University of Alberta

Stand-Level Response of Boreal Forest Songbirds to Experimental Partial-Cut Harvest in Northwestern Alberta

by

Robert Bruce Harrison ©

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ABSTRACT

This research is a component of the EMEND project in northwestern Alberta, initiated to determine how harvest and regeneration of upland mixedwoods can best be modelled on a natural disturbance regime. EMEND is an interdisciplinary experiment to compare partial retention cuts (0%, 10%, 20%, 50%, and 75%) in four cover types (Deciduous, Deciduous with spruce understory, Mixed, and Coniferous) with uncut forest, and with experimentally-burned stands. I studied forest breeding bird communities at EMEND for three years between 1998 (pre-treatment) and 2000, focussing on the response of songbirds to the partial harvesting, as detected by point count sampling. Partial cuts were generally intermediate (and varied in a linear fashion) between clearcuts and controls for community and species-level measures. Species which declined in abundance in partial cuts were typically dependent on shrubs and trees, whereas species which increased in abundance were typically ground nesters. In 2000 I added two survey techniques to better assess reproductive success: I monitored breeding behaviours of the Swainson's Thrush in Deciduous/Understory sites, and detected a negative impact of harvesting which point count surveys failed to reveal. I also used a call playback technique to increase bird observation rates at the community level, and collected significant additional information relating to productivity, across all cover and treatment types.

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Anyone who's lived through a Master's program knows that some of the most productive discussions come from one's graduate student colleagues. I'm obliged to Nicola Koper, in particular, for reminding me to keep the science in ecology, and to Alastair Franke for providing some great coffee table conversations about the 'big picture'.

Robin Naidoo preceeded me in this project, and I'm grateful for the valuable groundwork he set. We were both blessed with a remarkable field staff: Corry Dow, Shannon Quinn, and most importantly, Lisa Christensen, who spent two years at EMEND, and who supplied the continuity this study required. I appreciated their hard work, and just as importantly, their laughter at 4 in the morning, even in a snowstorm (yes, there were one or two, but don't worry, Fiona, I excluded penguins from the analyses).

In addition to its many measureable benefits, a multi-disciplinary, multi-partner project such as EMEND bears with it a number of 'unmeasureable' returns: bringing together so many young (and not so young) minds for a prolonged period inevitably sparks new interests, stimulates old ones, and spawns more than a few good ideas. I hope I've played some part in that, but regardless, I'm grateful to the many graduate students, field assistants and other scientists at EMEND who took the time to share their knowledge, ideas, and stories.

Most importantly, I am forever indebted to my wife Shari for re-arranging her life to accommodate my frequent forays into both the forest and the big city, and for lending an ear whenever I needed one. And a final thanks, for his patience, to my dog Cody, who still licks my face even when I've left him alone for weeks on end.

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Chapter 1 Thesis Introduction

1.1 Background

In recent years, much research attention has been focussed on songbirds, owing in part to observed declines in Neotropical migrant populations in eastern North America (e.g., Robbins et al. 1989, Sauer et al. 1996). Declines have been linked to loss and fragmentation of forest breeding habitats, due to factors such as clearcut logging, agricultural clearing and urban development. However, evidence suggests that alteration of wintering and migration ranges has also played a role (Robbins et al. 1989, Sherry and Holmes 1992, Rappole and McDonald 1994, Sauer et al. 1996). Despite the uncertainty regarding breeding range impacts, and a recent claim that evidence for a general decline of Neotropical migrants is weak (James 1998), concern for songbird populations in western North America is not misplaced. While similar population declines have not been detected in the west (Sauer and Droege 1992, Sauer et al. 1996), this may simply reflect the more intact nature of many western forests. Given our knowledge of forest harvesting impacts on bird communities, it seems reasonable to expect that there may be consequences to the large-scale harvesting now underway in these forests.

At the stand level, forest harvesting creates conditions amenable to species favouring early successional habitats (e.g., Crawford et al. 1981, Thompson et al. 1992), and generally leads to a decrease in the number of habitat dimensions available to birds (DesGranges and Rondeau 1993). In other words, the forest characteristics that create ecological niches for birds are those which are reduced by harvesting: vegetation composition and layering (MacArthur and MacArthur 1961, Franzreb and Ohmart 1978), snags and coarse woody debris (Niemi and Hanowski 1984, Hansen et al. 1991, Westworth and Telfer 1993) and stand age (Schieck and Nietfeld 1995, Kirk et al. 1996).

At the landscape scale, the issue is more complex: effects depend on clearcut size, arrangement and rotation period, and impacts may vary according to species, but the negative impacts at this larger scale are primarily due to habitat loss and fragmentation. Fragmentation effects are manifested through ecological mechanisms such as edge-related nest predation (Wilcove 1985, Donovan et al. 1995) and parasitism (Brittingham and Temple 1983, Robinson et al. 1993), and isolation effects (Faaborg et al. 1993, Andren 1994). In addition, some studies (e.g., Villard et al. 1993, King et al. 1996) have found that fragmentation reduces pairing success for area-sensitive species such as the Ovenbird (*Seiurus aurocapillus*). Forest fragmentation can be temporary, if created by harvesting and regeneration within a mature forest matrix, or permanent, if a result of land conversion (e.g., to agricultural use) within a forest matrix. In general, the effects of temporary fragmentation appear less severe, though information on the relative impacts of the two types is still lacking.

On a continent-wide basis, the relative impact of fragmentation on birds has been questioned. Much of the research has been conducted in eastern North America; in the west, fragmentation effects appear less significant (Vander Haegen and DeGraaf 1996, Donovan et al. 1997, Schmiegelow et al. 1997, Tewksbury et al. 1998), possibly due to factors relating to landscape context (e.g., permanency of habitat conversion in the forest matrix, degree of fragmentation, predator and parasite abundance) and natural disturbance regime. Nevertheless, the issue of logging impacts on bird habitat is significant in Alberta. In the last decade, large-scale harvesting of aspen has become a major industry in the province, and as of 1997, 40% of boreal and 75% of mixedwood areas were under tenure to logging companies (Schmiegelow and Hannon 1999). The standard silvicultural system involves two-pass or three-pass clearcutting, wherein roughly equal volumes of timber are harvested from alternating cut-and-leave blocks (Alberta Environmental Protection 1994), and oldest forests are given priority for harvest. Potential impacts are magnified by the multiple-use nature of the boreal forest, in which agricultural and oil/gas operations also convert large areas of forest to non-forest habitats.

Recently, efforts have been made to mitigate harvesting impacts on ecological integrity through a natural disturbance paradigm, which suggests that critical processes inherent in forest systems might be maintained by emulating natural disturbance patterns (DesGranges and Rondeau 1993, Hunter 1993a, Haila 1994), for instance via partial-cutting. Natural disturbances such as fire (the major agent of stand replacement in the western boreal forest) typically leave structural legacies of live and dead woody material, reducing the contrast between disturbed and undisturbed stands (Hansen et al. 1991). If partial-cutting can leave behind similar legacies, harvesting might better approximate natural patterns (Lee et al. 1997), and the impact of tree removal can be lessened (Merrill et al. 1998, Schieck et al. 2000).

The usefulness of the natural disturbance approach still requires substantial empirical support. There is debate as to whether logging can effectively mimic fire (DesGranges and Rondeau 1993, Hutto 1995) in terms of site disturbance, soil fertility, and residual snags and woody debris. Comparisons of fire- and logging-origin boreal stands indicate convergence over time for spider communities (Buddle et al. 2000), but only partial convergence in terms of vegetation (Crites 1999) and bird communities (Schulte and Niemi 1998, Hobson and Schieck 1999). More generally, the effects of partial cutting on bird communities have been studied throughout western North America, including areas in the western U.S.A. (Szaro and Balda 1979, Medin and Booth 1989), the Pacific Northwest (Hansen et al. 1995, Beese and Bryant 1999), and the British Columbia Interior (Steventon et al. 1998). In the boreal mixedwood forest of western Canada, Norton and Hannon (1997) and Tittler (1998) examined the effects of group retention harvesting in deciduous-dominated forest in northeastern Alberta. In general, these studies have indicated that partially-harvested stands initially retain a portion of the mature forest bird community not found in clearcuts, while still allowing the incursion of some early successional species.

The EMEND Project (**E**cosystem **M**anagement by **E**mulating **N**atural **D**isturbance) is an interdisciplinary research project initiated in 1995 in northwestern Alberta, Canada. EMEND is an attempt to model forest harvest and regeneration of upland mixedwood forests on natural disturbance regimes in northwestern Alberta, primarily via a comparison of partial-retention cuts (human-caused disturbances) with stands burned at a variety of intensities (natural disturbances). A cooperative effort between industry, government and university scientists, the EMEND framework provides an ideal opportunity for an integrated investigation into the effects of residual material management on ecosystem function, stand dynamics and biotic community structure. The initial harvesting implications have already been measured for a wide variety of ecosystem attributes, including regeneration, primary productivity, soils and nutrient cycling, and several vegetation and biodiversity indices. The ongoing nature of the project, in which selected indices will be re-measured every 5-10 years, will enable long-term research into the successional trajectories resulting from treatments.

This thesis is the result of three years of field study (1998-2000) of the effects of partial cutting at EMEND on songbird communities. Research was focussed on the short-term response of breeding boreal forest songbirds to various levels of partial cut harvesting, as detected by point count sampling (Chapter 2). To date, burn treatments have been mostly postponed due to inappropriate environmental conditions. In the final year of the study, I also investigated the utility of two alternative sampling methods in supplementing or replacing the point count technique (Chapter 3). Point counts estimate the relative abundance or density of birds, but many researchers (van Horne 1983 and others) have found that bird density may not be an accurate indicator of habitat quality. Because the alternative sampling methods incorporated more direct measures of reproductive success, I anticipated they would help me to more accurately link habitat quality to harvesting level. Chapter 4 concludes with a summary of research results and a discussion of suggested directions for future research.

Chapter 2 Response of A Forest Songbird Community to Experimental Partial-Cut Harvest

2.1 Introduction

Alberta has adopted a formal policy of sustained yield management for its forests (Alberta Environmental Protection 1996), and standards of conduct require managers to consider the impact of logging on other resources and forest users in their harvest operations (Alberta Environmental Protection 1994). These principles have the potential to help significantly with conservation of bird communities. Boreal forest studies in Alberta (Schieck and Nietfeld 1995) and western Canada (Kirk et al. 1996) have shown that older stands exhibit highest species richness, and conclude that if forest harvesting reduces the proportion of these stands in a landscape, some boreal bird species (and Neotropical migrants, in particular) may be negatively impacted. However, Schieck and Nietfeld (1995) stress that negative impacts may be lessened through the conservation of stand attributes such as live trees, snags, and downed woody material.

The EMEND project is one of the adaptive management elements in an integrated management plan developed by two of the major softwood and hardwood forestry operations in Alberta (Canadian Forest Products and Daishowa-Marubeni International). The management plan adopts a low risk strategy to ecosystem management through a coarse filter approach, in which forestlands are managed within a range of natural variability defined by factors such as species composition, age class distribution, stand size distribution and within-stand structure (T. Vinge, Canadian Forest Products, Hines Creek, AB, personal communication). In a coarse filter approach to ecosystem management, habitat diversity is used as a surrogate for biological diversity, with the assumption that if stand and landscape attributes are maintained within the range of natural variability, the habitat needs of most species will be met.

EMEND represented a good opportunity to explore the efficacy of the coarse filter approach, by testing whether traditional logging practices in the boreal mixedwood forest could be modified at the stand level to better accommodate non-timber values, such as avian biodiversity. In this chapter I detail the results of a three-year study (1998-2000) of the effects of partial cutting on songbirds, based on a point count sampling technique. Harvest effects were evaluated at the community, guild, and species levels. Burn treatments were intended for spring 1999 (immediately following harvesting), but were postponed due to poor burning conditions. To date, only three of the planned 28 burns have been completed; thus, it was not possible to incorporate a natural disturbance-comparison component into this thesis (though a sizeable pre-burn database now exists). Based in part on trends found in other partial cut studies in western North America, I predicted that partial cuts would be intermediate between clearcuts and unharvested controls for all community measures, in all forest cover types, and that measures would vary linearly with level of tree retention. I also predicted that guilds and species dependent on shrub or tree cover for nesting and foraging would be most negatively impacted by partial cutting, and that their abundance would also vary linearly with level of retention.

The project was designed to address questions at the level of the stand, and consequently cannot address larger scale ecological processes in an analytic manner. Landscape context can certainly influence bird community composition and structure, but I assume that landscape context did not change significantly during the period of the study, and that bird community responses are mainly due to the effects of harvesting treatments. Discussion will relate mainly to smaller scale mechanisms related to localized habitat manipulations.

2.2 Methods

2.2.1 Study Area

The EMEND project is located in the P2 forest management area (56° 44' N, 118° 20' W) near Hines Creek in northwest Alberta. The site is within the Lower Foothills section of the Boreal Forest region (Rowe 1972), in an area of upland mixedwood forests. Climate and precipitation are characterized by long, cold winters and mild to warm summers, with summer as the wettest season (Strong and Leggat 1981); mean summer precipitation ranges from 300 to 400 mm, and mean summer temperatures range from 10.0 to 12.5° C. Dominant tree species in this region, which are usually established as a result of fire, include trembling aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), and lodgepole pine (*Pinus contorta*). Older stands are characterized by white spruce (*Picea glauca*), and wet areas of black spruce (*P. mariana*) are interspersed throughout the landscape. Understory vegetation on mesic sites is commonly composed of wild rose (*Rosa* spp.), low bush-cranberry (*Viburnum edule*) and alder (*Alnus crispa, Alnus rugosa*). The topography is generally low and rolling, with some plateau areas, and soils are typically luvisolic (Strong and Leggat 1981).

2.2.2 Experimental Design and Objectives

EMEND is a large-scale experiment (> 1000 ha) designed to systematically study combinations of two driving variables: forest canopy composition and amount of residual structure left after harvest. Four mature forest cover types were represented: 1) deciduous-dominated (80-95%), 2) deciduous-dominated with coniferous understory (extensive and at least 50% of canopy height), 3) mixed (conifer and deciduous composition each 35-65%), 4) conifer-dominated (80-95%). Deciduous trees were primarily trembling aspen, with a secondary balsam poplar component; coniferous trees were almost exclusively white spruce. Within each cover type, six levels of tree retention were chosen: 0% (clearcut), 10%, 20%, 50%, and 75% and 100% (control). Three replicates of each treatment were selected for each forest type, to represent the range of conditions in the region (Table 2.1). In this thesis, I will use 'retention' and 'residual' as synonymous terms.

Table 2.1: Schematic representation of experimental layout at EMEND, Alberta, Canada.

		Cover Type			
		Deciduous	Deciduous / Understory	Mixed	Conifer (white spruce)
Retention Level	0% (clearcut)	□□□	□□□	□□□	□□□
	10%	□□□	□□□	□□□	□□□
	20%	□□□	□□□	□□□	□□□
	50%	□□□	□□□	□□□	□□□
	75%	□□□	□□□	□□□	□□□
	100% (control)	□□□	□□□	□□□	□□□
		(Each combination replicated three times)			

Site selection took place in 1997, through identification of reasonably homogeneous stands. Harvesting treatments were carried out in the winter of 1998-99 in cutblocks or 'compartments', each 8-10 ha in size. Harvesting was in a uniform shelterwood strip pattern (Figure 2.1), with 15m wide retention strips separated by 5 m wide machine corridors, oriented in a north/south direction (perpendicular to prevailing winds). Different levels of tree retention were attained by varying the degree of tree extraction from retention strips. Two additional elliptical patches (0.25 ha and 0.5 ha) of trees were retained in most of the harvested blocks, for use as intra-stand controls for other studies. Compartments were arranged in a partially blocked design, with constrained allocation of treatment types, and separated from the surrounding landscape (but not from each other) by 50-100 m buffers. EMEND was developed via the joint efforts of university, government and industry researchers prior to my involvement in the project, and, consequently, I had no input to its design or implementation.

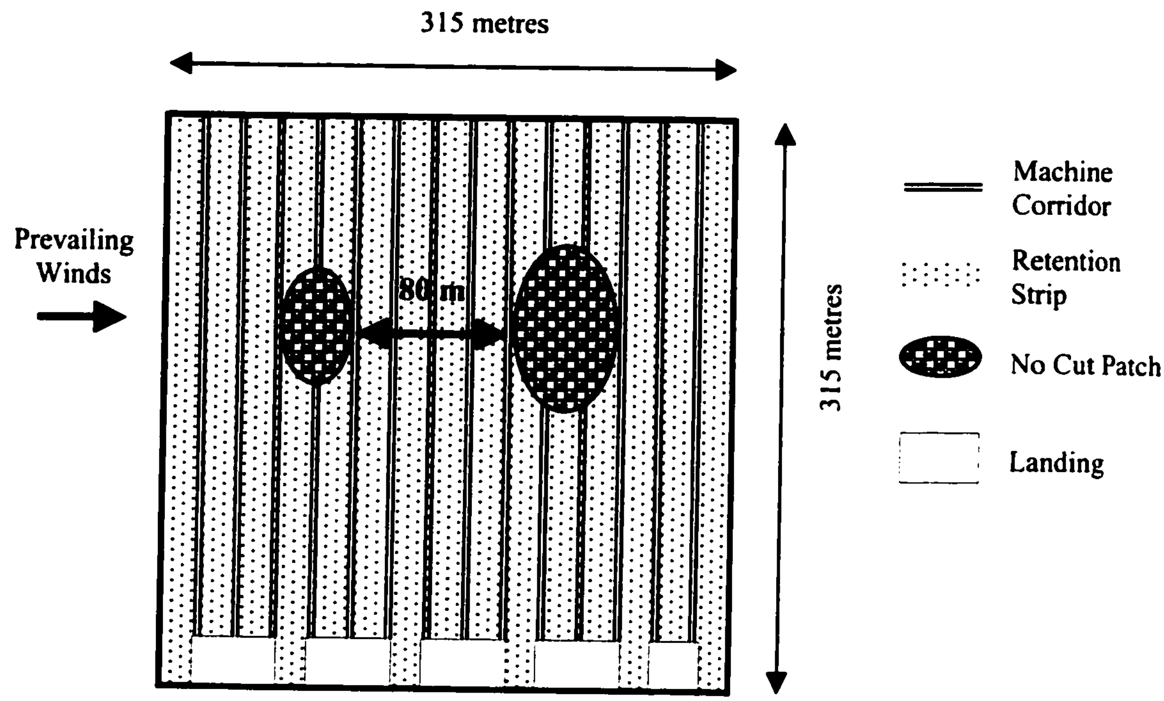


Figure 2.1: Schematic representation of compartmental layout at EMEND.

Three years of field research into forest bird communities were conducted at EMEND. Background data were collected in the spring/summer of 1998, and harvesting occurred the following winter. Post-treatment sampling was conducted in 1999 and 2000. Harvesting implications have been interpreted in relation to pre-harvest conditions and uncut control stands. In addition, standardized pre-treatment and initial post-treatment data on certain biotic and abiotic response variables (mostly relating to site productivity and diversity) have been collected by a 'Core' program to support experiment-wide interpretation of effects. These data are available for the use of all EMEND researchers. My major objectives were to monitor the immediate response of forest birds (at the community, guild and species levels) to varying levels of harvest, and to explore potential mechanisms responsible for the observed bird response, using data from other EMEND research into vegetation and invertebrate responses. Unfortunately, due to the timing of this study and some initial limitations in EMEND's data sharing capability, I have been able to incorporate only a limited amount of other EMEND research into my analyses. I also conducted a concurrent study of the distribution, characteristics and use of wildlife trees by birds in selected forest cover types in 1999 and 2000, but that research will be presented in a subsequent technical report.

2.2.3 Vegetation Surveys

1998 (Pre-disturbance)

The composition and structure of the vegetation surrounding each bird sampling station in each compartment was surveyed in August, using a protocol modified from Martin (1992a). Circular plots of 0.04 ha were centred on the station. Ground cover in seven categories (all green, grass, shrub, forb, leaf litter, downed woody debris, moss/fern) was estimated to the nearest 5%, in four nested 1 m^2 quadrats. Stems of shrubs between 50 and 140 cm high were also counted within these quadrats. Saplings (dbh<2.5 cm) and poles (dbh 2.5-8 cm), by species, were counted in a 0.008 ha nested subplot, and counts of tree species in four diameter classes (8-15 cm, 15-23 cm, 23-38 cm and >38 cm) were tallied for the entire plot. We also recorded the number of snags in five diameter classes (8-12 cm, 12-15 cm, 15-23 cm, 23-38 cm and >38 cm).

2000 (Post-disturbance, Year 2)

Vegetation surveys were conducted using the same methodology in the same compartments; however, the exact 1998 sampling points could not be relocated in many cases due to harvesting impacts on the station markers. Plots overlapping retention ellipses were moved outside the ellipse in a randomly chosen direction, to better represent treatment-related changes.

In addition, vegetation studies conducted by the 'Core' Program at EMEND in 1998 and 1999 included two components of immediate relevance to my project: shrub surveys (1998 only) and tree surveys (1998 and 1999). Both survey types were performed within six rectangular 0.008 ha mensuration plots in each compartment. Plots were randomly situated. Trees were counted and measured by species throughout the whole of each plot. Shrubs were counted and measured by species in two 0.002 ha nested subplots.

2.2.4 Bird Surveys

A fixed radius point count method was used in all three years of the study to estimate relative abundance within treatments. Surveys were conducted between mid May and early July in all years, as recommended by Ralph et al. (1995). A 'count' is a single round of surveying at a particular 'point' location. Every combination of cover type and treatment was sampled, and each compartment contained one or two randomly-situated points, depending on its configuration. Each point was visited 3-5 times during the breeding season.

During each visit, observers recorded all birds seen and heard within a given radius around the point, during a 5-minute sampling interval between 4:45 AM and 10:00 AM, consistent with the approach described by Hutto et al. (1986). Approximately half of the point count stations were 100 m radius counts, where observations were noted within two concentric circles: one at 50 m, one at 100 m. At the remaining points, observations were limited to one 50 m radius circle, due to compartment size constraints. Species name, behaviour, and mode of detection were all noted, and bird locations were mapped relative to the centre point and radii. Birds observed flying over the habitat were recorded in the field, but excluded from all analyses.

The methodology was standardized to reduce possible sources of bias (Verner 1985, Barker and Sauer 1995), and to reduce the effects of variable detectability among species (Pendleton 1995). Seasonal and diurnal timing were standardized among survey years. From one round to the next, each point was visited at a different time of the morning, by a different observer, to lessen the effects of temporal and observer biases. Surveys were not conducted if wind was above 25 km/h (Beaufort level 5; small branches move), or during rainfall more severe than a light drizzle. Either two or three observers conducted surveys, with some overlap of personnel between years. Observers were trained in detection and counting techniques, and were of comparable ability at visual and auditory identification of local breeding birds. We spread visits throughout the breeding season (e.g., one visit every 9 or 10 days) to address seasonal changes in the detectability of different species groups (Best 1981).

Point count stations were situated a minimum of 50m (small radii) or 100m (large radii) from compartment boundaries, and a minimum of 150m (all radii) from other stations in the compartment, to minimize the probability of encountering the same bird at more than one station. Independence was probably not achieved, particularly for conspicuous species, but observers tried to avoid counting the same individual at adjacent stations, which was aided by the relatively short count duration.

2.2.5 Analyses

Prior to performing analyses, data were tested for normality using scatterplots, Q-Q plots, and Kolmogorov-Smirnov tests, and for homoscedasticity using Levene's test (Conover 1980), except where noted. If necessary, data were transformed to meet assumptions of parametric statistical tests. If assumptions could not be met, weight estimation regression (in which data points within a group are weighted by the inverse of their group variance [SPSS Inc 1999]) and Kruskal-Wallis ANOVA were used. Because sample sizes were relatively small and variation was typically high, outliers were not removed, and an alpha of 0.10 was used for all tests. This increased power and lessened the possibility of Type II errors, which may have important consequences for monitoring of species (Thompson and Schwalbach 1995, Steidl et al. 1997). The Tukey correction for unplanned multiple comparisons was used where appropriate (Neter et al. 1985). Because the number of stations varied among compartments, sampling effort and precision also varied, and therefore a weighting factor was incorporated into analyses where possible. Except where noted, all analyses were conducted using SPSS Base 10.0 for Windows (SPSS Inc.

1999), and S-PLUS 2000 (Mathsoft Inc. 1999). GPOWER (Faul and Erdfelder 1992) was used to compute a priori power.

Vegetation

The 1998 and 2000 vegetation data sets contained the same 82 variables (with an additional 32 variables measured in 2000). Prior to statistical testing, the variables were reduced using three techniques. Variables which appeared similar in terms of habitat value were combined where possible (e.g., individual low shrub species). Principal components analysis (Gauch 1982, Kent and Coker 1992) was used to identify variables which contributed most to two principal summarizing gradients, as measured by large eigenvector loadings. Finally, correlation analysis was used to identify significantly correlated variables, so that 'representative' ones could be chosen.

Data could not be directly compared between years using a Repeated Measures Analysis of Variance (ANOVA), because some survey points could not be reliably relocated after harvest. Weighted least squares regression was used to test for significant linear or curvilinear trends in means among treatment levels. Variables were also analysed using multiple one-way fixed factor ANOVAs to identify significant differences among treatment means, with significance levels adjusted via a sequential Bonferroni technique for multiple tests (Rice 1990). A multivariate ANOVA was preferred, but the assumptions (Scheiner 1993) could not be met. Variables which were heteroscedastic among treatments were arcsine–transformed if measured in percent cover, or log (x+1) – transformed if measured in counts (Sokal and Rohlf 1997).

The shrub and tree components of the Core Crew data collection program were also analysed in the aforementioned manner, to determine whether this larger data set revealed patterns which our surveys lacked the power to detect.

Birds

All bird observations were recorded, but as these surveys involved point counts, I restricted analysis to those species which may be reliably detected using diurnal visual and auditory cues. This eliminated a number of species (Appendix 2), including those which don't call spontaneously, some inconspicuous species (e.g., those with soft or barely audible calls), and primarily nocturnal species (e.g., owls and nighthawks). Species with territories which typically exceed the compartment size at EMEND (e.g. woodpeckers) were also removed. Exceptions were made for Three-toed Woodpecker (*Picoides tridactylus)*, Yellow-bellied Sapsucker (*Dendroica petechia)*, Ruffed Grouse *(Bonasa umbellus)*, Solitary Sandpiper *(Tringa solitaria)* and Gray Jay *(Perisoreus Canadensis)*, all of which occurred in significant numbers and were regularly detected during point count surveys.

All analyses were initially performed including birds recorded only within the 50 m radius circles, even if the count occurred at station with a 100 m total radius. For the community level indices, a second set of analyses were conducted including birds within the largest possible radius at a given station (hereafter termed the 'large radius' data set), for comparison with the initial 50 m analyses (termed the 'small radius' data set).

Limiting most analyses to the smaller radius data set meant a potential loss of power of statistical tests (due to smaller data sets), but my reasons for doing so were multifold. The primary method of detection was via bird vocalizations, and auditory detectability and species differentiation becomes less accurate at distances between 50 and 100 m (Wolf et al. 1995, Schieck 1999), particularly for those species with higher minimum frequencies. Furthermore, as vocalization detectability varies among forest type and age (Schieck 1999), it is likely to also vary among harvesting retention levels, potentially leading to the conclusion that bird populations differ when they do not, or vice versa (e.g., Barker and Sauer 1995, Johnson 1995). However, detectability was not my only concern in limiting the survey radius. Due to the constrained size of the compartments and the variability in logging accuracy, stations intended to have 100 m radii sometimes overlapped block boundaries. Also, using a smaller radius increased independence of stations within the same compartment, reduced possible edge effects at compartment boundaries, and ensured that vegetation measurements were in closer proximity to bird locations, thereby increasing the accuracy of inferred bird-habitat relationships (Petit et al. 1995).

All but the control compartments contained two retention ellipses, which I expected to influence bird presence. Because the locations of the ellipses were not determined until after pre-harvest data collection, point counts were not situated in a systematic manner with regard to the ellipses, and the overlap between ellipses and count radius was greater in some stations than others. Consequently, data from some compartments were influenced more by the ellipses than others. As a result, birds observed exclusively within an ellipse during a count were excluded from the count, and bird abundances at the station were adjusted for the reduced sampling area. This adjustment was made for affected stations in the 0%, 10% and 20% treatments only; at higher levels, observers found it too difficult to distinguish retention ellipses from retained forest during a count. Stations which overlapped with ellipses for more than half their radius were excluded from analysis (n=4).

Species Abundance:

To better link abundance to breeding status, a weighted ranking system (Schmiegelow et al. 1997; Table 2.2) was used for analyses of relative abundance. Species abundance within each compartment was calculated as the mean rank per station per round. In 1998, three sampling rounds were conducted, and all rounds were included in the analyses. In 1999 and 2000, five rounds were conducted, but the earliest sampling session occurred during a period in which many birds were still migrating, and only rounds two through five were included for most species. For resident birds which breed earlier, rounds one through four were used, because many of these birds had already begun to move from their breeding habitats by round five.

Table 2-2: Breeding weights assigned to bird observations during point count surveys, 1998-2000.

Behaviour/Observation Type	Rank
Family group or juvenile	2.0
Adult carrying food or nesting material	2.0
Pair or nest	2.0
Distraction display	2.0
Singing or countersinging male	1.0
Territorial dispute	1.0
Calling adult	0.5
Adult observed visually	0.5

Community Indices:

Species richness: Number of species detected per station, in all counts within each year, was calculated. To enable comparisons between treatments, rarefaction was used to compensate for the different sampling efforts between compartments by standardizing all samples to a common size of one station (see James and Wamer 1982). For compartments with two stations, the number of individuals expected at a single station was estimated (with the assumption that individuals were uniformly distributed between stations), and the number of species expected in a sample of that size was interpolated. Biodiversity Professional 32 (McAleece 1997) was used to compute rarefactions. To eliminate fractional abundance values (a requirement for the rarefaction program), individual observations were not weighted as in Table 2.1.

Data were compared within treatments between years using a Repeated Measures ANOVA with contrasts, where assumptions could be satisfied. Data in each year were analysed using least squares regression, and a one-way ANOVA. Changes in species richness between years 1-2 and years 1-3 were also analysed as described above, and Analysis of Covariance (ANCOVA) was used to compare regression lines for richness change. Because I lacked confidence in the form of the underlying population distributions for each statistic, I used a method of bootstrapping (Efron and Tibshirani 1998) to estimate means and standard errors, and linear regression coefficients with bias-corrected confidence intervals, when assumptions could be met. Bootstrapped confidence intervals may be asymmetric about the mean; thus, they are presented in the form of a range of values.

ANCOVA was used to compare regression relationships between small and large radius data sets, and between rarefied and non-rarefied data sets, but data were often heteroscedastic, so data sets were also compared as follows: the difference in richness values between the two sets was calculated for each compartment, and differences were tested using a least squares regression to identify linear or curvilinear trends, wherein a significant trend indicated a significant change in richness pattern between data sets.

Species Similarity: Similarity of communities between 1998-1999 and 1998-2000 was measured using the Morisita-Horn Index (Magurran 1988), which is not sensitive to rare species occurrence and small sample sizes. Similarity was calculated using the EstimateS program (Colwell 2000). Data in each period were analysed using weighted least squares regression and a one-way ANOVA. ANCOVA was used to compare regression relationships between periods, and to compare the regression relationships between the small radius data set and the large radius set. Means, standard errors, and linear regression coefficients and confidence intervals were bootstrapped.

Species Diversity: Rank abundance plots (Magurran 1988) were generated for each cover type using Biodiversity Pro 32, which indicated that log series modeling would be most appropriate as a diversity measure. For both small and large radius data sets, log series alpha was computed using the EstimateS program. This program calculates alpha diversity using a bootstrapping technique, in which diversity (and a standard deviation) is reported for each treatment group. T tests (Sokal and Rohlf 1997) were used to compare within-year diversity for each treatment against the control value, and values for each treatment between years. I used Bartlett's test for homogeneity of variances (Sokal and Rohlf 1997).

Guild and Species Indices:

Species were grouped into foraging and nesting guilds based on Ehrlich et al. (1988). Foraging guilds were defined by method of feeding, including aerial gleaning, bark gleaning, foliage gleaning and ground foraging; nesting guilds were defined by nest location, and included cavity, ground, and shrub/tree. For each guild and each species, relative abundances were compared within treatments between years using a Repeated Measures ANOVA with contrasts, where assumptions could be satisfied. Data in each time interval were analysed using a weighted least squares regression and a one-way ANOVA. Abundance changes between years 1-2 and years 1-3 were analysed as above, and ANCOVA was used to compare regression relationships. Linear regression coefficients and confidence intervals were bootstrapped. Changes for each treatment within each period were compared to the control value using Independent-Samples T-tests.

Bird-Habitat Relationships:

To explore additional factors which might help to explain bird responses, stepwise multiple regressions were conducted using three vegetation variables from the 2000 surveys which weren't significantly correlated to harvesting treatment levels. A second series of tests was run using three variables which were correlated to treatment level, and which showed significant linear trends following harvesting. Multiple regressions were carried out on 2000 data for community indices (species richness and similarity) and finer scale elements (guild and species abundances).

2.3 Results

2.3.1 Vegetation

Pre-harvest

Data gathered by the Core Program in 1998 revealed that cover types were dominated by three tree species (Table 2.3). Densities ranged from a low of 930 trees/ha in Deciduous sites, to a high of 1494 trees/ha in Deciduous/Understory sites.

Table 2.3: Most abundant tree species recorded by Core Program in each cover type in 1998 (pre-harvest).

Cover Type	Tree Species	% Composition	Mean dbh (cm)	Mean age (years)
Deciduous	trembling aspen	56	22.2	93
	balsam poplar	30	24.0	79
	white spruce	6	16.6	48
Deciduous/Understory	trembling aspen	55	20.3	89
	balsam poplar	9	25.1	78
	white spruce	29	15.7	62
Mixed	trembling aspen	27	25.7	113
	balsam poplar	8	24.0	93
	white spruce	53	21.8	100
Coniferous	trembling aspen	11	29.3	122
	balsam poplar	3	29.0	122
	white spruce	75	21.6	113

For each cover type, 12-13 variables were chosen from the original data set (Appendix 3). ANOVA detected no pre-harvest differences between treatments for any of the vegetation characteristics measured in 1998, but some variables exhibited significant linear regressions within cover types. In Deciduous/Understory sites, ground litter cover declined slightly with increasing subsequent residual level ($p=0.046$, $r^2 = 0.226$). Similar slight declines were observed in Mixed sites for ground shrub cover ($p=0.055$, $r^2= 0.211$) and low shrub stems ($p=0.037$, $r^2=0.244$), and in Coniferous sites for deciduous stems ($p=0.018$, $r^2=0.301$). Each was included as a covariate in tests of bird indices in 1998, but as none were found to have a significant effect, they were excluded from further analyses. In every case, the observed pre-harvest trend was absent or reversed in the post harvest surveys.

Analysis of the larger vegetation data set collected by the Core Program in 1998 revealed similar results. None of the cover types differed with regard to shrub stem counts, deciduous or coniferous pole counts, or deciduous tree counts, and only the Coniferous sites showed a slight increasing regression of coniferous tree counts on assigned treatment ($p=0.088$, $r^2=0.171$).

Post-harvest

A number of variables in each cover type displayed a significant linear trend among treatments after harvest (Tables 2.4 a-d). Silviculture research trials involving small-scale (50m by 25m) mechanical site preparations were conducted in selected treatments in Deciduous and Coniferous sites in June 1999. To test whether these trials might have affected ground- and small shrub-nesting birds, I included presence of site preparation as a covariate in tests of bird indices. As it was found to have no significant effects, it was excluded from further analyses.

Post-harvest density averaged among cover types was as follows: 54 trees/ha (clearcuts); 283 trees/ha (10% retention); 425 trees/ha (20% retention); 510 trees/ha (50% retention); 760 trees/ha (75% retention); 1286 trees/ha (controls).

Table 2.4 a: Means (and standard deviations) of vegetation characteristics in Deciduous sites in 2000 (2^{nd} year post-harvest). The significance level within each vegetation layer was adjusted (from 0.10) via a sequential Bonferroni technique for multiple tests. Significant p values are in bold type. Means with the same letter are not significantly different from one another.

		Harvest Retention Level						ANOVA[6]	Linear Regression [7,8]			
		0%	10%	20%	50%	75%	100%	p	p	r^2	interc	slope
% Ground Cover [1]	All green	66.9 (8.1)	62.8 (10.0)	53.8 (6.2)	59.1 (14.2)	58.4 (8.9)	60.0 (7.3)	0.530	0.480			
	Shrub	40.6 (18.3)	32.3 (21.0)	28.4 (13.0)	31.2 (11.2)	37.8 (7.0)	25.6 (15.3)	0.726	0.455			
	Forb	25.3 (15.9)	26.3 (6.3)	25.9 (4.0)	29.4 (12.8)	27.5 (11.2)	29.1 (8.4)	0.990	0.512			
	Grass	3.8 (5.1)	3.2 (2.4)	5.1 (5.1)	4.4 (9.3)	0.9 (0.9)	7.1 (10.5)	0.855	0.886			
	Litter	37.5 (5.9) ^{a}	49.4 (9.4) ^{ab}	51.6 (6.9) ^{ab}	62.2 (5.1) ^{bc}	71.9 (3.6) ^{c}	75.0 (15.3) ^{c}	**0.000**	**0.000**	0.777	42.9	35.4
	DWD	48.4 (16.2) ^{a}	33.8 (25.6) ^{ab}	44.4 (4.4) ^{a}	29.4 (11.2) ^{ab}	27.8 (4.9) ^{ab}	12.0 (3.62) ^{b}	0.029	**0.001**	0.503	45.4	-30.1
Shrub Layer (stems)[2]	Low shrubs	594.0 (316.8)	471.2 (343.9)	343.6 (173.7)	373.1 (159.5)	294.5 (34.0)	314.2 (217.8)	0.475	**0.079**	0.181	495.9	-229.3
	Decid saplings	11.0 (11.7)	41.3 (40.5)	7.8 (4.4)	7.3 (6.0)	13.3 (19.5)	51.3 (21.7)	0.364	0.197			
	Tall shrubs [4]	12.3 (11.4)	70.3 (79.0)	11.3 (12.9)	12.0 (16.0)	28.8 (39.8)	102.5 (63.3)	0.342	0.101			
Canopy Layer (stems)[3]	Large snags [5]	0.0 (0.0) ^{a}	0.8 (1.1) ^{ab}	1.8 (1.5) ^{ab}	1.8 (1.5) ^{ab}	4.3 (2.9) ^{b}	4.8 (4.0) ^{b}	**0.040**	**<0.001**	0.508	*0.12*	*0.64*
	All snags	0.5 (0.7) ^{a}	1.0 (0.9) ^{ab}	2.0 (1.7) ^{ab}	2.3 (2.0) ^{ab}	6.8 (3.9) ^{b}	6.0 (2.6) ^{b}	**0.020**	**<0.001**	0.574	*0.20*	*0.69*
	Decid poles	1.3 (3.1) ^{a}	7.7 (10.8) ^{ab}	1.3 (3.1) ^{a}	5.1 (12.5) ^{a}	6.4 (5.4) ^{ab}	37.0 (36.9) ^{b}	**0.043**	**0.008**	0.361	*0.20*	*1.00*
	Decid trees	1.5 (2.1)	1.3 (1.2)	7.5 (3.7)	14.3 (4.8)	32.8 (16.0)	33.5 (4.5)	**(0.008)**	**(<0.001)**	0.915	-1.5	34.5

[1] average percent cover within four 1 m^2 quadrats
[2] mean number of stems per 0.008 ha subplot
[3] mean number of stems per 0.04 ha plot
[4] height > 1.4 m; includes deciduous saplings
[5] dbh > 12 cm
[6] p values in brackets determined by Kruskal-Wallis ANOVA
[7] p values in brackets determined by weight estimation regression
[8] italicized regression equations involve transformed variables

Table 2.4 b: Means (and standard deviations) of vegetation characteristics in Deciduous/Understory sites in 2000 (2[nd] year post-harvest). The significance level within each vegetation layer was adjusted (from 0.10) via a sequential Bonferroni technique for multiple tests. Significant p values are in bold type. Means with the same letter are not significantly different from one another.

		Harvest Retention Level						ANOVA[6]	Linear Regression [7,8]			
		0%	10%	20%	50%	75%	100%	p	p	r^2	interc	slope
% Ground Cover [1]	All green	50.0 (1.1)	45.0 (7.2)	50.0 (8.6)	52.8 (13.0)	42.5 (18.4)	55.3 (11.6)	0.624	0.622			
	Shrub	23.8 (12.4)	18.9 (4.2)	19.9 (13.9)	17.2 (9.5)	17.5 (9.9)	10.3 (5.1)	0.565	**0.061**	0.203	22.2	-10.0
	Forb	24.7 (6.4)	23.1 (8.0)	17.8 (3.3)	31.3 (11.6)	20.0 (13.6)	18.1 (8.9)	(0.307)	(0.457)			
	Litter	31.3 (1.1)	57.2 (1.9)	57.8 (6.9)	54.1 (6.0)	70.9 (17.1)	48.8 (18.0)	(0.177)	(0.171)			
	DWD	50.9 (9.4) [a]	31.6 (9.4) [bc]	23.4 (3.1) [bd]	36.3 (1.1) [b]	19.1 (4.6) [cd]	13.4 (9.0) [d]	**<0.001**	**<0.001**	0.513	40.3	-26.4
Shrub Layer (stems)[2]	Low shrubs	309.3 (209.1)	235.6 (293.0)	211.1 (233.3)	171.8 (65.5)	196.3 (171.2)	127.6 (157.4)	0.856	0.197			
	Decid saplings	5.8 (8.1)	13.5 (25.1)	0.0 (0.0)	3.0 (1.7)	3.8 (5.3)	0.0 (0.0)	(0.635)	(0.667)			
	Tall shrubs [4]	5.8 (8.1)	20.8 (42.8)	0.0 (0.0)	5.3 (7.2)	13.8 (19.5)	0.0 (0.0)	(0.213)	(0.484)			
Canopy Layer (stems)[3]	Small snags	0.0 (0.0) [a]	0.5 (1.2) [a]	1.3 (1.1) [ab]	0.8 (1.2) [ab]	2.0 (2.0) [ab]	1.0 (3.6) [b]	**0.032**	**0.001**	0.487	*0.05*	*0.59*
	Large snags [5]	0.3 (0.6) [a]	1.5 (1.2) [ab]	1.8 (1.1) [ab]	3.5 (2.5) [ab]	3.5 (7.0) [ab]	9.0 (5.2) [b]	**0.028**	**0.003**	0.436	*0.21*	*0.64*
	All snags	0.3 (0.6) [a]	1.0 (2.5) [ab]	2.0 (1.7) [ab]	4.3 (3.2) [bc]	5.5 (5.3) [bc]	14.0 (5.0) [c]	**0.001**	**<0.001**	0.688	*0.25*	*0.86*
	Decid trees	0.3 (0.6) [a]	3.0 (2.2) [a]	13.3 (6.7) [b]	14.8 (4.7) [b]	15.3 (8.5) [b]	33.5 (24.2) [b]	**0.001**	**<0.001**	0.557	*0.42*	*1.11*
	Conif stems	1.3 (1.8)	17.7 (16.7)	16.1 (15.0)	9.6 (2.0)	15.4 (21.1)	28.6 (12.9)	(0.110)	**(<0.001)**	0.747	0.8	17.9

[1] average percent cover within four 1 m^2 quadrats
[2] mean number of stems per 0.008 ha subplot
[3] mean number of stems per 0.04 ha plot
[4] height > 1.4 m; includes deciduous saplings
[5] dbh > 12 cm
[6] p values in brackets determined by Kruskal-Wallis ANOVA
[7] p values in brackets determined by weight estimation regression
[8] italicized regression equations involve transformed variables

Table 2.4 c: Means (and standard deviations) of vegetation characteristics in Mixed sites in 2000 (2nd year post-harvest). The significance level within each vegetation layer was adjusted (from 0.10) via a sequential Bonferroni technique for multiple tests. Significant p values are in bold type. Means with the same letter are not significantly different from one another.

		Harvest Retention Level						ANOVA[6]	Linear Regression [7,8]			
		0%	10%	20%	50%	75%	100%	p	p	r^2	interc	slope
% Ground Cover [1]	All green	45.9 (20.4)	48.8 (15.9)	30.0 (3.3)	53.8 (4.5)	48.1 (5.3)	56.6 (17.3)	(0.397)	0.105			
	Shrub	18.6 (16.4)	12.2 (2.3)	8.7 (3.8)	18.1 (3.9)	8.8 (4.8)	9.7 (3.6)	0.228	0.317			
	Forb	19.5 (9.6)	26.9 (11.5)	12.3 (6.0)	27.2 (8.1)	17.1 (10.8)	13.8 (6.1)	0.126	0.418			
	Moss	15.9 (38.1)	17.7 (28.9)	24.1 (19.2)	14.7 (10.1)	37.6 (46.0)	49.2 (19.8)	0.433	**0.035**	0.249	*0.30*	*0.45*
	DWD	42.2 (22.6) a	30.3 (12.4) ab	46.8 (4.7) a	34.1 (10.2) ab	24.4 (16.8) ab	12.3 (6.1) b	0.033	**0.003**	0.424	43.6	-27.3
Shrub Layer (stems) [2]	Low shrubs	162.0 (183.3)	186.5 (131.0)	102.1 (49.7)	196.3 (117.8)	112.9 (133.4)	166.9 (157.7)	0.869	0.969			
	Decid saplings	0.5 (1.2)	4.8 (5.6)	1.0 (1.3)	11.3 (15.4)	2.8 (3.0)	7.8 (18.2)	0.330	0.432			
	Tall shrubs [4]	1.0 (2.5)	7.0 (10.9)	1.2 (1.1)	20.8 (34.5)	4.0 (3.3)	16.3 (35.8)	0.329	0.225			
Canopy Layer (stems) [3]	Small snags	0.0 (0.0)	0.3 (0.6)	0.0 (0.0)	1.3 (1.1)	1.0 (1.7)	2.5 (2.1)	(0.044)	**(0.030)**	0.390	0.1	2.2
	Large snags [5]	0.0 (0.0)	2.3 (0.4)	2.0 (3.2)	2.8 (2.5)	2.0 (3.3)	6.0 (0.9)	(0.071)	**(<0.001)**	0.842	1.7	4.3
	All snags	0.0 (0.0)	2.5 (0.5)	2.0 (3.2)	4.0 (3.6)	3.0 (5.0)	8.5 (2.1)	(0.053)	**(<0.001)**	0.722	1.8	6.6
	Decid stems	0.0 (0.0)	5.3 (8.3)	4.0 (5.2)	6.0 (9.9)	8.3 (8.9)	17.5 (13.0)	0.167	**0.034**	0.251	2.0	11.4
	Conif stems	0.0 (0.0)	1.8 (1.1)	9.0 (2.6)	13.2 (20.4)	24.5 (9.4)	42.0 (23.1)	**(0.013)**	**(<0.001)**	0.746	-0.6	32.2

[1] average percent cover within four 1 m^2 quadrats
[2] mean number of stems per 0.008 ha subplot
[3] mean number of stems per 0.04 ha plot
[4] height > 1.4 m; includes deciduous saplings
[5] dbh > 12 cm
[6] p values in brackets determined by Kruskal-Wallis ANOVA
[7] p values in brackets determined by weight estimation regression
[8] italicized regression equations involve transformed variables

Table 2.4 d: Means (and standard deviations) of vegetation characteristics in Coniferous sites in 2000 (2nd year post-harvest). The significance level within each vegetation layer was adjusted (from 0.10) via a sequential Bonferroni technique for multiple tests. Significant p values are in bold type. Means with the same letter are not significantly different from one another.

		Harvest Retention Level						ANOVA[6]	Linear Regression[7,8]			
		0%	10%	20%	50%	75%	100%	p	p	r^2	interc	slope
% Ground Cover[1]	All green	53.1 (9.8) [ab]	39.7 (14.9) [a]	47.5 (16.4) [ab]	40.3 (20.1) [a]	70.0 (5.0) [ab]	75.9 (15.2) [b]	**0.015**	**0.006**	0.388	41.7	29.9
	Shrub	14.1 (3.6)	15.9 (7.0)	12.5 (3.8)	11.4 (8.1)	14.3 (9.0)	14.2 (9.3)	0.962	0.910			
	Litter	30.5 (5.8)	31.9 (17.0)	28.4 (23.8)	30.9 (12.3)	30.0 (1.8)	23.4 (29.9)	(0.920)	(0.480)			
	Moss	8.8 (5.8)	26.4 (12.5)	32.8 (26.4)	19.6 (12.1)	38.8 (21.8)	56.6 (37.5)	0.148	**0.015**	0.316	*0.39*	*0.40*
	DWD	54.1 (12.1) [a]	40.9 (1.3) [ab]	29.4 (6.7) [bc]	44.1 (4.4) [ab]	22.5 (6.9) [c]	17.5 (11.0) [c]	**<0.001**	**<0.001**	0.544	46.9	-28.5
Shrub Layer (stems)[2]	Low shrubs	117.8 (17.0)	220.9 (69.1)	117.8 (58.9)	142.4 (98.4)	255.3 (276.3)	162.0 (140.7)	0.649	0.524			
	Decid saplings	1.0 (1.4)	21.8 (18.0)	7.5 (15.9)	0.3 (0.6)	1.0 (0.9)	6.3 (13.7)	(0.125)	(0.900)			
	Tall shrubs[4]	1.0 (1.4)	33.3 (41.6)	16.8 (38.6)	0.3 (0.6)	1.0 (0.9)	13.8 (32.1)	(0.168)	(0.834)			
Canopy Layer (stems)[3]	Large snags[5]	1.0 (1.4) [a]	2.8 (2.7) [ab]	3.3 (1.2)) [ab]	3.3 (1.1) [ab]	3.3 (2.0) [ab]	5.8 (2.0) [b]	0.067	**0.006**	0.391	1.8	3.3
	All snags	1.0 (1.4) [a]	3.8 (3.1) [ab]	4.3 (2.0) [ab]	3.0 (1.7) [ab]	3.3 (2.0) [ab]	8.0 (3.0) [b]	**0.024**	**0.010**	0.350	2.2	4.3
	Decid stems	0.0 (0.0)	15.3 (33.4)	10.1 (24.0)	4.0 (3.0)	2.3 (2.0)	12.2 (19.6)	0.446	0.202			
	Conif stems	0.0 (0.0) [a]	6.5 (3.7) [b]	8.3 (1.6) [bc]	8.5 (4.5) [bc]	11.3 (4.3) [bc]	25.0 (13.1) [c]	**<0.001**	**<0.001**	0.559	*0.47*	*0.92*

[1] average percent cover within four 1 m^2 quadrats
[2] mean number of stems per 0.008 ha subplot
[3] mean number of stems per 0.04 ha plot
[4] height > 1.4 m; includes deciduous saplings
[5] dbh > 12 cm
[6] p values in brackets determined by Kruskal-Wallis ANOVA
[7] p values in brackets determined by weight estimation regression
[8] italicized regression equations involve transformed variables

2.3.2 Bird community indices

In total, 76 bird species were detected in forest sites at EMEND during point counts between 1998 and 2000 (Appendix 4), though five of these were waterfowl or water-associated species normally found in other habitat types. Foraging guilds were represented by aerial foragers (16 species), bark gleaners (9), foliage gleaners (23), and ground gleaners (23). Nesting guilds were represented by cavity nesters (15 species), ground nesters (22), and shrub/tree nesters (34).

Species Richness

Richness values are expressed as mean number of species detected per station. Table 2.5 displays the pre-harvest (1998) species richness for each treatment in each cover type, followed by changes in species richness recorded between 1998 and 1999 (first interval, one year post-harvest), and between 1998 and 2000 (second interval, two years post-harvest). Prior to harvest, treatment means were not significantly different in any of the cover types. After harvest, all cover types except Deciduous/Understory exhibited significant treatment differences and regressions (summarized by type in Table 2.6).

In Deciduous and Mixed sites, richness declined linearly with decreasing residual level in both time intervals, primarily due to decreases in the clearcuts and increases in the controls. In Coniferous sites, richness declined linearly with decreasing residual level in only the first time interval, primarily due to a decrease in the clearcuts. ANOVA could detect no significant differences between richness changes two years after harvest for Mixed and Coniferous sites, but for Deciduous sites, the richness declines in the clearcut and 20% residual treatments differed significantly from the increases in the 75% and control treatments two years post-logging. There was no interaction between time interval and linear trend in any of the cover types, but richness increased in every treatment between the first and second year post-harvest for three of the cover types (Deciduous sites: $p=0.001$; Mixed sites: $p=0.010$; Coniferous sites: $p=0.038$).

Table 2.5: Mean species richness per station in 1998 and richness changes between 1998-1999 (1st year post-harvest) and 1998-2000 (2nd year post-harvest), in each cover type (with standard error). Significant p values (<0.10) are in bold type. Where ANOVA detected a difference between treatments, means with the same letter are not significantly different from one another.

		Harvest Retention Level						ANOVA[1]	Linear Regression [2,3]				
		0%	10%	20%	50%	75%	100%	p	p	r^2	interc	slope	95% CI for slope
DECIDUOUS	1998	5.3 (0.1)	5.4 (0.3)	5.1 (0.4)	4.0 (0.8)	5.1 (0.5)	3.9 (1.2)	(0.733)	(0.260)				
	Δ 1998-1999	-4.1 (0.7) a	-2.2 (0.8) a	-2.1 (0.9) a	+1.2 (1.9) ab	-0.3 (0.5) ab	+4.1 (1.4) b	**0.019**	**<0.001**	0.535	*0.46*	*0.55*	*0.37 to 0.76*
	Δ 1998-2000	-1.8 (0.3) a	+1.0 (1.3) ab	-1.1 (0.9) a	+1.7 (0.5) ab	+3.4 (0.3) b	+5.2 (1.6) b	**0.008**	**<0.001**	0.519	*0.74*	*0.33*	*0.20 to 0.43*
DECIDUOUS / UNDERSTORY	1998	3.7 (0.9)	4.3 (1.0)	4.5 (0.2)	5.4 (0.6)	3.5 (1.3)	5.2 (0.4)	0.255	0.577				
	Δ 1998-1999	-1.9 (1.0)	+0.3 (1.2)	+0.8 (0.8)	-1.6 (1.5)	+3.0 (1.3)	+0.1 (1.7)	0.339	0.329				
	Δ 1998-2000	-0.5 (1.5)	+3.7 (0.6)	+0.8 (0.5)	-0.4 (1.1)	+2.9 (1.7)	-0.2 (1.6)	0.292	0.787				
MIXED	1998	4.8 (1.1)	6.4 (0.3)	3.0 (0.5)	3.6 (0.2)	4.5 (0.7)	4.9 (0.9)	0.182	0.796				
	Δ 1998-1999	-3.8 (1.4) a	-1.6 (1.0) ab	+1.1 (0.9) ab	+1.2 (0.1) b	-0.4 (0.9) ab	+2.3 (0.8) b	**0.031**	**0.014**	0.324	-1.9	4.0	2.2 to 6.6
	Δ 1998-2000	-2.4 (1.6)	-0.8 (0.9)	+3.0 (1.2)	+4.3 (1.5)	+1.2 (1.6)	+3.6 (2.0)	0.127	**0.058**	0.207	-0.4	4.5	0.6 to 7.7
CONIFEROUS	1998	5.3 (0.5)	5.0 (0.5)	5.5 (0.7)	4.8 (1.2)	4.3 (0.3)	5.2 (0.7)	0.944	0.619				
	Δ 1998-1999	-4.3 (0.3) a	-1.2 (0.8) ab	-1.6 (1.6) ab	+0.5 (1.4) b	+1.8 (0.5) b	+0.5 (1.1) b	**0.015**	**0.006**	0.388	*0.44*	*0.49*	*0.28 to 0.65*
	Δ 1998-2000	-2.8 (0.4)	-0.3 (0.6)	+2.2 (1.4)	+1.5 (0.6)	+0.9 (0.9)	+0.9 (1.5)	0.121	**0.033**	0.454 [4]			

[1] p values in brackets determined by Kruskal-Wallis ANOVA
[2] p values in brackets determined by weight estimation regression
[3] italicized regression equations involve transformed variables
[4] based on best-fit cubic regression

Table 2.6: Summary of regression trends observed for mean species richness changes between 1998-1999 and 1998-2000, in each cover type.

Period	Cover Type[1]			
	Deciduous	Deciduous / Understory	Mixed	Coniferous
Δ 1998-1999	↓	ns	↓	↓
Δ 1998-2000	↓	ns	↓	curv

[1] ↓ - declining linear trend with decreasing residual tree level; curv – significant curvilinear regression trend detected; ns – no significant regression trend detected

In comparing the smaller radius data set with the larger radius data, only the Deciduous sites displayed a significant difference in richness pattern: in 1999, the larger radius data exhibited a steeper positive trend, but in all years, the data sets were strongly correlated (r = 0.64 to 0.91). In the remaining three cover types, richness patterns did not differ, and data sets were strongly correlated in all years (Deciduous/Understory sites: r = 0.79 to 0.89; Mixed sites: r = 0.79 to 0.87; Coniferous sites: r = 0.69 to 0.85).

The relationship between the rarefied (small radius) data set and the non-rarefied data was similar. For Deciduous sites in 1999, the non-rarefied data exhibited a steeper positive trend, but in all years, data sets were strongly correlated (r = 0.75 to 0.97). No significant differences in richness pattern were detected in the other cover types, and data sets were strongly correlated in all years (Deciduous/Understory sites: r = 0.86 to 0.92; Mixed sites: r = 0.85 to 0.93; Coniferous sites: r = 0.76 to 0.89).

Species Similarity

The similarity of bird communities occupying the same compartments in different years was calculated for two periods: pre-harvest communities were compared to those in 1999 and 2000 (first and second years post-harvest, respectively). Similarity trends across treatments were significant for nearly every period in all cover types (Table 2.7), and generally declined with decreasing residual level (Table 2.8). This trend was evident in the second time interval in Deciduous sites, and in both time intervals in the other three cover types, and was due in part to the low similarity (or complete turnover) of bird communities in clearcuts between years. Despite the linear trends, ANOVA could not detect a difference in similarity among most of the harvest treatments during either period.

In three of the four cover types, there was no interaction between time interval and linear trend; the exception was the Deciduous type, where a marginally significant interaction (p=0.102) was detected, not unexpected given that a linear relationship was detected in only one of the time intervals. An overall increase in similarity across treatments between the first and second post-harvest year was detected for Mixed sites (p=0.032).

Analysis of covariance was used to compare corresponding similarity patterns between the smaller radius data set and the larger radius data for all cover types excluding Deciduous / Understory, for which the data were heteroscedastic. No interaction between radius and treatment pattern was detected for any cover type, in either time period. However, similarity values across treatments were significantly higher in the larger radius data set in both intervals for Deciduous (p=0.035, 0.089) and Coniferous (p=0.051, 0.079) sites, and in the first interval for Mixed sites (p=0.020). Consequently, the similarity values presented in Table 2.6 should be interpreted with caution, as the low nature of the values may reflect in part the small 50m sampling radius.

Table 2.7: Mean species similarity per compartment between 1998-1999 (1st year post-harvest) and 1998-2000 (2nd year post-harvest), in each cover type (with standard error). Significant p values (<0.10) are in bold type. Where ANOVA detected a difference between treatments, means with the same letter are not significantly different from one another.

		Harvest Retention Level						ANOVA[1]	Linear Regression[2]				
		0%	10%	20%	50%	75%	100%	p	p	r^2	interc	slope	95% CI for slope
DECIDUOUS	Δ 1998-1999	0.18 (0.14)	0.23 (0.05)	0.22 (0.09)	0.41 (0.17)	0.21 (0.07)	0.50 (0.15)	0.509	0.125				
	Δ 1998-2000	0.04 [a] (0.03)	0.28 [ab] (0.09)	0.13 [ab] (0.11)	0.27 [ab] (0.09)	0.36 [ab] (0.13)	0.60 [b] (0.14)	**0.057**	**0.001**	0.478	0.09	0.47	0.25 to 0.73
DECIDUOUS / UNDERSTORY	Δ 1998-1999	0.00 (0.00)	0.24 (0.08)	0.17 (0.04)	0.32 (0.11)	0.43 (0.17)	0.50 (0.12)	(0.165)	**(0.001)**	0.502	0.05	0.48	0.23 to 0.73
	Δ 1998-2000	0.00 [a] (0.00)	0.42 [ab] (0.10)	0.22 [ab] (0.09)	0.22 [ab] (0.08)	0.49 [b] (0.16)	0.42 [ab] (0.89)	**0.077**	**0.071**	0.189	0.20	0.27	0.02 to 0.49
MIXED	Δ 1998-1999	0.00 [a] (0.00)	0.18 [ab] (0.05)	0.16 [ab] (0.10)	0.19 [ab] (0.08)	0.39 [b] (0.06)	0.39 [b] (0.09)	**0.031**	**0.001**	0.518	0.07	0.36	0.15 to 0.44
	Δ 1998-2000	0.25 (0.17)	0.27 (0.15)	0.21 (0.13)	0.20 (0.09)	0.41 (0.13)	0.73 (0.04)	0.144	**0.012**	0.337	0.18	0.43	0.15 to 0.68
CONIFEROUS	Δ 1998-1999	0.00 [a] (0.00)	0.11 [a] (0.03)	0.28 [ab] (0.06)	0.29 [ab] (0.16)	0.34 [ab] (0.10)	0.62 [b] (0.11)	**0.022**	**0.000**	0.575	0.05	0.52	0.38 to 0.76
	Δ 1998-2000	0.00 (0.00)	0.24 (0.14)	0.33 (0.10)	0.33 (0.17)	0.50 (0.20)	0.48 (0.05)	0.191	**0.014**	0.322	0.13	0.42	0.26 to 0.61

[1] p values in brackets determined by Kruskal-Wallis ANOVA

[2] p values in brackets determined by weight estimation regression

Table 2.8: Summary of regression trends observed for mean species similarity between 1998-1999 and 1998-2000, in each cover type.

Period	Cover Type [1]			
	Deciduous	Deciduous / Understory	Mixed	Coniferous
Δ 1998-1999	↓	↓	↓	↓
Δ 1998-2000	ns	↓	↓	↓

[1] ↓ - declining linear trend with declining residual tree level; ns – no significant regression trend detected

Species Diversity

Log series alpha diversity was calculated for each treatment, in each cover type, in each year (Table 2.9). Prior to harvest, diversity differed between treatments and controls in only two cases: in Deciduous/Understory sites, 50% treatments were more diverse than the controls ($p<0.05$), and in Mixed sites, 20% treatments were less diverse ($p<0.1$) than the respective controls. Immediately after harvest, diversity decreased in most treatments, in all cover types except Deciduous/Understory, where slight non-significant increases were the norm. Two years after harvest, initial declines tended to become less significant in all cover types, and even changed to increases in some cases. It should be noted, however, that diversity in clearcuts still declined in 3 of the 4 cover types two years post-harvest. The large number of non-significant changes two years post-harvest (and one year post-harvest, in Deciduous/Understory sites) should be interpreted with caution; despite the lack of significant structural changes, there must still have been compositional changes, as evidenced by low species similarity values (Table 2.6) within the same periods.

Table 2.9: Species diversity per compartment in 1998 and change in diversity between 1998-1999 (1st year post-harvest) and 1998-2000 (2nd year post-harvest), in each cover type. Significant p values (<0.10) are in bold type.

Cover Type	% Harvest Retention	Log Series Alpha Diversity					
		1998 [1]	p [2]	Δ 1998-1999	p [3]	Δ 1998-2000	p [3]
DECID	0	8.5 (2.1)	>0.5	-5.3	**<0.05**	-4.6	**<0.05**
	10	9.1 (2.4)	>0.9	-6.2	**<0.02**	+0.3	>0.5
	20	9.6 (3.3)	>0.9	-5.2	**<0.1**	-3.6	>0.1
	50	6.7 (2.6)	>0.2	+3.4	>0.2	+0.7	>0.5
	75	9.9 (2.7)	>0.5	-2.1	>0.2	-1.4	>0.4
	100	9.4 (3.0)	NA	+1.2	>0.5	+0.5	>0.5
DECID / UNDERST	0	3.9 (1.2)	>0.2	+0.7	>0.5	+1.2	>0.4
	10	8.4 (2.5)	>0.1	+1.8	>0.4	+1.9	>0.2
	20	7.1 (2.5)	>0.2	+2.0	>0.4	-0.6	>0.5
	50	14.1 (5.2)	**<0.05**	-6.6	>0.1	-6.6	>0.1
	75	5.7 (1.8)	>0.5	+1.2	>0.4	+3.7	**<0.1**
	100	5.4 (1.4)	NA	+0.5	>0.5	-1.1	>0.2
MIXED	0	12.4 (4.2)	>0.2	-9.9	**<0.02**	-8.2	**<0.05**
	10	10.4 (2.6)	>0.5	-5.5	**<0.05**	-4.6	**<0.05**
	20	5.1 (2.2)	**<0.1**	-0.7	>0.5	+4.8	>0.1
	50	6.0 (2.1)	>0.1	-0.6	>0.5	+2.8	>0.1
	75	10.1 (3.6)	>0.5	0.0	1.0	-2.1	>0.4
	100	9.4 (2.3)	NA	-0.3	>0.5	+1.1	>0.5
CONIF	0	8.2 (2.0)	>0.5	-2.9	>0.2	-5.5	**<0.02**
	10	5.7 (1.8)	>0.1	+0.7	>0.5	-0.8	>0.5
	20	11.8 (3.4)	>0.2	-8.1	**<0.02**	+2.8	>0.2
	50	13.9 (4.7)	>0.2	-6.9	**<0.1**	-2.8	>0.4
	75	11.6 (4.5)	>0.4	-4.9	>0.1	-3.4	>0.2
	100	9.2 (2.6)	NA	-3.8	**<0.1**	+1.9	>0.4

[1] Standard errors in brackets
[2] Significance indicated for comparison between treatment value and control (100%) value
[3] Significance indicated for change in diversity between years

2.3.3 Bird response by guild

For each foraging and nesting guild in each cover type, the changes in mean abundance between 1998 and 1999 (first interval, one year post-harvest), and between 1998 and 2000 (second interval, two years post-harvest) were examined (Tables 2.10 a-d). Observed regression trends have also been summarized by cover type (Table 2.11). Per station bird abundances were very low for some guilds (e.g., aerial foragers), due to the low number of species in those guilds, and the relatively small sampling area (50 metre radius).

In general, foliage gleaner and shrub/tree nester abundance changes declined linearly with decreasing residual tree level in all cover types, in both time intervals. Conversely, ground forager (three cover types) and ground nester (two cover types) abundance changes increased linearly with decreasing residual tree level, in the second time interval. Aerial forager abundance changes declined in the second interval in Deciduous and Coniferous sites.

ANCOVA detected an overall increase in abundance between the first and second post-harvest year for foliage gleaners in three cover types (Deciduous: $p=0.023$; Deciduous/Understory: $p=0.099$; Mixed: $p=0.008$), ground foragers in three cover types (Deciduous: $p=0.038$; Mixed: $p=0.014$; Coniferous: $p=0.001$), ground nesters in all cover types (Deciduous: $p=0.002$; Deciduous/Understory: $p=0.007$; Mixed: $p=0.015$; Coniferous: $p=0.001$), and shrub/tree nesters in one cover type (Mixed: $p=0.008$).

Table 2.10 a: Mean guild abundance per station in 1998 and abundance changes between 1998-1999 and 1998-2000, in Deciduous sites (with standard error). Underlined changes differ significantly from changes in controls in same period. Significant p values (<0.10) are in bold.

			Harvest Retention Level						Linear Regression [1,2]				
			0%	10%	20%	50%	75%	100%	p	r^2	interc	slope	95% CI for slope
FORAGING GUILDS	Aerial	1998	0.27 (0.07)	0.33 (0.17)	0.33 (0.19)	0.33 (0.19)	0.27 (0.18)	0.63 (0.17)	0.125				
		Δ 1998-1999	-0.22 (0.13)	-0.14 (0.44)	-0.33 (0.19)	-0.25 (0.27)	-0.17 (0.00)	+0.11 (0.54)	0.347				
		Δ 1998-2000	-0.17 (0.10)	+0.08 (0.61)	-0.33 (0.19)	-0.33 (0.19)	-0.07 (0.18)	+0.74 (0.67)	**0.081**	0.184	*-0.15*	*0.24*	*0.08 to 0.51*
	Bark	1998	0.30 (0.15)	0.06 (0.06)	0.11 (0.11)	0.11 (0.11)	0.23 (0.15)	0.07 (0.07)	0.458				
		Δ 1998-1999	-<u>0.30</u> (0.15)	+0.02 (0.07)	-0.11 (0.11)	-0.11 (0.11)	+0.07 (0.36)	+0.11 (0.02)	**0.059**	0.206	-0.18	0.29	0.09 to 0.53
		Δ 1998-2000	-<u>0.30</u> (0.15)	+0.16 (0.13)	-0.02 (0.17)	-0.07 (0.14)	-0.08 (0.26)	+0.06 (0.07)	0.406				
	Foliage	1998	0.97 (0.24)	1.08 (0.30)	1.06 (0.31)	0.39 (0.31)	1.00 (0.50)	0.80 (0.65)	0.575				
		Δ 1998-1999	-<u>0.97</u> (0.24)	-<u>0.95</u> (0.14)	-<u>0.85</u> (0.36)	+0.44 (0.25)	-<u>0.15</u> (0.17)	+0.43 (0.31)	**<0.001**	0.627	-0.97	1.41	1.07 to 1.78
		Δ 1998-2000	-<u>0.92</u> (0.27)	-<u>0.37</u> (0.28)	-0.31 (0.64)	+0.78 (0.45)	+0.80 (0.41)	+0.55 (0.36)	**0.001**	0.489	-0.61	1.56	0.90 to 2.00
	Ground	1998	0.70 (0.20)	0.69 (0.19)	0.44 (0.11)	1.11 (0.15)	0.80 (0.37)	0.43 (0.31)	0.716				
		Δ 1998-1999	-0.40 (0.10)	+0.34 (0.41)	-0.05 (0.29)	-<u>0.82</u> (0.13)	-0.18 (0.22)	+0.19 (0.71)	(0.400)				
		Δ 1998-2000	+0.29 (0.24)	+0.57 (0.53)	+0.25 (0.27)	-0.03 (0.09)	-0.15 (0.64)	+0.02 (0.35)	(0.106)				
NESTING GUILDS	Shrub/ Tree	1998	0.77 (0.23)	1.17 (0.24)	1.22 (0.56)	0.67 (0.25)	0.93 (0.43)	0.87 (0.75)	0.778				
		Δ 1998-1999	-0.72 (0.28)	-0.90 (0.37)	-1.05 (0.58)	+0.21 (0.44)	-0.06 (0.10)	+0.36 (0.77)	**0.007**	0.376	-0.89	1.23	0.54 to 2.17
		Δ 1998-2000	-0.52 (0.30)	-0.31 (0.44)	-0.92 (0.71)	-0.08 (0.59)	+0.29 (0.37)	+0.66 (0.77)	**0.016**	0.313	-0.64	1.24	0.41 to 2.17
	Cavity	1998	0.30 (0.15)	0.06 (0.06)	0.06 (0.06)	0.11 (0.11)	0.30 (0.14)	0.00 (0.00)	(0.238)				
		Δ 1998-1999	-<u>0.30</u> (0.15)	+0.02 (0.07)	-0.06 (0.06)	-0.11 (0.11)	+0.03 (0.26)	+0.18 (0.21)	**0.036**	0.247	-0.18	0.33	0.11 to 0.64
		Δ 1998-2000	-<u>0.27</u> (0.17)	+0.23 (0.09)	+0.08 (0.13)	+0.14 (0.08)	-0.05 (0.19)	+0.18 (0.02)	**0.065**	0.393 [3]			
	Ground	1998	1.17 (0.08)	0.94 (0.25)	0.67 (0.19)	1.17 (0.17)	1.07 (0.51)	1.07 (0.48)	0.788				
		Δ 1998-1999	-0.86 (0.07)	+0.16 (0.44)	-0.23 (0.38)	-0.83 (0.15)	-0.39 (0.40)	+0.31 (0.64)	**0.072**	0.384 [3]			
		Δ 1998-2000	-0.30 (0.27)	+0.52 (0.61)	+0.43 (0.59)	+0.29 (0.18)	+0.26 (0.58)	+0.53 (0.48)	0.326				

[1] p values in brackets determined by weight estimation regression
[2] italicized regression equations involve transformed variables
[3] based on best-fit cubic regression

Table 2.10 b: Mean guild abundance per station in 1998 and abundance changes between 1998-1999 and 1998-2000, in Deciduous/Understory sites (with standard error). Underlined means differ significantly from changes in controls in same period. Significant p values (<0.10) are in bold.

			Harvest Retention Level						Linear Regression [1,2]				
			0%	10%	20%	50%	75%	100%	p	r^2	interc	slope	95% CI for slope
FORAGING GUILDS	Aerial	1998	0.08 (0.12)	0.33 (0.17)	0.00 (0.00)	0.25 (0.23)	0.08 (0.07)	0.00 (0.00)	(0.189)				
		Δ 1998-1999	-0.08 (0.12)	-0.23 (0.22)	0.00 (0.00)	-0.25 (0.23)	-0.08 (0.07)	0.00 (0.00)	0.467				
		Δ 1998-2000	-0.08 (0.12)	-0.33 (0.17)	0.00 (0.00)	-0.19 (0.15)	-0.02 (0.14)	0.00 (0.00)	0.160				
	Bark	1998	0.00 (0.00)	0.07 (0.07)	0.17 (0.14)	0.33 (0.00)	0.00 (0.00)	0.07 (0.12)	(0.526)				
		Δ 1998-1999	0.00 (0.00)	-0.07 (0.07)	-0.02 (0.25)	-0.33 (0.00)	0.00 (0.00)	-0.07 (0.12)	(0.445)				
		Δ 1998-2000	0.00 (0.00)	+0.01 (0.09)	-0.10 (0.19)	-0.30 (0.04)	0.00 (0.00)	+0.11 (0.24)	(0.211)				
	Foliage	1998	1.29 (0.20)	0.97 (0.37)	0.96 (0.34)	0.63 (0.20)	1.29 (0.64)	1.70 (0.32)	0.165				
		Δ 1998-1999	-<u>1.29</u> (0.20)	-0.22 (0.24)	-0.51 (0.24)	+0.19 (0.65)	+0.33 (0.41)	0.00 (0.12)	**0.017**	0.309	-0.68	1.00	0.77 to 1.25
		Δ 1998-2000	-<u>1.16</u> (0.24)	+0.63 (0.16)	-0.14 (0.23)	+0.41 (0.48	+0.21 (0.32)	+0.40 (0.65)	**0.064**	0.395 [3]			
	Ground	1998	0.67 (0.19)	0.57 (0.11)	0.67 (0.00)	0.71 (0.06)	0.67 (0.08)	0.53 (0.27)	(0.619)				
		Δ 1998-1999	-0.13 (0.31)	+0.16 (0.54)	+0.03 (0.31)	-0.24 (0.19)	+0.24 (0.13)	-0.23 (0.33)	0.629				
		Δ 1998-2000	+0.13 (0.42)	+<u>1.07</u> (0.17)	+<u>0.52</u> (0.42)	-0.18 (0.11)	+0.11 (0.17)	-0.38 (0.44)	**0.012**	0.336	0.67	-1.02	-1.52 to -0.29
NESTING GUILDS	Shrub/ Tree	1998	1.21 (0.10)	1.00 (0.46)	0.96 (0.18)	1.17 (0.25)	1.13 (0.54)	1.77 (0.53)	0.100				
		Δ 1998-1999	-<u>1.02</u> (0.22)	-0.09 (0.64)	-0.30 (0.10)	-0.23 (0.78)	+0.09 (0.57)	-0.22 (0.14)	**(0.088)**	0.172	-0.48	0.38	-0.06 to 0.83
		Δ 1998-2000	-0.91 (0.21)	+0.29 (0.17)	+0.09 (0.40)	-0.57 (0.53)	-0.03 (0.62)	-0.22 (0.42)	0.897				
	Cavity	1998	0.17 (0.24)	0.00 (0.00)	0.17 (0.10)	0.25 (0.12)	0.08 (0.07)	0.10 (0.11)	0.986				
		Δ 1998-1999	-0.17 (0.24)	+0.05 (0.09)	+0.08 (0.23)	-0.25 (0.12)	+0.01 (0.06)	-0.08 (0.13)	0.798				
		Δ 1998-2000	-0.17 (0.24)	+0.16 (0.09)	-0.06 (0.13)	-0.22 (0.16)	+0.04 (0.22)	+0.15 (0.22)	0.433				
	Ground	1998	0.67 (0.19)	0.93 (0.28)	0.67 (0.19)	0.50 (0.24)	0.83 (0.21)	0.43 (0.34)	0.252				
		Δ 1998-1999	-0.31 (0.18)	-0.31 (0.44)	-0.29 (0.18)	-0.16 (0.29)	+0.39 (0.30)	-0.01 (0.56)	0.119				
		Δ 1998-2000	-0.04 (0.29)	+0.93 (0.25)	+0.25 (0.25)	+0.53 (0.01)	+0.29 (0.44)	+0.19 (0.44)	0.572				

[1] p values in brackets determined by weight estimation regression
[2] italicized regression equations involve transformed variables
[3] based on best-fit cubic regression

Table 2.10 c: Mean guild abundance per station in 1998 and abundance changes between 1998-1999 and 1998-2000, in Mixed sites (with standard error). Underlined changes differ significantly from changes in controls in same period. Significant p values (<0.10) are in bold.

			Harvest Retention Level						Linear Regression [1,2]				
			0%	10%	20%	50%	75%	100%	p	r^2	interc	slope	95% CI for slope
FORAGING GUILDS	Aerial	1998	0.07 (0.12)	0.07 (0.08)	0.00 (0.00)	0.00 (0.00)	0.08 (0.12)	0.07 (0.08)	(0.842)				
		Δ 1998-1999	-0.07 (0.12)	+0.03 (0.07)	0.00 (0.00)	0.00 (0.00)	-0.08 (0.12)	-0.07 (0.07)	0.337				
		Δ 1998-2000	-0.07 (0.12)	-0.02 (0.02)	+0.08 (0.08)	+0.13 (0.07)	-0.08 (0.12)	+0.13 (0.18)	0.271				
	Bark	1998	0.13 (0.15)	0.20 (0.11)	0.11 (0.11)	0.08 (0.12)	0.25 (0.20)	0.10 (0.06)	0.898				
		Δ 1998-1999	-0.13 (0.15)	-0.20 (0.11)	-0.02 (0.17)	+0.01 (0.17)	-0.22 (0.21)	+0.05 (0.12)	0.355				
		Δ 1998-2000	-0.13 (0.15)	+0.15 (0.20)	-0.07 (0.14)	-0.02 (0.15)	-0.22 (0.21)	+0.23 (0.16)	0.484				
	Foliage	1998	1.03 (0.22)	1.40 (0.22)	0.78 (0.49)	1.17 (0.38)	1.13 (0.18)	2.20 (1.04)	0.128				
		Δ 1998-1999	-1.03 (0.22)	-0.51 (0.47)	-0.22 (0.59)	-0.51 (0.32)	-0.38 (0.06)	-0.43 (1.33)	**(0.004)**	0.413	-0.98	0.79	0.29 to 1.29
		Δ 1998-2000	-0.88 (0.30)	-0.33 (0.44)	-0.11 (0.82)	+0.18 (0.41)	+0.84 (0.57)	+0.35 (1.96)	**(0.001)**	0.485	-0.81	2.17	0.98 to 3.35
	Ground	1998	0.40 (0.14)	1.10 (0.25)	0.67 (0.29)	0.33 (0.00)	0.34 (0.32)	0.20 (0.11)	**0.032**	0.256	0.74	-0.55	-0.83 to -0.26
		Δ 1998-1999	-0.06 (0.41)	-0.15 (0.32)	-0.22 (0.12)	+0.42 (0.10)	-0.02 (0.36)	+0.15 (0.14)	0.254				
		Δ 1998-2000	+0.39 (0.37)	+0.28 (0.47)	+0.85 (0.34)	+0.85 (0.46)	+0.07 (0.06)	+0.05 (0.03)	**(0.099)**	0.161	0.36	-0.33	-0.72 to 0.07
NESTING GUILDS	Shrub/ Tree	1998	1.10 (0.19)	1.50 (0.41)	1.05 (0.55)	1.00 (0.29)	1.21 (0.18)	2.00 (1.31)	(0.804)				
		Δ 1998-1999	-1.07 (0.20)	-0.33 (0.52)	-0.45 (0.62)	-0.13 (0.32)	-0.21 (0.33)	-0.40 (1.47)	**(0.006)**	0.386	-1.01	1.27	0.42 to 2.12
		Δ 1998-2000	-0.62 (0.39)	-0.94 (0.65)	+0.17 (0.67)	+0.56 (0.58)	+0.95 (0.62)	+0.48 (1.95)	**(0.003)**	0.424	-0.68	2.27	0.87 to 3.68
	Cavity	1998	0.13 (0.15)	0.40 (0.21)	0.22 (0.11)	0.50 (0.39)	0.42 (0.20)	0.17 (0.08)	0.920				
		Δ 1998-1999	-0.13 (0.15)	-0.40 (0.21)	-0.13 (0.20)	-0.25 (0.37)	-0.35 (0.17)	+0.06 (0.18)	0.381				
		Δ 1998-2000	-0.13 (0.15)	+0.10 (0.28)	-0.12 (0.14)	-0.38 (0.41)	-0.39 (0.23)	+0.28 (0.22)	**0.029**	0.464 [3]			
	Ground	1998	0.40 (0.34)	0.87 (0.28)	0.28 (0.20)	0.08 (0.12)	0.17 (0.10)	0.40 (0.23)	0.235				
		Δ 1998-1999	-0.09 (0.58)	-0.09 (0.62)	+0.13 (0.22)	+0.29 (0.08)	-0.14 (0.10)	+0.08 (0.10)	0.204				
		Δ 1998-2000	+0.06 (0.50)	+0.93 (0.62)	+0.71 (0.11)	+0.95 (0.52)	+0.05 (0.05)	+0.00 (0.17)	**(<0.001)**	0.619	0.84	-1.00	-1.41 to -0.58

[1] p values in brackets determined by weight estimation regression
[2] italicized regression equations involve transformed variables
[3] based on best-fit cubic regression

Table 2.10 d: Mean guild abundance per station in 1998 and abundance changes between 1998-1999 and 1998-2000, in Coniferous sites (with standard error). Underlined changes differ significantly from changes in controls in same period. Significant p values (<0.10) are in bold.

			Harvest Retention Level						Linear Regression [1,2]				
			0%	10%	20%	50%	75%	100%	p	r^2	interc	slope	95% CI for slope
FORAGING GUILDS	Aerial	1998	0.20 (0.06)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.08 (0.07)	0.00 (0.00)	(0.106)				
		Δ 1998-1999	-<u>0.20</u> (0.06)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-0.08 (0.07)	0.00 (0.00)	(0.106)				
		Δ 1998-2000	-<u>0.17</u> (0.01)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-0.08 (0.07)	0.00 (0.00)	**(0.039)**	0.239	-0.07	0.10	0.01 to 0.19
	Bark	1998	0.40 (0.23)	0.08 (0.07)	0.25 (0.20)	0.13 (0.18)	0.08 (0.12)	0.27 (0.21)	0.605				
		Δ 1998-1999	-0.40 (0.23)	+0.04 (0.22)	-0.22 (0.23)	-0.09 (0.19)	-0.02 (0.15)	-0.14 (0.28)	0.450				
		Δ 1998-2000	-0.40 (0.23)	-0.05 (0.10)	0.00 (0.38)	+0.13 (0.10)	+0.07 (0.04)	-0.19 (0.19)	0.486				
	Foliage	1998	1.97 (0.46)	1.75 (0.20)	1.29 (0.18)	1.75 (0.07)	0.96 (0.14)	1.47 (0.40)	**(0.062)**	0.201	1.95	-0.79	-1.60 to 0.04
		Δ 1998-1999	-<u>1.97</u> (0.46)	-<u>0.99</u> (0.26)	-0.20 (0.58)	-0.91 (0.35)	+0.29 (0.32)	+0.11 (0.68)	**0.003**	0.429	-1.36	1.71	0.82 to 2.53
		Δ 1998-2000	-1.97 (0.46)	-<u>1.46</u> (0.30)	-0.39 (0.21)	-0.44 (0.29)	+0.20 (0.33)	-0.07 (0.71)	**0.001**	0.512	-1.49	1.80	0.83 to 2.55
	Ground	1998	0.20 (0.22)	0.33 (0.17)	0.56 (0.06)	0.33 (0.17)	0.58 (0.12)	0.40 (0.18)	0.300				
		Δ 1998-1999	+0.02 (0.26)	-0.05 (0.35)	-0.28 (0.20)	+0.29 (0.39)	+0.23 (0.44)	-0.20 (0.14)	0.938				
		Δ 1998-2000	+<u>0.72</u> (0.05)	+<u>1.00</u> (0.31)	+<u>0.41</u> (0.05)	+0.32 (0.13)	-0.05 (0.25)	-0.03 (0.22)	**<0.001**	0.563	*0.25*	*-0.31*	*-0.44 to -0.19*
NESTING GUILDS	Shrub/ Tree	1998	1.90 (0.18)	2.00 (0.27)	1.33 (0.17)	1.67 (0.00)	1.38 (0.31)	1.53 (0.37)	**(0.074)**	0.186	1.81	-0.52	-1.10 to 0.06
		Δ 1998-1999	-<u>1.82</u> (0.16)	-<u>1.11</u> (0.38)	-0.15 (0.44)	-0.64 (0.46)	-0.03 (0.36)	+0.19 (0.70)	**0.002**	0.451	*0.20*	*0.34*	*0.19 to 0.44*
		Δ 1998-2000	-<u>1.76</u> (0.22)	-1.21 (0.53)	-0.30 (0.20)	-0.45 (0.33)	-0.19 (0.17)	-0.18 (0.71)	**0.008**	0.368	*0.20*	*0.30*	*0.11 to 0.43*
	Cavity	1998	0.60 (0.34)	0.08 (0.07)	0.17 (0.10)	0.38 (0.18)	0.17 (0.14)	0.27 (0.21)	0.494				
		Δ 1998-1999	-0.60 (0.34)	+0.10 (0.31)	-0.07 (0.10)	-0.22 (0.23)	+0.21 (0.15)	-0.09 (0.23)	0.213				
		Δ 1998-2000	-0.57 (0.38)	-0.05 (0.10)	+0.21 (0.31)	+0.22 (0.25)	+0.11 (0.24)	+0.08 (0.11)	0.110				
	Ground	1998	0.27 (0.18)	0.08 (0.12)	0.60 (0.25)	0.17 (0.10)	0.17 (0.10)	0.33 (0.25)	0.958				
		Δ 1998-1999	-0.13 (0.12)	+0.01 (0.16)	-0.48 (0.29)	+<u>0.15</u> (0.13)	+0.24 (0.48)	-0.33 (0.25)	0.918				
		Δ 1998-2000	+<u>0.52</u> (0.36)	+<u>0.74</u> (0.18)	+0.11 (0.12)	+0.24 (0.16)	+0.21 (0.14)	-0.18 (0.26)	**0.005**	0.391	0.55	-0.65	-1.09 to -0.23

[1] p values in brackets determined by weight estimation regression

[2] italicized regression equations involve transformed variables

Table 2.11: Summary of regression trends observed for mean guild abundance changes between 1998-1999 and 1998-2000, in each cover type.

		Period	Cover Type [1]			
			Decid	Decid/Under	Mixed	Conif
FORAGING GUILDS	Aerial	Δ 1998-1999	ns	ns	ns	ns
		Δ 1998-2000	↓	ns	ns	↓
	Bark	Δ 1998-1999	↓	ns	ns	ns
		Δ 1998-2000	ns	ns	ns	ns
	Foliage	Δ 1998-1999	↓	↓	↓	↓
		Δ 1998-2000	↓	curv	↓	↓
	Ground	Δ 1998-1999	ns	ns	ns	ns
		Δ 1998-2000	ns	↑	↑	↑
NESTING GUILDS	Shrub/Tree	Δ 1998-1999	↓	↓	↓	↓
		Δ 1998-2000	↓	ns	↓	↓
	Cavity	Δ 1998-1999	↓	ns	ns	ns
		Δ 1998-2000	ns	ns	curv	ns
	Ground	Δ 1998-1999	curv	ns	ns	ns
		Δ 1998-2000	ns	ns	↑	↑

[1] ↓ - declining linear trend with decreasing residual tree level; ↑ - increasing linear trend with declining residual tree level; curv – significant curvilinear regression trend detected; ns – no significant regression trend detected

2.3.4 Bird response by species

Yearly abundances were analyzed for the 15-20 most abundant species in each cover type, or those detected in at least 5 of the 18 compartments (Appendix 5). Statistically significant mean abundance changes between 1998 and 2000 (relative to controls) have been summarized by cover type (Table 2.12). Significant linear regression trends were only detected for a few species in each cover type (Table 2.13 a-b).

Table 2.12: Summary of mean species abundance changes (relative to controls) observed in each cover type between 1998-2000. Percentages in the Cover Type columns refer to harvest retention levels in which the change occurred.

Species [1]	For/Nest Guild [2]	Change Relative to Controls	Cover Type			
			Decid	Decid/Under	Mixed	Conif
BTNW	F / ST	↓				10%
CAWA	A / G	↓	75%			
GCKI	F / ST	↓	20%			0%, 20%, 50%
OVEN	G / G	↓			10%	
RBNU	B / C	↓	0%			
REVI	A / ST	↓	0%, 20%			
SWTH	F / ST	↓			0%, 10%, 50%	
TEWA	F / G	↓	0%			
YBSA	B / C	↓	75%			
YRWA	F / ST	↓	10%, 20%	0%		0%, 10%, 20%
WETA	F / ST	↓				10%
CHSP	G / ST	↑		20%	50%	
DEJU	G / G	↑	0%	10%	20%, 50%	0%
GRJA	G / ST	↑				50%
LISP	G / G	↑		10%		
MOWA	F / G	↑			10%	
RBNU	B / C	↑				75%
WTSP	G / G	↑	10%		10%	
WWCR	F / ST	↑				75%
YRWA	F / ST	↑			50%	

[1] BTNW – Black-throated Green Warbler; CAWA – Canada Warbler; CHSP – Chipping Sparrow; DEJU – Dark-eyed Junco; GCKI – Golden-crowned Kinglet; GRJA – Gray Jay; LISP – Lincoln's Sparrow; MOWA – Mourning Warbler; OVEN – Ovenbird; RBNU – Red-breasted Nuthatch; REVI – Red-eyed Vireo; SWTH – Swainson's Thrush; TEWA – Tennessee Warbler; WETA – Western Tanager; WTSP – White-throated Sparrow; WWCR – White-winged Crossbill; YBSA – Yellow-bellied Sapsucker; YRWA – Yellow-rumped Warbler

[2] Foraging guilds: A - aerial, B - bark, F - foliage, G - ground; Nesting guilds: C - cavity, G - ground, ST - shrub/tree

Table 2.13 a: Linear regressions observed across treatments in Deciduous and Deciduous/Understory sites for species abundance changes between 1998-1999 and 1998-2000.

	Species[1]	For/Nest Guild [2]		Linear Regression [3]				
				p	r^2	interc	slope	95 % CI for slope
DECIDUOUS	REVI	A / ST	Δ 1998-1999	ns				
			Δ 1998-2000	**(<0.001)**	0.595	-0.17	0.36	0.20 to 0.52
	TEWA	F / G	Δ 1998-1999	**(0.002)**	0.463	-0.23	0.38	0.16 to 0.60
			Δ 1998-2000	**(0.001)**	0.492	-0.26	0.40	0.18 to 0.61
	WAVI	F / ST	Δ 1998-1999	**0.057**	0.208	-0.08	0.15	0.03 to 0.29
			Δ 1998-2000	ns				
	WTSP	G / G	Δ 1998-1999	ns				
			Δ 1998-2000	**(0.077)**	0.183	0.26	-0.26	-0.55 to -0.03
	YRWA	F / ST	Δ 1998-1999	**0.096**	0.164	-0.28	0.28	0.08 to 0.46
			Δ 1998-2000	**0.059**	0.206	-0.24	0.44	0.20 to 0.63
DECID/UNDERSTORY	CHSP	G / ST	Δ 1998-1999	**0.037**	0.245	0.24	-0.36	-0.64 to -0.11
			Δ 1998-2000	**0.028**	0.266	0.40	-0.47	-0.77 to -0.20
	DEJU	G / G	Δ 1998-1999	ns				
			Δ 1998-2000	**0.039**	0.241	0.29	-0.28	-0.46 to -0.06
	OVEN	G / G	Δ 1998-1999	**0.005**	0.393	-0.53	0.46	0.17 to 0.70
			Δ 1998-2000	**0.033**	0.253	-0.50	0.39	0.12 to 0.76
	WWCR	F / ST	Δ 1998-1999	**(0.007)**	0.379	0.00	0.24	0.07 to 0.40
			Δ 1998-2000	ns				

[1] CHSP – Chipping Sparrow; DEJU – Dark-eyed Junco; OVEN – Ovenbird; REVI – Red-eyed Vireo; TEWA – Tennessee Warbler; WAVI – Warbling Vireo; WTSP – White-throated Sparrow; WWCR – White-winged Crossbill; YRWA – Yellow-rumped Warbler

[2] foraging guilds: A - aerial, B - bark, F - foliage, G - ground; nesting guilds: C - cavity, G - ground, ST - shrub/tree

[3] p values in brackets determined by weight estimation regression

Table 2.13 b: Linear regressions observed across treatments in Mixed and Coniferous sites for species abundance changes between 1998-1999 and 1998-2000.

	Species[1]	For/Nest Guild [2]		Linear Regression [3]				
				p	r^2	interc	slope	95 % CI for slope
MIX	SWTH	F / ST	Δ 1998-1999	ns				
			Δ 1998-2000	**0.021**	0.290	-0.11	0.21	0.07 to 0.38
CONIFEROUS	BTNW	F / ST	Δ 1998-1999	**0.069**	0.192	-0.28	0.32	0.06 to 0.67
			Δ 1998-2000	ns				
	DEJU	G / G	Δ 1998-1999	ns				
			Δ 1998-2000	**0.026**	0.275	0.32	-0.35	-0.55 to -0.19
	GCKI	F / ST	Δ 1998-1999	**0.005**	0.404	-0.55	0.46	0.27 to 0.70
			Δ 1998-2000	**(0.015)**	0.315	-0.46	0.49	0.11 to 0.88
	LISP	G / G	Δ 1998-1999	ns				
			Δ 1998-2000	**(0.086)**	0.173	0.12	-0.15	-0.32 to 0.02
	YRWA	F / ST	Δ 1998-1999	**(0.001)**	0.501	-0.48	0.69	0.33 to 1.06
			Δ 1998-2000	**(<0.001)**	0.803	-0.48.	1.05	0.77 to 1.32

[1] BTNW – Black-throated Green Warbler; DEJU – Dark-eyed Junco; GCKI – Golden-crowned Kinglet; LISP – Lincoln's Sparrow; SWTH – Swainson's Thrush; YRWA – Yellow-rumped Warbler

[2] foraging guilds: A - aerial, B - bark, F - foliage, G - ground; nesting guilds: C - cavity, G - ground, ST - shrub/tree

[3] p values in brackets determined by weight estimation regression

Most declines relative to the controls were detected in the lower residual treatments, and species exhibiting these declines were typically dependent on shrubs and/or trees for nesting (and foraging), with the exceptions of Canada Warbler (*Wilsonia Canadensis*), Ovenbird and Tennessee Warbler (*Vermivora peregrina*), which are classified as ground nesters (and foragers, in the case of the Ovenbird). Most increases relative to the controls were also detected in the lower residual treatments (though a near-equal number of increases were observed in the 50% and 75% treatments), and species exhibiting these increases were typically ground nesters and/or foragers. Most gains were in the second year post-harvest.

2.3.5 Bird-habitat relationships

Two sets of stepwise multiple regressions involving three vegetation variables each were conducted for each cover type (Table 2.14).

Table 2.14: Vegetation variables added to harvesting treatment in stepwise multiple regressions in 2000, in each cover type.

Cover Type	Set 1: Variables not correlated to treatment level	Set 2: Variables correlated to treatment level
Deciduous	All green cover [1] Deciduous saplings [2] Coniferous stems [3]	DWD cover [1] Low shrub stems All snags [3]
Deciduous / Understory	All green cover Low shrub stems [2] Tall shrub stems [2,4]	DWD cover All snags Coniferous stems
Mixed	All green cover Low shrub stems Tall shrub stems	DWD cover All snags Coniferous stems
Coniferous	Litter cover [1] Low shrub stems Tall shrub stems	Moss cover [1] DWD cover All snags

[1] average percent cover within four 1 m^2 quadrats
[2] mean number of stems per 0.008 ha subplot
[3] mean number of stems per 0.04 ha plot
[4] height > 1.4 m; includes deciduous saplings

Analysis of community-level indices (species richness and species similarity) did not yield any significant models. However, a number of regressions involving guild abundances (Table 2.15) and species abundances (Table 2.16) were significant. Four of the models were particularly strong ($r^2 > 0.5$); all included either foliage gleaner or shrub/tree nester abundance as the dependent variable, and all included 'Tall shrub stems' (which incorporates deciduous saplings) as one of the independent variables added to Treatment.

Table 2.15: Significant stepwise multiple regressions of guild abundances in 2000, in each cover type.

Cover Type	Guild	Significant variables	Variable correlated to treatment?	Regression	
				p	r^2
Deciduous	Ground nester	DWD cover only	Y	**0.074**	0.186
Deciduous / Understory	Foliage gleaner	Treatment + Green cover + Tall shrub stems	- N N	**0.002**	0.640
	Shrub/tree nester	Large snags only	Y	**0.055**	0.211
Mixed	Foliage gleaner	Treatment + Tall shrub stems	- N	**<0.001**	0.741
	Shrub/tree nester	Treatment + Tall shrub stems	- N	**<0.001**	0.695
Coniferous	Bark gleaner	Low shrub stems only	N	**0.040**	0.238
	Shrub/tree nester	Treatment + Tall shrub stems	- N	**0.003**	0.533

Table 2.16: Significant stepwise multiple regressions of species abundances in 2000, in each cover type.

Cover Type	Species [1]	Significant variables	Variable correlated to treatment?	Regression	
				p	r^2
Deciduous	DEJU	DWD cover only	Y	**0.022**	0.288
Deciduous / Understory	None				
Mixed	None				
Coniferous	WTSP	Tall shrub stems only	N	**0.062**	0.201
	WTSP	Litter cover only	N	**0.036**	0.247

[1] DEJU – Dark-eyed Junco; WTSP – White-throated Sparrow

2.4 Discussion

2.4.1 Bird Community Response

My prediction that partial cuts would be intermediate between clearcuts and unharvested controls for all community measures, and that measures would vary linearly with level of retention, was nearly correct. In all cover types except Deciduous/Understory, less retention resulted in lower species richness in 1999 and 2000. In Deciduous/Understory sites, the extensive coniferous understory may have 'buffered' species loss in partial cuts; post-harvest vegetative structure appeared more dense and complex than in other cover types. Patterns of community similarity followed a similar trend in all four cover types: the lower the retention level, the lower the similarity between pre- and post-harvest communities. However, my prediction was slightly at odds with species diversity patterns: in three cover types, diversity decreased in most treatments immediately after logging, but in no discernable pattern.

The immediate positive increases in richness observed in the controls in the first year post-harvest may be evidence of 'crowding', wherein returning forest birds, upon finding their breeding sites denuded, move to adjacent areas with greater tree cover (Whitcomb et al 1981, Schmiegelow et al 1997). Increases in the second year post-harvest may be partially explained by the overall increase in richness across treatments in the same cover types in 2000. The reason for these increases (and the increases in overall abundance exhibited by many guilds in 2000) is unclear, but it may be related to regional fluctuations in songbird populations. Variation in climatic conditions during the survey periods was likely not the cause: survey dates in 2000 were wetter and colder on average than the corresponding period in 1999 (R. Hurdle, Natural Resources Canada, Edmonton, AB, personal communication).

For richness and similarity measures in two of the cover types (Deciduous and Deciduous/Understory), small 'spikes' were observed in the 10% retention treatments, where values were noticeably higher than in 0% or 20% retention blocks. Though not statistically significant, these spikes may indicate real biological advantages in 10% blocks, although it is difficult to identify what these might be.

In northeastern Alberta, Norton and Hannon (1997) studied the effect of group retention cuts (30% and 40% residual) on bird communities in predominantly hardwood stands. After one year, partial cuts were intermediate to clearcuts and controls in all measures, similar to the results reported here. At the same site 3 years post-logging, Tittler (1998) found that few bird species benefited from the higher retention level, perhaps because regeneration reduced differences in habitat quality, especially for birds associated with shrub/sapling cover. She also found lower community similarity between year 0 (pre-harvest) and year 3 than between year 0 and year 1, which she speculated might have resulted from an initial failure of some species to breed successfully, or from competition between forest-dwelling and early- successional species. I did not observe this at EMEND; in fact, for one cover type (Mixed), I detected higher community similarity between year 0 and year 2 than between year 0 and year 1.

2.4.2 Bird Response by Guild

The data also supported my second prediction, that guilds and species dependent on shrub or tree cover for nesting and foraging would be most negatively impacted by partial cutting. Among foraging guilds, foliage and ground gleaners accounted for most observations. For foliage gleaners (in general), less retention resulted in lower abundance, in all cover types, in both time intervals post-harvest, whereas for ground foragers, less retention resulted in higher abundance between 1998-2000, in all but Deciduous sites. Among nesting guilds, shrub/tree nesters and ground nesters accounted for most observations, and the trends exhibited by the groups were again contradictory. Less retention resulted in lower shrub/tree nester abundance in all cover types, in both time intervals, but higher ground nester abundance between 1998-2000, in Mixed and Coniferous sites.

Norton and Hannon (1997) found similar trends, observing that ground nesting and foraging guilds were affected less by harvesting than guilds relying on tree or shrub layers. Among ground-associated guilds, there was a shift towards those species more characteristic of open habitats. Tittler (1998) focused more on individual species, but did note an influx of open area birds into logged sites in the third year post-harvest, hypothesizing that by the first spring post-harvest, open area birds would not yet have had the opportunity to discover and colonize harvested areas, whereas dispersing birds during the first year would discover and colonize them by the second spring.
I detected a similar pattern at EMEND: ground nesters increased between the first and second years post-harvest in the 0% through 50% retention treatments in all cover types, and the abundance of ground foragers increased in all Deciduous/Understory sites, with most of the increases attributable to species classified as open-area birds by Tittler.

Use of guilds in analyzing species response may be criticized as lacking ecological meaning, as members of the same guild may not respond to disturbance in the same way (see Lindenmayer et al. 2000). For example, within a foraging guild (e.g., aerial foragers), there may be both open-area species and forest-dwelling species. Furthermore, the competitive exclusion principle (Gill 1995) suggests that members must have at least slightly different requirements to coexist. Nevertheless, classifying species into guilds is an attempt to tease out possible habitat-selection mechanisms. While relationships can be established between disturbance level and population abundance or fitness, the mechanisms linking the two (e.g., nest site availability, nest predation, food availability) often remain unclear (Marzluff and Sallabanks 1998). Nesting-related mechanisms likely play a significant role, as the effects of the treatments implemented in this study are most directly apparent on nest sites, and site availability may have an immediate effect on habitat selection (Krebs 1994). Alternatively, responses may be related to other mechanisms, such as intraspecific (social behaviour) and interspecific (e.g., competition, predation) interactions, and weather. The potential interaction between partial cutting and weather effects is largely unknown, but residents may be regulated by winter conditions, migration and nesting timing may be affected by rain and wind, and survivorship of young may be impacted by persistent cold wet weather (Elkins 1988).

2.4.3 Bird Response by Species

Abundance increases and decreases in treatments were examined relative to abundance changes in the controls, to account for experiment-wide fluctuations in species abundance (e.g., interannual variation in numbers). In all cover types, species that declined in the lower residual treatments (0%, 10%, 20%), relative to the controls, were typically dependent on shrubs/trees for nesting and foraging (e.g., Golden-crowned Kinglet [*Regulus satrapa*], Red-breasted Nuthatch [*Sitta Canadensis*], Red-eyed Vireo [*Vireo olivaceus*], Swainson's Thrush [*Catharus ustulatus*], Yellow-rumped Warbler [*Dendroica coronata*]) with the notable exception of the Ovenbird. Though the Ovenbird is a ground nester and forager, it clearly requires the presence of trees for its habitat: Schieck and Nietfeld (1995) classify it as most abundant in mature forests in Alberta aspen mixedwoods. Most losses persisted through both years, in all cover types. Species that increased in the lower residuals, relative to the controls, were typically ground nesters (e.g., Dark-eyed Junco [*Junco hyemalis*], Lincoln's Sparrow [*Melospiza lincolnii*], Mourning Warbler [*Oporornis Philadelphia*], White-throated Sparrow [*Zonotrichia albicollis*]). An exception to this was the Chipping Sparrow [*Spizella passerina*], which is generally considered a shrub/tree nester, although we observed this species nesting on the ground on several occasions in 2000. Most gains were largest in the second post-harvest year , in all cover types excepting Deciduous/Understory. Higher residuals (50%, 75%) exhibited similar patterns, with more increases among shrub/tree dependent species. Norton and Hannon (1997) also found that almost all species affected in a negative way by harvesting required trees or shrubs for foraging or nesting, and that abundances in partial cuts were intermediate between clearcuts and controls.

Species data were highly variable, and many comparisons may have lacked sufficient statistical power to detect differences between treatments. In qualitative terms, as retention level increased, the proportion of species increasing in abundance to species decreasing in abundance post-harvest also increased. Deciduous/Understory sites were an exception, where the 10% and 20% retentions were superior to the 50% and 75% residuals in maintaining species abundances. Among declining species with enough observations to be analyzed, the 10% and 20% residual treatments exhibited slightly fewer 'extinctions' than the clearcuts (where almost all declines were extinctions), and slightly more extinctions than the 50% and 75% residuals. Controls experienced almost no extinctions, in any cover type. Norton and Hannon (1997) also observed more extinctions in clearcuts than in partial cuts.

None of the species observed at EMEND are on the national list of species at risk prepared by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2001). Similarly, none of the species are designated 'at risk' in Alberta (Alberta Sustainable Resource Development 2001), but several are designated as 'sensitive', indicating that special attention may be required to prevent them from becoming at risk. These include the Bay-breasted Warbler (*Dendroica castanea*), Black-backed Woodpecker (*Picoides arcticus*), Black-throated Green Warbler (*Dendroica virens*), Canada Warbler, Cape May Warbler (*Dendroica tigrina*), Common Nighthawk (*Chordeiles minor*), Northern Goshawk (*Accipiter gentiles*), and Western Tanager (*Piranga ludoviciana*), all regularly detected at EMEND. Of these, the Canada warbler (in Deciduous sites), and the Black-throated Green Warbler (in Coniferous sites) exhibited significant decreases in the harvest treatments. Unfortunately, most of the others were observed too rarely to be analysed, yet these may be the ones most threatened by the truncation of stand age distribution implicit in a harvest rotation. Future researchers may wish to target these species using a more intensive sampling method (see Chapter 3). One other species found at EMEND, the Brown Creeper (*Certhia Americana*), is designated as 'status undetermined', indicating that we have insufficient knowledge to reliably evaluate its general status.

Irruptive species can also be problematic in studies of this temporal scope. For the White-winged Crossbill (*Loxia leucoptera*), populations likely follow cone crop outbreaks (Elkins 1988, Krebs 1994), and in 1999 only, we observed a major influx of this species in cover types with a coniferous component, in all treatments. Unsurprisingly, concurrent research showed that in terms of seed cone production at EMEND, 1999 was a 'bumper' year, and 2000 was a 'failure' year (J. Stewart, Natural

Resources Canada, Edmonton, AB, personal communication). Three of the warbler species observed at EMEND (Bay-breasted Warbler, Cape May Warbler and Tennessee Warbler) are known to thrive during spruce budworm outbreaks (Kaufman 1996), and one of these, the Tennessee Warbler, exhibited a relatively large influx across treatments during the study, in Deciduous/Understory sites in 2000. However, spruce budworms were only present at EMEND at endemic levels, well below the density at which they would be detected by conventional sampling (J. Volney, Natural Resources Canada, Edmonton, AB, personal communication).

The regression models revealed additional influential variables for some bird abundance measures, and these could prove valuable in developing habitat models for certain guilds or species. The emergence of tall shrub stems (which includes deciduous saplings) as an influential variable for foliage gleaners and shrub/tree nesters is in accord with our understanding of the ecological needs of these groups, as they are dependent almost by definition on shrubs and shrub foliage. The models also revealed relationships between vegetation structure and guild/species response which would otherwise have gone undetected. For example, the regression of White-throated Sparrow abundance upon ground litter cover wasn't unexpected, given the ground-foraging and ground-nesting habits of this species, but because there was no relationship between litter cover and treatment level (or because we lacked the power to detect one), we detected no trend in White-throated Sparrow abundance across treatments.

2.4.4 Limitations of This Study

Power

The power of a test is the probability of rejecting the null hypothesis when it is false, and is a function of the alpha or Type I error rate, the sample size, and the effect size. Given the relatively large number of treatments (6) in my project, and the relatively small number of replicates for each treatment level (3), I had only 25.5% power using ANOVA to detect a large effect size (0.40) as conventionally defined (Cohen 1992), even with an alpha of 0.10. With this number of treatments, 12 replicates per treatment would have been required to achieve a power of 80%. However, the conventional definition of effect size is arbitrary, and may not have any biological relevance for the system under study (Steidl et al. 1997, Gerard et al. 1998). Our current knowledge of bird communities in the vicinity of EMEND contains too many unknowns (e.g., the magnitude scale of natural variation in the system, including temporal fluctuations, and the magnitude of impacts required for a long-term effect).

While post-hoc power analysis is now common in ecological studies, I have not conducted a post-hoc assessment. Post-hoc power is calculated using effect sizes determined from observed sample differences, and this procedure invariably links high 'p' values with low power estimates (Steidl et al. 1997). Consequently, it provides no additional information. Using a large alpha value allowed me to minimize type II errors, which may carry higher risks than Type I errors for management decisions. Type II errors could lead to population declines for some bird species if management actions are based upon the results of low power tests which failed to detect negative effects of harvest treatments (Steidl et al. 1997).

Temporal Scale

The short time span of this research also limits its utility. While this study had the advantage of a strong pre- and post-harvest design, as did those of Norton and Hannon (1997) and Tittler (1998), longer-term responses may vary, as with those studies. For example, retaining mature forest trees may affect aspen and spruce regeneration if decreased light levels relative to clearcuts inhibit regrowth or suckering, and this would be reflected in future bird communities. Edge effects may only be realized over the longer-term, as predator and parasite populations may respond to the disturbance over a number of generations. As well, because partial cuts retain old-growth structural legacies, species favouring old stands may return to pre-harvest levels more rapidly in partial cuts than in clearcuts. Thus, the temporal scale of the research must be extended to accurately assess response, and provide reliable management recommendations.

Compartment Size

Finally, the size of the compartments at EMEND presented complications. A maximum of two point count stations could be situated within each 10 ha compartment. This resulted in small sample sizes for many species, and the concomitant high variability compromised my ability to detect changes post-harvest. The smaller block size also complicated my efforts to achieve independence of counts within the same compartment, and increased the likelihood of counting 'edge' birds along compartment boundaries. Furthermore, a compartment area of 10 ha may be too small a patch for some species in western forests (Hannon 1993). For example, the Ovenbird has often been classified as an 'area-sensitive species' due to its reliance on large patches of homogeneous mature forest habitat (Freemark and Collins 1992, Thompson et al. 1993), and pairing success among Ovenbirds has been positively correlated to forest patch size and distance from edge (Van Horn et al. 1995, Burke and Nol 1998). At EMEND, patch size effects for the Ovenbird might have occurred in the harvested compartments, which were typically adjacent to two or more treatment blocks, but were less likely in the controls, which were usually set apart from the other compartments and surrounded on three sides by undisturbed forest, potentially creating larger habitat patches. It is unclear whether the 50% and 75% retention levels, in particular, would have supported greater abundances if present in larger patches.

2.5 Forest Management Implications

A primary goal of this study was to provide site-specific and empirically-based guidelines to managers about residual tree management. In Deciduous, Mixed and Coniferous cover types, partial cuts were intermediate between clearcuts and controls in terms of species richness, diversity and similarity; in Deciduous/Understory sites, this pattern was observed for species diversity only. Partial cuts exhibited similar graded trends in terms of guild abundances. In Deciduous sites, harvesting generally impacted shrub/tree-associated groups negatively; in Deciduous/Understory sites, harvesting impacted shrub/tree-associated groups negatively and ground foragers positively; in Mixed and Coniferous sites, harvesting impacted shrub/tree-associated groups negatively and ground-associated groups positively. Species data were highly variable, but even high retention levels did not retain habitat for all forest bird species.

My research indicates that partial cutting offers some conservation advantages over clearcutting, at least in the short term, but as Hunter (1993b) points out, managing for biodiversity involves tradeoffs. Consequently, partial cutting should not be the only tool in a manager's toolbox. Where individual species of concern or high priority areas are involved, managers should consider a combined plan involving both a coarse and a fine filter approach (Squires et al. 1998) to ensure any special habitat needs are met. If partial cutting involves cutting a larger area to harvest the same timber volume, we must determine whether the biodiversity gains from partial-cutting outweigh the losses from forests which might otherwise remain unlogged. Finally, it's important to make the distinction between biodiversity and ecosystem integrity. As Simberloff (1999) points out, because ecological processes such as primary productivity may be preserved despite a loss of species, biodiversity as measured by species richness does not necessarily equate to ecosystem function, and the two terms should not be used synonymously.

As noted previously, this project was designed to address questions at the level of the stand. However, stand-level data, such as that collected at EMEND, may not provide accurate predictions unless supplemented by larger-scale information. Reasons for this include: 1) habitats may be patchily distributed throughout a landscape, and the distribution of birds may depend on factors such as patch area, degree of fragmentation and connectivity (Villard et al. 1998, Walters 1998); hence, species presence and abundance may depend upon landscape context; 2) metapopulation theory suggests that low quality or 'sink' bird populations may be sustained through immigration from neighboring sub-populations (e.g., Pulliam 1988, Martin 1992b), and therefore, breeding assemblages observed using point counts may be as much a reflection of neighboring habitats as of local habitat conditions; 3) Norton et al. (2000) found that some species in northwestern boreal mixedwoods may have been able to compensate for a loss of preferred forest habitat by utilizing other habitat types, at least temporarily. Consequently, caution should be exercised when extrapolating stand-level species response to habitat disturbance to a larger scale.

The data collected on songbirds and habitat at the EMEND site complements other, ongoing efforts to integrate information across different spatial scales and from various parts of the province. These data will be used to develop statistical models of bird distribution that will be linked to landscape-scale simulators of boreal forest dynamics, in order to evaluate various management scenarios and develop strategic policy alternatives for Alberta's boreal forest (see Schmiegelow et al. 1999).

EMEND addresses the question of 'how much residual is enough?' in a natural disturbance approach to forest management. It's a vital question, but not the only challenge faced by planners. In order for biodiversity to coexist with industrial forestry, management must also match natural disturbances in terms of spatial patterns (e.g., size and configuration of openings, within-stand structural features) and temporal scale (e.g., frequency of harvest) (Hunter 1993a). In other words, spatial and temporal heterogeneity should be maintained within the historic range of natural variability. This means managing for heterogeneity on many scales simultaneously (Hunter 1990). Haila et al. (1994) suggests identifying critical scales for a set of taxa, and using these as guidelines for planning forest operations over a large area. My study has provided information for the most diverse taxonomic group; nonetheless, I caution against applying these results to other fauna, which may respond to disturbance in very different ways, on much smaller or larger scales.

The prognosis for matching forest management to natural disturbance regimes in the boreal appears promising. Because the boreal forest is a resilient system with a naturally variable mosaic of habitats, continuity of habitat may be less important to boreal birds (Haila 1994) than to those in eastern forest types. However, large-scale forestry faces a number of hurdles, including: 1) estimates of mean annual burn rates in the boreal mixedwood are highly variable, and it may prove difficult to specify a valid target age class distribution through modeling (see Armstrong 1999); 2) unlike fires, logging operations create roads, which can represent permanent losses of habitat; 3) given the size of forest tenures, limits on cutblock dimensions, and safety concerns, we can't mimic the scale of large fires (Hunter 1993a). Finally, natural disturbance modelling should also incorporate smaller-scale disturbances such as tree-falls, windthrow and insect outbreaks, and their interactions with fire. Concurrent research projects at EMEND are examining some of these latter forms of disturbance.

Chapter 3 Assessment and Comparison of Alternative Survey Techniques

3.1 Introduction

Relative abundance or density, as derived from point counts, is frequently used to infer habitat quality, under the assumption that individuals will occur at greater densities in better quality habitats (with associated higher survival and reproduction rates). However, density can be misleading if not complemented by some measure of reproductive success (see van Horne 1983, Vickery et al. 1992a, Hagan et al. 1996, Purcell and Verner 1998). For example, song output can be a deceptive indicator of pairing status, since unpaired males may sing more frequently than paired males (Best 1981, Gibbs and Wenny 1993), and 'sink' populations with low reproductive output may be sustained at high densities through immigration into poor quality habitats (Pulliam 1988, Martin 1992a).

Though critical to assessing long-term population persistence, reproductive success is difficult to measure. Productivity may be directly monitored at nests (e.g., Mayfield 1975, Martin and Geupel 1993), or indirectly inferred through predation levels on artificial nests (e.g., Rudnicky and Hunter 1993, VanderHaegen and DeGraaf 1996, Donovan et al. 1997). However, nest monitoring techniques are logistically difficult and potentially disruptive to breeding birds, and artificial nest techniques are problematic for a number of reasons, e.g., human visitation may alter predation types and rates (see Major and Kendal 1996 for a review).

To alleviate some of these limitations, a number of other methods have been explored. Some researchers (e.g., Vickery et al. 1992b, Hartley 1994, Dale et al. 1997, Rangen et al. 2000) have attempted to develop productivity indices for habitat quality via the intensive monitoring of bird behaviours and fledgling presence on breeding grounds (a behaviour monitoring technique). Alternatively, Gunn et al. (2000) estimated the relative reproductive activity of forest songbird assemblages through the broadcast of Black-capped Chickadee (*Parus atricapillus*) mobbing calls to attract non-vocalizing birds and enable greater visual detection of reproductive activities (a call playback technique).

I used both these methods to assess bird communities at EMEND. The behaviour monitoring technique was used to assess productivity for one species, the Swainson's Thrush (*Catharus ustulatus*), in one cover type, in order to test whether density measures derived from concurrent point count surveys accurately reflected reproductive activity. With the chickadee mobbing call playback technique, my primary objective was to determine to what extent the technique increased the bird observation rate, and whether any increases were equal across treatments and consistent through the breeding season.

3.2 Methods

3.2.1 Behaviour Monitoring

In 2000, bird breeding behaviours and fledgling presence (after Vickery et al. 1992b) were monitored in one cover type (Deciduous/Understory, three replicates per treatment), on a single target species, the Swainson's Thrush. All harvest treatments were surveyed. Choice of target species was based on factors such as nesting and foraging niches, male participation in nest-tending, seasonal timing of breeding activities, detectability, expected treatment impact, and relative abundance (in 1999) in the various cover/treatment types.

The Swainson's Thrush is a neotropical migrant, classified as a foliage gleaner and a shrub/tree nester (Ehrlich et al. 1988), and is relatively secretive in its habits (Evans Mack and Yong 2000). It arrives in Alberta in mid-May, and, in general, inhabits heavily wooded forests with a mix of deciduous and coniferous trees (Semenchuk 1992). At EMEND, the highest densities of this species were found in Deciduous/Understory sites. Breeding requirements and phenology are largely unknown in the boreal region, but we observed adult arrivals in mid May, and juvenile presence in early-mid July.

Monitoring started in late May and continued until late July, and each compartment in each treatment was surveyed eight times. Visits were evenly spread throughout the breeding season to overlap the expected breeding chronology of Swainson's Thrush from arrival to fledging. From one round to the next, each compartment was visited at a different time of the morning to lessen temporal bias. Observers were assigned to the same set of compartments (one in each treatment type) throughout the breeding season, to take advantage of their familiarity with block and territory boundaries. Within a compartment, the observer walked transect lines in a systematic manner for a period of approximately two hours, between 0500 hrs and 1300 hrs, noting all occurrences and behaviours of the target species. Observations within each compartment were mapped.

3.2.2 Call Playbacks

Gunn et al. (2000) report that the mobbing call playback method provides an accurate and time-efficient method for estimating the relative reproductive activity of forest songbird communities in eastern forests. Mobbing refers to a situation where birds of a single species gather around a predator, changing position frequently, and vocalizing loudly (Curio 1978), thereby attracting birds of other species. To capitalize on this behavioural phenomenon, a surveyor may broadcast a recording of chickadee mobbing calls to attract nearby birds of all species and improve visual detection of reproductive activities such as adults carrying food, presumed pairing behaviour, etc. Gunn et al. (2000) found that this technique increased the probability of visually observing birds compared to silent counts. Furthermore, the reproductive index for two species (Ovenbird and Black-throated Blue Warbler [*Dendroica caerulescens*]) was consistent with data from a concurrent nest monitoring program on the same plots.

At EMEND, for point count rounds 2 through 5 in 2000 (spanning May 30 to July 6), playback sessions were conducted after each point count. The 5 minute passive point count period was followed by a 5 minute 'mobbing' broadcast period, followed by a 5 minute 'silent' period, which allowed shyer birds an opportunity to investigate. During the mobbing and silent periods (collectively termed the 'playback periods'), observers noted all new birds as well as previously-recorded birds that changed their activity. Since Black-capped Chickadees were present in all cover types, we expected most other species to be familiar with chickadee mobbing behaviour.

To broadcast the chickadee calls, we used Radio Shack CTR-01 tape recorders, with two KOSS SA/35 dual amplified portable stereo speakers (with bass boost and amplifier on), elevated approximately 1.5 m off the ground. Playback audio level was calibrated within each cover and treatment type to be barely audible to observers at 100 m. All cover types and all treatments were surveyed, but we sampled only stations at which 100m radius counts could be conducted, to avoid drawing in birds from outside habitats. Because not all compartments had at least one 100m radius station, some treatments were replicated only two times (Table 3.1).

Table 3.1: Schematic representation of experimental layout for call playback surveys.

		Cover Type			
		Deciduous (n=14)	Deciduous / Understory (n=16)	Mixed (n=15)	Conifer (n=14)
Retention Level	0% (clearcut)	□□	□□□	□□	□□
	10%	□□	□□	□□	□□
	20%	□□	□□□	□□□	□□
	50%	□□□	□□□	□□□	□□□
	75%	□□□	□□□	□□□	□□□
	100% (control)	□□	□□	□□	□□

3.2.3 Analyses

Prior to performing analyses, data were tested for normality using scatterplots and Q-Q plots, and for homoscedasticity using Levene's test (Conover 1980), except where noted. If necessary, data were transformed to meet assumptions of parametric statistical tests, and if assumptions could not be met, nonparametric tests were used. Because sample sizes were relatively small and variation was typically high, outliers were not removed, and an alpha of 0.10 was used for all tests. This increased power and lessened the possibility of Type II errors, which may have more important consequences for monitoring of species (Thompson and Schwalbach 1995, Steidl et al 1997). The Tukey correction for unplanned multiple comparisons was used where appropriate (Neter et al. 1985). Except where noted, all analyses were conducted using SPSS Base 10.0 for Windows (SPSS Inc. 1999). GPOWER (Faul and Erdfelder 1992) was used to compute power.

Behaviour Monitoring

Observations were weighted on a 5-point scale (Table 3.2) according to the strength of evidence of breeding success (see Evans Mack and Yong 2000). Within each compartment, territories of the Swainson's Thrush were identified based on clusters of observations, and each territory was assigned a reproductive rank corresponding to the highest breeding weight recorded for that territory during the breeding season. Territory ranks within a compartment were both summed and averaged to produce two different compartment values: a 'summed territory' rank and an 'averaged territory' rank. Data were analyzed using least squares regression, and one-way ANOVA. Variables which were heteroscedastic between treatments were log $(x+1)$ – transformed, and if transformations could still not satisfy assumptions, weight estimation regression (in which data points within a group are weighted by the inverse of their group variance [SPSS Inc 1999]) and Kruskal-Wallis ANOVA were used.

Table 3.2: Breeding weights assigned to bird observations during behaviour surveys in 2000.

Behaviour/Observation Type	Weight
Family group or juvenile	5.0
Brood or adult carrying food (late in season)	4.0
Clutch or distraction display or adult carrying food (early in season)	3.0
Pair or nest or adult carrying nesting material	2.0
Singing or countersinging male or territorial dispute	1.0
Calling adult or adult observed visually	0.5

Call Playbacks

All bird observations within each sampling period were recorded. We could not distinguish between 'responsive' birds and birds which simply chose the mobbing period to vocalize. As the call playback technique is less subject to limitations of the point count survey method, analyses were not restricted to 'reliably-detectable' species (see Chapter 2). As in Chapter 2, a weighted ranking system was used to better link abundance to breeding status (Table 2.1).

Analyses were only performed on birds recorded within the 50 m radius circles, due to the detectability and boundary constraints described in Chapter 2. I also reasoned that birds responding to the mobbing calls would be expected to do so within this narrower radius. However, it was recognized that the broadcast calls may have drawn in birds from outside the 50 m radius, and the effective sampling area of the playback technique may have been greater than that of the point count technique. Consequently, the methods were not directly compared; rather, I quantified the additional information provided by the inclusion of the playback periods. As in Chapter 2, birds observed exclusively within retention ellipses were excluded from analyses.

Observations were summarized within each sampling period (point count, mobbing and silent periods), and analyzed either by period, or by time interval (e.g., mobbing and silent periods combined). Data in each sampling period or interval were analyzed using least squares regression, and one-way ANOVA. Variables which were heteroscedastic between treatments were log (x+1) – transformed, and if transformations could still not satisfy assumptions, weight estimation regression and Kruskal-Wallis ANOVA were used. Correlations between variables were tested using Pearson's or Spearman's tests. To explore possible within-season fluctuations in observation rates, data were also summarized by sampling round through the breeding season, and tested using a Repeated Measures ANOVA (within-subjects effects). Because I lacked confidence in the form of the underlying population distributions for some statistics, I used a method of bootstrapping (Efron and Tibshirani 1998) to estimate linear regression coefficients with bias-corrected confidence intervals, when assumptions could be met.

I examined both total observations and 'reproductive' observations, which were ascribed to sightings indicative of at least pairing success (e.g., obvious pair, bird carrying food or nesting material, active nest, juveniles, distraction display), and which were primarily visual in nature. Total observations were subdivided into the appropriate foraging and nesting guilds (as in Chapter 2) and migratory guilds (based on Semenchuk 1992, Kaufman 1996) and analyzed accordingly. Responses for birds of individual species were also explored, but small sample sizes precluded most analyses. Finally, total observations were weighted using the 2-point scale detailed in Chapter 2 (Table 2.1), and re-analyzed as above.

3.3 Results

3.3.1 Behaviour monitoring

Using the 'summed territory' ranks for each compartment, mean reproductive ranks for Swainson's Thrush were calculated for each treatment (Figure 3.1). The mean rank observed in the controls was significantly higher than the other treatments ($p=0.002$), and a significant linear trend ($p=0.001$) was also detected, though a cubic regression provided the best fit ($p<0.001$, $r^2=0.744$). Compartment areas ranged from 8.0 ha to 11.9 ha, but when compartment area was included as a covariate, it was found to have a negligible effect.

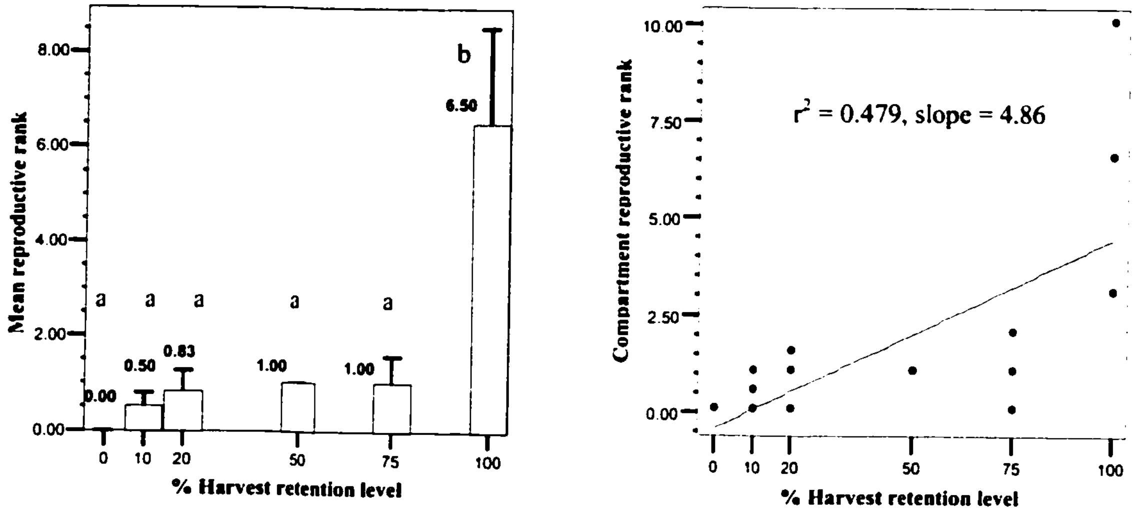


Figure 3.1: Reproductive ranks of Swainson's Thrush in Deciduous/ Understory sites in 2000, as detected by behaviour monitoring surveys. Means with the same letter are not significantly different from one another. Error bars represent 1 standard error.

In the controls, the number of territories within compartments, in whole or in part, ranged between 2 and 4. In all other treatments, either 0 or 1 territory was observed, and in none of these territories did the detections advance beyond singing males. Fledglings were observed on only three occasions: twice in controls, and once along the edge of (but not within) a 10% retention compartment.

Using the system detailed in Chapter 2 (Table 2.1), mean abundance on a 2-point scale was also calculated for each territory, then averaged within treatments, for comparison with patterns observed during point count surveys (Figure 3.2). Treatment means were significantly different for the behaviour survey data (Kruskal Wallis p=0.051), but not for the point count survey data (p=0.288). No correlation was detected between the two datasets (Spearman's p=0.172). The mean abundance values calculated by the two methods should not be directly compared because the sampling area is much larger for the behaviour monitoring technique within treatments (approximately 10 ha versus 0.8 ha for each point count station).

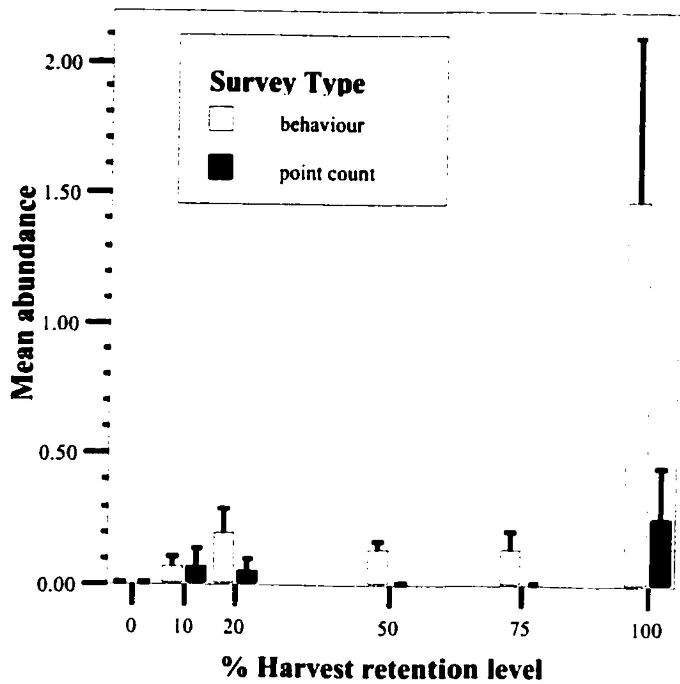


Figure 3.2: Mean abundance per station (point count surveys) or compartment (behaviour surveys) of Swainson's Thrush in Deciduous/Understory sites with variable retention in 2000. Error bars represent 1 standard error.

3.3.2 Call playbacks

Species Response

In total, 46 species (or 72% of the species detected during point counts in 2000) were observed during call playback surveys (Appendix 6). In Deciduous sites, Yellow-rumped Warbler, Tennessee Warbler and White-throated Sparrow were observed most often, representing 44% of playback detections. In Deciduous/Understory sites, Chipping Sparrow replaced White-throated Sparrow as third most-common, and the top three species accounted for 48% of all detections. In Mixed sites, Red-breasted Nuthatch, Chipping Sparrow and Yellow-rumped Warbler ranked highest, representing 37% of detections, and in Coniferous sites, Yellow-rumped Warbler, Dark-eyed Junco and Chipping Sparrow were the most common, representing 38% of all detections.

Species exhibiting 3 or more detections during playback periods were categorized as 'frequently-observed species'. Among the 12 frequently-observed species in Deciduous sites, Neotropical migrants were better represented (58%) than their proportion of the total playback survey species pool (52%), as were early migrants (70% vs. 58%). Among the 10 frequently-observed species in Deciduous/Understory sites, residents and short-distance migrants were better represented (30% each) than their proportions of the total mobbing playback species pool (22 and 26%, respectively), as were early migrants (86% vs. 58%). Among the 11 frequently-observed species in Mixed sites, residents were better represented (36%) than their proportion of the total playback survey species pool (22%), as were early migrants (71% vs. 58%). Among the 14 frequently-observed species in Coniferous sites, residents and short-distance migrants were better represented (36% each) than their proportions of the total playback survey species pool (22 and 26%), as were early migrants (89% vs. 58%).

Contribution of Call Playback Periods

The mobbing and silent periods of playback surveys accounted for a large portion (44%) of all bird observations during this study (Table 3.3). Among foraging guilds, foliage and ground gleaners formed the bulk of the playback observations (mirroring the point count results), in roughly equal proportions (43% and 42%) of their total detections. Among nesting guilds, shrub/tree and ground nesters accounted for most observations, with shrub/tree nesters exhibiting a higher proportion of their detections during playback periods (44% vs. 36%). Cavity nesters, though present in lower numbers than the aforementioned groups, had a high proportion of their detections (58%) during playback periods. This pattern was fairly consistent for each cover type. The playback observation rate in Mixed sites was slightly lower than in the others (38% vs. 45 - 47%).

Table 3.3: Percent of total survey observations accounted for by call playback portion of survey, in each cover type in 2000.

Cover Type	All Birds	Birds by Foraging Guild				Birds by Nesting Guild		
		Aerial	Bark	Foliage	Ground	Sh/Tree	Cavity	Ground
ALL TYPES	**44%**	45%	57%	43%	42%	44%	58%	36%
(n=59)	**(427/977)**	(20/44)	(42/74)	(213/495)	(152/364)	(217/488)	(85/146)	(125/343)
DECID	**45%**	47%	31%	50%	41%	54%	39%	40%
(n=14)	**(108/241)**	(14/30)	(5/16)	(54/109)	(35/86)	(47/87)	(11/28)	(50/126)
DEC/UNDER	**47%**	50%	71%	46%	45%	46%	79%	40%
(n=16)	**(121/259)**	(2/4)	(10/14)	(61/134)	(48/107)	(62/134)	(19/24)	(40/101)
MIXED	**38%**	50%	71%	35%	34%	37%	66%	19%
(n=15)	**(100/261)**	(4/8)	(17/24)	(48/139)	(31/90)	(56/152)	(33/50)	(11/59)
CONIF	**45%**	0%	50%	44%	47%	45%	50%	42%
(n=14)	**(98/216)**	(0/2)	(10/20)	(50/113)	(38/81)	(52/115)	(22/44)	(24/57)

No significant differences were detected between cover types in terms of total observations added per station during playback periods (p=0.441). At the guild level, only ground nesters exhibited significant differences between cover types (p=0.015), with Mixed sites contributing a smaller number of detections per station during the playback periods.

I also examined the data on a count by count basis to determine how often the call playback periods contributed information about a species (an individual of that species was detected only during the mobbing/silent periods, or the number of individuals increased during the mobbing/silent periods). Cover types were grouped, and the data are presented in Figure 3.3. In total, playback periods contributed information to 46% of species detections (744 in total). No significant differences between treatments were detected (p=0.952), indicating the playbacks were supplementing point counts at roughly the same proportion in all residual levels. For the individual cover types, the data were more variable, but again, treatments were not significantly different. When treatments were lumped, no significant differences were detected between cover types (p=0.739). These results underscore the significant contribution made by playbacks, and the relatively low variance further implies that playback observations were relatively well-distributed among the count surveys (e.g., we did not encounter a situation where a relatively small number of super-abundant mobbing responses accounted for most of the total playback observations).

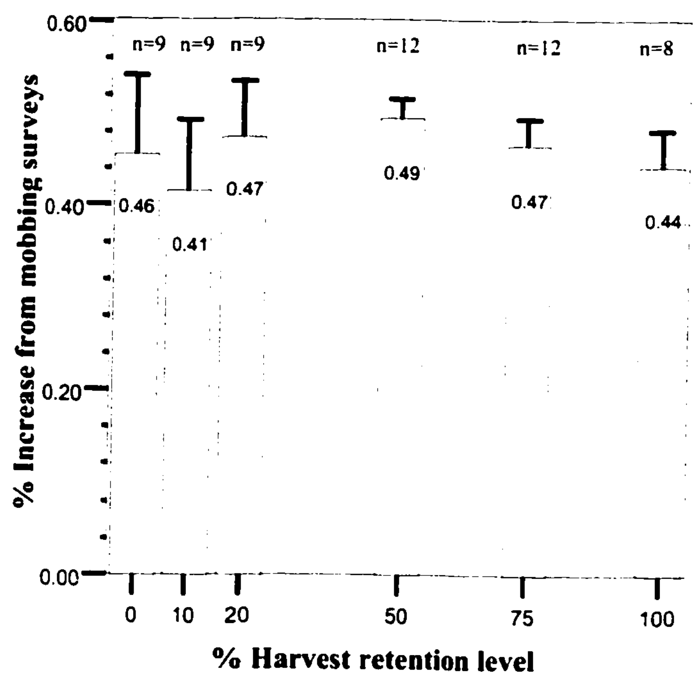
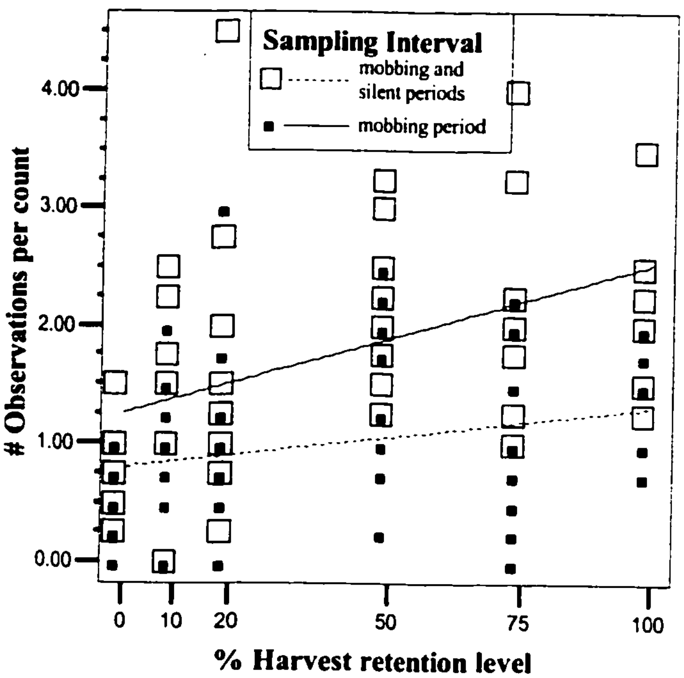


Figure 3.3: Percentage of detections in which the playback surveys (mobbing + silent periods combined) added information about a species, for all cover types in 2000. Error bars represent 1 standard error.

Playback Results Across Treatments

Data from the call playback surveys were analyzed in two sampling intervals: the mobbing call period alone, and the mobbing period combined with the silent (post-mobbing) period. For all cover types combined, linear trends in the total number of observations added across treatments were detected for both sampling intervals (Figure 3.4), indicating that playbacks reveal more previously-undetected birds in the higher retention levels. Interestingly, the slope of the increase during the second interval was over twice the slope observed for the first, possibly because a portion of the bird community in the higher retentions responded only after cessation of the calls. Alternatively, these birds might have been present but undetected during active broadcasting due to the proximity of the speakers to the observer. It should be noted that for each sampling interval, the r^2 value for the linear relationship was relatively low, indicating low explanatory strength. Data in the second sampling interval were correlated with the point count data (p=0.002, Pearson's r = 0.401).



Mobbing & silent periods:
$p<0.001$, $r^2 = 0.195$, slope = 1.29
(95% CI for slope = 0.75 to 1.82)

Mobbing period only:
$p=0.051$, $r^2 = 0.065$, slope = 0.51
(95% CI for slope = 0.13 to 0.89)

Figure 3.4: Observations added per count during playback surveys in all cover types in 2000, for sampling interval indicated.

Table 3.4 (a through d) displays the mean increase in bird observations per count in each cover type after both sampling intervals. Data were broken down by foraging and nesting guild. In Deciduous sites (Table 3.4 a), playback survey observations increased linearly with increasing residual tree level in both intervals (mobbing period and mobbing + silent periods). The trend in total observations can be ascribed largely to increasing trends in foliage gleaners (both intervals) and shrub/tree nesters (second interval), though these were countered somewhat by a declining trend in ground gleaners.

Table 3.4 a: Mean number of observations (with standard error) added per count during call playbacks in Deciduous sites in 2000, for sampling interval indicated. Significant p values (< 0.10) are in bold type. Means with the same letter are not significantly different.

Guild		Sampling Interval	Harvest Retention Level 0%	10%	20%	50%	75%	100%	ANOVA[1] p	Linear Regression[2] p	r²	interc	slope	95% CI for slope
	ALL	M[3]	0.50 (0.25)	1.25 (0.75)	1.13 (0.13)	1.67 (0.46)	0.67 (0.22)	1.88 (0.13)	(0.267)	**(0.008)**	0.458	0.79	0.93	0.29 to 1.56
		M+S[4]	0.63 (0.38) [a]	1.63 (0.63) [ab]	1.75 (0.25) [ab]	2.25 (0.58) [ab]	1.75 (0.29) [ab]	3.50 (0.00) [b]	**0.043**	**0.008**	0.455	1.08	1.87	1.32 to 2.42
FORAGING GUILDS	Aerial	M	0.00 (0.00)	0.00 (0.00)	0.13 (0.13)	0.00 (0.00)	0.00 (0.00)	0.75 (0.25)	**(0.052)**	Insufficient data				
		M+S	0.00 (0.00)	0.00 (0.00)	0.38 (0.38)	0.08 (0.08)	0.00 (0.00)	1.25 (0.00)	**(0.098)**	Insufficient data				
	Bark	M	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.08 (0.08)	0.17 (0.08)	0.13 (0.13)	(0.459)	Insufficient data				
		M+S	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.17 (0.17)	0.17 (0.08)	0.13 (0.13)	(0.529)	Insufficient data				
	Foliage	M	0.00 (0.00) [a]	0.25 (0.00)	0.25 (0.00)	1.33 (0.30) [c]	0.50 (0.14) [abc]	0.88 (0.13) [bc]	**0.009**	**0.058**	0.268	0.24	0.78	0.58 to 0.94
		M+S	0.00 (0.00)	0.50 (0.00) [ab]	0.38 (0.13) [ab]	1.50 (0.25)	1.25 (0.25)	1.75 (0.25)	**(0.048)**	**(<0.001)**	0.794	0.14	1.72	1.17 to 2.27
	Ground	M	0.50 (0.25)	1.00 (0.75)	0.75 (0.00)	0.25 (0.14)	0.00 (0.00)	0.13 (0.13)	(0.114)	**(0.002)**	0.584	0.73	-0.77	-1.18 to -0.36
		M+S	0.63 (0.38)	1.13 (0.63)	1.00 (0.00)	0.50 (0.14)	0.33 (0.22)	0.38 (0.13)	0.407	**(0.004)**	0.247	1.01	-0.70	-1.13 to -0.27
NESTING GUILDS	Shrub / Tree	M	0.25 (0.25)	0.25 (0.25)	0.38 (0.13)	0.67 (0.22)	0.25 (0.14)	0.75 (0.25)	0.398	0.218				
		M+S	0.38 (0.38)	0.50 (0.25)	0.63 (0.13)	0.75 (0.25)	1.17 (0.22)	1.50 (0.25)	0.113	**0.001**	0.591	0.35	1.08	0.63 to 1.50
	Cavity	M	0.00 (0.00) [a]	0.00 (0.00) [a]	0.00 (0.00) [a]	0.50 (0.14) [b]	0.17 (0.08) [ab]	0.25 (0.00) [ab]	**0.024**	**0.095**	0.214	0.05	0.30	0.19 to 0.35
		M+S	0.00 (0.00) [a]	0.00 (0.00) [a]	0.06 (0.00) [a]	0.58 (0.22) [b]	0.17 (0.08) [ab]	0.25 (0.00) [ab]	**0.014**	**(0.015)**	0.400	-0.01	0.27	0.06 to 0.48
	Ground	M	0.25 (0.00)	1.00 (0.50)	0.75 (0.25)	0.50 (0.25)	0.25 (0.00)	0.88 (0.13)	(0.186)	(0.157)				
		M+S	0.25 (0.00) [a]	1.13 (0.38) [bc]	1.13 (0.13) [bc]	0.92 (0.22) [bc]	0.42 (0.08) [abc]	1.75 (0.25) [c]	**0.006**	0.335				

[1] p values in brackets determined by Kruskal-Wallis ANOVA
[2] p values in brackets determined by weight estimation regression
[3] observations added during mobbing call period
[4] observations added during mobbing call period + silent period

Table 3.4 b: Mean number of observations (with standard error) added per count during call playbacks in Dec./Under. sites in 2000, for sampling interval indicated. Significant p values (< 0.10) are in bold. Means with the same letter are not significantly different.

		Sampling Interval	Harvest Retention Level						ANOVA[1]	Linear Regression[2,3]				
			0%	10%	20%	50%	75%	100%	p	p	r^2	interc	slope	95% CI for slope
	ALL	M[4]	0.42 (0.08)	1.00 (0.50)	1.50 (0.76)	1.17 (0.30)	1.58 (0.55)	0.88 (0.13)	0.357	0.189				
		M+S[5]	0.83 (0.08)	2.00 (0.50)	2.17 (1.18)	1.83 (0.36)	2.83 (0.82)	1.63 (0.38)	0.317	0.149				
FORAGING GUILDS	Aerial	M	0.00 (0.00)	0.00 (0.00)	0.08 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	(0.502)	Insufficient data				
		M+S	0.00 (0.00)	0.00 (0.00)	0.17 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**(0.098)**	Insufficient data				
	Bark	M	0.00 (0.00)	0.00 (0.00)	0.17 (0.17)	0.17 (0.08)	0.25 (0.25)	0.13 (0.13)	(0.654)	(0.103)				
		M+S	0.00 (0.00)	0.00 (0.00)	0.17 (0.17)	0.17 (0.08)	0.42 (0.42)	0.13 (0.13)	(0.654)	(0.113)				
	Foliage	M	0.17 (0.08)	0.25 (0.00)	0.92 (0.55)	0.33 (0.08)	0.67 (0.42)	0.75 (0.25)	0.366	0.142				
		M+S	0.17 (0.08) a	0.88 (0.13) ab	1.08 (0.71) ab	0.83 (0.17) ab	1.42 (0.55) ab	1.50 (0.50) b	**0.097**	**0.014**	0.361	*0.10*	*0.12*	*0.06 to 0.18*
	Ground	M	0.25 (0.14)	0.75 (0.50)	0.33 (0.08)	0.67 (0.22)	0.67 (0.22)	0.00 (0.00)	0.103	0.606				
		M+S	0.67 (0.17)	1.13 (0.63)	0.75 (0.25)	0.83 (0.22)	1.00 (0.29)	0.00 (0.00)	0.260	0.300				
NESTING GUILDS	Shrub / Tree	M	0.00 (0.00)	0.63 (0.13)	0.58 (0.22)	0.50 (0.14)	0.42 (0.30)	0.75 (0.25)	0.237	0.178				
		M+S	0.25 (0.14)	1.13 (0.38)	1.00 (0.50)	1.08 (0.30)	1.25 (0.52)	1.25 (0.25)	0.480	0.113				
	Cavity	M	0.17 (0.17)	0.00 (0.00)	0.42 (0.42)	0.25 (0.14)	0.25 (0.25)	0.13 (0.13)	0.944	0.805				
		M+S	0.17 (0.17)	0.13 (0.13)	0.50 (0.50)	0.25 (0.14)	0.50 (0.38)	0.13 (0.13)	0.965	0.718				
	Ground	M	0.25 (0.14) ab	0.38 (0.38) ab	0.50 (0.14) ab	0.42 (0.08) ab	0.92 (0.22) b	0.00 (0.00) a	**0.080**	0.714				
		M+S	0.42 (0.30)	0.75 (0.00)	0.67 (0.22)	0.50 (0.22)	1.08 (0.22)	0.25 (0.25)	0.201	0.803				

[1] p values in brackets determined by Kruskal-Wallis ANOVA
[2] p values in brackets determined by weight estimation regression
[3] italicized regression equations involve transformed variables
[4] observations added during mobbing call period
[5] observations added during mobbing call period + silent period

Table 3.4 c: Mean number of observations (with standard error) added per count during call playbacks in Mixed sites in 2000, for sampling interval indicated. Significant p values (< 0.10) are in bold type. Means with the same letter are not significantly different.

		Sampling Interval	Harvest Retention Level 0%	10%	20%	50%	75%	100%	ANOVA[1] p	Linear Regression[2] p	r^2	interc	slope	95% CI for slope
	ALL	M[3]	0.63 (0.38)	0.38 (0.38)	0.92 (0.51)	1.83 (0.36)	0.42 (0.30)	0.88 (0.13)	0.160	0.785				
		M+S[4]	0.88 (0.63)[a]	0.88 (0.88)[a]	1.50 (0.72)[a]	3.08 (0.08)[a]	1.33 (0.22)[a]	1.88 (0.38)[a]	**0.094**	0.275				
FORAGING GUILDS	Aerial	M	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.08 (0.08)	0.00 (0.00)	0.00 (0.00)	(0.549)	Insufficient data				
		M+S	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.17 (0.17)	0.17 (0.17)	0.00 (0.00)	(0.664)	Insufficient data				
	Bark	M	0.00 (0.00)	0.13 (0.13)	0.17 (0.17)	0.50 (0.25)	0.08 (0.08)	0.13 (0.13)	(0.377)	(0.634)				
		M+S	0.00 (0.00)	0.13 (0.13)	0.33 (0.22)	0.75 (0.50)	0.17 (0.08)	0.13 (0.13)	(0.364)	(0.413)				
	Foliage	M	0.13 (0.13)	0.25 (0.25)	0.42 (0.22)	0.92 (0.46)	0.25 (0.25)	0.38 (0.13)	0.525	0.696				
		M+S	0.13 (0.13)	0.50 (0.50)	0.50 (0.25)	1.42 (0.60)	0.75 (0.25)	1.38 (0.13)	0.244	**0.052**	0.260	0.36	1.00	0.54 to 1.40
	Ground	M	0.50 (0.25)	0.00 (0.00)	0.33 (0.22)	0.33 (0.08)	0.08 (0.08)	0.38 (0.38)	0.387	0.750				
		M+S	0.75 (0.50)	0.25 (0.25)	0.67 (0.30)	0.75 (0.14)	0.25 (0.25)	0.38 (0.38)	0.650	0.407				
NESTING GUILDS	Shrub / Tree	M	0.25 (0.00)	0.00 (0.00)	0.42 (0.22)	1.17 (0.46)	0.08 (0.08)	0.50 (0.25)	(0.146)	(0.995)				
		M+S	0.50 (0.25)	0.38 (0.38)	0.67 (0.22)	1.92 (0.46)	0.75 (0.38)	1.13 (0.63)	0.155	0.248				
	Cavity	M	0.00 (0.00)	0.38 (0.38)	0.25 (0.14)	0.67 (0.22)	0.25 (0.25)	0.38 (0.13)	0.477	0.460				
		M+S	0.00 (0.00)	0.38 (0.38)	0.50 (0.29)	1.08 (0.46)	0.42 (0.22)	0.75 (0.25)	0.382	0.256				
	Ground	M	0.38 (0.38)	0.00 (0.00)	0.25 (0.25)	0.00 (0.00)	0.08 (0.08)	0.00 (0.00)	(0.631)	(0.860)				
		M+S	0.38 (0.38)	0.13 (0.13)	0.33 (0.22)	0.08 (0.08)	0.17 (0.17)	0.00 (0.00)	0.795	0.196				

[1] p values in brackets determined by Kruskal-Wallis ANOVA
[2] p values in brackets determined by weight estimation regression
[3] observations added during mobbing call period
[4] observations added during mobbing call period + silent period

Table 3.4 d: Mean number of observations (with standard error) added per count during call playbacks in Coniferous sites in 2000, for sampling interval indicated. Significant p values (< 0.10) are in bold type. Means with the same letter are not significantly different.

		Sampling Interval	Harvest Retention Level						ANOVA[1]	Linear Regression[2]				
			0%	10%	20%	50%	75%	100%	p	p	r^2	interc	slope	95% CI for slope
	ALL	M[3]	0.13 (0.13)	1.13 (0.13)	0.38 (0.38)	1.08 (0.44)	1.17 (0.17)	1.25 (0.25)	0.162	**0.041**	0.303	0.49	0.88	0.53 to 1.19
		M+S[4]	0.38 (0.13) [a]	1.63 (0.13) [ab]	1.25 (0.25) [ab]	2.17 (0.44) [b]	2.50 (0.38) [b]	2.00 (0.50) [ab]	**0.044**	**0.011**	0.431	1.04	1.56	0.96 to 2.15
FORAGING GUILDS	Aerial	M	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.000	Insufficient data				
		M+S	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.000	Insufficient data				
	Bark	M	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.08 (0.08)	0.33 (0.22)	0.00 (0.00)	(0.321)	Insufficient data				
		M+S	0.00 (0.00)	0.00 (0.00)	0.13 (0.13)	0.42 (0.17)	0.33 (0.22)	0.00 (0.00)	(0.144)	Insufficient data				
	Foliage	M	0.00 (0.00)	0.38 (0.38)	0.13 (0.13)	0.58 (0.22)	0.42 (0.30)	1.00 (0.25)	0.260	**0.026**	0.349	0.10	0.72	0.37 to 1.20
		M+S	0.00 (0.00)	0.50 (0.50)	0.50 (0.25)	1.00 (0.29)	1.33 (0.51)	1.75 (0.50)	0.158	**0.002**	0.559	0.17	1.59	0.91 to 2.25
	Ground	M	0.13 (0.13)	0.75 (0.50)	0.25 (0.25)	0.42 (0.42)	0.42 (0.42)	0.25 (0.00)	0.924	0.920				
		M+S	0.38 (0.13)	1.13 (0.38)	0.63 (0.13)	0.75 (0.50)	0.83 (0.36)	0.25 (0.00)	0.681	0.645				
NESTING GUILDS	Shrub / Tree	M	0.00 (0.00)	0.38 (0.13)	0.25 (0.25)	0.42 (0.17)	0.42 (0.30)	0.75 (0.00)	0.294	**0.042**	0.301	0.14	0.52	0.23 to 0.80
		M+S	0.25 (0.25) [a]	0.63 (0.13) [ab]	0.75 (0.00) [ab]	0.92 (0.22) [ab]	1.42 (0.22) [b]	1.38 (0.13) [b]	**0.026**	**<0.001**	0.670	0.42	1.11	0.83 to 1.43
	Cavity	M	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.33)	0.42 (0.30)	0.38 (0.38)	(0.514)	**(0.089)**	0.222	-0.02	0.50	-0.09 to 1.09
		M+S	0.00 (0.00)	0.00 (0.00)	0.13 (0.13)	0.75 (0.29)	0.67 (0.42)	0.50 (0.50)	(0.157)	**(0.009)**	0.450	-0.03	0.91	0.28 to 1.53
	Ground	M	0.13 (0.13)	0.75 (0.00)	0.13 (0.13)	0.33 (0.33)	0.33 (0.33)	0.13 (0.13)	0.684	0.552				
		M+S	0.13 (0.13)	1.00 (0.25)	0.38 (0.13)	0.50 (0.38)	0.42 (0.30)	0.13 (0.13)	0.465	0.480				

[1] p values in brackets determined by Kruskal-Wallis ANOVA
[2] p values in brackets determined by weight estimation regression
[3] observations added during mobbing call period
[4] observations added during mobbing call period + silent period

In Deciduous/Understory sites (Table 3.4 b), the playback observation rate per count exhibited no linear trends or differences in means. Among the foraging guilds, a significant increasing linear trend was observed for foliage gleaners in the second sampling interval, but among nesting guilds, no linear trends were detected. Mixed sites (Table 3.4 c) exhibited a near identical pattern to Deciduous/Understory sites, with a significant linear trend detected only for foliage gleaners, and only in the second sampling interval. In Coniferous sites (Table 3.4 d), playback observations increased linearly with increasing residual tree level in both intervals. Similar to the Deciduous sites, the trend in total observations can be ascribed largely to increasing trends in foliage gleaners (both intervals) and shrub/tree nesters (both intervals).

Observations were also weighted using the 2-point ranking scale detailed in Chapter 2 (Table 2.1), and examined using regression analysis (Appendix 7). Among the various foraging and nesting guilds, patterns across treatments in the 'weighted' dataset were almost identical to those exhibited in the 'unweighted observations' dataset (Table 3.4). In several cases, I detected a positive correlation between the weighted playback observations of a particular guild and observations made during concurrent point counts, indicating that playback surveys would have exacerbated trends observed during point count surveys for these groups. This was observed for foliage gleaners (Deciduous and Deciduous/Understory sites) and shrub/tree nesters (Deciduous and Coniferous sites).

In terms of species richness, linear trends across treatments in the number of species added per station during the playback periods were observed for three of the four cover types (Figure 3.5). The playbacks revealed more previously-undetected species in the higher retention levels in Deciduous/Understory, Mixed, and Coniferous sites. These results are similar to the preceding section dealing with total observations added across treatments (however, in that section it was Deciduous and Coniferous sites which exhibited linear trends).

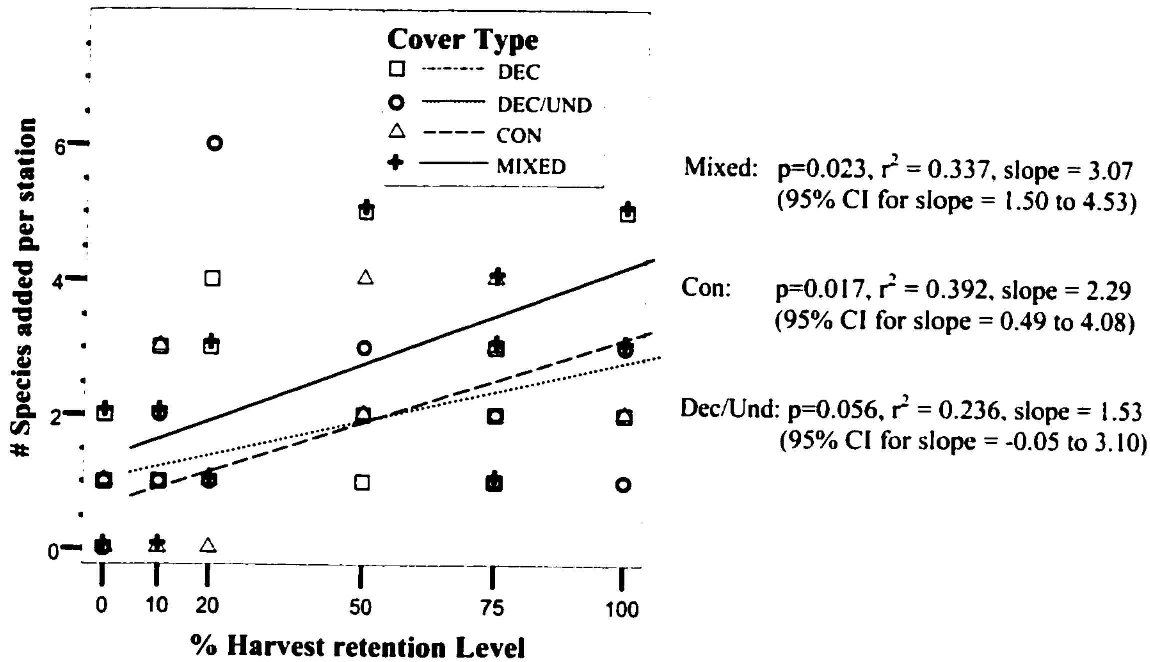


Figure 3.5: Number of species added per station during playback periods in each cover type in 2000.

Playback Results Across Breeding Season

Total observations were also analyzed by round throughout the breeding season (sampling rounds 2-5). Table 3.5 displays the mean additions in bird observations per station during the point count, mobbing and silent sampling periods. Treatments were grouped for this analysis. When all cover types were considered together, a marginally-significant drop in observations was detected between rounds 3 and 4, for the mobbing call period (p=0.090). On a cover type by cover type basis, no significant differences in observations were detected between rounds, for any sampling interval.

Table 3.5: Mean number of observations (with standard error) added per station in each cover type in 2000, for sampling period or interval indicated. Significant p values (< 0.10) are in bold type.

Cover Type	Sampling Interval	Sampling Round 2 (30 May-6 June)	Sampling Round 3 (8 June-14 June)	Sampling Round 4 (22 June-28 June)	Sampling Round 5 (1 July-6 July)	Rep. Meas. ANOVA p
ALL TYPES (n=59)	PC [1]	2.46 (0.25)	2.64 (0.24)	2.03 (0.22)	2.19 (0.22)	0.194
	M [2]	1.32 (0.20)	1.17 (0.19)	0.80 (0.18)	0.78 (0.16)	**0.090**
	M+S [3]	2.10 (0.23)	1.98 (0.26)	1.46 (0.22)	1.69 (0.23)	0.191
DECIDUOUS (n=14)	PC	2.64 (0.52)	2.71 (0.49)	1.86 (0.47)	2.29 (0.51)	0.670
	M	1.79 (0.42)	1.14 (0.33)	0.71 (0.27)	1.07 (0.35)	0.181
	M+S	2.29 (0.45)	1.79 (0.46)	1.43 (0.33)	2.21 (0.45)	0.366
DECIDUOUS/ UNDERSTORY (n=16)	PC	2.69 (0.50)	2.56 (0.45)	1.75 (0.36)	1.63 (0.31)	0.135
	M	1.50 (0.45)	1.19 (0.45)	0.56 (0.22)	1.19 (0.38)	0.373
	M+S	2.25 (0.56)	2.13 (0.67)	1.25 (0.31)	1.94 (0.53)	0.520
MIXED (n=15)	PC	2.47 (0.58)	2.73 (0.53)	2.47 (0.57)	3.07 (0.55)	0.776
	M	1.07 (0.33)	1.13 (0.41)	1.00 (0.54)	0.33 (0.21)	0.452
	M+S	1.87 (0.42)	1.87 (0.43)	1.80 (0.62)	1.13 (0.45)	0.615
CONIFEROUS (n=14)	PC	2.00 (0.41)	2.57 (0.51)	2.07 (0.35)	1.79 (0.30)	0.549
	M	0.93 (0.34)	1.21 (0.37)	0.93 (0.37)	0.50 (0.23)	0.527
	M+S	2.00 (0.41)	2.14 (0.52)	1.36 (0.50)	1.50 (0.39)	0.566

[1] observations added during point count period
[2] observations added during mobbing call period
[3] Observations added during mobbing call period + silent period

Reproductive Observations

Playback periods accounted for a large portion (64%) of all reproductive observations during surveys as a whole, and in each of the four cover types (Table 3.6). The number of reproductive observations was relatively low (comprising only 7.5% of total observations), and variance was typically high. Hence, no significant differences were detected between cover types in terms of reproductive observations added per station during playback surveys (p=0.569), despite the apparent disparity between Mixed sites and the other three cover types.

Table 3.6: Percent of reproductive observations accounted for by call playback portion of survey, in each cover type in 2000.

Cover Type	% of Total Reproductive Observations
All Types (n=59)	64% (47/74)
Deciduous (n=14)	65% (11/17)
Deciduous / Understory (n=16)	75% (15/20)
Mixed (n=15)	43% (10/23)
Coniferous (n=14)	79% (11/14)

All cover types were grouped for analysis of reproductive observations across treatments (Figure 3.6). No significant differences in treatment means (p=0.364 and 0.815) or linear trends across treatments (p=0.134 and 0.651) were detected for either sampling interval.

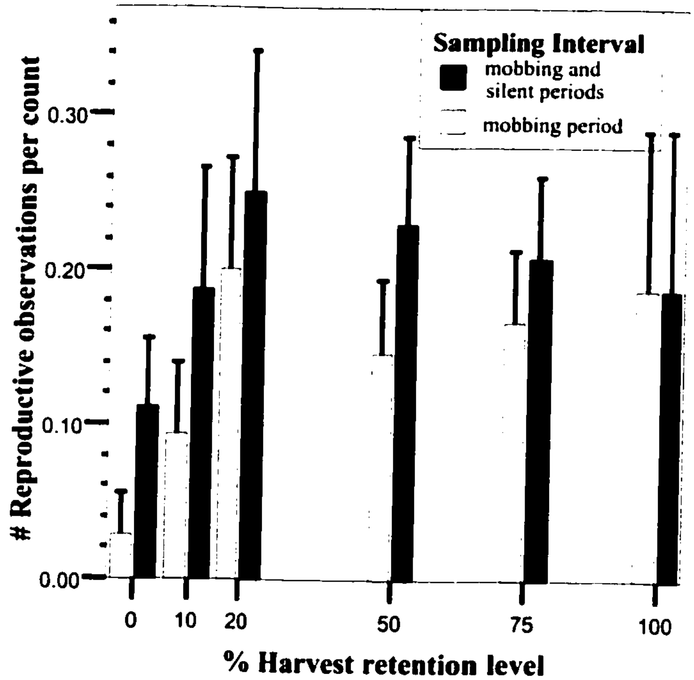


Figure 3.6: Reproductive observations added per count during playback surveys in all cover types in 2000, for sampling interval indicated. Error bars represent 1 standard error.

Reproductive observations were also analyzed by round throughout the breeding season (Figure 3.7). Treatments were grouped for this analysis. I detected a significant difference between rounds for the mobbing period (p=0.047), but not for the point count period (p=0.188) or the combined mobbing/silent interval (p=0.271). Still, the data suggest notable trends throughout the breeding season: the call playback technique drew out more 'reproductive birds' than the point count technique earlier in the season, but in the latter stages of breeding, this pattern was reversed.

3.4 Discussion

Point count survey results may be difficult to interpret if birds crowd into undisturbed areas or settle into sub-optimal habitat in the short term (Hagan et al. 1996), as changes in

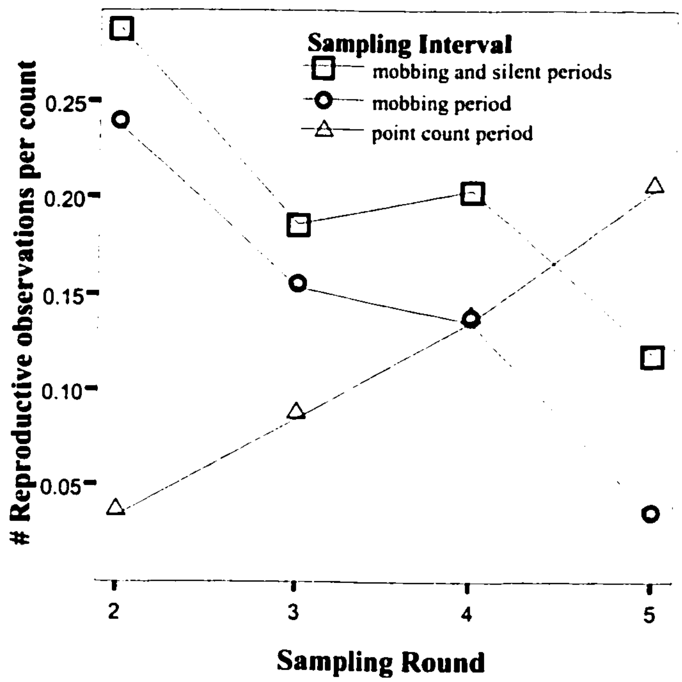


Figure 3.7: Reproductive observations added per count during playback surveys in all cover types and treatments in 2000 (n=59), for sampling round indicated.

numbers of singing males may not accurately reflect a species' reproductive success (or activity). For example, song output can be a misleading indicator of pairing status when unpaired male Ovenbirds crowded into non-ideal habitats sing more than paired ones (Gibbs and Wenny 1993). Given the relatively short duration of this research, a productivity component was included to address this concern.

3.4.1 Behaviour monitoring

On the 5-point scale of reproductive ranks, I detected a significant difference in the numbers of Swainson's Thrush between the controls and all other treatments, and all harvest treatments supported relatively low densities, suggesting that any logging in Deciduous/Understory forests may substantially reduce habitat quality for this species. However, two of the three control blocks were set apart from the other blocks and surrounded on three sides by undisturbed forest, whereas the harvested compartments were typically adjacent to two or more treatment blocks, leading me to speculate that the relatively low productivity observed in the harvest treatments may partially be ascribed to landscape context. Swainson's Thrush may be an 'area-sensitive' species: Hannon (1993) did not find it in patches <10 ha in an agricultural matrix in Alberta, and Evans et al. (1998) found it was sensitive to fragmented landscapes in the northern Rockies. Accordingly, habitat in the 50% and 75% retentions, in particular, which may have proven adequate in a larger patch, might have been rendered less suitable by the relatively small compartment size and adjacent low retention treatments.

For the data presented in Figure 3.1, I calculated each compartment rank as the summation of all territory ranks within its boundaries. However, because there was no complementary pre-harvest data collected using this technique, I could not assess whether the observed post-harvest treatment effects were partly due to existing pre-harvest differences in the number of territories per compartment. Had I used the 'averaged territory' rank for each compartment to avoid this problem, this would have created another problem: a compartment with a single territory ranked 2.0 would have been equivalent to a compartment with four territories, each ranked 2.0. Regardless, when the data were re-analysed in this fashion (and a weighting factor incorporated), results were similar (B. Harrison, unpublished data).

Pre-harvest behaviour monitoring data might also have helped to clarify an unexpected qualitative difference observed among treatments: mean abundances in the 50% and 75% retention blocks were less than that found in the 20% retention blocks. Data collected via the point count technique in 1998 suggest that this result may have been due to pre-harvest differences in the number of territories within those blocks (see Appendix 5), although differences in abundance among treatments in 1998 were not significant.

Evans Mack and Yong (2000) provide a review of the response of Swainson's Thrush to forest harvesting, and note that effects may vary with geographic differences in habitat utilization. In general, this species prefers unlogged forest to clearcuts or low residuals in western North America. However, early-successional closed canopy habitats (20 or more years post-harvest) have also been found to support relatively high densities in western N.A., possibly due to the dense regrowth which may follow logging. Medin and Booth (1989) found a positive response to low removal selection cuts in Idaho, but both Norton and Hannon (1997) and Tittler (1998) reported a negative response to moderate removal partial cuts in northeast Alberta. I observed a negative response to all levels of partial cutting at EMEND. Since Swainson's Thrush populations appear to be most regulated by the production of young on breeding grounds (Johnson and Geupel 1996), results from the Alberta studies, including EMEND, are disconcerting. Though responses have only been monitored in the short-term to date, the low densities observed after logging should serve as a warning flag for this species.

When adjusted to the same 2-point scale used in the point count surveys (Chapter 2), the pattern observed in the behaviour monitoring surveys did not change from that of the 5-point scale. However, the point count surveys failed to reveal any significant differences between treatment means or any linear trends. So why did the behaviour surveys identify a difference not detected during the passive point counts? Partial cuts may truly be 'sinks' for this species: populations in harvesting treatments may consist mostly (or entirely) of non-reproducing birds, and point counts do not typically discriminate between these and reproducing birds. Extending point count visits later in the breeding season (to coincide with the latter stages of the behaviour surveys) might have led to higher-ranking observations at a time when reproductive evidence is more obvious. Alternatively, the answer may lie in the nature of the species: the Swainson's Thrush is a naturally shy species, and a more active method of observation might have led to better detection frequency. It should also be noted that behaviour monitoring involved a substantially higher sampling intensity.

Avian reproductive indices have been developed for grassland environments (Vickery et al. 1992b, Dale et al. 1997), and are considered to be reliable indicators of reproductive output, but attempts to develop such indices in forest environments have met with limited success. Rangen et al. (2000) applied a similar technique for community surveys in young and old mixedwood stands in Alberta, and found that density and habitat quality were not tightly linked. However, they concluded their approach was impractical in complex forests, due to methodological problems such as restricted visibility, and the large number of independent replicates required for sufficient power. My study did not face the same visibility problems; conditions were relatively good in most treatments due to the strip-wise nature of the logging. Unfortunately, the large personnel and time requirement for breeding behaviour surveys makes this method inappropriate for community level studies. If an observer were to attempt to survey even 8-10 species on a given visit, the more secretive ones (such as Swainson's Thrush) would be prohibitively difficult to locate and follow. A more promising approach is to target one or two species of management concern, in situations where the additional information on reproductive success merits the extra time and effort.

3.4.2 Call playbacks

Because the effective sampling area of the call playback technique may have been greater than that of the point count technique, I chose to not directly compare the methods, and instead quantified the additional information provided by the inclusion of the playback periods. I found that the call playback periods contributed information at a significant and constant rate across cover types, whether analysed in terms of total observations, or count by count. Gunn et al. (2000) conducted their work in mature deciduous (New Brunswick) and coniferous (Quebec) forests, and detected similar trends to this study in terms of number of species detected during mobbing surveys, and domination of surveys by a few species. As in this study, Gunn et al. also found that playback surveys contributed significantly to their knowledge of communities: they detected an equal or greater number of birds 75% of the time, and concluded that playback surveys in conjunction with point counts census an area more thoroughly than point counts alone.

Resident species, short-distance migrants and early migrants made up a disproportionately high percentage of the most-frequently observed species during my playback surveys, compared to their occurrence in the study area. These groups commonly nest earlier than Neotropical migrants and late migrants, and would be expected to show more parental-type responses throughout the study period (late May to early July). Residents, as a group, are of conservation concern in boreal forests (Schmiegelow and Mönkönnen, In Press), and are often not well sampled during conventional point count survey periods, due to the earlier onset of breeding activities. Thus, call playback surveys may be particularly advantageous for these species.

Across treatments, the overall results suggest that playbacks revealed more previously-undetected birds in the higher retention levels. On a cover type by cover type basis, in terms of total observations, this trend was evident in the Deciduous and Coniferous sites. By guilds, the trend was observed for foliage gleaners (all cover types), and shrub/tree nesters and cavity nesters (two cover types each), but the reverse trend was found for ground foragers (one cover type). For species richness, the trend was evident in Deciduous/ Understory, Mixed and Coniferous sites. These results suggest that the playback technique may be superior to the more passive point count technique in detecting birds in higher retention levels (as compared to clearcuts and 10% or 20% residuals), perhaps due to the increased structural complexity of these habitats. However, due to the relatively low explanatory strength of the overall trend detected, I recommend caution in its application. As in Gunn et al. (2000), I found the 5-minute post-mobbing silent period to be of value, as indicated by the additional information gathered during this period, and the possible tendency of a portion of the bird community in higher retention areas, in particular, to remain unresponsive during active broadcasting of the calls.

In comparison to total observations, a higher proportion of the 'reproductive' observations were recorded during the playback periods (64% vs. 44%). Unfortunately, we recorded too little reproductive activity to analyse these observations in much depth, but the fact that playbacks detected reproductive activity nearly twice as often as point counts suggests that the technique did achieve its intended goal of providing significant additional visual information relating to productivity. This was exhibited in all cover and treatment types (though sample sizes were low and variance was high), and was particularly evident early in the breeding season. Later in the season, the point count technique provided more initial detections of 'reproductive birds', perhaps because as breeding progressed, reproductive activity became more conspicuous, and was consequently detected earlier in the survey procedure (e.g. within 5 minutes of arriving at a station).

Compared to the behaviour monitoring technique, the chickadee call playback technique was more suitable for gathering data about the entire assemblage of species in a forest or treatment type. Used as a complement to point count surveys, it enabled us to gather a significant amount of additional visual information, with more flexibility in diurnal and seasonal timing, and little additional effort or equipment requirements. Consequently, this research supports Gunn et al.'s (2000) conclusion that the mobbing call playback method provides a time-efficient complement to a point count survey program, in which researchers can cover a larger area more effectively with a relatively small extra time requirement. Passive point counts should still be included as a component in a survey program, as some species may not respond to chickadee mobbing calls (Hurd 1996).

The technique does present some logistical problems which researchers will have to address. Ideally, sound levels should be calibrated to treatment and forest types, but we found that the commercial sound meter equipment available to us was unable to function properly in EMEND's structurally-complex forests, and sound levels were necessarily estimated by ear. Also, the effective sampling area of the technique is uncertain, complicating comparisons with fixed radius point count surveys. If, for example, birds were drawn in from a 100 m radius circle, the effective sampling area would be four times that of the 50 m radius point counts. For studies using a larger point count radius, the uncertainty of the playback sampling radius may not be an issue.

While both techniques explored in this chapter dealt with the reproductive activity of songbirds at EMEND, they addressed different questions. The behaviour monitoring approach was intended to evaluate the accuracy of concurrent point count surveys (with the assumption that behaviour monitoring better represents productivity). The answer was relatively unambiguous, at least for one species in one forest type. While behaviour monitoring may not be practical as a broad-scale technique, it should be seriously considered when the consequences of being wrong are critical for a species of concern. With the call playbacks, I was interested in quantifying the additional information provided by the approach, relative to point counts. Playbacks contributed information at a significant and constant rate, particularly for groups typically not well-sampled, and was most useful early in the breeding season. These results notwithstanding, neither technique is suggested as a substitute for point count sampling; the point count method is still most appropriate in community-level studies of this nature, and the other two should be considered complementary, rather than replacement, techniques.

Chapter 4 Thesis Conclusions

4.1 Summary of Research Findings

The effects of large-scale forest harvesting on forest songbirds, and Neotropical migrants in particular, might be mitigated through emulation of natural disturbance patterns via partial-cutting. In this thesis I explored the short-term, stand-level response of breeding boreal forest songbirds to various levels of partial cut harvesting at the EMEND project, in northwestern Alberta. Four cover types were represented: Deciduous-dominated, Deciduous-dominated with coniferous understory, Mixed, and Conifer-dominated. Deciduous trees were primarily trembling aspen, with a secondary balsam poplar component; coniferous trees were almost exclusively white spruce. To detect birds, we primarily used a fixed radius point count technique, and Chapter 2 details the results obtained with this sampling method. However, recognizing the risks associated with using point count data alone to infer habitat quality, I decided to supplement the picture with a better measure of reproductive success, and Chapter 3 details the results obtained using two alternative sampling methods designed to detect more information about bird productivity. As EMEND is an experiment to model forest harvesting on the local natural disturbance regime, I had also planned to compare the partial cuts with stands burned at a variety of intensities. Unfortunately, wet weather dictated the postponement of most burn treatments during my research period, and comparisons of partial-cut vs. burn communities will have to be undertaken by future researchers.

Summary of Chapter 2: Response of a Forest Songbird Community to Experimental Partial-Cut Harvest

Similar to the results of prior research elsewhere in boreal Alberta (Norton and Hannon 1997, Tittler 1998), partial cuts at EMEND were typically intermediate between clearcuts and controls for community and species-level measures. Point count sampling detected linear trends in species richness and similarity across treatments in most cover types. For example, the number of species post-harvest typically declined in a graduated manner in the lower residual treatments (0%, 10%, 20%), and increased in the higher residuals (50%, 75%, 100%), possibly due to 'crowding'. Linear trends were also detected at the guild level: less retention resulted in lower foliage gleaner and shrub/tree nester abundance in all cover types, but higher ground forager (all but Deciduous sites) and ground nester abundance (Mixed and Coniferous sites). Species data were highly variable, but species that declined in the lower residual treatments (relative to the controls) were typically dependent on shrubs/trees for nesting and foraging, and most losses persisted through both years, in all cover types. Species that increased in the lower residuals (relative to the controls) were typically ground nesters, and most gains were largest in the second year post-harvest. Higher residuals exhibited similar patterns, with more increases among shrub/tree dependent species.

Summary of Chapter 3: Assessment and Comparison of Alternative Survey Techniques

In the behaviour monitoring component of this research, I detected a significant difference in the numbers of Swainson's Thrush post-harvest between the controls and all other treatments, and all harvesting treatments supported relatively low densities, suggesting that any logging in Deciduous/Understory forests may substantially reduce habitat quality for this species. In contrast, the point count surveys failed to reveal any significant differences between treatment means, possibly because the point count is a passive sampling technique, and as such tends to under-estimate the occurrence of naturally shy species such as the Swainson's Thrush. Unfortunately, even with the excellent visibility and access conditions at EMEND, the large personnel and time requirement for breeding behaviour surveys makes this method inappropriate for targeting more than one or two species.

In the call playback component of this research, I found that the playback surveys contributed information at a significant and constant rate across cover types. Most species detected during concurrent point counts were also detected during playbacks, and residents, short-distance migrants and early migrants made up a disproportionately high percentage of the most-frequently observed species. Across treatments, playbacks revealed more previously-undetected species in the higher retention levels in three cover types, and they revealed more previously-undetected individuals in the higher retention levels in two cover types (primarily due to trends among foliage gleaners and shrub/tree nesters). This suggests that the playback technique may be superior to the conventional point count technique in detecting birds in higher retention levels, perhaps due to the increased structural complexity of these habitats. Similar patterns were observed when observations were weighted to better link abundance to breeding status. In comparison to total observations, a higher proportion of 'reproductive' observations were recorded during the playback periods. Though in-depth analyses of reproductive activity were precluded by a lack of data, results suggest that the technique did provide significant additional visual information relating to productivity, across cover and treatment types. In summary, despite certain technical hurdles, this research supports a prior contention (Gunn et al. 2000) that for community-level studies, the call playback technique provides an efficient complement to a point count survey program, in which a larger area can be covered more effectively with a relatively small extra time requirement.

4.2 Management Implications

The application of partial cutting to a landscape (particularly at high retention levels) necessitates the harvest of areas which might otherwise remain uncut, if harvest volumes are to remain the same. The utility of this approach depends on the management goals for the landscape, and whether potential species declines and losses incurred in the harvested areas are acceptable. Clearly, the needs of all species will not be met by partial cutting, as evidenced by the species lost from the strip-pattern partial cuts at EMEND. However, a number of species declined in, but did not disappear from, partial cuts, and the results of Chapter 2 indicate that partial cutting offers some advantages over clearcutting in conserving some elements of biodiversity (at least in the short term, at the stand level). Nevertheless, results presented in Chapter 3 suggest that data obtained from point count surveys should be interpreted with caution - partial cuts at EMEND may not be intermediate in terms of bird productivity, at least for some species, which diminishes the apparent biodiversity benefits of strip harvesting.

Considering the relatively small benefits accrued in lower retention treatments (10%, 20%), I suggest these levels of partial cutting, in a strip pattern, are not justified from a short-term biodiversity perspective. Higher retention levels (50%, 75%), with correspondingly greater biodiversity advantages, appear more worthwhile, but their application should be carefully evaluated in the context of landscape-level management. Higher retention levels may be dictated for management of species of concern, or in sensitive areas, but monitoring of breeding behaviours of some species should be undertaken to assess whether these treatments offer productivity advantages over clearcutting. I emphasize that these recommendations are based on short-term research only, and any management action based on them should be accompanied by a longer-term monitoring scheme.

4.3 Recommendations for Future Research

Post-treatment surveys should be completed on experimental burn blocks, to enable comparisons with post-treatment communities on logged sites. This element is critical to validation of the natural disturbance model at EMEND. In conjunction with studies of the burned blocks, harvested blocks should be periodically re-monitored to compare successional trajectories in clearcuts and partial cuts. The partial retention of old-growth stand remnants may enable bird communities in partial-cut treatments to converge on those in the controls more quickly than clearcut communities. However, the rate of convergence could depend on a number of factors which may not be fully realized for several years. For example, the increased edge created through partial cutting could potentially lead to increased nest predation (King et al. 1998), competitive exclusion by species better able to utilize the surrounding matrix (Haila et al. 1989), and increased rates of parasitism by Brown-headed Cowbirds (*Molothrus ater*) (Robinson et al. 1993).

It should, however, be noted that we detected Brown-headed Cowbirds at EMEND on only two occasions, both times along roadways.

Thompson et al. (1993) suggested that partial cutting may result in a worse situation than clearcutting, as group-cuts create more edge per unit area, and a greater area must be harvested to extract the same timber volume. However, it's debatable whether an increase in edge will necessarily result in population declines of forest birds. In northeastern Alberta, Tittler (1998) and Song and Hannon (1999) found no evidence of elevated nest predation along cutblock edges in the boreal mixedwood, in the short-term. Due to the frequent nature of fire disturbance there has always been edge in the boreal between regenerating and mature areas, and partial cut edges may even prove 'softer' than clearcut edges, due to the additional vegetative structure and narrower openings. Exploration of edge effects is complicated by the site-specific nature of the phenomenon, and the complex array of factors involved. For example, nest predation risk is a function not only of type and configuration of edge, but also of nest density and detectability, local and landscape predator abundances, and landscape alternate prey abundance (Donovan et al. 1997). Tewksbury et al. (1998) observed higher predation rates in forested western landscapes as compared to fragmented eastern landscapes dominated by agriculture, probably reflecting the greater role played by forest predators.

A chickadee call playback technique, used in conjunction with passive point counts, is recommended for any future monitoring program. However, future research into the efficacy of the playback technique should investigate whether increases in detection rates would accrue at the same rate in a passive point count survey period of the same duration (e.g. conduct 15 minute passive point count periods concurrently with 15 minute call playback surveys). This would address the question: were the observed increases in this study due to the playbacks, or were they simply due to an additional 10 minutes of observation time per count?

The behaviour monitoring technique employed in this project carries some rather significant limitations, but there are circumstances in which the additional information it provides on reproductive success merits the extra time and effort. A productivity index should be considered for species at risk (e.g., threatened or endangered species) or species of management concern (e.g., regionally important species), in particular those that are not well-sampled by point counts. Though none of the species we detected at EMEND are designated 'at risk' in Alberta, several are designated as 'sensitive'. Close attention should be directed at these species in future monitoring of partial-cut sites, either at EMEND or elsewhere, and it should be recognized that the habitat needs of some species (e.g., Black-throated Green Warbler, Canada Warbler, Cape May Warbler) may not be sufficiently met by a coarse filter approach.

Landscape context may have played a role in treatment responses observed for "area-sensitive" species such as Ovenbird and Swainson's Thrush at EMEND. The influence of landscape context on these species (and others) could be explored quantitatively using the following ad-hoc approach: broadly classify habitats within a 500 m radius around each compartment, then use the proportions of intact to harvested forest as a covariate in analyses to assess the influence of neighbouring habitats on bird indices within compartments. All survey points and compartment boundaries are geospatially-referenced, and the appropriate GIS coverages are available for the EMEND area.

As they become available, results from other projects at EMEND should be used to investigate possible mechanisms for observed bird responses. Several studies concurrent to this one examined various aspects of invertebrate response to the harvesting disturbances. Insofar as they serve as potential food sources for some bird species, some of the invertebrate groups studied (e.g., bark beetles, lepidopterans) may influence habitat suitability for birds, and the responses of these invertebrates to harvesting may help to elucidate the relationship between disturbance level and bird abundance.

EMEND consists of a wider range of harvest retention levels than most other partial-cut studies in western North America. In an experimental sense, this was a favourable approach, but operationally, it's probably unrealistic to expect widespread implementation of the higher retention levels, other than in spot treatments in sensitive areas. Based on the expected increased economic costs, and associated logistical and regeneration difficulties, it's more likely that the 10% or 20% retention levels will be adopted. Given that a large component of the bird community was lost in each cover type at these lower levels, future researchers may wish to assess whether conditions could be ameliorated by altering the spatial distribution of the residual trees. Working in harvested areas of the boreal mixedwood, including Norton and Hannon's (1997) study site, Schieck et al. (2000) found that retaining trees in a clumped rather than a scattered pattern resulted in bird communities which were more similar to those in old-growth forest. This would represent a trade-off of sorts, in which certain species would be favoured over others (e.g., those which require only a few scattered trees for perching or nesting), but it remains a potential management option for mature-forest species.

Further bird studies in northwestern Alberta will enable researchers to acquire a better knowledge of the natural range of spatial and temporal variability in area bird communities. Without this information, the interpretation of what constitutes a significant harvesting effect can still only be made on general statistical principles, and may have little biological relevance. For example, in examining the power of my statistical tests, I decided that conventionally-defined effect sizes may not be appropriate for the systems at EMEND; consequently, I did not attempt to estimate power for my tests. But the power issue is highly relevant for many of the species-level treatment comparisons. Although field observations suggested that a majority of species did in fact experience a treatment-related impact, ANOVA testing failed to detect treatment differences for many of these, presumably due to high variability. Because a statistically non-significant result does not necessarily equate to a 'biologically non-significant' harvesting impact, the status of many bird species at EMEND should be accompanied by a large question mark. As future local research is added to the mix, we will at least have the means to determine whether we had the power to detect an effect.

Finally, it should be remembered that no ecological experiment occurs in a vacuum: the landscape matrix in which the EMEND project is embedded is bound to change over time, and if these changes cannot be avoided, they should at least be recognized. For example, a more developed and fragmented forest region could encourage the invasion of more avian nest parasites and predators, changing the nature and rate of edge processes, and perhaps invalidating some of the conclusions of this study. Future researchers at EMEND should keep this in mind.

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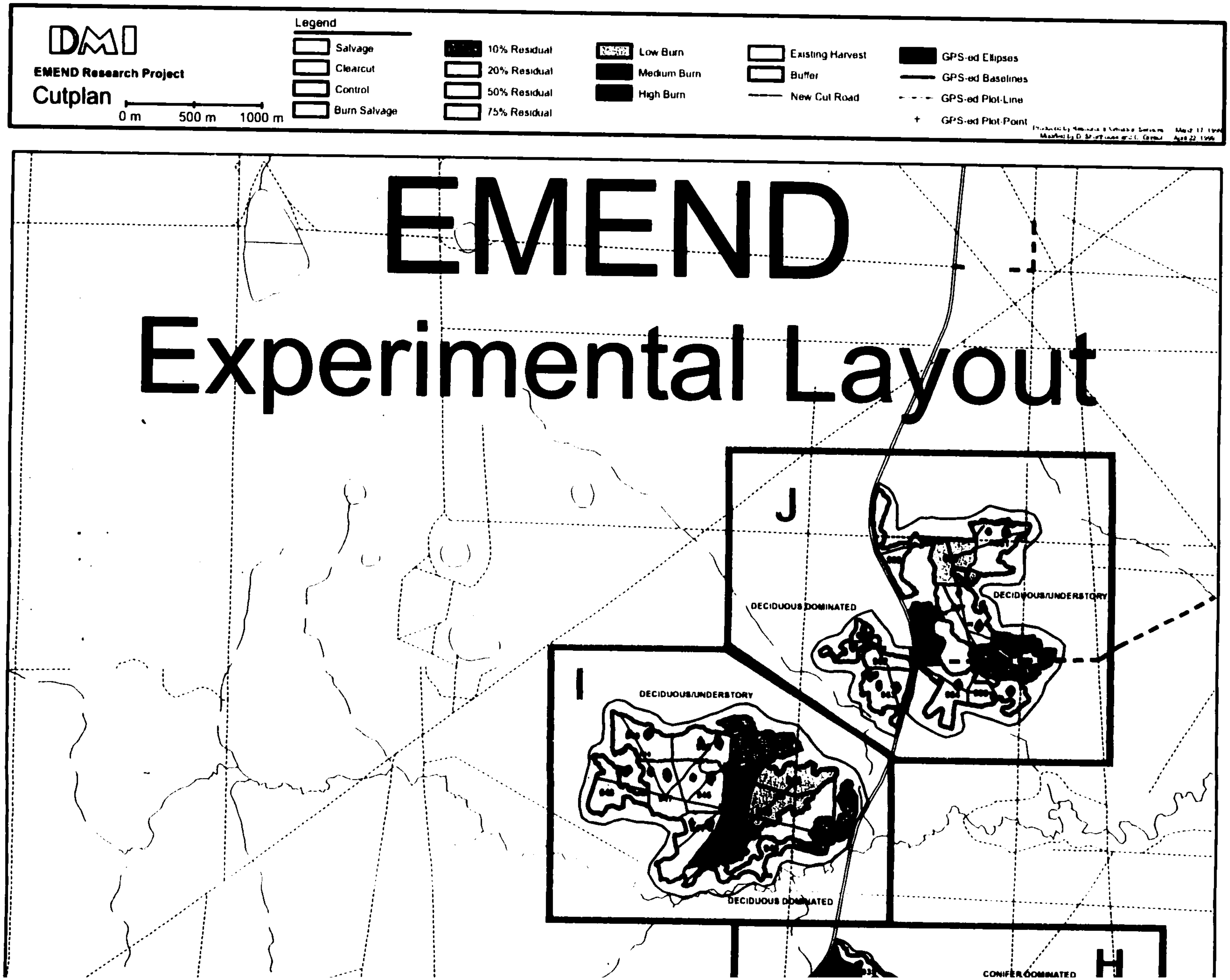
APPENDICES

Appendix 1: Experimental Layout at EMEND

(following page)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75% Residual
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High Burn
Existing Harvest
Buffer
New Cut Road
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GPS-ed Baselines
GPS-ed Plot-Line
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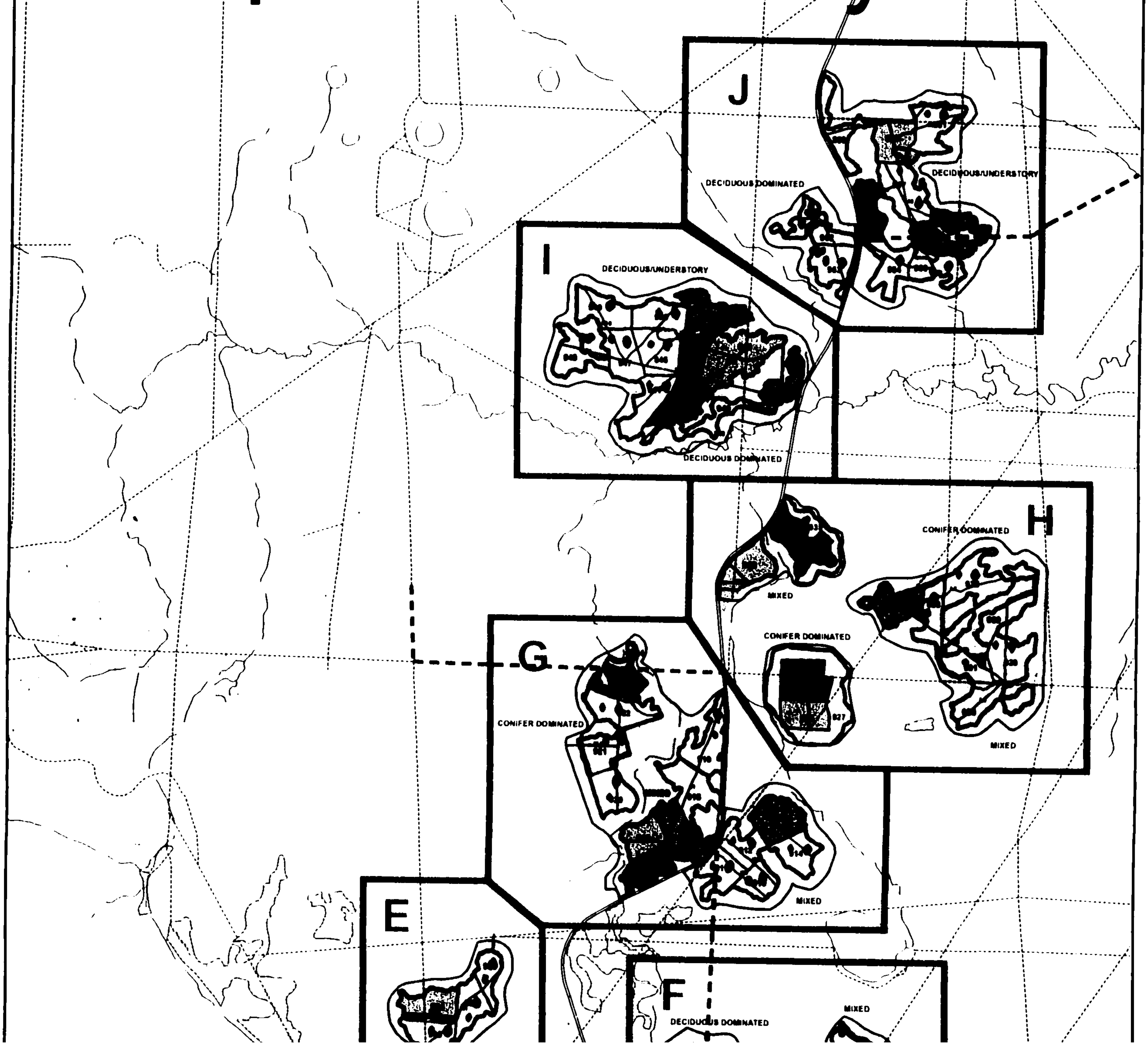
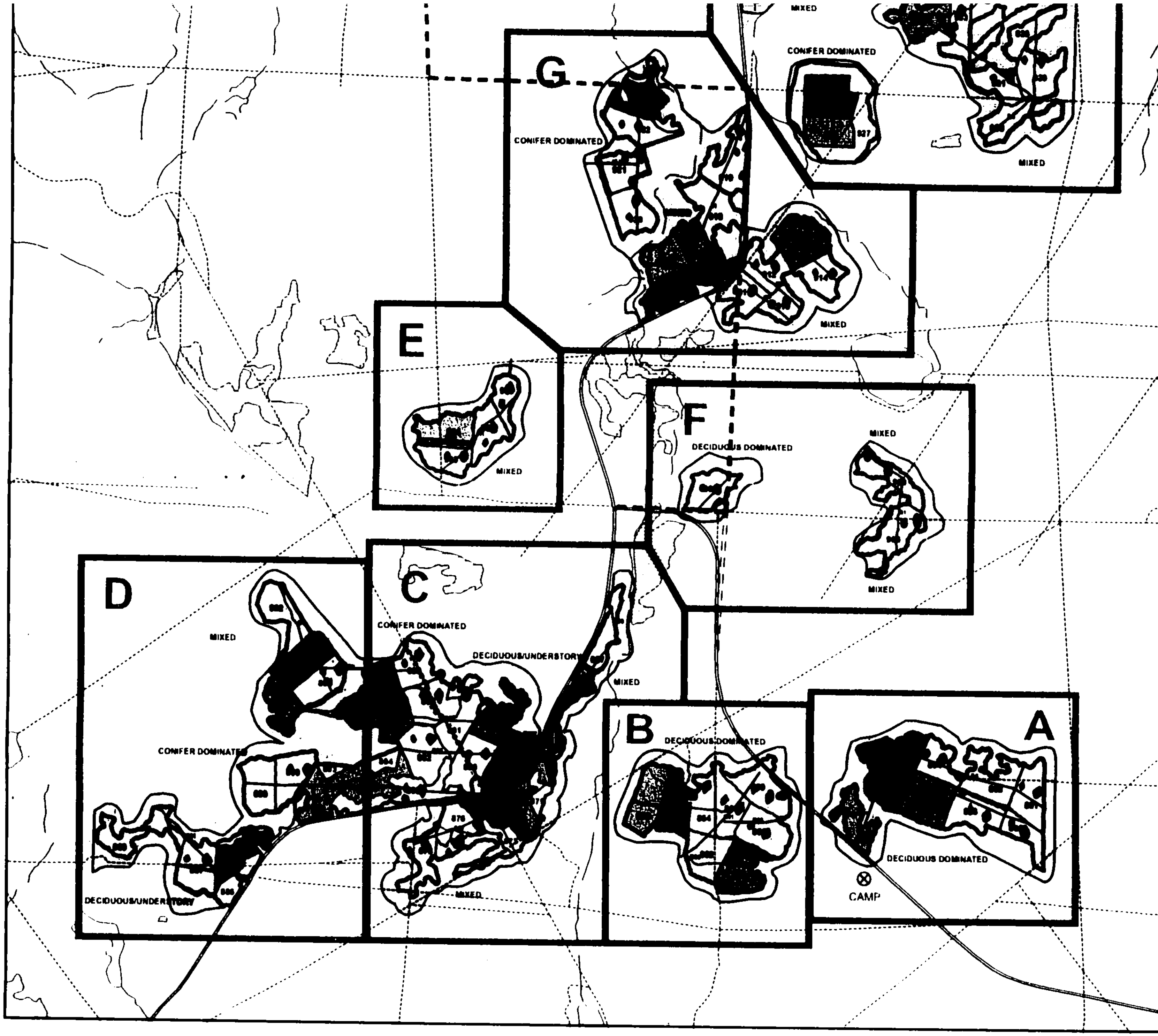
Experimental Layout





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Appendix 2: Bird species observed in forest sites at EMEND but excluded from analyses of point count survey data in all years in which they were observed.

Species	Scientific Name
Barred Owl	*Mniotilta varia*
Black-backed Woodpecker	*Picoides arcticus*
Common Raven	*Corvus corax*
Common Snipe	*Gallinago gallinago*
Downy Woodpecker	*Picoides pubescens*
Hairy Woodpecker	*Picoides villosus*
Killdeer	*Charadrius vociferus*
Northern Flicker	*Colaptes auratus*
Northern Goshawk	*Accipiter gentilis*
Pileated Woodpecker	*Dryocopus pileatus*

Appendix 3: Means (and standard deviations) of vegetation characteristics in Deciduous and Deciduous/Understory sites in 1998 (pre-harvest). Significance values in brackets were determined by Kruskal-Wallis ANOVA.

		Deciduous Retention Level						ANOVA	Deciduous / Understory Retention Level						ANOVA
		0%	10%	20%	50%	75%	100%	p	0%	10%	20%	50%	75%	100%	p
% Ground Cover [1]	All green	57.9 (21.1)	50.5 (18.9)	58.1 (7.6)	55.4 (12.1)	44.5 (6.4)	64.0 (8.7)	0.355	45.3 (17.9)	45.5 (11.1)	56.6 (13.8)	55.9 (4.7)	44.4 (14.0)	60.0 (24.3)	0.513
	Shrub	34.8 (21.6)	29.9 (24.4)	48.4 (23.8)	59.2 (20.8)	53.5 (19.1)	38.8 (18.5)	0.361	26.9 (8.8)	16.3 (17.8)	26.6 (16.1)	27.8 (16.7)	30.6 (26.7)	18.2 (32.6)	0.816
	Forb	38.3 (18.8)	47.6 (9.5)	26.6 (4.0)	27.5 (9.0)	41.0 (12.6)	36.3 (5.4)	(0.101)	42.2 (22.0)	45.3 (32.7)	25.3 (8.9)	37.3 (19.6)	37.6 (43.7)	25.6 (9.5)	0.788
	Grass	25.6 (38.0)	8.7 (10.1)	25.3 (20.2)	12.6 (13.9)	3.9 (5.1)	17.3 (13.8)	0.532							
	Litter	25.6 (14.6)	23.8 (6.9)	21.5 (7.0)	30.0 (13.5)	31.7 (8.7)	26.0 (7.1)	0.582	37.5 (21.9)	34.5 (1.6)	30.0 (10.6)	21.3 (2.2)	33.8 (13.4)	19.8 (12.0)	0.201
	DWD	8.8 (2.0)	14.7 (4.7)	15.1 (3.8)	8.1 (4.4)	15.1 (3.7)	12.0 (6.9)	0.120	10.0 (3.4)	12.6 (6.9)	11.4 (4.0)	13.1 (9.2)	16.3 (13.5)	15.6 (6.5)	0.851
Shrubs (stems) [2]	Low shrubs	601.1 (354.0)	572.3 (291.3)	700.7 (158.5)	751.3 (107.9)	658.6 (100.1)	564.5 (337.7)	0.866	347.9 (210.3)	282.2 (71.6)	426.3 (158.2)	406.7 (199.0)	294.0 (267.8)	294.0 (317.6)	0.873
Canopy (stems) [3]	Large snags [4]	1.5 (1.9)	3.4 (0.8)	4.8 (4.4)	2.3 (2.5)	1.8 (2.2)	2.8 (1.8)	0.372	2.8 (3.5)	4.4 (3.4)	1.8 (1.1)	3.0 (2.5)	1.5 (1.5)	3.6 (2.1)	0.539
	All snags	6.0 (6.0)	6.0 (2.4)	6.0 (5.2)	3.7 (1.5)	6.0 (9.7)	3.6 (2.0)	(0.790)	6.3 (4.1)	10.4 (7.9)	10.5 (4.9)	5.0 (3.3)	6.3 (4.6)	9.6 (3.7)	0.449
	Decid poles	20.4 (43.7)	18.4 (25.7)	5.1 (4.4)	10.2 (10.2)	26.5 (19.2)	15.3 (19.8)	0.757	1.3 (3.1)	1.0 (3.2)	0.0 (0.0)	14.0 (34.4)	19.1 (27.0)	0.0 (0.0)	(0.779)
	Decid trees	25. 3 (5.1)	16.8 (16.2)	24.3 (7.6)	25.7 (6.8)	24.2 (15.1)	25.2 (1.8)	(0.965)	22.3 (11.5)	21.0 (5.9)	32.8 (13.2)	25.8 (7.5)	16.8 (10.1)	22.2 (18.1)	0.536
	Conif stems	1.9 (3.3)	13.0 (18.2)	3.5 (5.0)	0.0 (0.0)	1.8 (1.8)	0.2 (0.4)	(0.322)	10.8 (6.3)	42.9 (52.6)	30.3 (18.5)	5.5 (5.3)	13.6 (19.3)	33.1 (29.4)	(0.383)

[1] average percent cover within four 1 m^2 quadrats
[2] mean number of stems per 0.008 ha subplot
[3] mean number of stems per 0.04 ha plot
[4] dbh > 12 cm

Appendix 3 (continued): Means (and standard deviations) of vegetation characteristics in Mixed and Coniferous sites in 1998 (pre-harvest). Significance values in brackets were determined by Kruskal-Wallis ANOVA.

		Mixed Retention Level						ANOVA	Coniferous Retention Level						ANOVA
		0%	10%	20%	50%	75%	100%	p	0%	10%	20%	50%	75%	100%	p
% Ground Cover [1]	All green	56.8 (20.9)	61.8 (27.0)	71.3 (24.1)	60.0 (18.4)	66.9 (17.4)	64.0 (17.6)	0.944	5.4 (7.1)	7.7 (2.6)	13.4 (13.5)	15.1 (8.0)	14.7 (10.3)	8.0 (7.0)	0.439
	Shrub	33.1 (24.0)	28.6 (30.1)	8.6 (2.9)	23.2 (18.2)	14.4 (28.1)	8.9 (8.2)	0.352	11.8 (1.5)	18.3 (19.1)	16.3 (16.8)	16.4 (15.2)	23.9 (16.5)	11.6 (12.7)	0.825
	Forb	31.6 (25.6)	33.3 (24.2)	31.7 (27.0)	31.6 (14.7)	23.5 (14.9)	25.0 (28.7)	0.980							
	Moss	19.4 (37.1)	22.3 (40.6)	48.4 (32.0)	29.9 (36.4)	49.2 (33.8)	43.9 (41.2)	0.727	44.5 (19.7)	46.7 (37.9)	45.7 (42.9)	45.7 (5.5)	35.3 (36.4)	59.8 (41.5)	0.932
	Litter								14.8 (10.8)	12.9 (8.1)	13.1 (7.5)	14.4 (9.8)	8.9 (0.9)	11.2 (6.2)	0.884
	DWD	14.7 (2.2)	6.9 (8.7)	9.4 (1.0)	14.3 (7.6)	9.4 (9.7)	13.1 (4.4)	(0.372)	25.3 (1.8)	14.7 (16.3)	14.3 (3.6)	23.3 (7.6)	16.1 (13.2)	14.6 (10.8)	0.419
Shrubs (stems) [2]	Low shrubs	517.4 (273.9)	450.8 (300.9)	280.9 (171.2)	499.8 (363.6)	284.2 (381.2)	199.9 (122.6)	0.460	282.2 (159.7)	421.4 (359.5)	356.7 (93.8)	289.1 (76.9)	387.1 (215.7)	235.2 (63.5)	0.693
Canopy (stems) [3]	Small snags	2.6 (3.4)	6.0 (4.7)	2.3 (1.5)	1.5 (2.9)	7.0 (5.8)	3.6 (1.2)	0.264	4.2 (2.9)	5.0 (6.2)	3.6 (2.3)	0.8 (0.6)	3.0 (4.2)	2.8 (1.8)	0.535
	Large snags [4]	4.0 (3.4)	3.6 (3.2)	6.3 (1.2)	1.3 (1.5)	1.5 (1.5)	3.0 (0.9)	0.107	2.8 (2.0)	5.0 (2.5)	3.0 (0.9)	1.3 (0.6)	3.0 (2.2)	2.2 (1.0)	0.105
	All snags	6.6 (6.8)	9.6 (7.2)	8.7 (2.5)	2.8 (2.5)	8.5 (5.3)	6.6 (1.9)	0.436	7.0 (0.9)	10.0 (8.5)	6.6 (2.9)	2.0 (0.0)	6.0 (4.6)	5.0 (2.6)	(0.221)
	Decid stems	18.1 (10.7)	12.2 (6.2)	17.7 (21.9)	9.8 (15.8)	6.5 (3.2)	11.2 (15.3)	0.808	55.7 (98.9)	7.0 (5.0)	6.2 (3.9)	3.5 (1.2)	5.3 (3.3)	7.7 (18.1)	(0.668)
	Conif stems	24.8 (28.2)	15.4 (17.4)	17.7 (11.0)	33.9 (30.7)	30.2 (13.0)	26.6 (17.9)	0.789	18.1 (4.0)	18.8 (12.1)	28.5 (9.2)	25.8 (9.6)	14.0 (13.0)	26.6 (10.3)	0.275

[1] average percent cover within four 1 m^2 quadrats
[2] mean number of stems per 0.008 ha subplot
[3] mean number of stems per 0.04 ha plot
[4] dbh > 12 cm

Appendix 4: Species codes, common names and scientific names for all bird species observed in forest sites at EMEND.

Species Code	Common Name	Scientific Name	Foraging Guild [1,2]	Nesting Guild [1,3]
ALFL	Alder Flycatcher	*Empidonax alnorum*	A	ST
AMKE	American Kestrel	*Falco sparverius*	A	C
AMRE	American Redstart	*Setophaga ruticilla*	A	ST
AMRO	American Robin	*Turdus migratorius*	G	ST
BAOW	Barred Owl	*Strix varia*	A	C
BAWW	Black and White Warbler	*Mniotilta varia*	B	G
BBWA	Bay-breasted Warbler	*Dendroica castanea*	F	ST
BBWO	Black-backed Woodpecker	*Picoides arcticus*	B	C
BCCH	Black-capped Chickadee	*Parus atricapillus*	F	C
BOCH	Boreal Chickadee	*Parus hudsonicus*	F	C
BPWA	Blackpoll Warbler	*Dendroica striata*	F	ST
BRCR	Brown Creeper	*Certhia Americana*	B	C
BTNW	Black-throated Green Warbler	*Dendroica virens*	F	ST
CAGO	Canada Goose	*Branta Canadensis*	AQ	G
CAWA	Canada Warbler	*Wilsonia Canadensis*	A	G
CCSP	Clay-coloured Sparrow	*Spizella pallida*	G	ST
CEWA	Cedar Waxwing	*Bombycilla cedrorum*	F	ST
CHSP	Chipping Sparrow	*Spizella passerina*	G	ST
CMWA	Cape May Warbler	*Dendroica tigrina*	F	ST
COGO	Common Goldeneye	*Bucephala clangula*	AQ	C
COLO	Common Loon	*Gavia immer*	AQ	G
CONI	Common Nighthawk	*Chordeiles minor*	A	G
CORA	Common Raven	*Corvus corax*	G	ST
COSN	Common Snipe	*Gallinago gallinago*	G	G
COWA	Connecticut Warbler	*Oporornis philadelphia*	G	G
DEJU	Dark-eyed Junco	*Junco hyemalis*	G	G
DOWO	Downy Woodpecker	*Picoides pubescens*	B	C
GBHE	Great Blue Heron	*Ardea herodias*	AQ	ST
GCKI	Golden-crowned Kinglet	*Regulus satrapa*	F	ST
GRJA	Gray Jay	*Perisoreus canadensis*	G	ST
HAWO	Hairy Woodpecker	*Picoides villosus*	B	C
HETH	Hermit Thrush	*Catharus guttatus*	G	G
KILL	Killdeer	*Charadrius vociferus*	G	G
LEFL	Least Flycatcher	*Empidonax minimus*	A	ST
LEYE	Lesser Yellowlegs	*Tringa flavipes*	G	G
LISP	Lincoln's Sparrow	*Melospiza lincolnii*	G	G
MALL	Mallard	*Anas platyrhynchos*	AQ	G
MAWA	Magnolia Warbler	*Dendroica magnolia*	A	ST
MOWA	Mourning Warbler	*Oporornis philadelphia*	F	G
NOFL	Northern Flicker	*Colaptes auratus*	G	C
NOGO	Northern Goshawk	*Accipiter gentilis*	A	ST
NOHA	Northern Harrier	*Circus cyaneus*	A	G
NOWA	Northern Waterthrush	*Seiurus noveboracensis*	G	G
OCWA	Orange-crowned Warbler	*Vermivora celata*	F	G
OSFL	Olive-sided Flycatcher	*Contopus borealis*	A	ST
OVEN	Ovenbird	*Seiurus aurocapillus*	G	G
PHVI	Philadelphia Vireo	*Viro philadelphicus*	A	ST
PISI	Pine Siskin	*Carduelis pinus*	F	ST

Appendix 4 (continued): Species codes, common names and scientific names for all bird species observed in forest sites at EMEND.

Species Code	Common Name	Scientific Name	Foraging Guild [1, 2]	Nesting Guild [1, 3]
PIWO	Pileated Woodpecker	*Dryocopus pileatus*	B	C
PUFI	Purple Finch	*Carpodacus purpureus*	G	ST
RBGR	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	F	ST
RBNU	Red-breasted Nuthatch	*Sitta Canadensis*	B	C
RCKI	Ruby-crowned Kinglet	*Regulus calendula*	F	ST
REVI	Red-eyed Vireo	*Vireo olivaceus*	A	ST
RUGR	Ruffed Grouse	*Bonasa umbellus*	F	G
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*	G	G
SASP	Savannah Sparrow	*Passerculus sandwichensis*	G	G
SOSA	Solitary Sandpiper	*Tringa solitaria*	G	ST
SOVI	Solitary or Blue-headed Vireo	*Vireo solitarius*	F	ST
SSHA	Sharp-shinned Hawk	*Accipiter striatus*	A	ST
SWTH	Swainson's Thrush	*Catharus ustulatus*	F	ST
TEWA	Tennessee Warbler	*Vermivora peregrina*	F	G
TRSW	Tree Swallow	*Tachycineta bicolor*	A	C
TTWO	Three-toed Woodpecker	*Picoides tridactylus*	B	C
VATH	Varied Thrush	*Ixoreus naevius*	G	ST
VEER	Veery	*Catharus fuscescens*	G	G
WAVI	Warbling Vireo	*Vireo gilvus*	F	ST
WETA	Western Tanager	*Piranga ludoviciana*	F	ST
WIWA	Wilson's Warbler	*Wilsoni pusilla*	F	G
WIWR	Winter Wren	*Troglodytes troglodytes*	G	C
WTSP	White-throated Sparrow	*Zonotrichia albicollis*	G	G
WWCR	White-winged Crossbill	*Loxia leucoptera*	F	ST
WWPE	Western Wood Peewee	*Contopus sordidulus*	A	ST
YBSA	Yellow-bellied Sapsucker	*Dendroica petechia*	B	C
YEWA	Yellow Warbler	*Sphyrapicus varius*	F	ST
YRWA	Yellow-rumped Warbler	*Dendroica coronata*	F	ST

[1] from Erhlich et al (1988)

[2] foraging guilds: A – aerial foragers, AQ – aquatic feeders, B – bark gleaners, F – foliage gleaners, G – ground foragers

[3] nesting guilds: C – cavity nesters, G – ground nesters, ST - shrub/tree nesters

Appendix 5: Mean bird abundance per station by species in Deciduous sites. Underlined means have changed significantly from 1998 values relative to changes in controls during same period. Only significant p values are shown.

Species	For/Nest Guild [1]		Harvest Retention Level 0%	10%	20%	50%	75%	100%	ANOVA [2] p
		1998	0.000	0.083	0.000	0.000	0.067	0.000	
AMRE	A / ST	1999	0.000	0.000	0.000	0.000	0.100	0.300	
		2000	0.000	0.132	0.000	0.000	0.100	0.325	
		1998	0.000	0.000	0.000	0.000	0.000	0.000	
BCCH	F / C	1999	0.000	0.000	0.000	0.000	0.025	0.000	
		2000	0.026	0.135	0.044	0.208	0.100	0.075	
		1998	0.067	0.083	0.111	0.222	0.200	0.233	
CAWA	A / G	1999	0.000	0.000	0.000	0.000	0.000	0.200	**(0.060)**
		2000	0.000	0.000	0.000	0.000	0.050	0.450	
		1998	0.000	0.042	0.000	0.000	0.000	0.000	
CHSP	G / ST	1999	0.000	0.000	0.000	0.083	0.000	0.000	
		2000	0.100	0.336	0.171	0.000	0.100	0.000	
		1998	0.200	0.125	0.056	0.333	0.000	0.067	
COWA	G / G	1999	0.000	0.000	0.000	0.000	0.000	0.000	
		2000	0.000	0.066	0.000	0.167	0.000	0.150	
		1998	0.000	0.000	0.000	0.000	0.000	0.000	
DEJU	G / G	1999	0.025	0.168	0.086	0.000	0.125	0.000	
		2000	0.279	0.068	0.132	0.250	0.100	0.000	
		1998	0.133	0.333	0.278	0.000	0.200	0.000	
GCKI	F / ST	1999	0.000	0.000	0.000	0.000	0.000	0.000	
		2000	0.000	0.000	0.000	0.000	0.050	0.000	
		1998	0.067	0.000	0.000	0.111	0.000	0.333	
LEFL	A / ST	1999	0.000	0.066	0.000	0.083	0.000	0.200	
		2000	0.000	0.083	0.000	0.000	0.000	0.300	
		1998	0.000	0.000	0.000	0.000	0.000	0.000	
LISP	G / G	1999	0.100	0.000	0.088	0.000	0.000	0.000	
		2000	0.306	0.268	0.000	0.125	0.000	0.000	
		1998	0.000	0.000	0.000	0.000	0.000	0.000	
MOWA	F / G	1999	0.000	0.000	0.000	0.000	0.000	0.100	**(0.059)**
		2000	0.026	0.135	0.351	0.167	0.150	0.100	
		1998	0.267	0.250	0.278	0.222	0.600	0.133	
OVEN	G / G	1999	0.000	0.000	0.000	0.000	0.100	0.350	**(0.084)**
		2000	0.000	0.000	0.000	0.000	0.200	0.150	**(0.089)**
		1998	0.000	0.000	0.000	0.000	0.000	0.000	
RBGR	F / ST	1999	0.000	0.000	0.000	0.000	0.050	0.250	
		2000	0.000	0.000	0.000	0.000	0.225	0.075	**(0.016)**

Appendix 5 (continued): Mean bird abundance per station in Deciduous sites.

Species	For/Nest Guild[1]		Harvest Retention Level 0%	10%	20%	50%	75%	100%	ANOVA[2] p
		1998	0.300	0.000	0.056	0.111	0.200	0.000	
RBNU	B / C	1999	0.000	0.000	0.000	0.000	0.000	0.000	
		2000	0.000	0.083	0.088	0.000	0.150	0.000	
		1998	0.133	0.167	0.111	0.000	0.000	0.000	
REVI	A / ST	1999	0.000	0.000	0.000	0.000	0.000	0.000	
		2000	0.000	0.066	0.000	0.000	0.050	0.200	(0.100)
		1998	0.100	0.042	0.000	0.111	0.067	0.067	
SWTH	F / ST	1999	0.000	0.000	0.000	0.167	0.000	0.050	
		2000	0.000	0.000	0.042	0.083	0.075	0.050	
		1998	0.333	0.292	0.056	0.000	0.067	0.467	
TEWA	F / G	1999	0.000	0.132	0.042	0.083	0.050	0.450	
		2000	0.000	0.334	0.217	0.292	0.575	0.550	
		1998	0.067	0.083	0.111	0.000	0.133	0.133	
WAVI	F / ST	1999	0.000	0.000	0.000	0.000	0.225	0.150	**(0.086)**
		2000	0.000	0.000	0.000	0.000	0.200	0.150	
		1998	0.233	0.188	0.111	0.389	0.067	0.100	
WTSP	G / G	1999	0.179	0.797	0.217	0.208	0.350	0.100	
		2000	0.251	0.519	0.395	0.292	0.250	0.100	
		1998	0.000	0.063	0.000	0.000	0.033	0.000	
YBSA	B / C	1999	0.000	0.083	0.000	0.000	0.300	0.075	
		2000	0.000	0.075	0.000	0.042	0.000	0.075	
		1998	0.133	0.292	0.611	0.278	0.200	0.067	
YRWA	F / ST	1999	0.000	0.000	0.044	0.250	0.150	0.050	
		2000	0.000	0.107	0.088	0.417	0.325	0.225	

Deciduous / Understory sites

Species	For/Nest Guild		0%	10%	20%	50%	75%	100%	p
		1998	0.000	0.200	0.000	0.083	0.083	0.000	
AMRE	A / ST	1999	0.000	0.000	0.000	0.000	0.000	0.000	
		2000	0.000	0.000	0.000	0.000	0.000	0.000	
		1998	0.167	0.000	0.000	0.000	0.000	0.000	
BCCH	F / C	1999	0.000	0.050	0.036	0.000	0.000	0.025	
		2000	0.000	0.029	0.000	0.000	0.125	0.075	
		1998	0.000	0.000	0.000	0.042	0.083	0.133	
CHSP	G / ST	1999	0.063	0.333	0.205	0.094	0.063	0.000	
		2000	0.302	0.245	0.646	0.063	0.188	0.050	
		1998	0.000	0.000	0.083	0.000	0.000	0.000	
DEJU	G / G	1999	0.135	0.114	0.250	0.188	0.188	0.000	
		2000	0.063 [ab]	0.462 [b]	0.335 [ab]	0.125 [ab]	0.063 [ab]	0.000 [a]	**0.049**

Appendix 5 (continued): Mean bird abundance per station in Deciduous/Understory sites.

Species	For/Nest Guild[1]		Harvest Retention Level 0%	10%	20%	50%	75%	100%	ANOVA[2] p
GCKI	F / ST	1998	0.125	0.000	0.250	0.083	0.083	0.467	
		1999	0.000	0.000	0.000	0.000	0.000	0.050	
		2000	0.000	0.000	0.000	0.063	0.000	0.075	
GRJA	G / ST	1998	0.000	0.100	0.083	0.250	0.000	0.100	
		1999	0.125	0.000	0.107	0.094	0.000	0.025	
		2000	0.000	0.319	0.036	0.000	0.031	0.000	
LISP	G / G	1998	0.000	0.000	0.000	0.000	0.000	0.000	
		1999	0.109	0.000	0.000	0.000	0.000	0.000	**(0.060)**
		2000	0.234	0.324	0.000	0.000	0.063	0.000	**(0.033)**
OVEN	G / G	1998	0.667	0.400	0.417	0.167	0.375	0.233	
		1999	0.000	0.000	0.000	0.000	0.063	0.200	
		2000	0.000	0.000	0.000	0.063	0.063	0.100	
RBNU	B / C	1998	0.000	0.000	0.083	0.250	0.000	0.067	
		1999	0.000	0.000	0.000	0.000	0.000	0.000	
		2000	0.000	0.026	0.000	0.000	0.000	0.175	
SWTH	F / ST	1998	0.083 [a]	0.133 [a]	0.292 [a]	0.083 [a]	0.083 [a]	0.400 [a]	**0.081**
		1999	0.000	0.026	0.000	0.000	0.250	0.300	**(0.008)**
		2000	0.000	0.077	0.031	0.000	0.000	0.300	
TEWA	F / G	1998	0.000	0.400	0.000	0.000	0.333	0.133	
		1999	0.000	0.057	0.063	0.063	0.250	0.150	
		2000	0.130	0.814	0.416	0.500	0.438	0.525	
WAVI	F / ST	1998	0.083	0.067	0.000	0.167	0.292	0.200	
		1999	0.000	0.051	0.000	0.063	0.250	0.150	
		2000	0.000	0.000	0.063	0.063	0.188	0.100	
WTSP	G / G	1998	0.000	0.067	0.000	0.167	0.125	0.000	
		1999	0.109	0.225	0.067	0.031	0.531	0.075	
		2000	0.198	0.125	0.031	0.219	0.375	0.000	
WWCR	F / ST	1998	0.000	0.000	0.000	0.000	0.000	0.000	
		1999	0.000	0.083	0.000	0.125	0.188	0.300	
		2000	0.000	0.000	0.000	0.000	0.000	0.000	
YRWA	F / ST	1998	0.750	0.200	0.333	0.292	0.500	0.467	
		1999	0.000	0.205	0.244	0.438	0.094	0.450	
		2000	0.000	0.421	0.277	0.344	0.281	0.575	

Appendix 5 (continued): Mean bird abundance per station in Mixed sites.

Species	For/Nest Guild[1]		Harvest Retention Level						ANOVA[2]
			0%	10%	20%	50%	75%	100%	p
		1998	0.000	0.000	0.111	0.333	0.000	0.067	
BOCH	F / C	1999	0.000	0.000	0.000	0.031	0.000	0.075	
		2000	0.000	0.050	0.060	0.000	0.000	0.025	
		1998	0.133	0.200	0.000	0.250	0.083	0.267	
BTNW	F / ST	1999	0.000	0.000	0.000	0.063	0.000	0.050	
		2000	0.000	0.000	0.000	0.063	0.313	0.150	**(0.052)**
		1998	0.067	0.067	0.000	0.000	0.000	0.000	
CHSP	G / ST	1999	0.000	0.150	0.000	0.250	0.063	0.150	
		2000	0.263	0.150	0.414	0.313	0.250	0.100	
		1998	0.067	0.133	0.000	0.000	0.000	0.067	
DEJU	G / G	1999	0.250	0.100	0.363	0.125	0.000	0.000	
		2000	0.063 [a]	0.200 [a]	0.612 [a]	0.594 [a]	0.031 [a]	0.100 [a]	**0.069**
		1998	0.200	0.500	0.333	0.375	0.250	0.400	
GCKI	F / ST	1999	0.000	0.000	0.000	0.000	0.000	0.075	**(0.005)**
		2000	0.000	0.000	0.000	0.094	0.000	0.350	**(0.084)**
		1998	0.200	0.233	0.389	0.167	0.083	0.067	
GRJA	G / ST	1999	0.000	0.025	0.044	0.000	0.188	0.025	
		2000	0.125	0.000	0.282	0.125	0.000	0.050	
		1998	0.000	0.067	0.000	0.000	0.000	0.000	
MOWA	F / G	1999	0.000	0.000	0.000	0.000	0.000	0.000	
		2000	0.057	0.233	0.000	0.125	0.063	0.000	
		1998	0.000	0.400	0.222	0.083	0.083	0.067	
OVEN	G / G	1999	0.000	0.000	0.000	0.000	0.000	0.150	
		2000	0.000	0.000	0.000	0.000	0.000	0.000	
		1998	0.000	0.000	0.000	0.000	0.000	0.100	
PISI	F / ST	1999	0.000	0.050	0.127	0.000	0.188	0.175	
		2000	0.000	0.000	0.000	0.031	0.000	0.050	
		1998	0.067	0.133	0.111	0.083	0.167	0.067	
RBNU	B / C	1999	0.000	0.000	0.088	0.063	0.000	0.050	
		2000	0.000	0.050	0.000	0.031	0.000	0.150	
		1998	0.067	0.133	0.000	0.083	0.167	0.067	
SWTH	F / ST	1999	0.000	0.000	0.000	0.000	0.031	0.225	
		2000	0.000	0.000	0.042	0.000	0.125	0.250	
		1998	0.133	0.200	0.000	0.000	0.083	0.267	
TEWA	F / G	1999	0.000	0.000	0.000	0.000	0.000	0.300	**(0.060)**
		2000	0.000	0.350	0.167	0.250	0.000	0.300	

Appendix 5 (continued): Mean bird abundance per station in Mixed sites.

Species	For/Nest Guild[1]		Harvest Retention Level 0%	10%	20%	50%	75%	100%	ANOVA[2] p
WTSP	G / G	1998	0.000	0.067	0.000	0.000	0.000	0.000	
		1999	0.029	0.608	0.042	0.250	0.000	0.025	(0.026)
		2000	0.114	0.558	0.042	0.063	0.125	0.000	
WWCR	F / ST	1998	0.000	0.000	0.000	0.000	0.167	0.067	
		1999	0.000 [a]	0.492 [b]	0.185 [ab]	0.188 [ab]	0.188 [ab]	0.375 [ab]	**0.069**
		2000	0.000	0.000	0.083	0.000	0.000	0.025	
YRWA	F / ST	1998	0.300	0.167	0.333	0.125	0.375	0.733	
		1999	0.000 [a]	0.150 [ab]	0.248 [ab]	0.375 [b]	0.219 [ab]	0.250 [ab]	**0.065**
		2000	0.094 [a]	0.200 [a]	0.321 [a]	0.594 [ab]	0.875 [b]	0.825 [b]	**0.002**

Coniferous sites

Species	For/Nest Guild		0%	10%	20%	50%	75%	100%	p
BOCH	F / C	1998	0.067	0.000	0.000	0.083	0.000	0.000	
		1999	0.000	0.000	0.000	0.000	0.000	0.000	
		2000	0.000	0.000	0.000	0.031	0.063	0.125	
BTNW	F / ST	1998	0.267	0.417	0.083	0.000	0.083	0.067	
		1999	0.000	0.000	0.000	0.000	0.000	0.100	
		2000	0.000	0.000	0.063	0.063	0.000	0.050	
CHSP	G / ST	1998	0.000	0.167	0.000	0.083	0.167	0.000	
		1999	0.055	0.064	0.000	0.063	0.000	0.100	
		2000	0.081	0.383	0.375	0.063	0.219	0.150	
CMWA	F / ST	1998	0.000	0.083	0.000	0.083	0.083	0.067	
		1999	0.000	0.000	0.063	0.000	0.125	0.000	
		2000	0.000	0.000	0.000	0.000	0.000	0.050	
DEJU	G / G	1998	0.000	0.000	0.167	0.083	0.167	0.067	
		1999	0.082	0.063	0.000	0.063	0.094	0.000	
		2000	0.405	0.350	0.156	0.313	0.188	0.050	
GCKI	F / ST	1998	0.533	0.583	0.375	0.417	0.250	0.333	
		1999	0.000	0.063	0.000	0.000	0.000	0.300	(0.019)
		2000	0.000	0.063	0.031	0.031	0.031	0.225	
GRJA	G / ST	1998	0.067	0.167	0.208	0.000	0.167	0.133	
		1999	0.000	0.128	0.094	0.031	0.063	0.050	
		2000	0.000	0.189	0.156	0.063	0.031	0.025	(0.099)
LISP	G / G	1998	0.000	0.000	0.000	0.000	0.000	0.000	
		1999	0.000	0.000	0.000	0.000	0.063	0.000	
		2000	0.326	0.188	0.063	0.000	0.000	0.000	

Appendix 5 (continued): Mean bird abundance per station in Coniferous sites.

Species	For/Nest Guild[1]		Harvest Retention Level 0%	10%	20%	50%	75%	100%	ANOVA[2] p
		1998	0.067	0.000	0.083	0.333	0.125	0.200	
PISI	F / ST	1999	0.000	0.096	0.375	0.281	0.250	0.175	
		2000	0.000	0.000	0.000	0.000	0.000	0.000	
		1998	0.400	0.083	0.083	0.083	0.083	0.200	
RBNU	B / C	1999	0.000	0.125	0.000	0.031	0.063	0.075	
		2000	0.000	0.031	0.125	0.063	0.156	0.025	
		1998	0.067	0.083	0.083	0.083	0.000	0.133	
SWTH	F / ST	1999	0.000	0.000	0.000	0.000	0.063	0.100	**(0.025)**
		2000	0.000	0.000	0.000	0.000	0.000	0.125	
		1998	0.200	0.083	0.083	0.000	0.000	0.067	
TEWA	F / G	1999	0.000	0.000	0.000	0.000	0.000	0.000	
		2000	0.000	0.064	0.188	0.000	0.094	0.050	
		1998	0.000	0.167	0.083	0.000	0.000	0.000	
WETA	F / ST	1999	0.000	0.000	0.000	0.063	0.000	0.025	
		2000	0.000	0.000	0.000	0.000	0.063	0.050	
		1998	0.133	0.000	0.083	0.167	0.083	0.067	
WIWR	G / C	1999	0.000	0.000	0.063	0.125	0.313	0.050	**(0.061)**
		2000	0.000	0.000	0.125	0.188	0.063	0.100	
		1998	0.000	0.000	0.083	0.000	0.000	0.133	
WTSP	G / G	1999	0.056	0.032	0.125	0.250	0.250	0.000	
		2000	0.056	0.222	0.063	0.031	0.031	0.050	
		1998	0.067	0.000	0.000	0.083	0.083	0.133	
WWCR	F / ST	1999	0.000 [a]	0.411 [ab]	0.531 [b]	0.313 [ab]	0.594 [b]	0.400 [ab]	**0.019**
		2000	0.000	0.064	0.000	0.125	0.156	0.100	
		1998	0.567	0.333	0.375	0.417	0.333	0.467	
YRWA	F / ST	1999	0.000	0.125	0.125	0.188	0.219	0.475	
		2000	0.000	0.095	0.281	0.719	0.625	0.525	**(0.021)**

[1] foraging guilds: A – aerial foragers, B – bark gleaners, F – foliage gleaners, G – ground foragers
nesting guilds: C – cavity nesters, G – ground nesters, ST – shrub/tree nesters

[2] significance levels in brackets determined by Kruskal-Wallis ANOVA

Appendix 6: Species observed during Black-capped Chickadee mobbing call playback surveys at EMEND in 2000.

Species Code	Common Name	Number of Detections Added in Harvest Treatments During Playback Periods				Migratory Guild [1, 2]
		DEC	DEC/UND	MIXED	CONIF	
ALFL	Alder Flycatcher	2	0	0	0	NTM
AMRE	American Redstart	2	0	0	0	NTM
AMRO	American Robin	1	2	2	0	SD
BAWW	Black and White Warbler	0	0	0	0	NTM
BBWA	Bay-breasted Warbler	0	0	1	0	NTM
BBWO	Black-backed Woodpecker	0	0	0	1	RES
BCCH	Black-capped Chickadee	6	5	9	8	RES
BOCH	Boreal Chickadee	0	2	6	3	RES
BRCR	Brown Creeper	0	1	0	1	RES
BTNW	Black-throated Green Warbler	1	0	4	2	NTM
CAWA	Canada Warbler	6	0	0	0	NTM
CHSP	Chipping Sparrow	8	15	12	10	NTM
CMWA	Cape May Warbler	0	0	0	0	NTM
CORA	Common Raven	0	0	0	0	RES
COWA	Connecticut Warbler	2	1	0	0	NTM
DEJU	Dark-eyed Junco	5	11	5	11	SD
GCKI	Golden-crowned Kinglet	0	0	1	3	SD
GRJA	Gray Jay	0	6	8	4	RES
HAWO	Hairy Woodpecker	0	0	1	3	RES
HETH	Hermit Thrush	0	0	0	0	SD
LEFL	Least Flycatcher	0	1	1	0	NTM
LISP	Lincoln's Sparrow	5	3	2	3	NTM
MAWA	Magnolia Warbler	0	0	1	0	NTM
MOWA	Mourning Warbler	3	0	0	3	NTM
NOFL	Northern Flicker	0	2	0	0	SD
NOGO	Northern Goshawk	0	0	0	0	RES
OSFL	Olive-sided Flycatcher	0	0	0	0	NTM
OVEN	Ovenbird	2	1	0	0	NTM
PISI	Pine Siskin	2	2	4	7	SD
RBGR	Rose-breasted Grosbeak	2	0	0	0	NTM
RBNU	Red-breasted Nuthatch	3	9	13	4	RES
RCKI	Ruby-crowned Kinglet	0	0	0	0	SD
REVI	Red-eyed Vireo	4	1	2	0	NTM
SOSA	Solitary Sandpiper	0	0	0	2	NTM
SOVI	Solitary Vireo	0	2	1	1	NTM
SWTH	Swainson's Thrush	2	3	1	1	NTM
TEWA	Tennessee Warbler	15	17	3	0	NTM
TTWO	Three-toed Woodpecker	0	0	1	1	RES
WAVI	Warbling Vireo	3	2	0	0	NTM
WETA	Western Tanager	0	0	4	4	NTM
WIWR	Winter Wren	0	0	1	1	SD
WTSP	White-throated Sparrow	12	7	1	7	SD
WWCR	White-winged Crossbill	0	2	2	1	SD
YBSA	Yellow-bellied Sapsucker	2	0	2	0	SD
YEWA	Yellow-Warbler	0	0	0	1	NTM
YRWA	Yellow-rumped Warbler	20	26	12	16	SD

[1] from Semenchuk (1992) and Kaufman (1996)

[2] migratory guilds: NTM – Neotropical migrants, RES – residents, SD – short-distance migrants

Appendix 7: Linear regression analysis of abundance rank additions across treatments during call playbacks in 2000, for sampling interval indicated. Significant p values (< 0.10) are in bold type.

Cover Type			Sampling Interval	Linear Regression [1]				
				p	r^2	interc	slope	95% CI
DECIDUOUS	Foraging Guilds	Aerial	M [2]	Insufficient data				
			M+S [3]	Insufficient data				
		Bark	M	Insufficient data				
			M+S	Insufficient data				
		Foliage	M	**0.013**	0.413	0.14	0.84	0.68 to 0.97
			M+S	**0.001**	0.630	0.21	1.35	1.10 to 1.62
		Ground	M	**(<0.001)**	0.744	0.67	-0.81	-1.10 to -0.51
			M+S	**(0.028)**	0.341	0.88	-0.60	-1.12 to -0.08
	Nesting Guilds	Shrub / Tree	M	**0.097**	0.212	0.21	0.38	0.09 to 0.74
			M+S	**0.002**	0.566	0.31	0.84	0.52 to 1.17
		Cavity	M	**(0.003)**	0.526	-0.01	0.22	0.09 to 0.35
			M+S	**(0.006)**	0.478	0.01	0.20	0.07 to 0.34
		Ground	M	(0.384)				
			M+S	(0.753)				
DECIDUOUS/UNDERSTORY	Foraging Guilds	Aerial	M	Insufficient data				
			M+S	Insufficient data				
		Bark	M	(0.209)				
			M+S	**(0.098)**	0.183	0.01	0.17	-0.04 to 0.38
		Foliage	M	0.282				
			M+S	**0.029**	0.296	0.14	0.21	0.12 to 0.31
		Ground	M	0.636				
			M+S	**0.097**	0.185	0.26	-0.15	-0.25 to -0.06
	Nesting Guilds	Shrub / Tree	M	(0.189)				
			M+S	0.265				
		Cavity	M	Insufficient data				
			M+S	Insufficient data				
		Ground	M	0.819				
			M+S	0.795				

[1] p values in brackets determined by weight estimation regression
[2] observations added during mobbing call period
[3] observations added during mobbing call period + silent period

Appendix 7 (continued): Linear regression analysis of abundance rank additions across treatments during call playbacks in 2000, for sampling interval indicated. Significant p values (< 0.10) are in bold type.

Cover Type			Sampling Interval	Linear Regression [1]				
				p	r^2	interc	slope	95% CI
MIXED	Foraging Guilds	Aerial	M [2]	Insufficient data				
			M+S [3]	Insufficient data				
		Bark	M	Insufficient data				
			M+S	Insufficient data				
		Foliage	M	0.548				
			M+S	0.113				
		Ground	M	0.489				
			M+S	0.331				
	Nesting Guilds	Shrub / Tree	M	(0.235)				
			M+S	0.251				
		Cavity	M	(0.375)				
			M+S	0.581				
		Ground	M	(0.903)				
			M+S	0.212				
CONIFROUS	Foraging Guilds	Aerial	M	Insufficient data				
			M+S	Insufficient data				
		Bark	M	(0.443)				
			M+S	0.243				
		Foliage	M	**(<0.001)**	0.652	-0.01	0.65	0.35 to 0.96
			M+S	**(<0.001)**	0.731	0.06	1.29	0.80 to 1.78
		Ground	M	0.681				
			M+S	0.323				
	Nesting Guilds	Shrub / Tree	M	**0.048**	0.288	0.05	0.13	0.06 to 0.20
			M+S	**<0.001**	0.665	0.36	0.87	0.61 to 1.18
		Cavity	M	**(0.076)**	0.240	-0.01	0.36	-0.04 to 0.76
			M+S	**(0.006)**	0.480	-0.03	0.57	0.20 to 0.95
		Ground	M	0.301				
			M+S	0.221				

[1] p values in brackets determined by weight estimation regression
[2] observations added during mobbing call period
[3] observations added during mobbing call period + silent period