and thus, there was still suitable habitat available for this species, which is known to prefer foraging in the canopy and along the branches of live conifers (Ghalambor and Martin 1999).

Although there was some variation among forest types, eight songbird species were significantly more abundant in burned forest than in either unburned or salvaged areas. Most studies previously undertaken in burned forests have

Table 4. Percent indicator values for species occurring in unburned and burned aspen forest.

Species	% indicator value		<i>p</i>	Guild*			
	Unburned	Burned		Migration	Nest site	Nest type	Foraging
Ovenbird	65	26	0.003	LD	G	O	GI
Tennessee warbler	51	6	0.056	LD	S	O	FI
Yellow-rumped warbler	30	45	0.514	SD	C	O	FI
Rose-breasted grosbeak	30	5	0.373	LD	C	O	FI
Red-eyed vireo	27	45	0.381	LD	C	O	FI
Connecticut warbler	27	12	0.569	LD	G	O	FI
Black and white warbler	20	2	0.467	LD	G	O	FI
Ruby-crowned kinglet	19	2	0.611	SD	C	O	FI
Swainson's thrush	17	21	0.999	LD	S	O	GI
Blue jay	17	0	0.461	PR	C	O	OM
Magnolia warbler	15	22	0.808	LD	S	O	FI
Red-breasted nuthatch	13	30	0.690	PR	C	CV	BI
Hermit thrush	8	22	0.715	SD	S	O	GI
Philadelphia vireo	8	8	0.999	LD	C	O	FI
White-throated sparrow	5	79	<0.001	SD	G	O	OM
Mourning warbler	2	31	0.156	LD	G	O	FI
Winter wren	2	19	0.597	SD	G	CV	GI
Alder flycatcher	1	36	0.128	LD	S-G	O	AI
Yellow warbler	1	35	0.136	LD	S	O	FI
Brown creeper	0	42	0.037	PR	C	CV	BI
House wren	0	42	0.043	LD	C	CV	FI
Chestnut-sided warbler	0	42	0.038	LD	S	O	FI
Chipping sparrow	0	42	0.033	LD	S	O	OM
Olive-sided flycatcher	0	33	0.089	LD	C	O	AI
Least flycatcher	0	33	0.095	LD	S	O	AI
Western wood pewee	0	25	0.212	LD	C	O	AI
Gray jay	0	17	0.468	PR	C	O	OM

Note: Species are presented by descending percent indicator value for each treatment.

*LD, long distance; SD, short distance; PR, permanent resident; G, on ground; C, in large canopy tree; S, in shrubs, saplings, or understory trees; O, open cup; CV, cavity or hole; FI, foliage insectivore; BI, bark insectivore; GI, ground insectivore; OM, omnivore.

found strong associations of both three-toed woodpeckers and black-backed woodpeckers with burned forests (Imbeau et al. 1999; Hobson and Schieck 1999; Hutto 1995; Harris 1982; Apfelbaum and Haney 1981). Although woodpeckers were not formally included in our analysis, both species were only detected in burned forests. The eight songbird species that were more abundant in burned areas than unburned areas included the olive-sided flycatcher, western wood-pewee, brown creeper, Tennessee warbler, chestnut-sided warbler, chipping sparrow, American robin, and dark-eyed junco. Despite differences in forest type and geographic location, other studies have also reported these species to be more abundant in burned areas. Hutto (1995) in Rocky Mountain pine forests and Apfelbaum and Haney (1981) in jack pine and black spruce forests of Minnesota, found that the olive-sided flycatcher was more abundant in burned than in unburned forests. In addition, chipping sparrows, dark-eyed juncos, brown creepers, and American robins were more abundant in burned stands (Apfelbaum and Haney 1981; Hutto 1995) than in post-harvest stands (Hobson and Schieck 1999; Imbeau et al. 1999). The brown creeper, dark-eyed junco, and chipping sparrow are species most typically associated with mature stands (Smith 1993; but see Farr 1993; Hutto 1995). Although the chestnut-sided

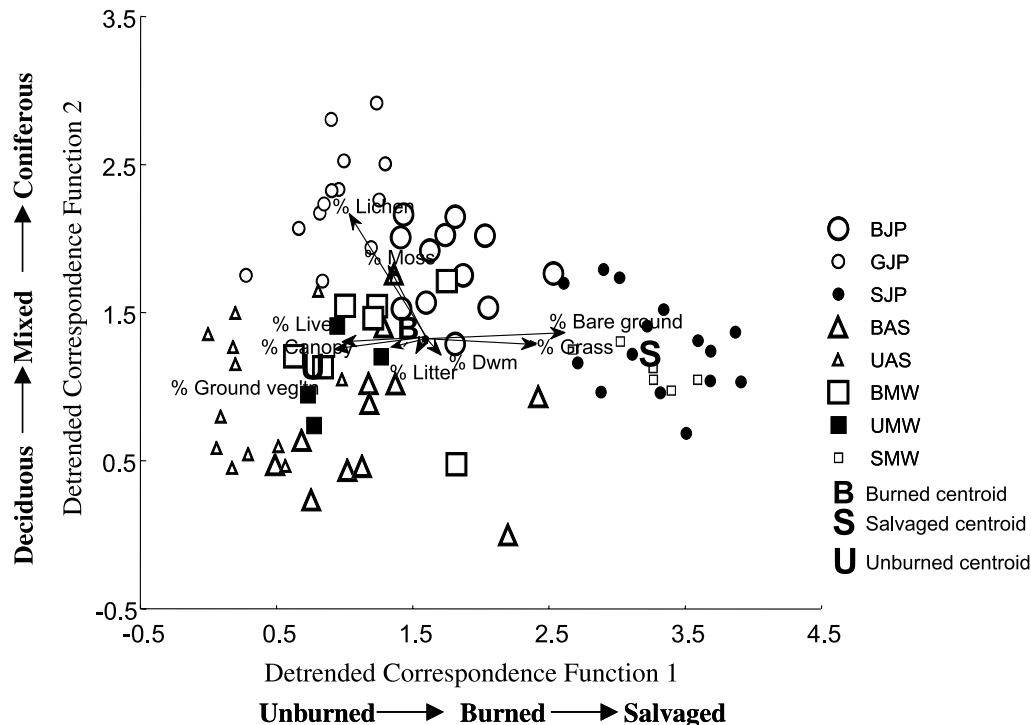
warbler has not previously been associated with burned areas, it is considered an early successional species (Farr 1993; Kirk et al. 1996), which may account for its increased abundance in burned aspen stands. Thus, burned forest habitats appear to be important for a wide range of species.

There were a number of species that occurred in both unsalvaged and salvaged areas (e.g., white-throated sparrow) suggesting that these species may be less sensitive to the effects of salvaging. This likely occurred because salvaged areas have some of the same habitat characteristics as burned areas. Burned aspen had a strong regenerating aspen understory. Aspen suckers were also the most abundant cover provided by salvaged mixedwood areas. These characteristics represent typical habitat for species that nest and forage on or near the ground (Dunn and Garrett 1997).

Guilds

Another way of evaluating the impact of salvage logging on the boreal forest songbird community is to examine changes in guild composition. Although all three migratory guilds (resident, short distance, long distance) were represented in burned forests and unburned forests, we found that resident species were the least likely to be detected in salvaged areas. This is consistent with the results of Imbeau et

Fig. 2. DCA results for sites in all forest types. Two-dimensional plot shows differences in bird communities among sites. Sites that are close together have similar bird communities and sites that are far apart have different bird communities. Confidence ellipses include 80% of sites in each forest and treatment type. Data used to construct Figs. 2–4 were obtained from a single DCA analysis, but Figs. 3 and 4 were plotted separately to aid interpretation.



al. (1999), which showed that the majority of species occurring in harvested areas were neotropical migrants.

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). Hutto (1995) found that 78% of birds using burned forests were insectivores. In our study, insectivores accounted for the largest proportion of the burned forest songbird community (90–100%). Aerial insectivores, in particular, were most abundant in burned areas, likely because they rely on standing dead trees as perch sites from which to sally from and catch prey (Hutto 1995). Despite an abundance of downed trees, bark probing insectivores did not occur in salvaged areas. Species whose maximum abundance occurred in salvaged areas tended to be omnivorous or foliage (shrub) insectivores.

In terms of nesting habitat, species whose maximum abundance occurred in salvaged areas tended to be ground or shrub nesters. Not surprisingly, species that generally require standing trees with or without foliage for nesting were excluded from this habitat. Two cavity nesters were detected in salvaged areas: tree swallows and house wrens. Tree swallows are known to forage in open habitats, while the house wren is known to avoid thick vegetation and was likely nesting in the occasional standing trees left behind or along the edge of the burned forest.

Response of the songbird community

Based on species composition, our ordination results separated sites along the first axis according to treatment (unburned, burned, or salvaged), while the site order along the

second axis corresponded to a forest type gradient (deciduous, mixedwood, coniferous). This result is consistent with other studies, which have found that bird communities vary along a forest type continuum from deciduous to coniferous (Welsh and Loughheed 1996; Kirk et al. 1996). Most other community studies have evaluated changes in bird communities in response to treatments or across different age-classes in one forest type (e.g., Schieck et al. 1995; Hobson and Schieck 1999; Imbeau et al. 1999). Hobson and Schieck (1999) found significant differences in communities among post-fire and post-harvest stands of different age-classes in mixedwood forest. Imbeau et al. (1999) examined the same question but in black spruce forests and also found significant differences in community composition. Although post-harvest stands are different from salvaged stands in that they have not been burned prior to harvest, our results are similar. Each forest type in our study except mixedwood was significantly separated along the first axis among treatments.

Our results indicate that salvage logging generates a community assemblage of songbirds distinct from the community found in burned forests. Hobson and Schieck (1999) found that the bird communities in post-fire and post-harvest mixedwood forest were distinct. Based on our ordination results, the difference between the unburned and salvaged songbird community was greater than between burned and unburned forests. Thus, we conclude that salvaging represents a greater disturbance than fire alone.

Strengths and limitations of the study

Our results are based on the relative abundance of songbird species in different habitat types. Although some species are more abundant in burned habitat, this area may

Fig. 3. Two-dimensional plots depicting DCA results for (a) jack pine, (b) mixedwood, and (c) aspen forests. Confidence ellipses include 80% of sites in each treatment type.

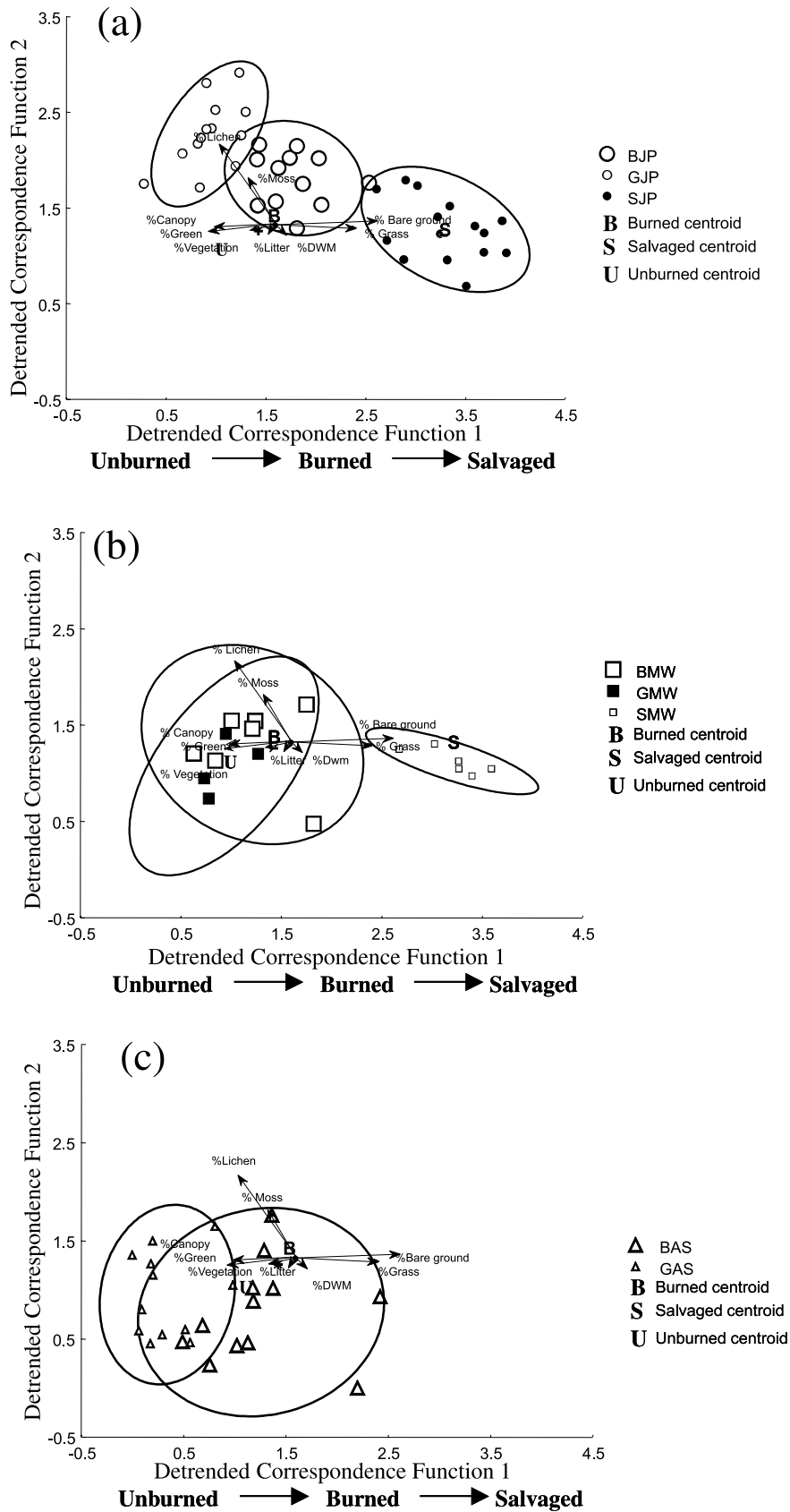


Table 5. Tests for statistical differences in bird communities among three forest types and two treatment types in boreal forest of Saskatchewan.

Forest	Comparison type	<i>N</i>	<i>F</i>	<i>P</i>
Mixedwood	All sites	3	3.57	0.001
	Burned vs. unburned	2	0.95	0.540
	Burned vs. salvaged	2	3.65	0.001
Jack pine	All sites	3	7.16	0.001
	Burned vs. unburned	2	2.95	0.001
	Burned vs. salvaged	2	5.02	0.001
Aspen	Burned vs. unburned	2	1.87	0.001
	Unburned	All sites, all forest types	3	4.19
Burned	All sites, all forest types	3	4.05	0.001
Salvaged	All sites, all forest types	2	2.57	0.200

Note: Tests were conducted using a bootstrap Monte Carlo procedure in a canonical correspondence analysis, with forest types and treatment types coded as dummy variables and included as the only environmental variables (Hobson and Schieck 1999; ter Braak 1992). *N*, number of stand types included in the analysis.

actually act as a habitat sink with large numbers of birds occurring but not breeding successfully (Donovan et al. 1995; Reijnen and Foppen 1995; Pulliam 1988). We did not measure reproductive success, and abundance is not necessarily an accurate assessment of habitat quality (Van Horne 1983). Measures of reproductive success, such as nest success and fledgling survival, would compliment our results (Anders et al. 1997). In addition, resident species are better detected by surveys undertaken in April, and thus, this group was likely underrepresented in our study.

Another potential limitation was that burning did not occur with equal intensity. Although the majority of trees in burned stands had been killed, all stands did not contain the same quantity of live residual trees. Our sample sizes did not permit an independent examination of the effect of fire intensity. Thus, poor separation between unburned and burned mixedwood in particular was probably due in large part to unsalvaged mixedwood stands used in this study having burned at a lower intensity (thus resulting in the presence of live residual trees) than the other forest types.

However, despite these limitations, the fact that we collected data for a number of habitat types within one burn increases the general applicability of our results. Our design allowed us to examine how the songbird community uses a broad spectrum of habitats in a post-fire setting. A species that may appear rare in one forest type may actually be quite abundant in another, which is especially important when addressing management questions that require knowledge about the relative importance of different forest types.

Implications for conservation and management

To our knowledge, no other study has quantitatively evaluated the impact of salvage logging practices on songbirds in North America. Where policy exists regarding this practice, it has been developed in the absence of scientific data to support it. Our results demonstrate that early post-fire habitats represent important habitat for songbirds, which corroborates other studies examining bird community composition in post-fire habitats (Hutto 1995; Hobson and Schieck 1999; Imbeau et al. 1999).

We found that salvaging eliminated some resident species and reduced the number of insectivores in the songbird community. The reduction in insectivores may not be a concern during the breeding season when prey are not likely limiting. However, resident species may rely on the wood-boring insects associated with post-fire stands as an important winter prey base. Furthermore, salvage logging reduces the number of available nesting sites for both cavity and canopy nesters. Thus, resident species may be more at risk from this practice than tropical migrants (Imbeau et al. 2001).

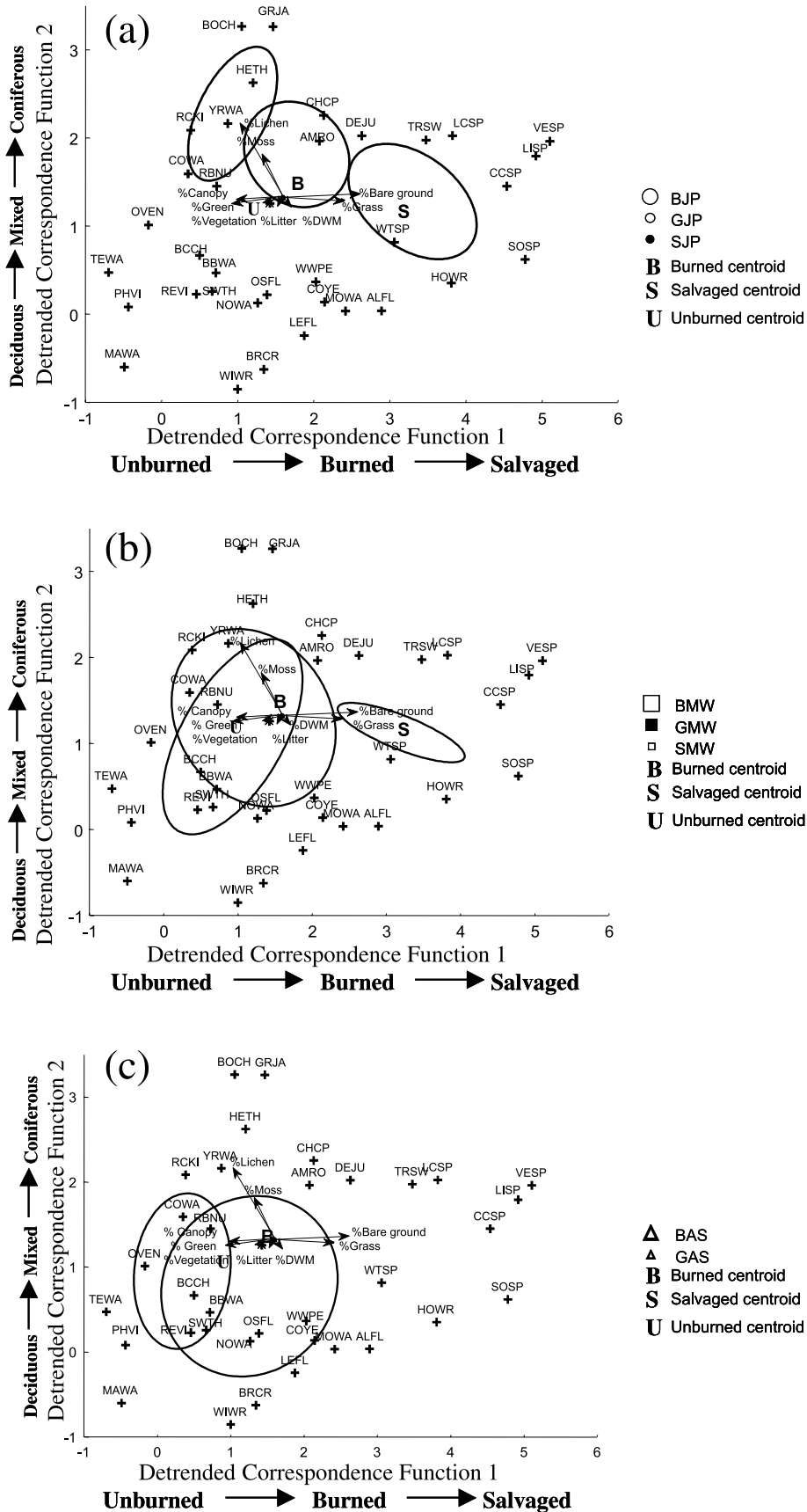
Because burned forests provide some degree of structure and cover, these areas may also help to maintain the connectivity of the landscape, especially between unburned patches of forest left in the wake of the fire. The approach to salvaging in this area is to harvest mainly dead trees and to leave unburned forest stands within the boundaries of the fire intact resulting in disconnected patches of green forest that may inhibit the movement of some species with more restricted habitat preferences (Machtans 1996; Desrochers and Hannon 1997; Rail et al. 1997).

From a conservation perspective, species that occur in many cover types are less at risk than species with more restricted habitat requirements (Hutto 1995; Imbeau et al. 2001). The capacity of a species to use open areas (caused by salvaging or harvesting), young forests or sapling stages, and mature forests will influence the likelihood it will experience a population decline as a result of habitat loss. Therefore, species that are relatively restricted to older forests, which are most valuable commercially, and to burned forests, which are now more frequently harvested, should evoke the greatest concern. Species that fit these criteria include the black-backed woodpecker, three-toed woodpecker, brown creeper, and olive-sided flycatcher (Apfelbaum and Haney 1981; Hutto 1995; Hobson and Schieck 1999; Imbeau et al. 1999; Drapeau et al. 1999). The northern hawk owl and western wood-pewee demonstrate more plasticity in their habitat use but may also be vulnerable (Westworth and Telfer 1993; Hobson and Schieck 1999). Black-backed woodpecker populations may be maintained by a network of unsalvaged burns (Hutto 1995; Murphy and Lehnhausen 1998), and this may also be true of the other species found to be most abundant in burns.

A current belief in forest management is that in order for harvesting to be sustainable, the patterns of harvesting should emulate natural disturbance as much as possible (e.g., Attiwill 1994; Bunnell 1995; Stelfox 1995; DeLong and Tanner 1996). However, clearcuts and fires are distinct for several major reasons including (i) logging causes a greater site disturbance because of equipment and road construction; (ii) logging generally results in the removal of all stems from a site; (iii) fire leaves live residual stands, burned trees, and downed woody debris; (iv) fire size, frequency, and distribution is different from cutblocks; and (v) fire is not predictable and does not target the most economically valuable stands or tree types (Thompson 1993; Hutto 1995). Although salvaged areas are different from harvested areas in that they have been burned, they are otherwise more similar to harvested areas than to post-fire forests.

We suggest that salvage logging practices, like harvesting practices, should be undertaken in a manner that best emulates natural disturbances. The primary change that must oc-

Fig. 4. Two-dimensional plot depicting DCA results for (a) jack pine, (b) mixedwood, and (c) aspen forests. Confidence ellipses include 80% of sites in each treatment type. Points for sites have been removed and ordination results for bird species added. Codes for species names are located in Appendix Table A1.



cur is to ensure adequate retention of standing dead trees on the landscape. Salvage logging reduces structural heterogeneity provided by standing burned trees as the forest regenerates around them. Therefore, if salvaging is necessary to minimize economic losses we propose the following to maintain a larger number of standing burned trees on the landscape. First, some areas should be set aside within large burns and remain unsalvaged (Hutto 1995). These areas should represent as many forest types as possible, including stands of commercially valuable forest (i.e., large trees). Currently, many of the burned stands left unsalvaged are smaller trees with little merchantable value. At the landscape level, maintaining all successional stages will result in the highest diversity of species (Crête et al. 1995). A second option may be to salvage smaller areas, which would reduce the size of gaps between patches of unburned forest. Since burned forests likely represent good foraging areas for birds, burned forest should be left unsalvaged adjacent to unburned patches so that species that cannot nest in the burned forest, but may forage there extensively, can also benefit.

Our study lends empirical support to the recommendations of previous authors who suggest that the retention of large burned trees of many different forest types on the landscape is essential for healthy bird communities (Welsh 1993; Hutto 1995; Hobson and Shieck 1999; Imbeau et al. 1999). This recommendation, in combination with ensuring a continuing supply of different forest types, tree species, and forest ages, will contribute to maintaining future avian biodiversity and potentially the biodiversity of the forest in general (Mönkkönen and Welsh 1994).

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Appendix A

Table A1. Maximum abundance per station for each species in each of the forest and treatment types sampled 1998.

Species	Code	Forest and treatment type*											
		SMW	UMW	BMW	BJP	SJP	UJP	BAS	UAS				
Three-toed woodpecker, <i>Picoides tridactylus</i> (2) [†]	TTWO	—	—	—	0.08±0.08	—	—	—	—	—	—	—	—
Black-backed woodpecker, <i>Picoides arcticus</i> (2)	BBWO	—	—	0.14±0.14	0.17±0.11	—	—	—	—	—	—	—	—
Olive-sided flycatcher, <i>Contopus borealis</i> (20)	OSFL	—	0.25±0.25	0.14±0.14	0.42±0.15	—	0.08±0.08	—	—	—	0.33±0.14	—	—
Western wood-pewee, <i>Contopus sordidulus</i> (9)	WWPE	—	—	—	0.33±0.19	—	—	—	—	—	0.25±0.13	—	—
Yellow-bellied flycatcher, <i>Empidonax flaviventris</i> (3)	YBFL	—	—	—	—	—	—	—	—	—	0.08±0.08	—	—
Alder flycatcher, <i>Empidonax alnorum</i> (21)	ALFL	—	0.25±0.25	0.14±0.14	0.08±0.08	0.53±0.17	—	—	—	—	0.50±0.19	0.08±0.08	—
Least flycatcher, <i>Empidonax minimus</i> (9)	LEFL	—	—	—	0.08±0.08	—	—	—	—	—	0.50±0.26	0.08±0.08	—
Eastern phoebe, <i>Sayornis phoebe</i> (2)	EAPH	—	0.50±0.29	—	—	—	—	—	—	—	—	—	—
Easter kingbird, <i>Tyrannus tyrannus</i> (1)	EAKI	0.17±0.17	—	—	—	—	—	—	—	—	—	—	—
Tree swallow, <i>Tachycineta bicolor</i> (14)	TRSW	0.33±0.21	—	0.14	0.33±0.19	0.27±0.12	—	—	—	—	0.08±0.08	—	—
Gray jay, <i>Perisoreus canadensis</i> (41)	GRJA	0.17±0.17	0.25±0.25	0.29±0.18	0.75±0.33	0.13±0.09	0.85±0.22	—	—	—	0.33±0.33	—	—
Blue jay, <i>Cyanocitta cristata</i> (2)	BLJA	—	—	—	—	—	—	—	—	—	—	—	0.17
Black-capped chickadee, <i>Poecile atricapillus</i> (3)	BCCH	—	—	0.14±0.14	—	—	—	—	—	—	—	—	—
Boreal chickadee, <i>Parus hudsonicus</i> (8)	BOCH	—	0.25±0.25	—	0.25±0.13	—	0.15±0.10	—	—	—	—	0.50±0.15	0.33±0.14
Red-breasted nuthatch, <i>Sitta canadensis</i> (46)	RBNU	—	0.75±0.25	0.71±0.18	0.50±0.15	—	0.46±0.14	—	—	—	—	0.42±0.15	—
Brown creeper, <i>Certhia americana</i> (6)	BRCR	—	—	0.14±0.14	—	—	—	—	—	—	—	0.33±0.19	—
House wren, <i>Troglodytes aedon</i> (20)	HOWR	0.67±0.21	—	0.14±0.14	0.08±0.08	0.27±0.12	—	—	—	—	—	—	—
Winter wren, <i>Troglodytes troglodytes</i> (15)	WIWR	—	0.50±0.29	0.14±0.14	0.25±0.13	—	—	—	—	—	0.25±0.13	0.08±0.08	—
Ruby-crowned kinglet, <i>Regulus calendula</i> (46)	RCKI	—	0.75±0.25	0.71±0.36	0.17±0.11	—	0.23±0.12	—	—	—	0.08±0.08	0.25±0.13	—
Swainson's thrush, <i>Catharus ustulatus</i> (17)	SWTH	—	—	0.29±0.18	0.08±0.08	—	0.08±0.08	—	—	—	0.42±0.15	0.42±0.19	—
Hermit thrush, <i>Catharus guttatus</i> (74)	HETH	—	0.25±0.25	0.14±0.14	1.00±0.21	0.07±0.07	1.00±0.23	—	—	—	0.50±0.26	0.25±0.13	—
American robin, <i>Turdus migratorius</i> (18)	AMRO	0.17±0.17	0.25±0.25	0.14±0.14	0.67±0.22	0.07±0.07	—	—	—	—	0.08±0.0	—	—
Blue-headed vireo, <i>Vireo solitarius</i> (22)	BHVI	—	??±0.25	0.29±0.18	0.33±0.19	—	0.92±0.18	—	—	—	0.08±0.08	—	—
Philadelphia vireo, <i>Vireo philadelphicus</i> (6)	PHVI	—	—	—	—	—	0.08±0.08	—	—	—	0.17±0.11	0.17±0.11	—
Red-eyed vireo, <i>Vireo olivaceus</i> (60)	REVI	—	0.75±0.25	0.43±0.20	—	—	0.46±0.18	—	—	—	1.08±0.19	0.92±0.26	—
Tennessee warbler, <i>Vermivora peregrina</i> (23)	TEWA	—	0.25±0.25	0.57±0.20	—	—	0.08±0.08	—	—	—	0.25±0.13	0.75±0.22	—
Yellow warbler, <i>Dendroica petechia</i> (8)	YEWA	—	—	0.14±0.14	—	—	—	—	—	—	0.42±0.15	0.08±0.08	—
Chestnut-sided warbler, <i>Dendroica pensylvanica</i> (6)	CSWA	—	—	—	—	—	—	—	—	—	0.50±0.19	—	—
Common yellowthroat, <i>Geothlypis trichas</i> (10)	COYE	—	0.50±0.29	—	0.08±0.08	0.20±0.11	—	—	—	—	0.08±0.08	—	—
Magnolia warbler, <i>Dendroica magnolia</i> (23)	MAWA	—	0.50±0.29	0.29±0.18	—	—	—	—	—	—	0.58±0.23	0.50±0.26	—
Cape May warbler, <i>Dendroica tigrina</i> (1)	CMWA	—	—	—	—	—	0.08±0.08	—	—	—	—	—	—
Yellow-rumped warbler, <i>Dendroica coronata</i> (174)	YRWA	—	1.50±0.29	2.29±0.29	1.67±0.33	—	2.46±0.27	—	—	—	1.25±0.28	0.83±0.17	—
Black-throated green warbler, <i>Dendroica virens</i> (2)	BTWA	—	0.25±0.25	—	—	—	0.08±0.08	—	—	—	—	—	—
Bay-breasted warbler, <i>Dendroica castanea</i> (5)	BBWA	—	0.50±0.29	0.14±0.14	—	—	—	—	—	—	0.08±0.08	—	—
Black and white warbler, <i>Mniotilta varia</i> (6)	BWWA	—	—	—	—	—	—	—	—	—	0.08±0.08	0.33±0.19	—
American redstart, <i>Setophaga ruticilla</i> (2)	AMRE	—	—	—	—	—	—	—	—	—	0.08±0.08	0.08±0.08	—
Ovenbird, <i>Seiurus aurocapillus</i> (122)	OVEN	—	1.75±0.25	1.29±0.42	0.08±0.08	—	0.77±0.77	—	—	—	1.50±0.34	2.75±0.08	—
Northern waterthrush, <i>Seiurus noveboracensis</i> (7)	NOWA	—	0.75±0.25	0.14±0.14	—	0.07±0.07	—	—	—	—	—	—	—
Connecticut warbler, <i>Oporornis agilis</i> (23)	COWA	—	0.50±0.29	—	0.17±0.17	—	0.08±0.08	—	—	—	0.33±0.14	0.58±0.23	—

Mourning warbler, <i>Oporornis philadelphia</i> (22)	MOWA	1.17±0.31	0.25±0.25	0.14±0.14	—	—	—	—	0.50±0.19	0.17±0.17
Canada warbler, <i>Wilsonia canadensis</i> (1)	CAWA	—	—	—	—	—	—	—	0.08	—
Western tanager, <i>Piranga ludoviciana</i> (1)	WETA	—	—	0.14±0.14	—	—	—	—	—	—
Rose-breasted grosbeak, <i>Pheucticus melanocephalus</i> (7)	RBGR	—	—	—	—	—	—	—	0.17±0.11	0.42±0.15
Chipping sparrow, <i>Spizella passerina</i> (98)	CHSP	0.67	—	0.29±0.18	1.33±0.31	0.73±0.18	0.69±0.21	0.50±0.19	0.08±0.08	0.08±0.08
Clay-colored sparrow, <i>Spizella pallida</i> (54)	CCSP	1.83	—	0.14±0.14	—	1.73±0.34	—	0.08±0.08	—	—
Vesper sparrow, <i>Poocetes gramineus</i> (6)	VESP	—	—	—	—	0.27±0.12	—	—	—	—
Song sparrow, <i>Melospiza melodia</i> (9)	SOSP	0.17±0.17	—	—	—	0.40±0.19	—	—	—	—
Sharp-tailed sparrow, <i>Ammodramus caudacutus</i> (1)	STSP	—	—	—	—	0.07±0.07	—	—	—	—
Le Conte's sparrow, <i>Ammodramus leconteii</i> (3)	LCSP	—	—	—	—	0.20±0.14	—	—	—	—
Lincoln's sparrow, <i>Melospiza lincolni</i> (17)	LISP	0.17±0.17	—	—	—	0.53±0.19	—	—	—	—
White-throated sparrow, <i>Zonotrichia albicollis</i> (273)	WTSP	5.50±0.22	0.75±0.25	1.86±0.5	1.75±0.39	4.00±0.37	—	2.50±0.4	0.42±0.019	—
Dark-eyed junco, <i>Junco hyemalis</i> (61)	DEJU	1.00±0.37	—	0.29±0.18	1.00±0.21	0.47±0.17	0.15±0.10	—	0.08±0.08	—
Pine siskin, <i>Carduelis pinus</i> (2)	PISI	—	—	—	—	—	0.08±0.08	0.08±0.08	—	—

Note: Values are means ± SEs.

*SMW, salvaged mixedwood; BMW, burned mixedwood; UMW, unburned mixedwood; SJP, salvaged jack pine; BJP, burned jack pine; UJP, unburned jack pine; BAS, burned aspen; UAS, unburned aspen.

[†]Overall number of individuals detected of each species.