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# Short-term Responses of Breeding Birds to Alternative Harvest Methods in Boreal Mixedwoods



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# SHORT-TERM RESPONSES OF BREEDING BIRDS TO ALTERNATIVE HARVEST METHODS IN BOREAL MIXEDWOODS

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## Abstract

We surveyed breeding bird communities in 1993-1995 in second-growth boreal mixedwoods near Black Sturgeon Lake in northwestern Ontario as part of a larger study of effects of disturbance on ecosystem processes. Experimental harvest treatments of varying intensity were distributed among 33 blocks in aspen-spruce-fir stands. Point counts were used to measure occurrence, relative abundance, and species diversity one year before and two years after harvest. Following harvest, bird communities in clear cuts (>90% removal) differed significantly from controls (0% removal) and those in partial cuts (70% removal). Partial cuts and controls differed slightly, but mostly in the second year after harvest. Half of the abundant and widespread species either disappeared or decreased significantly in abundance following clear cutting (primarily mature forest, tree nesting and tree foraging species), while no species disappeared and relatively few decreased in abundance following partial cutting. A few species increased significantly in the clear cut and partial cut treatments following harvest (primarily open habitat and ground nesting, low foraging species). Neo-tropical migrants, short distance migrants and residents were all represented in the affected species, indicating that the response was to local habitat conditions (i.e., harvest treatments). Partial cutting, proposed as an alternative silviculture system in boreal mixedwood forests in Ontario, retained most of the avifauna of pre-harvest forests over the short-term.

Key words: Black Sturgeon Lake, boreal mixedwood forest, breeding birds, habitat change, timber harvest, habitat structure, Ontario)

## Introduction

Sustainable management of forests for timber and non-timber values requires an understanding of the responses of ecosystem components and processes to disturbances. A multi-disciplinary and multi-agency project was established to study such effects in boreal mixedwood forest near Black Sturgeon Lake in northwestern Ontario (Scarratt 2001). Alternatives to the prevailing clear cut harvesting system in boreal Ontario were incorporated in this project in part as a result of public input to environmental assessments of the late 1980s and early 1990s (Class Environmental Assessment of Timber Management on Crown Lands in Ontario 1988-1992). Among the public expressions of concern at that time were the need for alternatives to traditional clear cutting and the need for more attention to potential responses of wildlife (e.g., breeding birds) to intensive forest management. The study reported here was developed as the bird response assessment of the alternate harvesting method component Black Sturgeon Boreal Mixedwood Research Project.

Bird responses to a number of forest harvesting practices are becoming increasingly well understood (Nietfeld and Telfer 1991, Telfer 1993, Wedeles and Van Damme 1995, Weeber 1999a, Hannon 2005). Species- and community-level responses have been documented for most harvesting practices through studies conducted in a wide range of forest types across North America. Less often, however, have studies spanning a wide range of harvesting intensities been conducted within a single forest type. Forest managers faced with decisions involving bird community priorities are thus forced to rely on comparisons among different harvesting systems from spatially and temporally disjunct studies that are usually based on different sampling protocols. While the results of many of these studies are similar, basing decisions on results extrapolated from forest types or geographic areas different from those being managed may lead to inappropriate decisions in specific forest management planning scenarios.

Two approaches are commonly employed in studying the effects of forest harvesting on birds. One is to examine longer-term effects of one or more silvicultural treatments by surveying birds in a number of stands harvested at different times in the past (e.g., Robinson and Robinson 1999, Jobes et al. 2004). The other approach is to consider short-term effects by comparing stands harvested simultaneously under different silvicultural prescriptions (e.g., Norton and Hannon 1997, Chambers et al. 1999). A number of studies comparing bird responses to two harvesting intensities using the latter approach have been conducted in several forest types (e.g., mixed hardwoods in West Virginia, Duguay et al. 2000; fir forest in British Columbia, Lance and Phinney 2001; hickory-oak forest in Missouri, Gram et al. 2003), as well as one incorporating four levels of harvesting intensity (hickory-oak forest in MU, Annand and Thompson 1997). We are aware of only one other study that has examined short-term bird responses along a gradient of harvesting intensity in a forest type in Canada similar to the Black Sturgeon Forest (aspen-spruce in Alberta, Norton and Hannon 1997), and none in the same forest type (aspen-fir-spruce) in Ontario.

This study examined bird community responses to three levels of harvesting intensity relative to uncut controls in an aspen-fir-spruce system to determine the extent to which various intensities altered forest bird communities in the short-term. We compared species occurrence, abundance, and diversity in patch cuts (15-20% volume removal), partial cuts (60-70% removal), and clear cuts (>90% removal) with equivalent blocks of uncut "control" (embedded in a matrix of harvesting activity) and a reference stand (spatially removed from harvesting) to provide managers working in the aspen-fir forest type with the knowledge necessary for making informed bird-related management planning decisions.

## Methods

### Study Area

Detailed information on the Black Sturgeon Boreal Mixedwood Research project (hereafter BSBMP) study area is available in Scarratt (2000). Soils, vegetation, and forestry history are all described in that report, which also gives maps, photographs and diagrams of the overall project, within which this bird component was nested.

The study was conducted near Black Sturgeon Lake, 120 km northeast of Thunder Bay, Ontario (49° 11.4' N, 88° 42.5' W) from May-September, 1993, February-August, 1994, and May-August 1995. The study area was located within the Black Sturgeon Forest Management Unit licensed to Bowater Inc. of Thunder Bay and lay in a matrix of adjacent forest operationally clear-cut between 1993 and 1996 (Scarratt 2001) (Fig. 1).

The forest on the research site at the time of the study was second growth, having been harvested between 1937 and 1945 for both sawlogs and pulp. The pre-harvest survey of the research site (1993) indicated that the average stand composition (volume basis) was 60% Trembling Aspen (*Populus tremuloides*, Michx.), 12% Balsam Fir (*Abies balsamea*, (L.) Mill.), 11% White Spruce

(*Picea glauca*, (Moench) Voss), 9% White Birch (*Betula papyrifera*, Marsh.), and 3% Black Spruce (*Picea mariana*, (Mill.) with scattered Jack Pine (*Pinus banksiana*, Lamb.), and White Pine (*Pinus strobus*, L.) (Scarratt 2001). The Balsam Fir was in various states of vigour/decline following prolonged spruce budworm (*Choristoneura fumiferana* (Clemens)) outbreaks in the area (Scarratt 2001, Sanders 1996, Sanders et al., unpublished).

### Spatial Arrangements of Treatments and Field Sampling Design

Terminology used in this report is as follows: Forest = the Black Sturgeon Forest timber operating area (or equivalent unit elsewhere); Stand = a stand identified by the BSBMP from one or more Forest Resources Inventory identified stands; Block = a 9 or 10 ha rectangle harvested or otherwise treated or scheduled to be treated; Station = a bird monitoring location where repeated point counts were conducted; Line = a linear transect along which stations were located.

We used two stands (Stand 1, Stand 2) of the alternative harvest component of the BSBMP and a third stand (Stand 3) of the fire ecology component of the BSBMP to assess breeding bird communities. Additionally, we used a fourth stand located west of the Black Sturgeon road opposite the former Black Sturgeon Lake Field Station to monitor inter-annual changes. Stand 4 was chosen as it was similar in composition to the stands identified for treatment, was not subject to any recent anthropogenic disturbances, contained a research site that had been used for spruce budworm research since 1966 and was monitored as a Breeding Bird Survey site (named BAA) monitored from 1966 to 1997 by Dr. Chris Sanders (Sanders 1970, Sanders, C.J., Fillman, D. and Welsh, D.A. Changes in bird populations during a complete spruce budworm cycle in northwestern Ontario. Unpublished MS, CFS & CWS., Scarratt 2001) (Fig. 1).

In 1993, a preliminary site assessment of Stands 1-3 was made on behalf of all projects by the BSBMP coordinator to determine current site characteristics (the most recent Forest Resource Inventory was in 1975). This was needed to permit allocation of experimental harvest treatments. Resulting stand characteristics are described in detail in Scarratt (2000). This pre-harvest assessment survey established transects of varying length at 100m spacing. Stands 1 and 2 were subsequently harvested in the winter of 1993-1994. Stand 3 was to be treated and burned to determine fuel loading under different treatment regimes, and an additional treatment was included (partial tramping of dead balsam fir). However, Stand 3 was not burned until the third year after cutting, allowing us to incorporate some of its experimental blocks in the bird study as additional treatment replicates. Some problems surrounding sampling design preclude Stand 3 from being included in all analyses.

### Harvest Treatments

Treatment blocks of 10 ha (in the harvesting component) and 9 ha (in the fire ecology component) were assigned to one of four general harvest treatments: no harvest (hereafter Control, or 0% volume removal), patch cut (15-20% volume removal), partial cut (60-70% volume removal, and clear cut (>90% volume removal). Within these general treatment categories, there was some variation in the exact harvesting method. Clear cutting was done by both full-tree extraction (standard feller-buncher and grapple skidder) and tree-length extraction (single-grip feller-delimber and grapple skidder). Partial cutting was done by full-tree extraction (as above), cut-to-length system (single-grip harvester and forwarder) and partially delimbed full-tree extraction (manual felling and cable skidding). Patch cutting was done by partially delimbed full-tree extraction (as above). In the fire ecology component, a partial tramping treatment (50% of dead balsam was tramped) was a rough equivalent of partial cutting and two of these were included as replicates in our partial cutting treatments.

Overall, the treatments formed a gradient of harvesting intensity that served as the principal axis of potential impact/response by birds. As well, the harvest created a density/canopy gradient that is expected to affect bird responses. However, the different harvesting methods applied within each major treatment add variation to the post-harvest vegetation structure and consequent habitat features available to birds. Additionally, the harvesting was conducted by operators who had been trained on site but had no previous experience with the partial cutting methods, and thus learned as they went (Scarratt 2001). This led to differences in amounts of ground disturbance, debris, ground vegetation destruction and other characteristics. Clear cutting removed all merchantable timber, including balsam fir, and non-merchantable fir was knocked down; this left blocks with few residual standing trees. Partial cutting removed about two-thirds of the merchantable volume, including all merchantable balsam fir and the smaller aspen, but left a relatively uniform canopy of good quality aspen and 20-30 large white spruce seed trees in each block. Patch cutting consisted of 5 m wide clear cut strips cut 50 m apart, plus 21 m diameter circular clear cuts spaced every 50 m along the cut strip. All trees were removed from the strips and patches, leaving 80 percent of the standing volume with no additional disturbance between strips. Spatial arrangement of stands and allocation of harvest treatments and methods by block are shown in Figure 1. Further details about the experimental design, harvesting methods, and the pre- and post-harvesting conditions are found in Scarratt (2000).

As noted, the Reference stand was spatially removed from harvesting activities and remained unharvested for the duration of the study. It was selected and studied to provide an indication of inter-annual variability of bird response variables independent of the harvesting practices and to examine the influence of landscape configuration on bird response.

**Bird Surveys**

Bird community composition was characterized using ten-minute variable-distance point counts. Detected birds were recorded using notation and protocols of the Forest Bird Monitoring Program (FBMP) of the Canadian Wildlife Service. Birds detected were recorded on field sheets as being within 50 m radius circles from the listing point or beyond 50 m. For surveys done along lines within mature forest (1993 all "blocks" and 1994-1995 Reference stand), the practical detection limits were assumed to be 100m (Wolf et al. 1995, Schieck 1997), and birds detected at other stations within blocks were indicated on survey sheets to eliminate duplication. In 1994 and 1995, (post-harvest) only birds seen or heard within the treatment block being surveyed were recorded (i.e., birds heard but determined to be in buffers or beyond were not recorded). All birds seen or heard, plus nests and pairs observed during surveys, were recorded. Prior to 1997, the FBMP protocol assigned a value of 2 to all singing males under the assumption that all males were paired, which may not always be the case (Environment Canada 2004). To minimize potential over-inflation of real abundances, singing males, active nests, and pairs were assigned a value of 1 in this study. Thus, data generally reflect abundances of male birds in the study area. Flyovers were noted as such following the FBMP Protocol (1993) (PIROP) with modifications (D. Welsh, *pers. comm.*). All stations were sampled twice during the breeding season by one of two observers. One observer conducted surveys for all three years of the study; the second observer differed annually. Surveys were completed by 11:30, and were not conducted in unsuitable weather conditions. Sampling was done from 6-19 June and 22 June-2 July 1993. Post-harvest bird communities were sampled 6-19 June and 22 June-2 July, 1994 and 15-27 June and 27 June-14 July, 1995.

Nocturnal owl monitoring surveys were conducted in February, March and April 1994 at the research site in general, but not at the treatment block level, and no pre- and post-harvest or among stand analyses were possible. Territory mapping on selected treatment blocks occurred in June and July 1994, but these data have not been analyzed in this report.

The locations of harvest treatment blocks within Stands 1-3 had not been determined at the time bird breeding needed to be measured in 1993. Thus, the 1993 (pre-harvest) bird point count surveys were conducted along every second assessment transect at 200m spacing. This yielded 2 to 6 point count stations/transect for a total of 101 point count stations along 19 transects (Fig. 2). Twelve additional transects (40 stations) were surveyed in the Reference stand. Sampling effort is summarized for each treatment by year in Table 1.

We assumed that sets of 4 point count stations along the transects, each ≥ 200 apart, would be able to serve as pre-harvest data when the 9-10 ha (300m x 300m or 315m x 320m) harvest blocks were over-laid. In fact, sets of pre-harvest point count stations along transects did not spatially correspond exactly to the post-harvest treatment blocks. Thus, the post-harvest (1994, 1995) bird point count surveys were conducted at five point count stations established in a quincunx arrangement in each of the 9- or 10-ha treatment blocks (Fig. 3). With this arrangement, corner stations (A-D) were 200m apart within blocks and 50m from block boundaries. The fifth station (E) allowed for more complete coverage of the treatment blocks. All point count stations established in treatment blocks in 1994 were used again in 1995, but these were unique from 1993 point count stations. The locations of point count stations within the Reference stand were constant throughout the three years of the study (Fig. 4). Because of the unavoidable differences in pre- and post-treatment approaches, we adjusted the abundance data before analysis to represent the abundance of individuals per 10 ha so between-year and between-treatment comparisons could be made.

**Analysis**

Species occurrence and richness were based on all species detected that are known to undertake nesting activities in forest uplands. Flyovers and species not effectively monitored by auditory point count methods (e.g., resident woodpeckers) and/or those with very large home ranges (e.g., Common Raven, Pileated Woodpecker) were not included in community-level analyses (Table 2). To allow for direct pre- and post-harvest bird community comparisons, individual point count data collected in 1993 were grouped together in sets of 4 stations that emulated the four corner design of the post-harvest data. Each set was then assigned as a proxy for a pre-harvest state to a particular treatment block. Although this approach meant that we used some points more than once, we treated them as independent points to build a community structure. Treatment Blocks were then used as experimental units in most analyses.

The number of individuals recorded at the points within a block during each survey period (1993 = 4 points/block, 1994-1995 = 5 points/block) was summed by species, and the maximum sum recorded in the two visits in that year was used as the measure of abundance for each species for that year. All identified and unidentified woodpeckers were grouped into a surrogate species (WOODZ) that was used as an index of cavity-nester abundance, but not included as a species in other analyses (Appendix 1).

For all community-level analyses, we used the software program PERMANOVA (Anderson 2005) to conduct non-parametric analyses of variance (NPMANOVA; Anderson 2001, McArdle and Anderson 2001) on mean abundances. This program uses randomized permutations and Monte-Carlo tests to conduct both an omnibus F-test and post-hoc comparisons. Although the PERMANOVA program is ideal for handling non-normal ecological data, the current version of the software has the limitation that the experimental design must be balanced. The post-harvest sampling design had 10 replicates within each of Control, Partial, and Clear Cut treatments. The 1993 data set, however, had 6, 8, and 6 replicates for the same treatments, respectively. Thus, the appropriate number of treatment blocks was randomly removed for pre-/post-harvest analyses, leaving us with 6 replicates per treatment for these tests.

Point count data were summed and log transformed (ln (count + 1)) to better simulate a Gaussian distribution. Kruskal-Wallis ANOVAs by ranks were used to identify species-level differences when NPMANOVA post hoc tests identified among-year and/or among-treatment differences.

Only three blocks were treated with the Patch Cut harvesting system. Due to this small number of replicates, Patch Cuts have been excluded from community level analysis but occurrence, species richness, species diversity, abundance, and other measures are provided in tables and figures for visual, qualitative comparisons with other treatments.

In addition to analyses of abundance of individual species in relation to treatments, groupings of species based on similarity in ecological traits were also analyzed in relation to treatments (groupings were determined from review of: Birds of North America: Life histories for the 21st Century. A. Poole and F. Gill [Eds.], American Ornithologist's Union, Cornell Lab of Ornithology, and Academy of Natural Sciences, Philadelphia, PA.) (Table 2). The groupings included migration distance, nesting location, breeding habitat, forest type preference, foraging location, food type preference, and foraging guild. Combined abundance of birds within these groupings was analyzed among treatments and between years through a series of one factor Kruskal-Wallis tests.

We considered Bonferroni-corrected (Zar 1996) p-values $< 0.1$ as significant for all analyses in this paper to reduce the risk of committing Type II errors (Askins et al. 1990; Sallabanks et al. 2000).

**Pre Harvest versus Post Harvest Comparisons: Assumptions**

Short-term response to the harvest treatment disturbance, in terms of species occurrence, species abundance (numbers of individuals per 10 ha, per station, mean and ranks among treatments and categories), species richness (cumulative number of species per treatment), species evenness, Shannon's diversity (H) were the major measurements. Due to the unavoidable logistic/design problems that precluded determining exact locations of the 9-10 ha treatment blocks before the pre-harvest bird breeding season took place, we could not, in a strict sense, always make these comparisons between identical sampling locations for pre- and post-treatment periods. Our approach required testing assumptions about the proposed treatment stands in 1993. The first assumption was that bird community characteristics were similar **within** each treatment stand. This was reasonable for Stand 2 because it was classified as one stand type (Scarratt 2001). However, Stand 1 comprised parts of two different FRI stand-types, so we needed to test whether or not the points from the southern portion of Stand 1 (Stand 1-S) were similar to those of the northern part (Stand 1-N). We used a 1 factor (Year), 3 level (Stand 1-N, Stand 1-S and Stand 2) NPMANOVA design with 6 replicates per level. Additionally, as there was an unbalanced number of stations in each stand, two stations were dropped from Stand 1-S and 4 points from Stand 2. In both cases, the stations that were dropped were on the edge of the Stand, and did not overlap spatially with any of the post-harvest treatment blocks.

**Treatment Stands versus Reference stands**

For the Reference stand to be used to inform interpretations of comparisons of treatment stands, we needed to determine if the Reference stand bird community was similar to Stands 1 and 2 pre-harvest, and to determine if there were any differences in the Reference stand among years. In both cases, we used NPMANOVA with multiple comparisons.

**Bird Data - Pre and post harvest comparisons**

The pre-harvest configuration of sampling stations in Stand 3 did not permit the generation of comparable pre- and post-harvest data sets, so pre- versus post-harvest analyses were limited to 6 replicates of 3 treatments based on data from Stands 1 and 2 only (Partial Cut, Clear Cut and Control). However, post-harvest configuration in Stand 3 allowed a full post-harvest among-treatments comparison using all three stands, which gave us 10 replicates.

**Habitat relationships**

The harvest treatments were expected to change the biological and structural characteristics of bird habitat in a number of ways. These characteristics were assumed *a priori* to be important explanatory factors in bird community responses. Habitat data were not gathered in all years at all stations or treatments. The best data to characterize the forest vegetation in each treatment block come from sets of 10m x 10m (0.1ha) Permanent Sample Plots (PSPs) ($n$ = 10/block) that were sampled both before and after harvest (Scarratt 2001). Other habitat characterization surveys were conducted in August-September 1993, July to August 1994 and July to August 1995 using a wildlife habitat protocol developed by A. Rodgers (Hutchison 1996). All bird point count stations in Stands1-3 and Reference stand were categorized using the Forest Ecosystem Classification (FEC) for northwestern Ontario (Sims et al. 1989) during 1993 (i.e., pre-harvest).

The extent of our analyses on bird-habitat relationships was based on the PSP data set, but was limited for a number of reasons. First, post-harvest habitat conditions were only characterized in 1994. Second, fewer blocks, and fewer habitat variables per block, were sampled in 1994 than in

1993 (PSPs: $n_{1993} = 21$, $n_{1994} = 13$). As a result, only 1 of 6 Clear Cut blocks and none of the Patch cut blocks was sampled in 1994, so we had to remove these treatments from pre- versus post-harvest analyses. Third, we paired the data such that only those blocks for which habitat was measured in both 1993 and 1994 were used to ensure that we were not biasing the ordinations by flooding them with pre-harvest data. This left us with only 12 blocks of a potential 21 (4 Control and 8 Partial cuts). Finally, none of the variables measured in the PSPs provided a good portrayal of the vertical structure of the forest, which has been identified as an important component contributing to bi rd diversity (Holmes et al. 1979, Smith and Shugart 1987).

As the ratio of habitat variables to sites approaches unity in multivariate ordinations, the constraints on the ordination axes become progressively weaker, and spurious species-habitat relationships could be identified as significant (McCune and Grace 2002). With this in mind, we examined the correlation structure of the available habitat data and chose 4 variables that were: 1) uncorrelated or only weakly inter-correlated, (2) seen as most relevant to predicting bird community and species distribution, and (3) easily measured in the field. The 4 variables selected were: stem count of live coniferous trees (>5cm diameter at breast height), basal area ($m^2$/ha) of living conifers, basal area of living deciduous trees, and total snag count.

Non-metric multidimensional scaling (NMDS) is considered the best multivariate ordination approach for ecological data (McCune and Grace 2002). We used the autopilot feature in PC-ORD v.4.25 (McCune and Mefford 1999, which uses the algorithms of Kruskal, 1964, and Mather, 1976) to perform NMDS on the 4 selected habitat variables and log-transformed bird abundance data. We used the Sorensen (Bray-Curtis) distance measure and conducted 40 runs on randomized data from random starting coordinates.

We conducted two NMDS ordinations. The first was on 1993 data for the 12 blocks to examine species-habitat relationships in the pre-harvest environment. The second ordination used the same 12 blocks, but included both 1993 and 1994 data to examine changes in the system following harvest. For all ordinations, bird species that occurred in <10% of the plots were removed to reduce the disproportionate influence of rare species on the results. This left us with 30 and 31 of the 38 species used in the NPMANOVA analysis set for the 1993 and 1993-1994 ordinations, respectively.

## Results

### Bird communities

The initial condition: pre-harvest (1993)

The total number of presumed breeding species recorded in all years in all stands at the Black Sturgeon research site was 70, 65 of which were detected during point counts (Table 2). This does not include fly-overs (e.g., Canada goose, common loon) which were not deemed to be species breeding in forest uplands. Fifty of the 65 species occurred in 1993 (55 if we include Stand 4). Thirty-eight species occurred in more than 5% of point counts in at least one treatment-year combination and were included in community-level analyses. Another 27 species were recorded in point counts but not included in community level analyses for one of three reasons: they occurred in less than 5% of counts, they have territories ≥ 10 ha and would not be expected to show a treatment-level response, and/or they are non-territorial, nomadic or irruptive species or species with highly clustered territories.

Species accumulation curves in Partial cuts for all years (Fig. 5a) indicated that 97-100% of species were recorded in 6 treatment blocks. Only the Patch Cut treatment ($n = 3$) fell below that number in any year. Species accumulation curves in both post-harvest years in all treatments (including harvested blocks) indicated a somewhat greater spread (78-95% of species documented in 6 blocks), but still showed that 93-100% were recorded in 9 blocks (and both post-harvest years had 10 replicates per treatment; Figure 5b). From these results, we are confident that only the rarest of species would be missed by our sampling effort, and the common and dominant members of the community are well represented in even our lowest effort among the main treatments (Control, Partial Cut, and Clear Cut). Species occurrence in the Patch Cut Treatment was limited by the number of replicate blocks (3).

Abundance (total individuals detected per station), richness (number of species detected per treatment block), diversity (Shannon's Index) and evenness were calculated for bird communities in all years and treatments (Table 3). All four measures of the community for all four treatments were similar in 1993, except species richness in Patch Cuts (lower because of lower number of replicates).

Frequency of occurrence (percentage of treatment blocks in which they were recorded in each year) is given in Table 4. Six species occurred in 100% of blocks in all four treatments in 1993: Bay-breasted Warbler, Ovenbird, Swainson's Thrush, Red-eyed Vireo, Winter Wren and Yellow-rumped Warbler. An additional 12 species were recorded in all four treatments (but not in 100% of blocks of each treatment), and an additional 10 were recorded in the three main treatments (but not in 100% of each treatment) in 1993. Thus, 28 of 38 most common and dominant species were shared across the sampled areas in the initial forest condition.

These 38 species spanned several life history groupings (Table 5). Nearly half (18) were Neo-Tropical Migrants, 13 were Short Distance Migrants and the remainder (7) were Residents. Over two-thirds (26) prefer to nest in Trees (10 of those in Cavities), while a quarter (11) prefer to nest on the Ground and relatively few in Shrubs (2). A similar composition among preferred foraging location was evident: 24 were Tree foragers, 11 were Low level foragers (ground and shrubs) and 3 were Generalist foragers. Species with a preference for Coniferous Forest and Mixed Coniferous-Deciduous Forest were equally numerous (15) and those with a preference for Deciduous Forest were less so (8). Within each grouping, Neo-Tropical Migrant species, Deciduous preferring species, Tree nesting species, and Low foraging species had the highest mean abundance level (Table 5). Responses of these ecological groupings to harvest treatments are presented below, but it is clear that birds of relatively mature forest conditions dominated the make-up of the initial forest. Therefore, the major treatment effects (tree removal up to 90%, disturbance of residual lower level vegetation) could be expected to significantly alter the bird community composition.

The abundance of each species (number of individuals/10 ha) was also quite similar across all treatment blocks in 1993 (Table 6). Four of the six most frequently occurring species by spatial measures (above) were also the top four most abundant numerically (Table 7), although the order was slightly altered: Ovenbird, Red-eyed Vireo, Swainson's Thrush, Bay-breasted Warbler. Winter Wren and Yellow-rumped Warbler were among the top seven most abundant species in all four treatments, while Cape May Warbler, Yellow-bellied Flycatcher and Blackburnian Warbler were among the top nine most abundant in all four treatments. Within the ecological groupings, abundance was similar among the four treatments in 1993 (Table 5).

These simple comparisons notwithstanding, constraints on the pre- versus post-harvest design required that we more formally determine similarities in bird communities among stands before harvest. Fortunately, the NPMANOVA test revealed that bird community structure in the two FRI stand types (Stand 1-N and Stand 1-S) were not significantly different. Therefore, we pooled the data from both parts of Stand 1 to compare directly to Stand 2. We found that bird communities in Stands 1 and 2 were not significantly different from one another in the pre-harvest year. Stand 3 (the Fire Ecology stand) was monitored with only 15 stations in 1993 and thus was considerably under-sampled for determining bird species composition that year (this is the reason for the lower replicate number in 1993 in Tables 3-7). However, all species found in Stand 3 in 1993 were found in the other three stands, and the relative abundance of species in Stand 3 (not included here) was similar to the other three stands, thus we assumed that Stand 3 treatment block bird communities were also similar in the initial year.

The planned purpose of the Reference Stand was to track composition of bird communities in a contiguous forest over the experimental period in comparison to changes in treatment blocks (including the unharvested Controls) set within a matrix of operational or experimentally cut forest (i.e., an attempt to look at landscape level effects). Unfortunately, although the Reference Stand showed little obvious difference in its bird community compared with initial conditions in Stands 1 and 2 (Appendix 2), the NPMANOVA test indicated that it differed significantly. We therefore excluded it from among-stand analyses.

On the basis of the similarities in bird species composition, frequency of occurrence and numerical abundance, treatment blocks were considered valid replicates for description of the bird community of upland boreal mixedwood forests in the Black Sturgeon Lake research site. We used all replicated treatments distributed across all stands to make formal comparisons within years among treatments and within and among years in community level analyses (below).

<u>Bird community changes from before (1993) to after harvest (1994, 1995)</u>

As noted, species richness was similar among all treatment blocks pre-harvest. It did not differ among the three years within the Control blocks or Partial Cut blocks. However, it was significantly lower in Clear Cut blocks in both 1994 and 1995 compared to all other treatments. Partial Cut blocks had similar species richness to Controls, except in 1995 (Fig. 6).

Abundance (mean number of individuals per point count) showed a similar pattern to richness. Abundance did not differ among treatments pre-harvest, but Clear Cut blocks had significantly fewer individuals than all other treatments in both 1994 and 1995. Again, Partial Cut blocks did not differ from Controls except in 1995, when they were lower (Fig. 7). Following that pattern, diversity was lower in the Clear Cut blocks in both 1994 and 1995, but all other treatments were similar.

Overall NPMANOVA tests on communities (using abundance as the metric) showed that there was significant interaction between year and treatment when considering all treatments and all years (1993, 1994, 1995) simultaneously ($p = 0.0002$) as well as significant differences in bird community response to the three treatments ($p = 0.0002$). These comparisons are limited to Stands 1 and 2 because of insufficient pre-harvest sampling in Stand 3, thus treatment replicates are 6-8.

Post hoc multiple comparisons within years but between Control, Clear Cut and Partial Cut treatments showed no significant difference in bird communities in 1993, but differences did occur as expected between treatments in both post harvest years. Clear Cut differed significantly from both Partial Cuts and Control blocks in 1994 ($p = 0.0004$, $p = 0.0002$ respectively) and again in 1995 ($p = 0.0008$, $p = 0.0002$). Likewise, Partial Cut differed from Control blocks in both 1994 and 1995 ($p = 0.0028$, $p = 0.0008$ respectively).

Post hoc multiple comparison testing revealed that within-treatment change was significant for the two harvest treatments between years. There were differences between the pre-harvest community in 1993 and the post-harvest community in 1994 ($p = 0.0004$) and similarly between a long and in a long and here in an 1993 and 1995 ($p = 0.0002$) within Clear Cuts. Likewise, there were pre- versus post-harvest differences between 1993 and 1994 ($p = 0.0042$), between 1993 and 1995 ($p = 0.0004$) within Partial Cuts. Additionally, there were differences between the two post-harvest years (1994 and 1995) within Partial Cuts. The Control blocks did not change among the three pre- and post-harvest years.

<u>Bird communities after harvest only (1994, 1995)</u>

By analyzing only post-harvest years (1994 and 1995) the sample size per treatment increases from 6 to 10 blocks, thus reducing the effects of local variation on the tests. This set of data was tested with NPMANOVA which revealed the only significant differences were between Treatments, with no Treatment-Year interaction. Control, Partial Cut and Clear Cut treatments all differed from one another at the community level ($p < 0.001$).

<u>Changes in abundance at the species level</u>

As the results of the overall NPMANOVA indicated, there were significant differences in the bird communities within each of the post-harvest years. Testing species abundances for differences at the treatment level within each year using Kruskal-Wallis tests allows us to determine which species are most significantly affected by differing levels of tree removal. While the results for species that showed significant differences are presented below, Appendices 3-6 contain p-values for all of the species level K-W tests.

Between treatments – pre-harvest

No species showed significant differences between treatments in the pre-harvest year. This reinforces the NPMANOVA test results which showed no difference among experimental blocks at the community level in the pre-harvest year.

Within treatments – changes from pre- harvest to post-harvest

Within the Control blocks, no species had any significant change in abundance among any of the years, confirming that it is valid to use them as representative of an unaffected population in all years for among treatment comparisons. With this in mind, we looked at the treatment effect within each of the post-harvest years.

Considering only the Clear Cut treatment blocks sampled in all three years ($n = 6$), 9 of the 38 species present in $\geq 5\%$ of point counts had a significant (at alpha = 0.1) decline in abundance from their 1993 levels: Bay-breasted Warbler, Blackburnian Warbler, Yellow-rumped Warblers, Ovenbird, Red-eyed Vireo, Swainson's Thrush, Yellow-bellied Flycatcher, Black-backed Woodpecker and Red Breasted Nuthatch (Fig. 8).

Within the Partial Cut treatment blocks, fewer species had significant increases or decreases in abundance from pre- to post-harvest than in Clear Cut blocks (Fig. 9). Bay-breasted Warbler, Swainson's Thrush and Ovenbird all declined in abundance over the years, with Swainson's Thrush and White-throated Sparrow showing a delayed response as the difference only became significant in the second post-harvest year. Mourning Warbler and White-throated Sparrow were the only species to show an increase in abundance in response to the Partial Cut regime, and both were significantly higher in both post-harvest years compared with 1993.

Within and among Treatments – Post-harvest comparisons

Considering only post-harvest comparisons, a larger sample size of treatment blocks is available ($n = 10$ per treatment). In 1994, 11 species showed significant change in abundance between treatments (Fig. 10): Bay-breasted Warbler, Blackburnian Warbler, Golden-crowned Kinglet, Ovenbird, Red-eyed Vireo, Swainson's Thrush, Tennessee Warbler, Winter Wren and Yellow-rumped Warbler were less abundant and White-throated Sparrow and Lincoln's Sparrow were more abundant. All species were significantly different between Clear Cut and Control treatments (except Winter Wren), while Ovenbird, Swainson's Thrush and White-throated Sparrow were also significantly different between Partial Cuts and Controls. Additionally, Bay-breasted Warbler, Blackburnian Warbler, and Red-eyed Vireo had noticeably decreased abundance between Partial cuts and Clearcuts. The Winter Wren was the only species with significantly higher abundance in Partial Cuts versus Clear Cuts, but it was not different between Partial Cuts and Controls.

In 1995, 12 species showed significant change in abundance between treatments: Bay-breasted Warbler, Blackburnian Warbler, Golden-crowned Kinglet, Ovenbird, Red-eyed Vireo, Swainson's Thrush, Tennessee Warbler, Winter Wren, Yellow-rumped Warbler had lower abundances in both Cut treatments, while White-throated Sparrow, Lincoln's Sparrow and Mourning Warbler had higher abundances (Fig. 11). In addition to the significant change for all species between Control and Clear Cut, 3 species were significantly different in Partial Cut versus Control (Bay-breasted Warbler, Ovenbird, and Swainson's Thrush were less abundant). White-throated and Lincoln's Sparrow, and Mourning Warbler all had significantly more individuals detected in Clear Cut than Control, and the White-throated Sparrow also had significantly higher abundance in Partial Cut compared to Control.

**Responses within Ecologically Similar Species Groups**

Migration Distance

Birds were categorized as Residents, Short Distance Migrants, or Neotropical Migrants. No migration group experienced a change in abundance within the Control blocks, but they showed variable responses to the Cut treatments (Fig. 12a, 12b). Only Neotropical Migrants were significantly negatively impacted within the Partial Cut. However, all three groups experienced significant declines in abundance from pre- to post-harvest within the Clear Cut treatments, despite significant increases in White-throated Sparrow, Lincoln's Sparrow and Mourning Warbler.

Nesting Location

The four nesting location preference categories used for analysis were Tree, Cavity, Ground and Shrub. None of the nesting groups showed significant change in abundance between years within the control blocks. Tree and Cavity nesters both declined significantly ($p < 0.0001$) from 1993 to 1994 and 1995 in the Clear Cut Treatments (Fig. 13a, 13b). Tree nesters also declined significantly each year in the Partial Cut treatments, with both 1993 and 1994 being significantly different from 1995 ($p < 0.0001$). Although abundance of Shrub nesters declined steadily from 1993 to 1995, they did not significantly decrease until 1995 ($p = 0.0082$).

Forest Age

Of the three forest age (habitat) preference categories (Mature Forest, Young Forest and Generalist), the Generalist species and Mature Forest species showed significant declines in abundance from the pre- to post-harvest years ($p < 0.0001$) (Fig. 14a). Mature Forest preferring birds were also significantly lower in abundance in the partial cut treatments ($p < 0.0001$) in the second post-harvest year compared with pre-harvest (Fig. 14b). There were no significant changes in abundance among the forest age preference groups in the Control blocks between years.

Forest Composition

Birds were categorized by preference for forest tree composition (Coniferous, Deciduous or Generalist). None of the forest composition groups changed abundance in the Control blocks over the years (Fig. 15a). All three groupings had significantly lower abundance in post-harvest years within the Clear Cut treatments (Coniferous $p < 0.0001$; Deciduous, $p = 0.0006$;

Generalist, $p < 0.0001$), however, Deciduous forest birds differed only between the pre-harvest and second year post-harvest. Generalists ($p = 0.0025$) and Coniferous ($p < 0.0001$) species declined significantly from pre-harvest to the second year post-harvest within Partial Cuts, and Coniferous associated species declined significantly in the first year post-harvest as well (Fig. 15b).

Foraging Location

Each species was assigned to a foraging location group based on their preference for feeding along the vertical gradient in the forest. These categories were Generalists, Tree Feeders and Low/Shrub Feeders. Tree Feeders were significantly less abundant in both Clear Cuts and Partial Cuts between 1993 and 1994, and 1993 and 1995 ($p < 0.0001$) (Fig. 16a, 16b). Again, there were no significant increases or decreases shown in any of the categories in Control blocks among years.

Food Type

The three groups used to categorize the species into different food type preference groups were: Invertebrate, Seed and Invertebrate-Seed Mix. Both Invertebrate and Invertebrate-Seed Mix feeders significantly declined in abundance between pre- and post-harvest years. In the Clear Cut treatments the decline in abundance was significant ($p < 0.0001$) from 1993 to 1994 and 1995 (Fig. 17a). In the Partial Cuts, the decrease was significant only between 1993 and the second year post harvest (Invertebrate, $p = 0.0077$; Invertebrate-Seed Mix, $p = 0.0032$) (Fig. 17b). No significant changes were observed among food type groups in the Control treatment blocks.

Foraging Guild

Species were assigned to one of 6 foraging guilds, which are simply combinations of foraging location and food type. The six categories were GEN-INV, TREE-INV, SEED, TREE-INVMIX, LOW-INVMIX and LOW-INV. TREE-INV, LOW-INVMIX and TREE-INVMIX all significantly declined between pre-harvest and both post harvest years ($p < 0.0001$) in Clear Cut treatments. In Partial Cuts, TREE-INV and LOW-INVMIX differed significantly between 1993 and 1995. There were no significant changes in abundance among years in the Control treatments.

At the level of the Kruskal-Wallis test, there were no species that showed significant change in the partial cut treatments from 1993 – 1995 at the 5% level adjusted for 38 tests.

**Bird-Habitat Relationships**

Pre- and post-harvest habitat conditions obtained from the PSP data and used in analyses of bird-habitat relationships are summarized in Table 8.

Pre-harvest

Non-metric Multidimensional Scaling extracted a two-dimensional solution for the pre-harvest data, which had an 85% coefficient of determination between real and ordinated data (Table 9). Basal area of living deciduous trees did not contribute significantly to this solution.

In this ordination, basal area of living conifers (BA-C) opposes number of snags (DTOTCOUN) along Axis 1, separating sites with large, living conifers and few snags from those with fewer large living confers and more snags (Fig. 18). The number of living conifer stems (CNT-C) is uncorrelated with either of these two variables, and parallels Axis 2, reflecting increased conifer stem densities, independent of tree size. Habitat vectors are short relative to dispersion of sites and species, indicating low variability in these metrics in the pre-harvest environment, and suggesting that other, non-measured habitat characteristics are also influencing bird community composition in this system. Control and Partial cuts are generally interspersed throughout the ordination, indicating relative pre-harvest homogeneity between treatments.

The most abundant species (e.g., Ovenbird, Red-eyed Vireo) tend to be closer to the centre of the ordination, conifer associates (e.g., Golden-crowned Kinglet, Cape May Warbler) are along the BA-C vector, and cavity nesters/snag feeders (e.g., Red-breasted Nuthatch, Black-capped Chickadee) are along the DTOTCOUN vector. The exception to the latter is the position of the Yellow-bellied Sapsucker at the extreme end of the BA-C vector, which reflects this species' use of live trees for foraging.

Pre-/Post-harvest

NMDS extracted a three-dimensional solution for the pre-/post-harvest data, which had an 87% coefficient of determination between real and ordinated data (Table 9). Interpretation of the third axis was difficult, and the overall pattern in habitat and species placements along this axis were similar to those along Axis 2, so results presented are based on Axes 1 and 2 only, which had a combined coefficient of determination between real and ordinated data of 70% (Table 9).

All 4 habitat vectors closely parallel Axis 2 in the pre-/post-harvest ordination, which appears to reflect the openness of the forest, with more densely-stocked blocks towards the top of the ordination, and more open ones towards the bottom (Fig. 19a). All Control blocks and all pre-harvest Partial blocks are in the top half of the ordination, and all post-harvest Partial blocks (i.e., "4-xxxPC") are in the lower half, indicating that Partial cutting 'opened up' the forest. Shifts in the positions of Control blocks from 1993 to 1994 (i.e., "3-xxxCO" to "4-xxxCO") are generally perpendicular to Axis 2, indicating relative homogeneity between years in terms of the measured environmental variables, and a between-year influence of one or more habitat characteristics that were not measured in this study. The pronounced shifts in the pre- and post-harvest positions of Partial cuts blocks parallel Axis 2, indicating comparatively large changes in habitat characteristics following harvest in this treatment. Habitat vector lengths are longer relative to the dispersion of all pre-harvest blocks and post-harvest Control blocks than in the first ordination, indicating that the measured habitat variables have a proportionately greater influence when considering the pre- and post-harvest environment simultaneously.

Patterns in individual species' positions along Axis 2 in the pre-/post-harvest ordination reflect their known habitat preferences, and parallel the relationships in habitat characteristics described by this axis: closed-forest species (e.g., Golden-crowned Kinglet, Ovenbird) are towards the top, open-area species (e.g., Mourning Warbler, Northern Flicker) are near the bottom, and forest species that use open areas (e.g., Chipping Sparrow, Magnolia Warbler) are roughly central (Fig. 19b). The pattern in species' positions along Axis 1 is less clear, but the position on the left half of the ordination of species that nest in cavities and/or feed on insects living in dead wood suggests that this axis may reflect forest age.

## Discussion

### Bird Communities of Black Sturgeon

The birds of the Black Sturgeon Lake area have been studied over several decades. An initial study was conducted in 1945 by Kendeigh (1947). A comparative follow-up study was conducted in 1966-1968 by Sanders (1970), who also initiated a long-term survey of breeding birds in two plots at the research site (Sanders et al., unpublished MS). The forest each surveyed was representative of boreal forest in northwestern Ontario at those respective times but Kendeigh's plots had very little trembling aspen and he was emphatic about the conifer domination (balsam, then spruce). Sanders' plots were more mixed conifer-deciduous with white birch and balsam fir each dominant in one. Although the forests had all of the major trees and understory species compared with the forest at the time of our survey (Scarratt 2001), they differed in age and structure with respect to the effect of budworm mortality. In 1945, the forest was at the peak of a budworm outbreak. In 1966, the forest was relatively young and represented post-budworm mortality regeneration, and was at the endemic (i.e., low insect density) stage of the budworm cycle. At the time of our research (1993-1995), the Black Sturgeon Forest was nearing the end of a spruce budworm outbreak which occurred in the 1980s and 1990s (Sanders et al., unpublished MS; Scarratt 2001). The forest had a mean age of 55 years and was dominated by Trembling Aspen, but with good representation of canopy white spruce and some canopy (but more understory) balsam fir, although many of the trees of these two species were dead as a result of the budworm.

The responses of forest birds to spruce-budworm densities are well documented (Kendeigh 1947, Hensley and Cope 1951, Morris et al. 1953, Sanders 1970, Crawford and Titterington 1979, Crawford et al. 1983, Crawford and Jennings 1989). Several bird species respond numerically and functionally to increasing budworm densities, depending on the stage of the cycle. Some are found at high densities during outbreaks but may be nearly absent at the endemic phase (Sanders 1970); these include Bay-breasted Warbler, Blackburnian Warbler, Cape May Warbler and Tennessee Warbler. All of these species were among the spatially most widespread species at Black Sturgeon during our three year study, presumably reflecting relatively high budworm densities even though the outbreak was nearing its end. In part, this may be attributed to momentum in the local breeding populations due to breeding philopatry of successful birds and natal philopatry of their offspring.

The breeding birds of Black Sturgeon during this study were typical of the boreal forests containing admixtures of aspen, spruce, and balsam fir (Erskine 1977). Sanders (1970) listed 44 species during his 3 year survey of two plots similar in size to each of our treatment blocks. All but two of his species were recorded in our 3 year survey, and 29 of his species were among the 38 species found in ≥5% of our point counts. Kendeigh (1947) listed 56 species in one year, most on four plots similar in size to each of our treatment blocks, but some in adjacent areas. All but two of his species were seen recorded by us, and he listed 36 of our 38 most frequent species. In all three studies at Black Sturgeon, wood warblers (Parulidae) and sparrows and allies (Fringillidae and Emberizidae) dominate the avifauna. Kendeigh (1947) and Sanders (1970) conducted their studies using repeated visits and intensive territory mapping methods, whereas we conducted repeated point counts which indicate relative abundance of singing birds. It has been noted that abundance alone may have little to no relationship with breeding activity/success (VanHorne 1983, Vickery et al. 1992.), particularly in forested systems (Betts et al. 2005).

**Bird-Habitat Relationships**

Our analyses of bird-habitat relationships did not consider Clear Cut and Patch Cut treatments post-harvest and were based on a subset of the larger data set (12/21 blocks), therefore our results and the following discussion are descriptive, rather than explanatory. However, the ordinations we conducted reasonably reflected patterns in the system under study, based on their final stress and instability values (Clarke 1993, McCune and Grace 2002). Individual bird species' positions on the ordinations corresponded to their known habitat preferences (Weeber 1999b) and the interspersion of Control and Partial cuts in the pre-harvest ordination corresponded with the results of NPMANOVA regarding pre-harvest similarity in the bird communities in these two treatments. The most abundant species tended to be closer to the centre of the pre-harvest ordination because the variability in the measured habitat characteristics was too low to influence their abundances. Many of these species were mature forest birds that were ubiquitous in the system, and were among those that had significant responses to Partial cutting (e.g., Ovenbird, Bay-breasted Warbler, Swainson's Thrush).

Habitat vectors were short relative to the dispersion of sites and species in the pre-harvest ordination, suggesting low variability in measured habitat metrics in the pre-harvest environment and indicating that bird community composition in the system was also influenced by other, non-measured habitat characteristics (e.g., Rotenberry 1985). The first axis in the pre-/post-harvest ordination also reflected variation due to habitat characteristics not measured in this study. The placement of species that nest in cavities and/or feed on insects living in dead wood on the left half of this ordination suggests that this first axis reflected some measure of forest age or extent of decay in snags. Perhaps the opening up of areas around Control blocks led to increased windthrow in these blocks following harvest (Gardiner et al. 1997) and reduced the number of standing older snags in the blocks post-harvest.

Although it is unclear what unmeasured habitat conditions influenced bird community structure in the study area, all of the species that responded either negatively or positively in abundance to

Patch cutting were positioned close to and along Axis 2 in the pre-/post-harvest ordination (decreased abundance: Ovenbird, Swainson's Thrush, Bay-breasted Warbler; increased abundance: White-throated Sparrow and Mourning Warbler) indicating that the habitat variables included in the ordination reasonably reflected the stand characteristics important to these species. Bird species typical of mature forests were in the top half of this ordination, as were all Control blocks and all pre-harvest Partial blocks, and bird species typical of open areas or young forests were in the lower half of the ordination, as were all post-harvest Partial blocks. An axis showing these patterns in species placement in an unharvested system would be interpreted as representing a gradient in forest age or successional stage. Thus, Partial cutting 'opened up' the forest and attracted species typical of an early-successional forest in our study area.

Basal area of living deciduous trees was not influential in the pre-harvest ordination, despite its being uncorrelated with basal area of living conifers (r = 0.004 for 1993). The occurrence and spatial configuration of the proportionately smaller conifer component in pre-harvest stands (30% by volume) may have had a greater influence on the variability in the bird community than did the ubiquitous deciduous trees (Titterington et al. 1979). The inclusion of basal area of deciduous trees, and its strong correlation with basal area of coniferous trees, in the pre-/post-harvest ordination is likely due to the removal of both types of trees during Partial cutting. The uncorrelated or inversely correlated habitat characteristics in the pre-, harvest system were 'swamped' by the post-harvest conditions, which made the unharvested habitat comparatively homogenous.

As noted, the time period of this study corresponded with the final years of a long-term, regional spruce budworm outbreak. The opposition of basal area of living conifers and numbers of snags along the first axis of the pre-harvest ordination may reflect variability in the system attributable to this outbreak. Blocks affected more heavily by budworms would be expected to have fewer living, and thus more dead, trees.

**Bird Responses to Harvest Treatments**

The gradient in tree removal and residual vegetation across the three harvest treatments had predictive content regarding bird responses. The removal of virtually all living and dead trees of merchantable size in the Clear Cut treatment was expected to result in the absence or large decrease in abundance of species that require mature forest trees for nesting and foraging. Nineteen of 32 abundant and widespread species in the pre-harvest year were not detected in the first year post-harvest (e.g., Bay-breasted Warbler, Blackburnian Warbler, Red-eyed Vireo, Swainson's Thrush, Yellow-bellied Flycatcher, and Black-backed Woodpecker). Notable and significant decreases occurred in (e.g., Yellow-rumped Warblers, Ovenbird and Red Breasted Nuthatch). Some species increased significantly (e.g., White-crowned Sparrows, Mourning Warbler) and one not present in the pre-harvest stands arrived (presumably) from adjacent forests or habitats (Lincoln's Sparrow). In the second year post-harvest, four of the pre-harvest species absent in the first year post-harvest were detected, including (Magnolia Warbler and Purple Finch). Predictably, these changes resulted in post-harvest bird communities dominated by early successional stage and open habitat species (Welsh 1981, Mather and Welsh 1995, Wedeles and Van Damme 1995, Weeber 1999b).

The removal of up to 70% of merchantable volume in Partial Cut treatments, but more importantly the retention of a well-distributed canopy of large aspen and significant understory spruce and balsam fir, was planned with the expectation that many of the pre-harvest birds would be retained at least in presence if not in pre-harvest abundance. In fact, this result was apparent after harvest, as none of the widespread and abundant species disappeared, and fewer species (compared with Clear Cut treatments) declined significantly in abundance in the (i.e., Bay-breasted Warbler and Ovenbird in the first year) and Swainson's Thrush in the second post-harvest year. Mourning Warbler and White-throated Sparrow both increased in abundance, presumably in response to the opening up of the forest. In effect, this treatment may have emulated to some extent an over-mature forest, by creating openings in the canopy which allowed light to penetrate. Monitoring changes in understory vegetation and tree regeneration in partial cutting situations over time would help determine whether this is the case. Unfortunately, the research site burned in a wildfire in 1999 (Scarratt 2001) so this will have to be done elsewhere (e.g., Hannon 2005).

Patch Cut treatments, in which only 20-30% of trees were removed in a "strip" clear-cutting pattern were expected to retain most if not all of their pre-harvest avifauna. Lack of replicates makes our results qualitative only. There was no strong pattern of obvious community change in Patch Cut treatments, but virtually all pre-harvest species appeared to be retained post-harvest (Cape May Warbler and Tennessee Warbler disappeared in the second year post-harvest). There was some indication that ground-nesting, low foraging species might have increased in abundance (e.g., White-throated Sparrow, Mourning Warbler), likely due to the presence of new forest openings. Another potential effect of this type of strip cutting which creates linear pathways leading into the interior of stands is increased predation near these edges (Manolis et al. 2000; although predation and nest success were not measured in our study). Falardeau et al. (1999) conducted a study in conifer dominated boreal forest where a similar strip cut approach was used. They found no increase in predation, but did find predictable increases in the presence and abundance of open country species.

Control treatments had no significant differences among years in species occurrence or abundance. However, mean abundance for a few species did show a tendency to increase in the first year post-harvest. This could represent a crowding effect, wherein returning breeders (particularly tree-nesting and tree-foraging species) from previous years did not find suitable habitat on their territories in adjacent Cut blocks and attempted to settle in Control Blocks (or Partial and Patch blocks; Norton and Hannon 1997, Schmiegelow et al. 1997).

Responses of boreal birds to partial harvesting methods in comparison with clear cutting methods and unharvested forest has been undertaken in a large project across the Canadian boreal since our study was done (Norton and Hannon 1997, Hannon 2005). They looked at many vertebrate and plant responses in a variety of boreal forest types, at both the stand and the landscape level. Results of their work at the stand level are very similar to ours.

The primary question that our study attempted to test was whether alternatives to clear-cutting had potential to reduce the immediate effect on breeding bird populations. For reasons stated above, our results are limited to answering that question for Partial Cut treatments only. We concluded that immediately post-harvest (1-2 years), Partial Cut stands did retain much of the avifauna of pre-harvest stands. Tittler et al. (2001) and Hannon (2005) caution that partial cutting at an operationally feasible level in aspen-fir stands was "not an option provide habitat at the stand or landscape level for all of the avifauna" (notably rare species).

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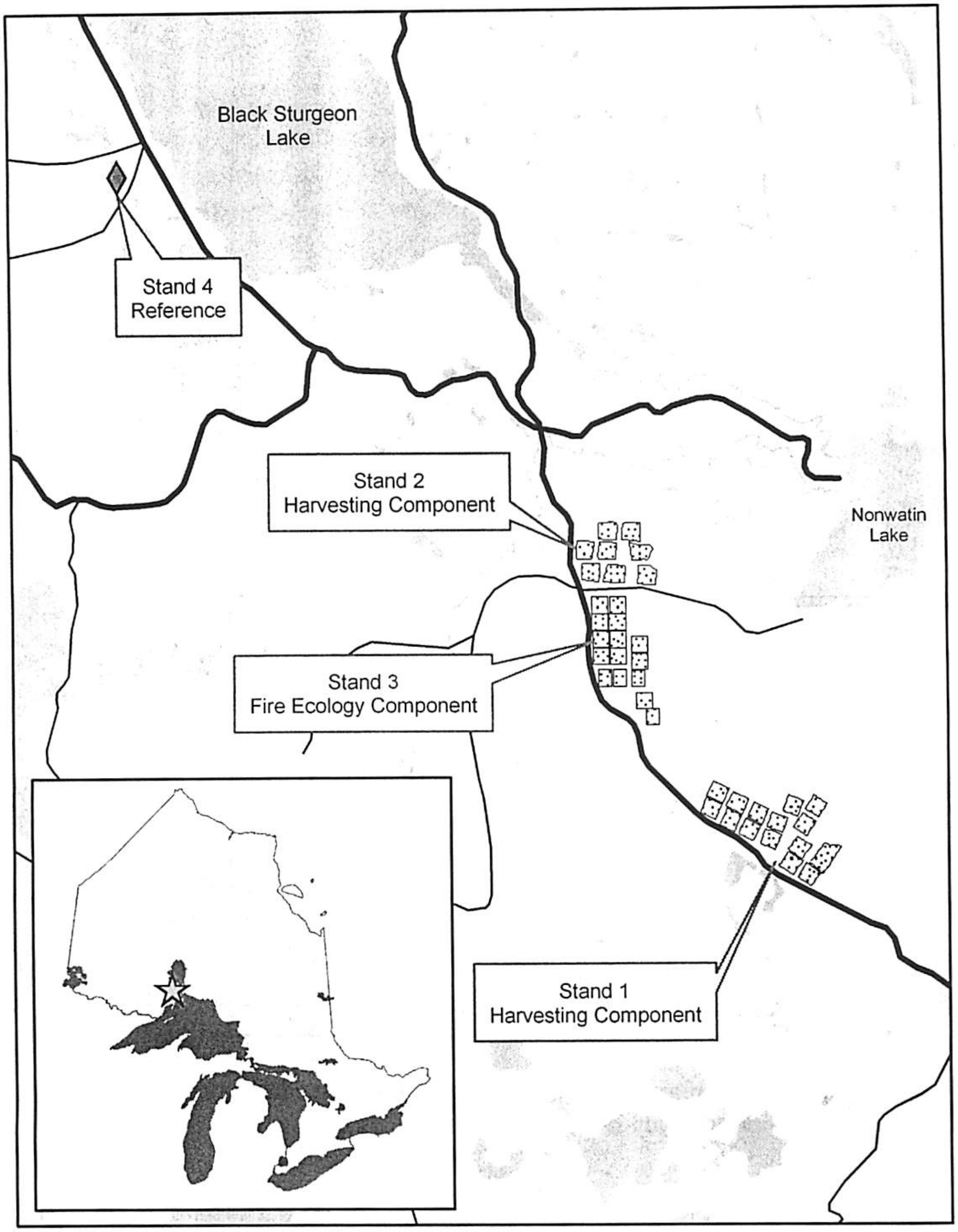


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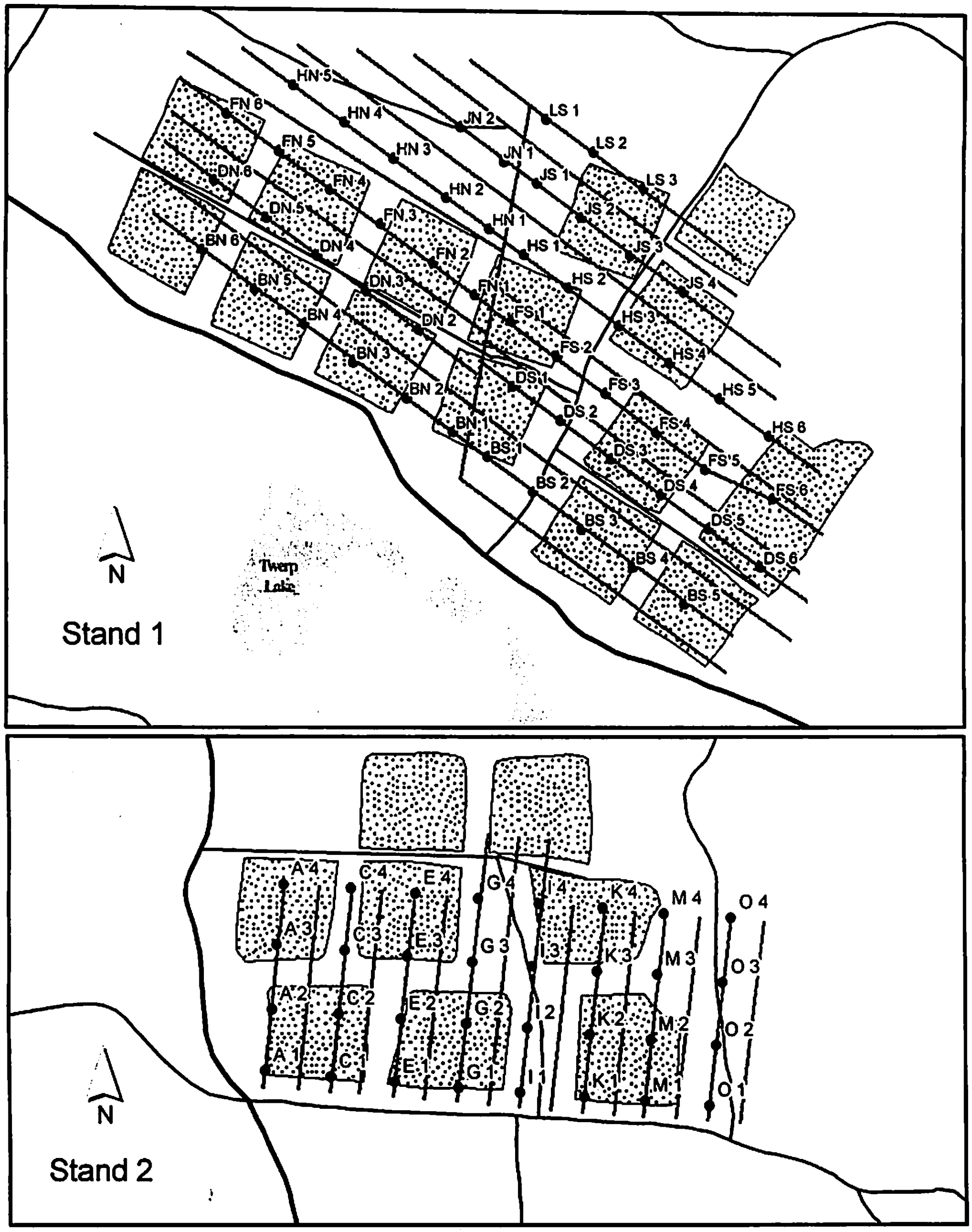


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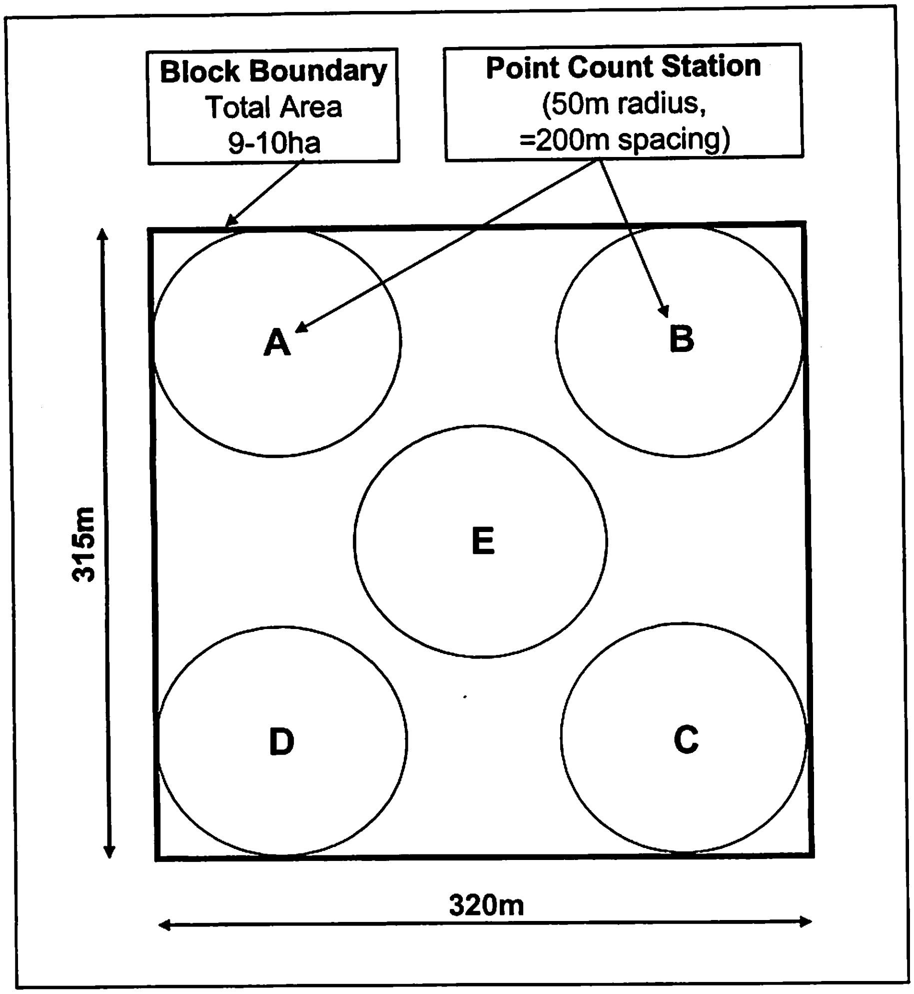


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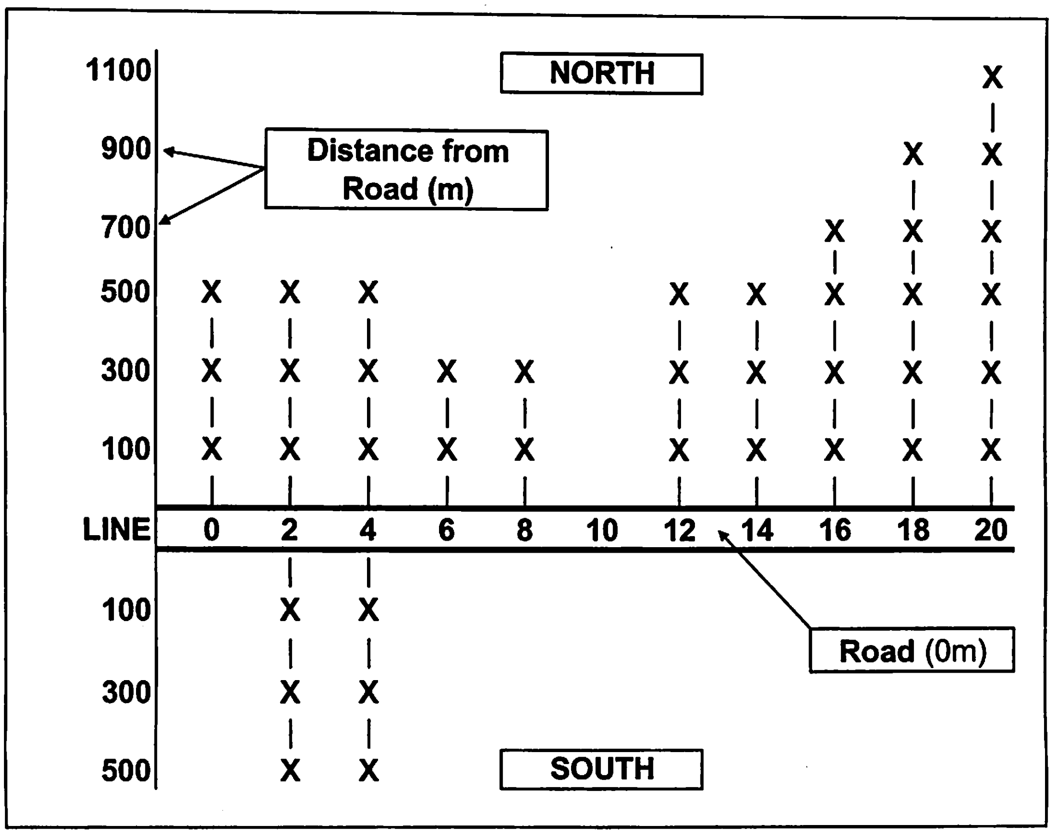



**Figure 4.** Layout of Reference stand point count stations.

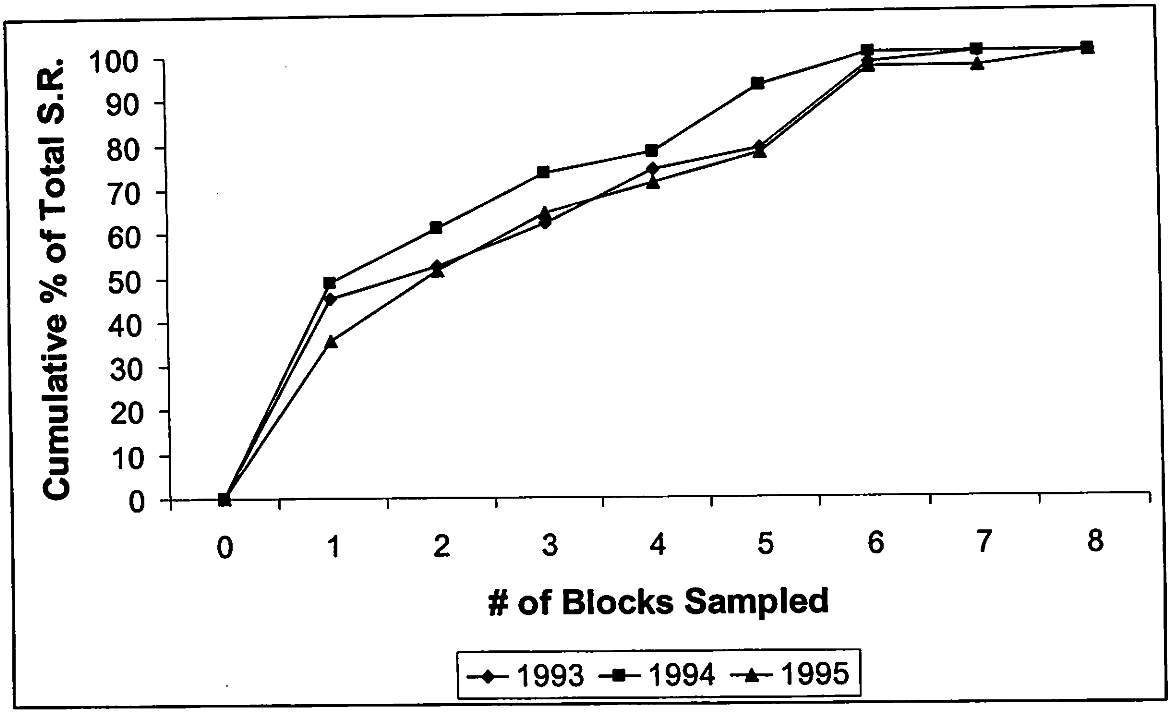



**Figure 5a.** Cumulative percent of total species richness as a function of sampling effort in Partial cut blocks in Black Sturgeon study area, 1993-1995. Ninety-seven to 100% of total species richness was documented by 6 blocks.

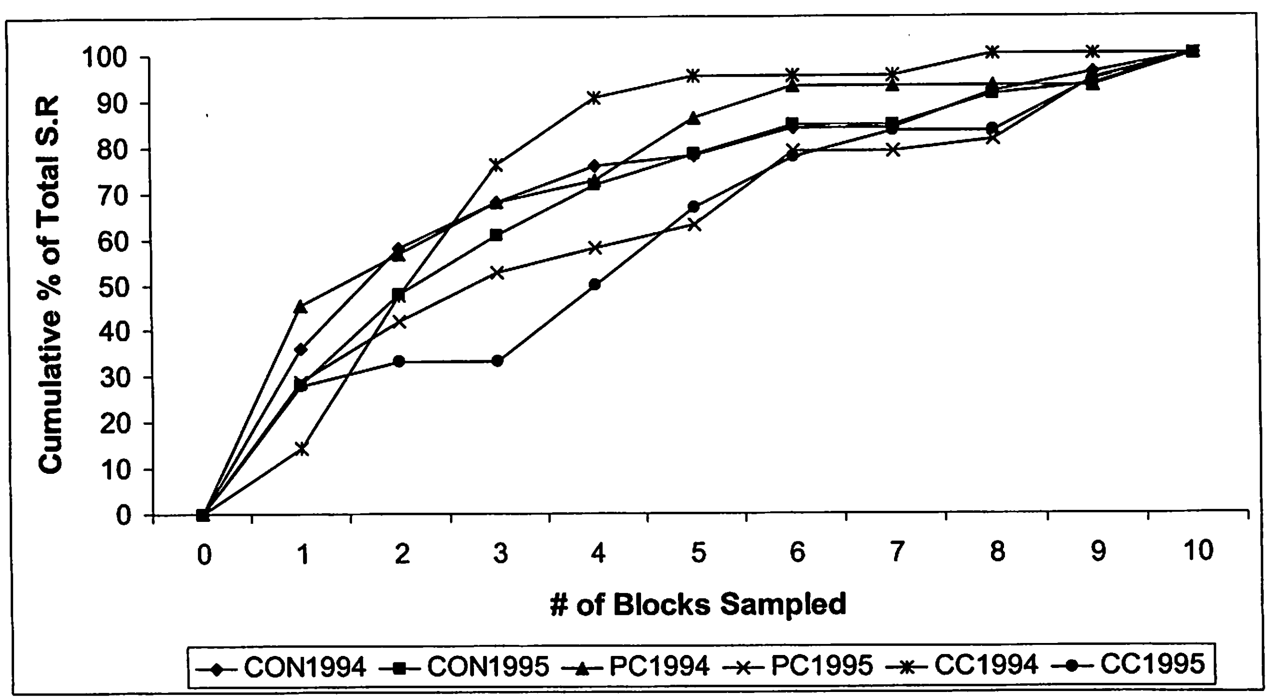



**Figure 5b.** Cumulative percent of total species richness as a function of sampling effort in post-harvest treatment blocks in Black Sturgeon study area, 1994-1995. Seventy-eight to 95.2% of total species richness was documented by 6 blocks (CON: 84.0-84.8; PC: 78.9-93.2; CC: 77.8-95.2), and 93.2-100% of total species richness was documented by 9 blocks.

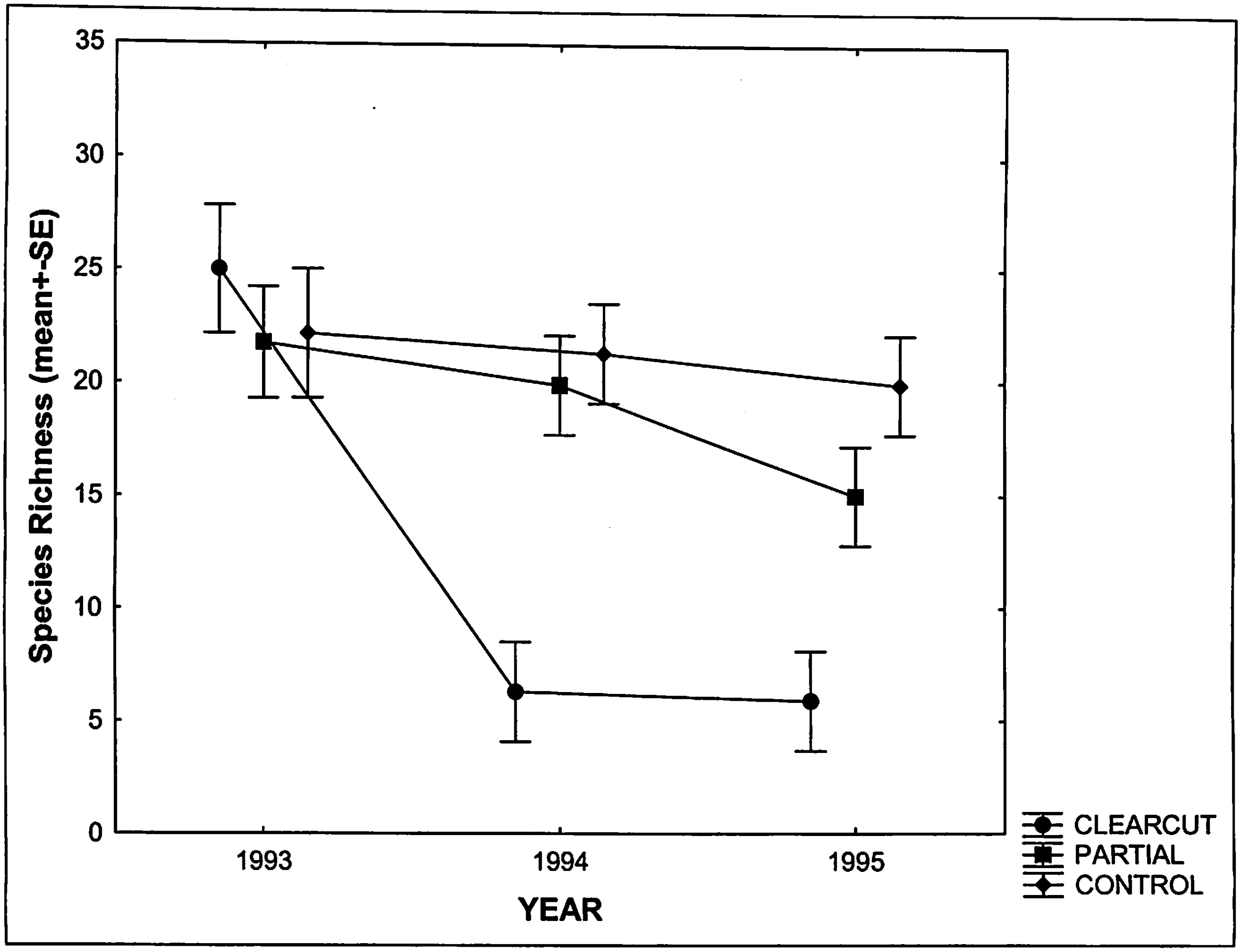
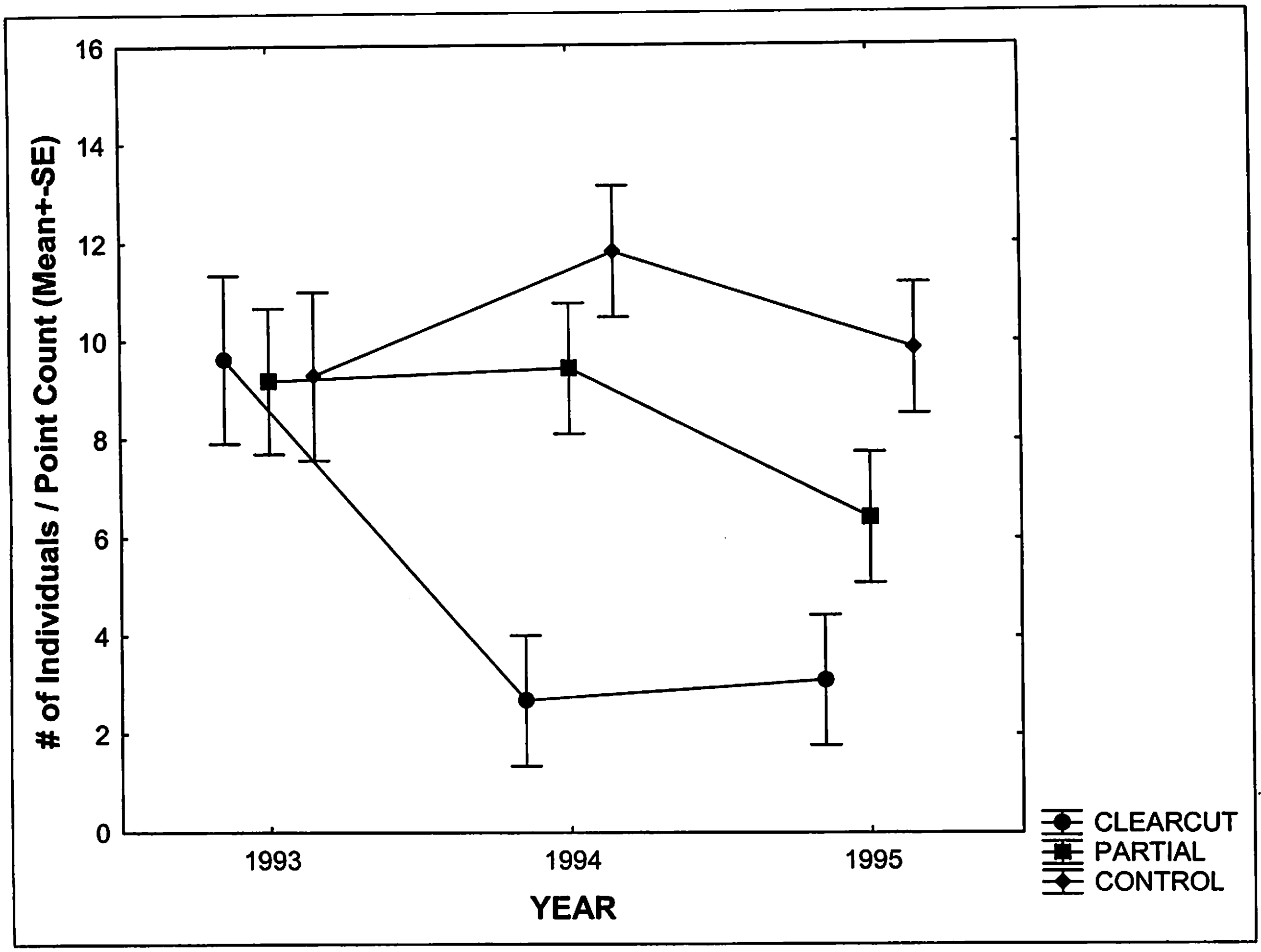



**Figure 6.** Number of species detected per block (mean±SE) in Black Sturgeon study area, 1993-1995.

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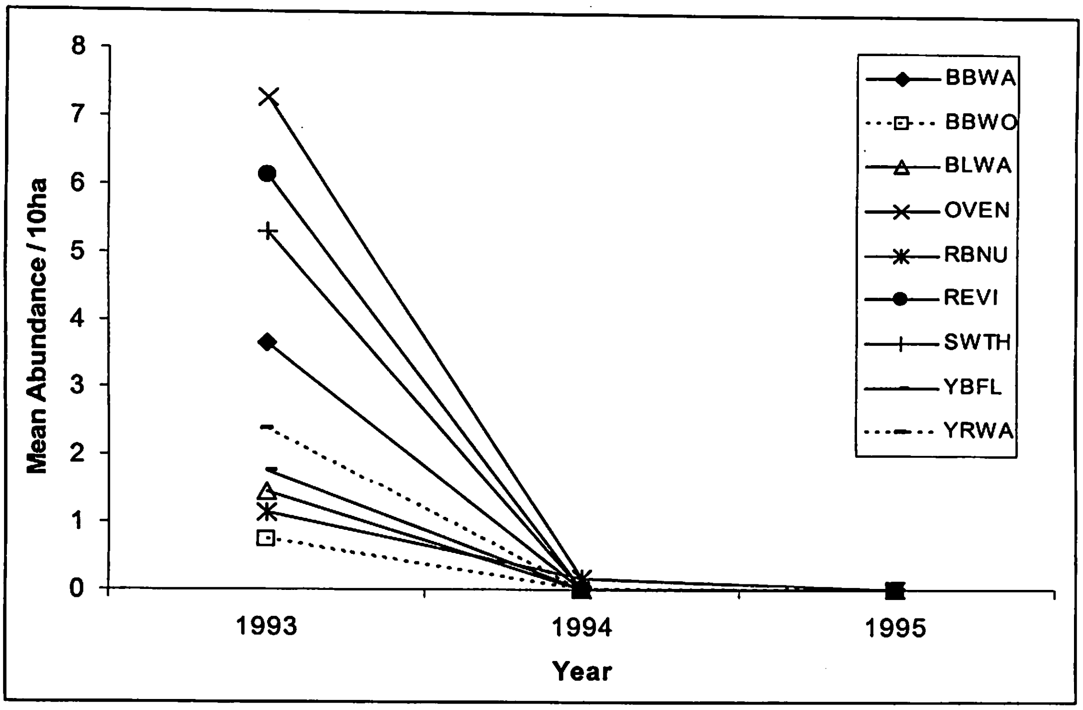
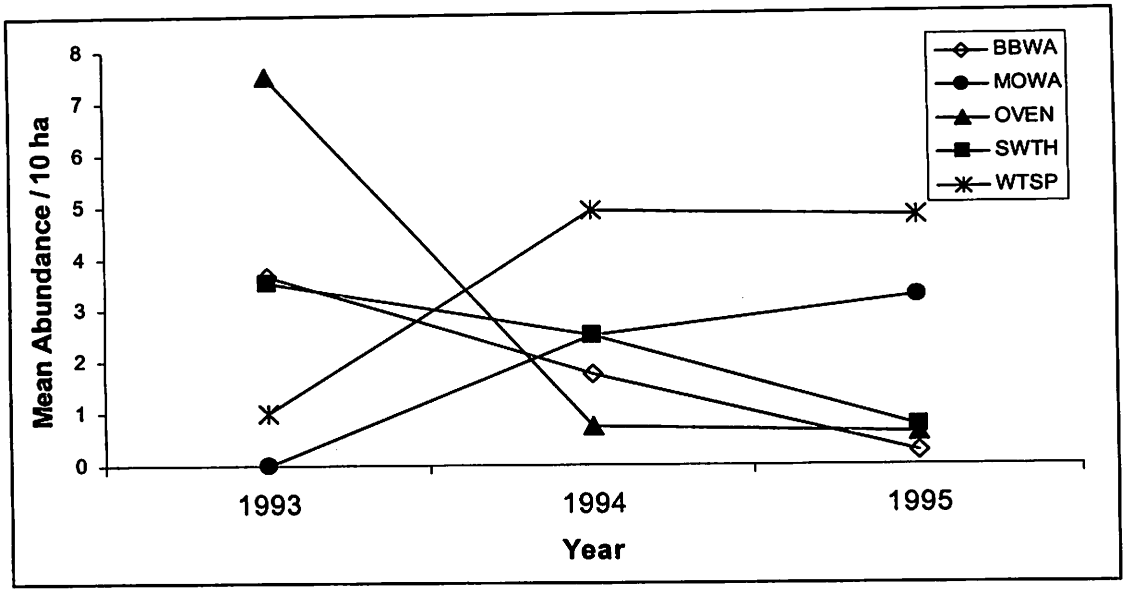



**Figure 8.** Mean species abundance per year within Clear Cut treatment blocks for all species which showed significant declines in abundance between pre- and post-harvest years ($n = 6$).

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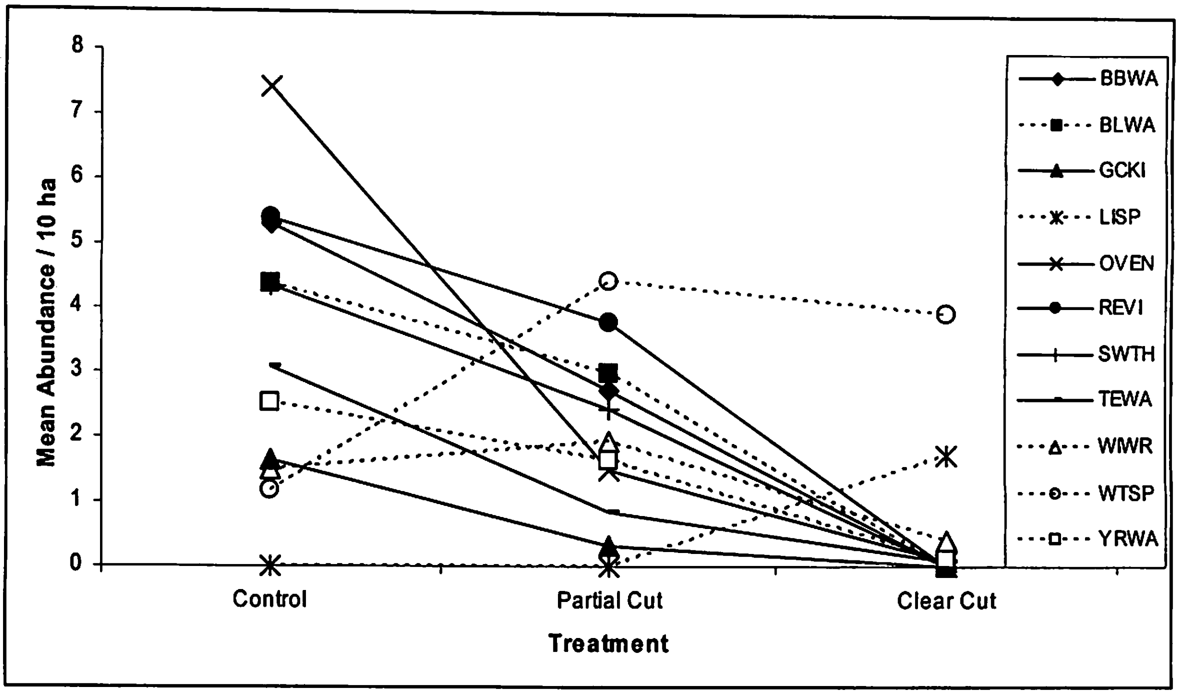



**Figure 10.** Species identified as showing significant differences between treatments in the first year post harvest (1994). Significance level is Bonferroni corrected for 38 species at an alpha level of 0.1 ($n = 10$).

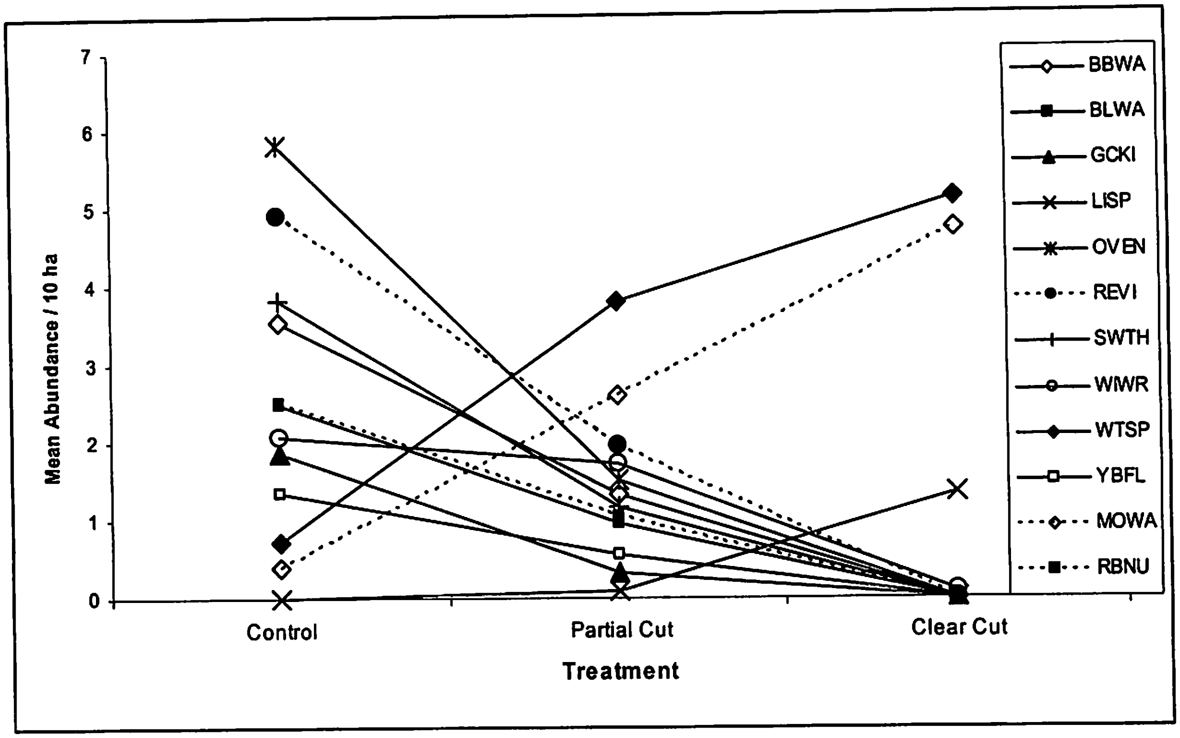
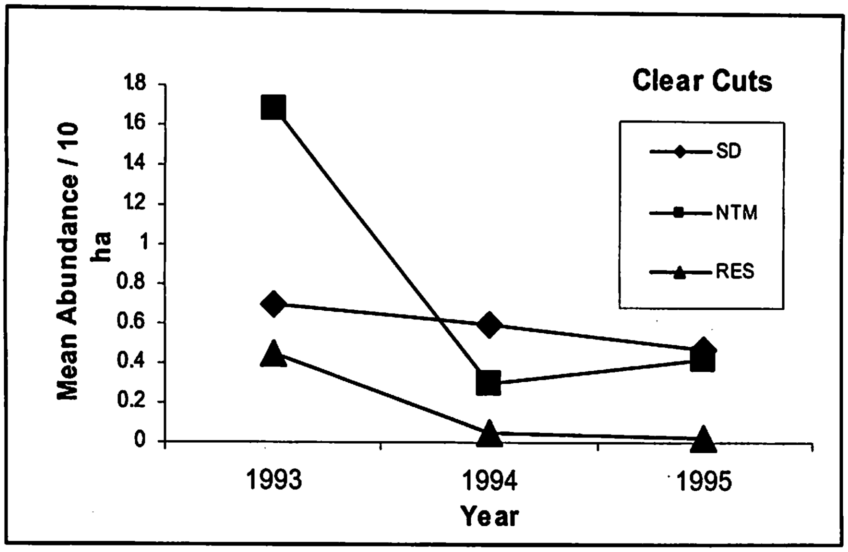
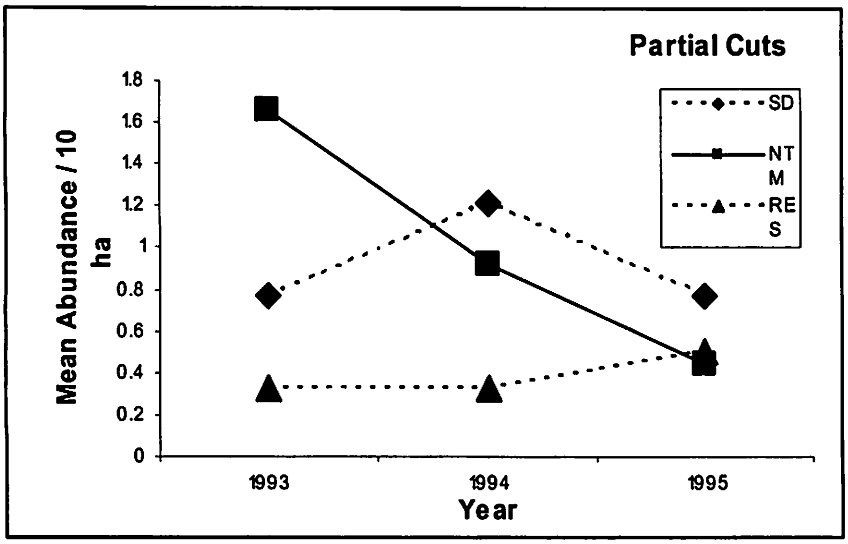



**Figure 11.** Species identified as showing significant differences between treatments in the second year post harvest (1995). Significance level is Bonferroni corrected for 38 species at an alpha level of 0.1 ($n = 10$).

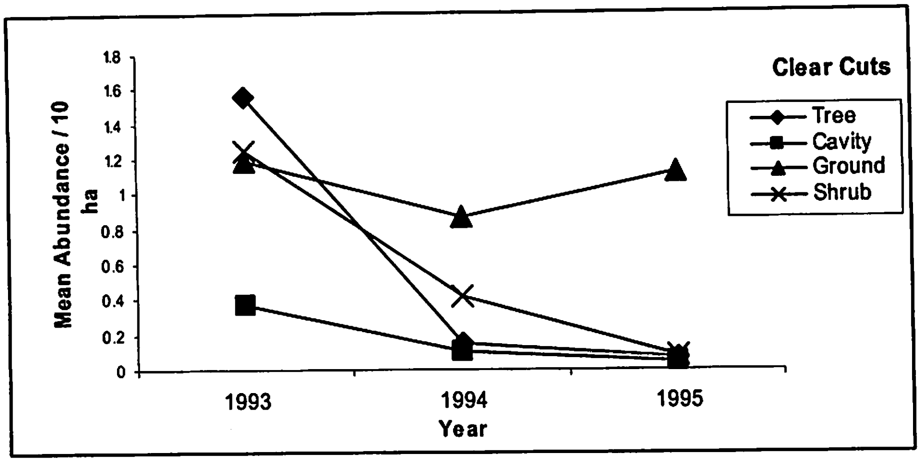



(a)

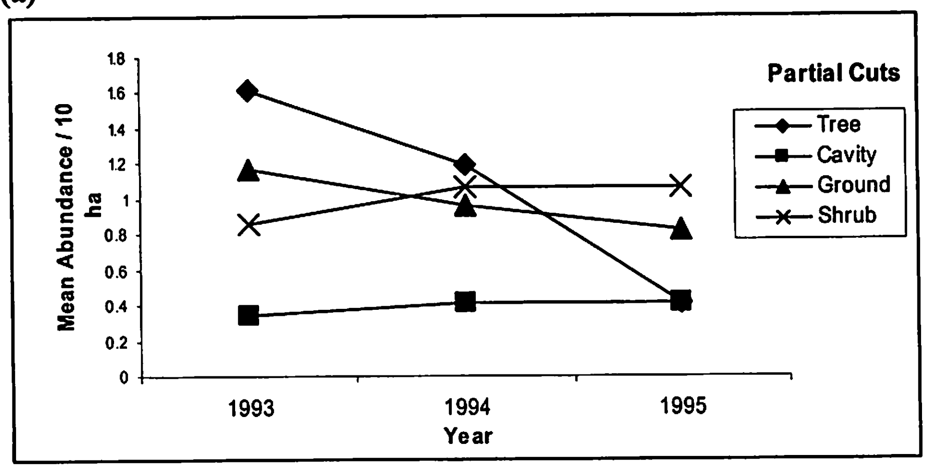



(b)

**Figure 12.** Change in abundance within each migration category between years for both clear Cuts (a) and Partial Cuts (b). Dotted lines indicate non-significant change.




(a)




(b)

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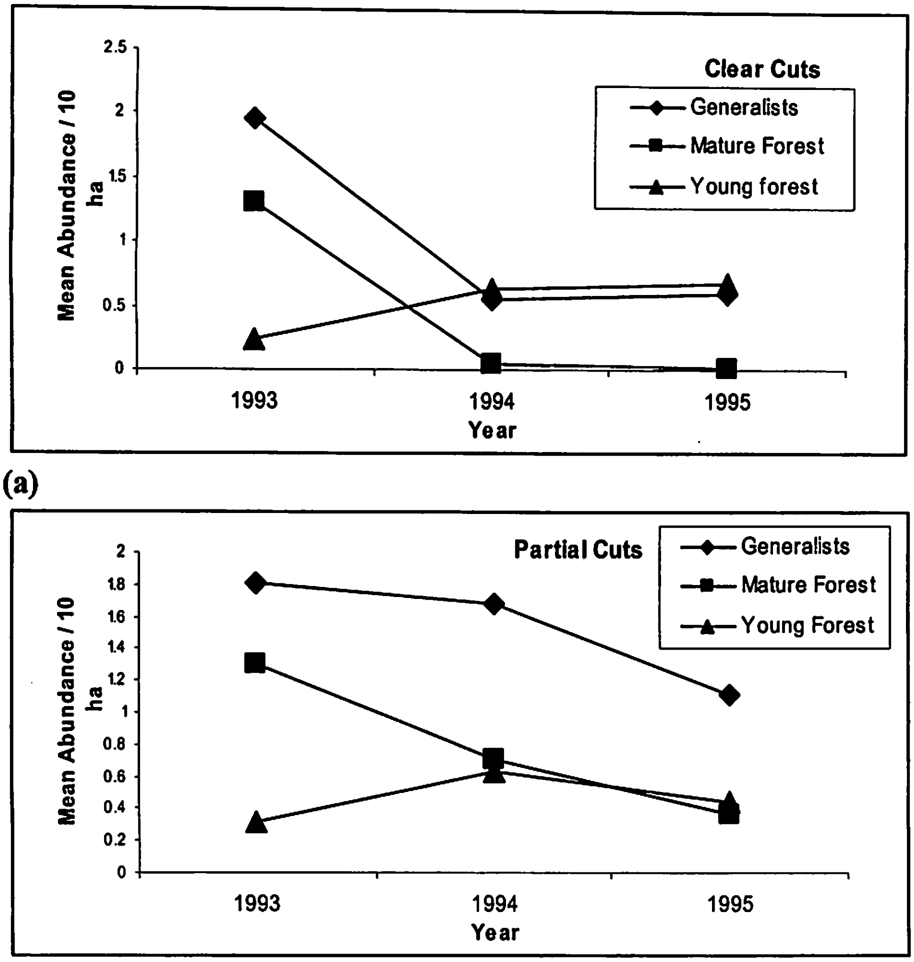


(a)



(b)

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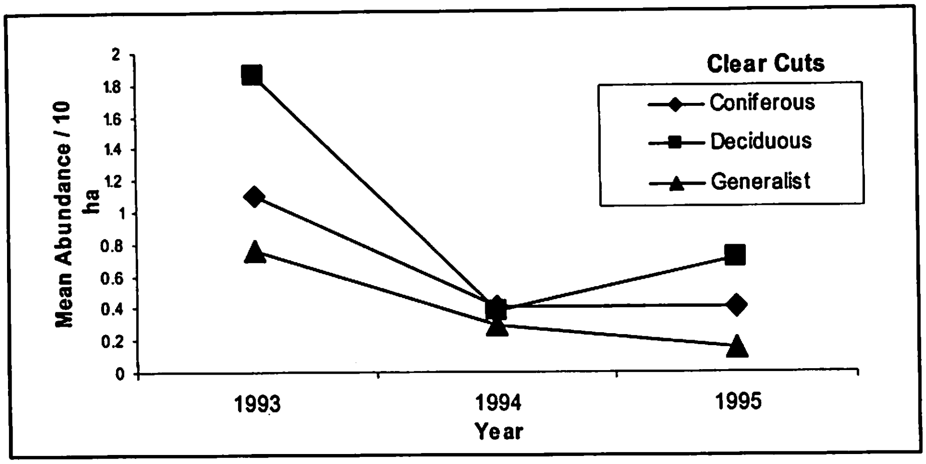
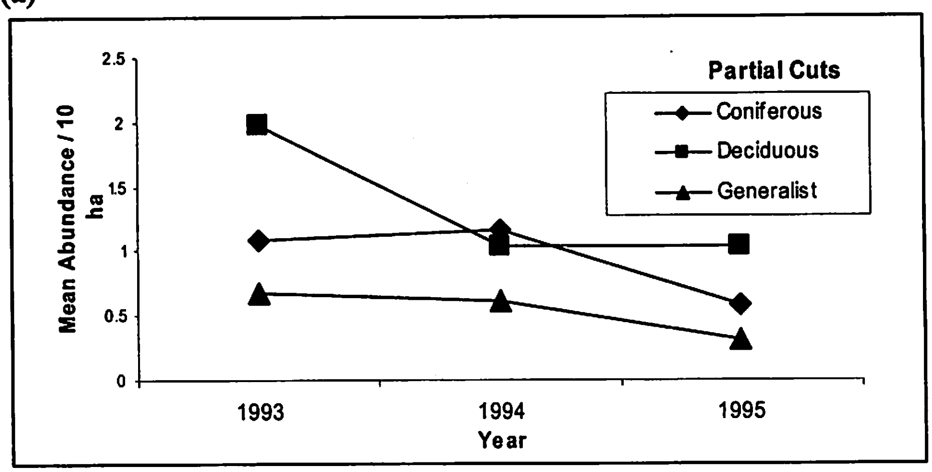
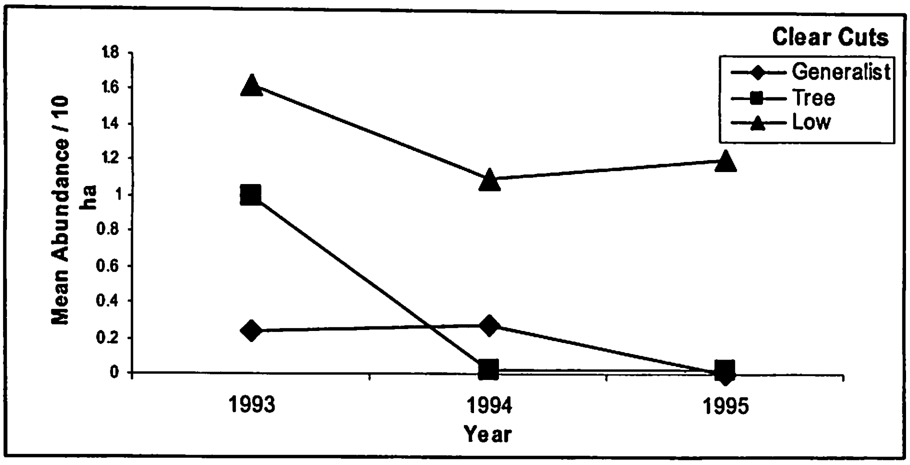



(a)

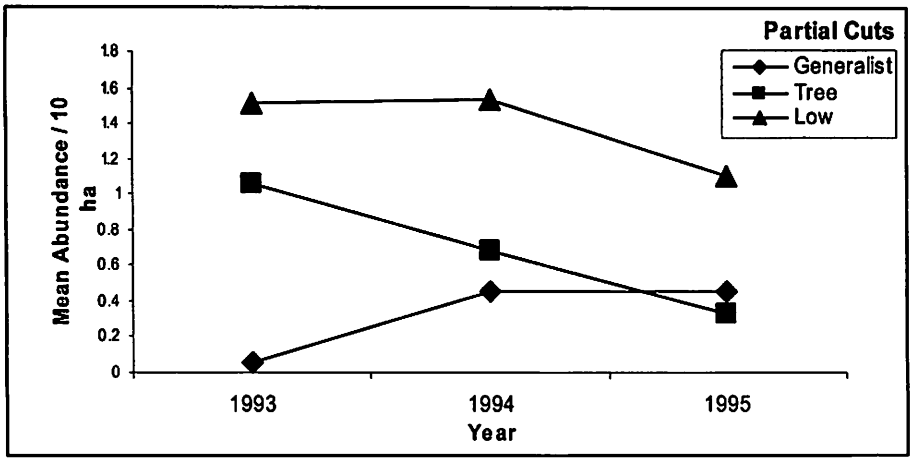



(b)

**Figure 15.** Change in abundance within each forest composition category between years for both clear Cuts (a) and Partial Cuts (b).

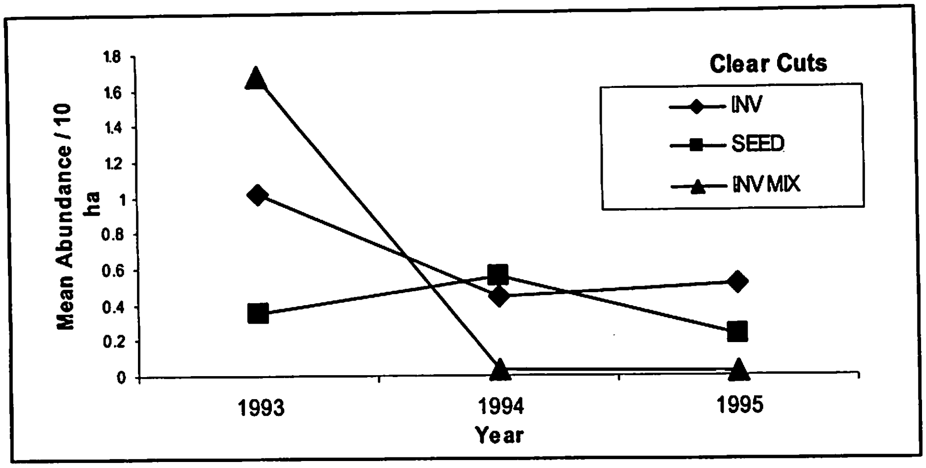



(a)

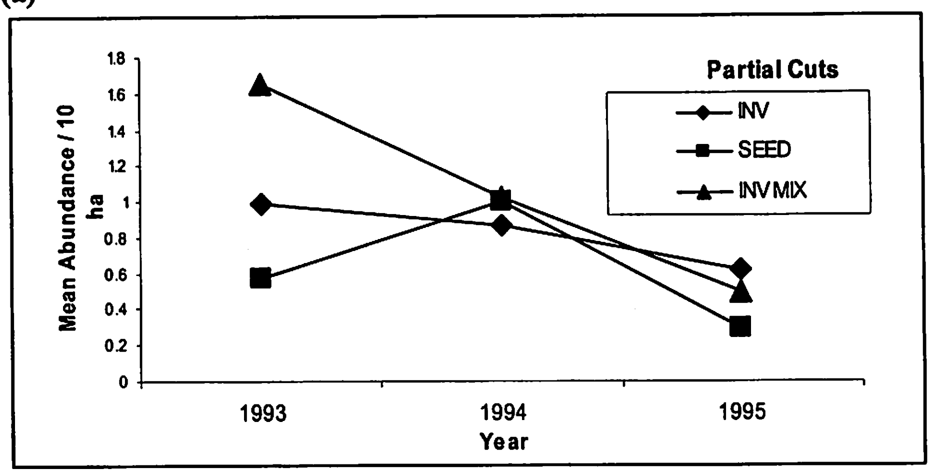



(b)

**Figure 16.** Change in abundance within each foraging location category between years for both clear Cuts (a) and Partial Cuts (b).




(a)




(b)

**Figure 17.** Change in abundance within each food type category between years for both clear Cuts (a) and Partial Cuts (b).

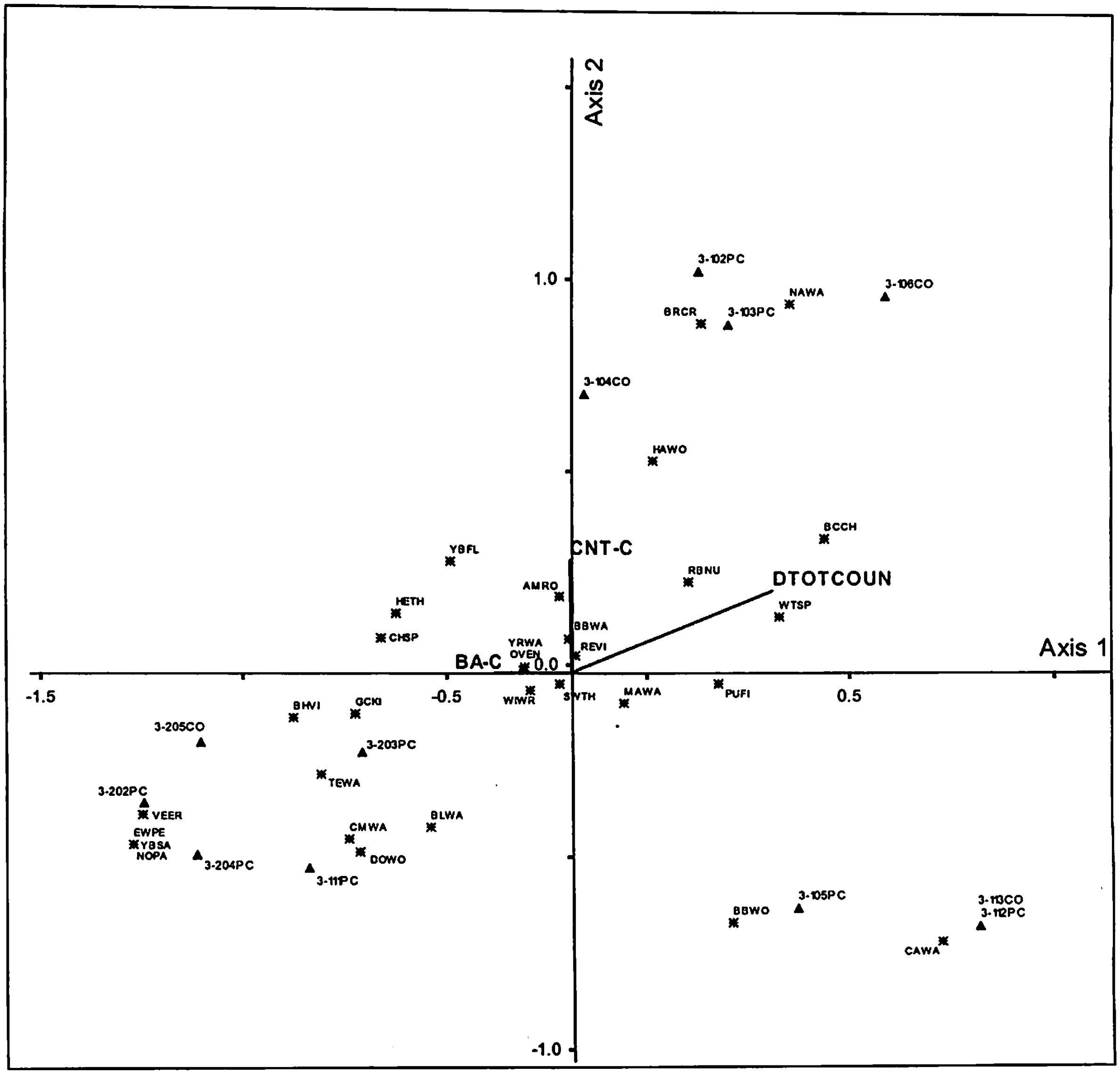
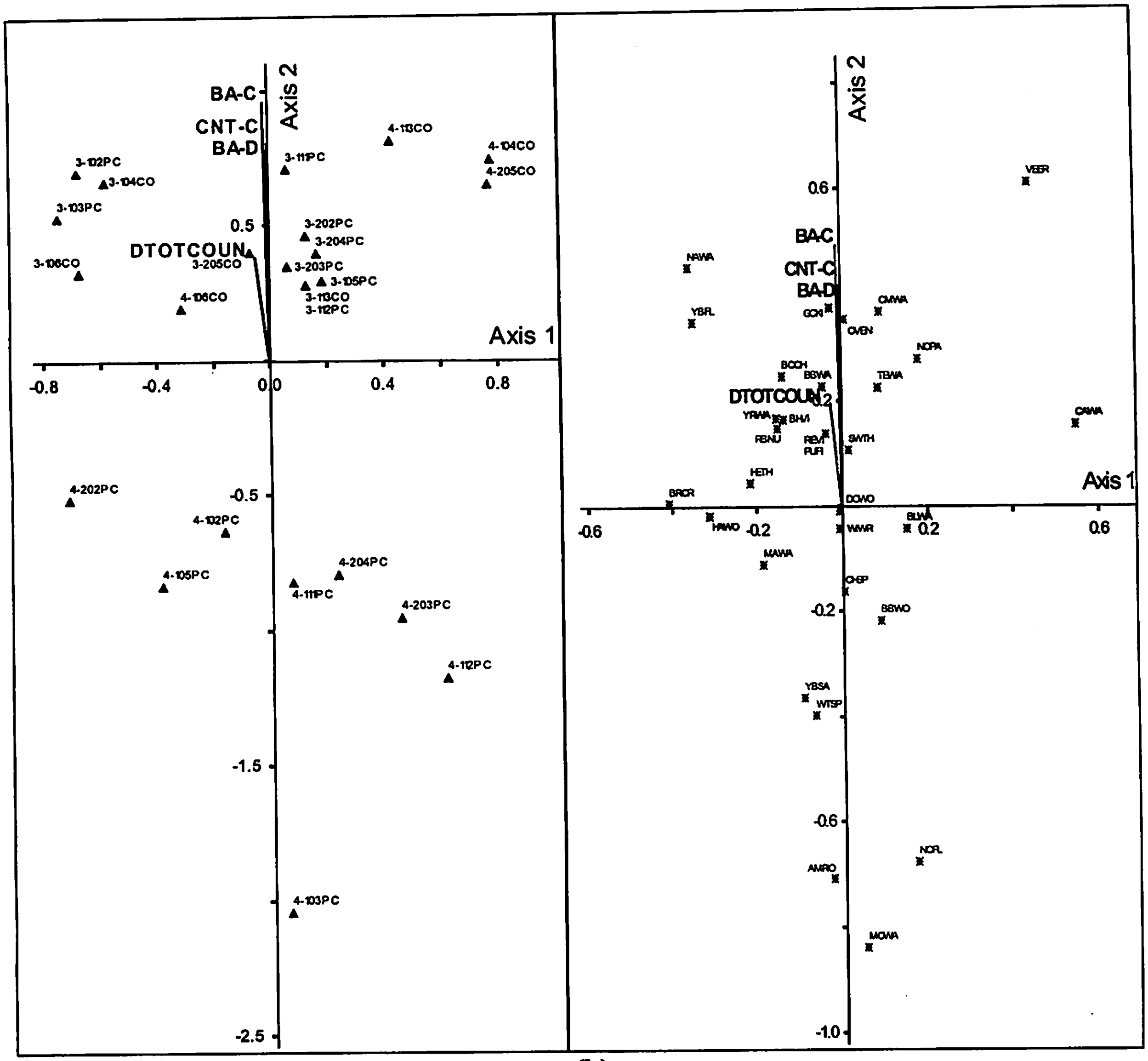



**Figure 18.** Non-metric multidimensional scaling ordination of pre-harvest species, treatment blocks, and habitat variables in Black Sturgeon study area, 1993. Asterisks indicate species, triangles indicate blocks, and vectors represent gradients in habitat variables. Species codes are explained in Table 2. Nomenclature followed for blocks: "year-standblocktreatment" (e.g., 3-106CO = 1993 control block 6 in stand 1). Habitat Variables: BA-C – basal area ($m^2$/ha) of living conifers, BA-D (not shown; see text) – basal area ($m^2$/ha) of living deciduous trees, CNT-C – living coniferous tree stem count, DTOTCOUN – total snag count. Species in this ordination that demonstrated significant changes in abundance after Partial cutting were the Ovenbird (OVEN), Bay-breasted Warbler (BBWA), Swainson's Thrush (SWTH), and White-throated Sparrow (WTSP).




**(a)** **(b)**

**Figure 19.** Non-metric multidimensional scaling ordination of pre- and post-harvest treatment blocks and habitat variables (a), and species and habitat variables (b) in Black Sturgeon study area, 1993-1994. Asterisks indicate species, triangles indicate blocks, and vectors represent gradients in habitat variables. Nomenclature followed for blocks: "year-standblocktreatment" (e.g., 3-106CO = 1993 control block 6 in stand 1). Habitat Variables: BA-C – basal area ($m^2$/ha) of living conifers, BA-D – basal area ($m^2$/ha) of living deciduous trees, CNT-C: living coniferous tree stem count, DTOTCOUN – total snag count. Species in this ordination that demonstrated significant changes in abundance after Partial cutting were the Ovenbird (OVEN), Bay-breasted Warbler (BBWA), Swainson's Thrush (SWTH), White-throated Sparrow (WTSP), and Mourning Warbler (MOWA). Note slightly different scales in (a) and (b).

**Table 1.** Number of blocks and point count stations by treatment and year for study on short-term response of boreal forest birds to different harvesting intensities in northern Ontario, 1993-95. Block sizes (ha) are in parentheses.

| | Number of Blocks / Point Count Stations | | | | | | |
|---|---|---|---|---|---|---|---|
| | TREATMENT* | | | | | | |
| Year | Pre-harvest 8-24 ha | Reference 8-24 ha | Control 9-10 ha | Patch Cut 9-10 ha | Partial Cut 9-10 ha | Clearcut 9-10 ha | TOTAL |
| 1993 | 19/101 | 12/40 | --- | --- | --- | --- | 31/141 |
| 1994 | --- | 12/40 | 10/50 | 3/15 | 10/50 | 10/50 | 45/205 |
| 1995 | --- | 12/40 | 10/50 | 3/15 | 10/50 | 10/50 | 45/205 |

* Pre-harvest: 1993 surveys, conducted prior to harvesting; Reference: block not harvested during study, spatially removed from harvesting activities; Control: block not harvested during study, within matrix of harvesting activities; Patch Cut: 15-20% volume removal; Partial Cut: 60-70% volume removal; Clear Cut: >90% volume removal

**Table 2.** Species documented in Black Sturgeon study area, 1993-1995, and their life-history traits. Species are listed in alphabetical order by common name in each category. Latin names follow the American Ornithologists' Unions checklist, 7th ed. (A.O.U. 1998).

| | | | **Life History Characteristics*** | | |
|---|---|---|---|---|---|
| **Species** | **Latin Name** | **Code** | **Migration Status** | **Nest Placement** | **Foraging Location** |
| **Species Documented in Point Counts and Included in Community-Level Analyses**** | | | | | |
| American Robin | *Turdus migratorius* | AMRO | SD | TREE | GEN |
| Bay-breasted Warbler | *Dendroica castanea* | BBWA | NTM | TREE | TREE |
| Black-backed Woodpecker | *Picoides arcticus* | BBWO | RES | CAV | TREE |
| Black-capped Chickadee | *Poecile atricapillus* | BCCH | RES | CAV | TREE |
| Blue-headed Vireo | *Vireo solitarius* | BHVI | NTM | SAP | TREE |
| Blackburnian Warbler | *Dendroica fusca* | BLWA | NTM | TREE | TREE |
| Boreal Chickadee* | *Poecile hudsonica* | BOCH | RES | CAV | TREE |
| Brown Creeper | *Certhia americana* | BRCR | SD | CAV | TREE |
| Canada Warbler | *Wilsonia canadensis* | CAWA | NTM | GND | GEN |
| Chipping Sparrow | *Spizella passerina* | CHSP | SD | TREE | LOW |
| Cape May Warbler | *Dendroica tigrina* | CMWA | NTM | TREE | TREE |
| Chestnut-sided Warbler* | *Dendroica pensylvanica* | CSWA | NTM | SHR | GEN |
| Dark-eyed Junco* | *Junco hyemalis* | DEJU | SD | GND | LOW |
| Downy Woodpecker | *Picoides pubescens* | DOWO | RES | CAV | TREE |
| Eastern Wood-Peewee* | *Contopus virens* | EWPE | NTM | TREE | TREE |
| Golden-crowned Kinglet | *Regulus satrapa* | GCKI | SD | TREE | TREE |
| Hairy Woodpecker | *Picoides villosus* | HAWO | RES | CAV | TREE |
| Hermit Thrush | *Catharus guttatus* | HETH | SD | GND | LOW |
| Lincoln's Sparrow* | *Melospiza lincolnii* | LISP | NTM | GND | LOW |
| Magnolia Warbler | *Dendroica magnolia* | MAWA | NTM | TREE | TREE |
| Mourning Warbler | *Oporornis philadelphia* | MOWA | NTM | GND | LOW |
| Nashville Warbler | *Vermivora ruficapilla* | NAWA | NTM | GND | TREE |
| Northern Flicker | *Colaptes auratus* | NOFL | SD | CAV | LOW |
| Northern Parula | *Parula americana* | NOPA | NTM | TREE | TREE |
| Ovenbird | *Seiurus aurocapillus* | OVEN | NTM | GND | LOW |
| Purple Finch | *Carpodacus purpureus* | PUFI | SD | TREE | TREE |
| Red-breasted Nuthatch | *Sitta canadensis* | RBNU | RES | CAV | TREE |
| Ruby-crowned Kinglet* | *Regulus calendula* | RCKI | SD | TREE | TREE |
| Red-eyed Vireo | *Vireo olivaceus* | REVI | NTM | TREE | TREE |
| Swainson's Thrush | *Catharus ustulatus* | SWTH | NTM | TREE | LOW |
| Tennessee Warbler | *Vermivora peregrina* | TEWA | NTM | GND | TREE |
| Three-toed Woodpecker* | *Picoides dorsalis* | TTWO | RES | CAV | TREE |
| Veery | *Catharus fuscescens* | VEER | NTM | GND | LOW |
| Winter Wren | *Troglodytes troglodytes* | WIWR | SD | SHR | LOW |
| White-throated Sparrow | *Zonotrichia albicollis* | WTSP | SD | GND | LOW |
| Yellow-bellied Flycatcher | *Empidonax flaviventris* | YBFL | NTM | GND | TREE |
| Yellow-bellied Sapsucker | *Sphyrapicus varius* | YBSA | SD | CAV | TREE |
| Yellow-rumped Warbler | *Dendroica coronata* | YRWA | SD | TREE | TREE |

**Table 2 (continued).**

| Species | Latin Name | Code | Life History Characteristics | | |
|---|---|---|---|---|---|
| | | | Migration Status | Nest Placement | Foraging Location |
| **Species Documented in Point Counts but not Included in Community-Level Analyses** | | | | | |
| ***Rare Species: Present in =5% of Point Counts*** | | | | | |
| American Goldfinch | *Carduelis tristis* | AMGO | SD | GEN | TREE |
| American Kestrel | *Falco sparverius* | AMKE | SD | CAV | TREE |
| American Redstart | *Setophaga ruticilla* | AMRE | NTM | SAP*** | GEN |
| Black-and-white Warbler | *Mniotilta varia* | BAWW | NTM | GND | TREE |
| Black-throated Blue Warbler | *Dendroica caerulescens* | BTBW | NTM | SHR | GEN |
| Black-throated Green Warbler | *Dendroica virens* | BTNW | NTM | TREE | TREE |
| Clay-colored Sparrow | *Spizella pallida* | CCSP | NTM | SHR | LOW |
| Common Yellowthroat | *Geothlypis trichas* | COYE | NTM | SHR | LOW |
| Gray Catbird | *Dumetella carolinensis* | GRCA | SD | SHR | GEN |
| Merlin | *Falco columbarius* | MERL | NTM | TREE | TREE |
| Philadelphia Vireo | *Vireo philadelphicus* | PHVI | SD | TREE | TREE |
| Rose-breasted Grosbeak | *Pheucticus ludovicianus* | RBGR | NTM | TREE | TREE |
| Red Crossbill | *Loxia curvirostra* | RECR | RES | TREE | TREE |
| Ruffed Grouse | *Bonasa umbellus* | RUGR | RES | GND | GEN |
| Scarlet Tanager | *Piranga olivacea* | SCTA | NTM | TREE | TREE |
| Sharp-shinned Hawk | *Accipiter striatus* | SSHA | SD | TREE | GEN |
| ***Species with Large (>10ha) Territories*** | | | | | |
| American Crow | *Corvus brachyrhynchos* | AMCR | RES | TREE | GEN |
| Common Raven | *Corvus corax* | CORA | RES | TREE | LOW |
| Gray Jay | *Perisoreus canadensis* | GRJA | RES | TREE | TREE |
| Pileated Woodpecker | *Dryocopus pileatus* | PIWO | RES | CAV | TREE |
| ***Non-territorial Species or Species with Clustered Territories*** | | | | | |
| Blue Jay | *Cyanocitta cristata* | BLJA | RES | TREE | GEN |
| Broad-winged Hawk | *Buteo platypterus* | BWHA | NTM | TREE | TREE |
| Cedar Waxwing | *Bombycilla cedrorum* | CEDW | SD | TREE | TREE |
| Evening Grosbeak | *Coccothraustes vespertinus* | EVGR | RES | TREE | TREE |
| Least Flycatcher | *Empidonax minimus* | LEFL | NTM | TREE | TREE |
| Pine Siskin | *Carduelis pinus* | PISI | SD | TREE | TREE |
| White-winged Crossbill | *Loxia leucoptera* | WWCR | RES | TREE | TREE |
| **Other Species Noted in Study Area but not Documented in Point Counts** | | | | | |
| Alder Flycatcher | *Empidonax alnorum* | **ALFL** | NTM | SHR | TREE |
| Great-crested Flycatcher | *Myiarchus crinitus* | **GCFL** | NTM | CAV | TREE |
| Northern Waterthrush | *Seiurus noveboracensis* | **NOWA** | NTM | GND | LOW |
| Song Sparrow | *Melospiza melodia* | **SOSP** | SD | GND/SHR | LOW |
| Wood Thrush | *Hylocichla mustelina* | **WOTH** | NTM | SAP | LOW |

* Life-history characteristics from Birds of North America species accounts (Gill, Ed.). **Migration Status:** RES - year-round resident, SD = short-distance migrant (winters in N.A.), NTM - neotropical migrant (winters S. of U.S.); **Nest Placement:** CAV - cavity, GND - ground, SHR - shrub, SAP - sapling, TREE - tree; **Foraging Location:** TREE - trees, LOW - ground &/or shrubs, GEN - generalist, feeds anywhere

** All 38 of these species were included in NPMANOVA analyses. The 7 asterisked species were comparatively rare (<10% of blocks) in the multivariate ordination data sub-set, so they were excluded to reduce their influence on the ordinations.

*** Grouped with TREE nesters for life-history analysis.

**Table 3.** Abundance, richness, diversity, and evenness of bird communities in Black Sturgeon study area, 1993-1995. Numbers of blocks are in parentheses. Post-harvest data for Control, Partial, and Clear Cut blocks are from stands 1-3. Data for all treatments in 1993 and for Patch cuts in all years are for Stands 1 and 2 only ($n_{1993control} = 6$, $n_{1993partial} = 8$, $n_{1993clearcut} = 6$, $n_{Patch,all\ years} = 3$).

| | CONTROL | | | PATCH | | | PARTIAL | | | CLEARCUT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 (6) | 1994 (10) | 1995 (10) | 1993 (3) | 1994 (3) | 1995 (3) | 1993 (8) | 1994 (10) | 1995 (10) | 1993 (6) | 1994 (10) | 1995 (10) |
| Mean Number of Individuals / Station* | 9.3 | 11.8 | 9.9 | 8.7 | 11.2 | 6.8 | 9.2 | 9.4 | 6.4 | 9.6 | 2.7 | 3.1 |
| Total Species Richness | 43 | 50 | 46 | 27 | 31 | 18 | 42 | 44 | 38 | 45 | 21 | 18 |
| (range/block) | (17-27) | (17-25) | (13-25) | (15-23) | (20-24) | (13-16) | (18-28) | (14-24) | (9-23) | (20-30) | (3-10) | (4-9) |
| Mean Shannon's Diversity Index (H') | 2.95 | 2.78 | 2.72 | 2.83 | 2.81 | 2.40 | 2.91 | 2.77 | 2.45 | 3.07 | 1.58 | 1.49 |
| (range/block) | (2.69-3.17) | (2.55-2.97) | (2.37-2.96) | (2.54-3.03) | (2.73-2.87) | (2.25-2.56) | (2.75-3.19) | (2.5-2.99) | (1.94-2.95) | (2.83-3.29) | (0.95-2.18) | (1.09-1.94) |
| Evenness ($E_H$) | 0.96 | 0.91 | 0.92 | 0.94 | 0.91 | 0.91 | 0.95 | 0.93 | 0.92 | 0.96 | 0.91 | 0.86 |
| (range/block) | (0.95-0.97) | (0.87-0.95) | (0.83-0.95) | (0.93-0.97) | (0.89-0.92) | (0.88-0.93) | (0.94-0.96) | (0.92-0.95) | (0.88-0.95) | (0.94-0.97) | (0.82-1.0) | (0.76-0.97) |

* Calculated as: [Total # of individuals in treatment-year class / # of point counts per treatment-year class] to account for slight differences in pre- and post-harvest protocols.

**Table 4.** Frequency of occurrence (% of treatment blocks) of species in Black Sturgeon study area, 1993-1995. Zeros have been removed for ease of interpretation. Numbers of treatment blocks are in parentheses. Species are sorted in order of decreasing occurrence in Control blocks. Species codes are explained in Table 2.

| | CONTROL | | | PATCH | | | PARTIAL | | | CLEARCUT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 |
| Species | (6) | (10) | (10) | (3) | (3) | (3) | (8) | (10) | (10) | (6) | (10) | (10) |
| BBWA | 100 | 100 | 100 | 100 | 100 | 67 | 100 | 90 | 40 | 100 | | |
| OVEN | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 70 | 70 | 100 | 10 | |
| SWTH | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 60 | 100 | | |
| REVI | 100 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 70 | 100 | | |
| WIWR | 100 | 90 | 100 | 100 | 100 | 67 | 100 | 100 | 90 | 100 | 40 | 10 |
| YRWA | 100 | 90 | 80 | 100 | 100 | 67 | 100 | 70 | 50 | 100 | 10 | |
| CHSP | 83 | 80 | 90 | 100 | 100 | 67 | 75 | 90 | 60 | 67 | 80 | 60 |
| PUFI | 83 | 80 | 30 | 67 | 67 | 33 | 75 | 60 | 30 | 50 | | 20 |
| BLWA | 83 | 70 | 90 | 67 | 100 | 100 | 75 | 80 | 50 | 100 | | |
| YBFL | 83 | 60 | 60 | 100 | 100 | 33 | 75 | 30 | 20 | 100 | | |
| MAWA | 83 | 30 | 50 | 33 | 33 | 33 | 88 | 60 | 20 | 67 | | 10 |
| RBNU | 67 | 80 | 90 | 67 | 67 | 67 | 75 | 60 | 70 | 100 | 10 | |
| WTSP | 67 | 70 | 70 | 67 | 100 | 67 | 63 | 100 | 80 | 100 | 90 | 100 |
| CMWA | 67 | 70 | 40 | 67 | 67 | | 75 | 30 | 20 | 67 | | |
| HETH | 67 | 50 | 70 | 67 | 33 | 100 | 75 | 50 | 30 | 83 | 10 | |
| HAWO | 67 | 20 | 10 | 100 | 33 | 33 | 38 | 30 | 20 | 67 | | 10 |
| TEWA | 50 | 90 | 10 | 100 | 100 | | 50 | 50 | 20 | 67 | 10 | |
| GCKI | 50 | 70 | 70 | 67 | 33 | 67 | 88 | 20 | 30 | 50 | | |
| BCCH | 50 | 30 | 30 | | | 33 | 25 | 40 | 50 | 17 | | |
| BRCR | 50 | 30 | 20 | | 33 | | 25 | 60 | 20 | 67 | | |
| DOWO | 50 | 10 | 10 | 33 | 33 | 33 | 50 | 30 | 50 | 67 | 10 | |
| BHVI | 50 | 10 | | 33 | 33 | | 50 | 20 | 10 | 67 | | |
| AMRO | 33 | 70 | 70 | 67 | 67 | 67 | 13 | 80 | 90 | 33 | 60 | 20 |
| MOWA | 33 | 10 | 30 | | 33 | 33 | | 80 | 80 | 17 | 50 | 100 |
| NAWA | 17 | 40 | 40 | | 67 | | 13 | | 20 | 33 | | |
| BBWO | 17 | 30 | 20 | 33 | 33 | | 38 | 40 | 40 | 83 | | |
| RCKI | 17 | 30 | 20 | | 33 | | | 10 | 10 | 17 | | |
| VEER | 17 | 20 | 20 | | 33 | | 25 | | | 17 | | |
| CAWA | 17 | 20 | 10 | | | | 13 | 10 | | 17 | | |
| BOCH | 17 | 20 | | | | | | | | 17 | | |
| NOFL | 17 | 10 | | | | | 13 | 40 | | 17 | 40 | 20 |
| YBSA | | 10 | 20 | | 33 | | 25 | 20 | 30 | | | |
| DEJU | | 10 | 10 | | 33 | | | 10 | | | | 10 |
| NOPA | | 10 | 10 | | 33 | | 25 | 10 | | | | |
| EWPE | | 10 | | | | | 25 | | | | | |
| TTWO | | | 10 | | 33 | | | | | | | |
| CSWA | | | | | | | | 10 | 20 | 33 | 20 | |
| LISP | | | | | | | | | 10 | | 70 | 80 |

**Table 5.** Mean abundance (individuals/10ha) sharing various life-history characteristics in Black Sturgeon study area, 1993-1995. Details on each species' life-history categories are in Table 2.

| | | CONTROL | | | PATCH | | | PARTIAL | | | CLEARCUT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *n** | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 |
| **Migration Category**** | | | | | | | | | | | | | |
| NTM | 18 | 1.62 | 2.04 | 1.41 | 1.49 | 2.06 | 1.02 | 1.66 | 1.09 | 0.65 | 1.69 | 0.20 | 0.35 |
| RES | 7 | 0.40 | 0.37 | 0.50 | 0.39 | 0.33 | 0.33 | 0.32 | 0.32 | 0.50 | 0.45 | 0.03 | 0.01 |
| SD | 13 | 0.86 | 1.03 | 0.93 | 0.61 | 0.85 | 0.87 | 0.78 | 1.31 | 0.79 | 0.71 | 0.59 | 0.52 |
| **Preferred Forest Type** | | | | | | | | | | | | | |
| DEC | 8 | 1.77 | 1.80 | 1.56 | 1.56 | 2.00 | 1.25 | 1.98 | 1.09 | 1.06 | 1.86 | 0.23 | 0.59 |
| CON | 15 | 1.17 | 1.54 | 1.09 | 0.94 | 1.40 | 0.91 | 1.09 | 1.33 | 0.72 | 1.10 | 0.38 | 0.43 |
| GEN | 15 | 0.76 | 1.01 | 0.80 | 0.72 | 0.89 | 0.56 | 0.67 | 0.68 | 0.41 | 0.76 | 0.26 | 0.14 |
| **Nesting Location** | | | | | | | | | | | | | |
| CAV | 10 | 0.34 | 0.31 | 0.40 | 0.27 | 0.30 | 0.23 | 0.34 | 0.40 | 0.41 | 0.38 | 0.07 | 0.03 |
| GND | 11 | 1.24 | 1.45 | 1.07 | 1.17 | 1.52 | 0.94 | 1.16 | 1.03 | 0.88 | 1.18 | 0.67 | 1.03 |
| SHR | 2 | 1.15 | 0.74 | 1.03 | 0.73 | 1.00 | 0.83 | 0.86 | 1.02 | 1.02 | 1.25 | 0.31 | 0.05 |
| TREE | 15 | 1.58 | 2.14 | 1.54 | 1.36 | 1.91 | 1.18 | 1.62 | 1.44 | 0.65 | 1.56 | 0.18 | 0.10 |
| **Preferred Foraging Location** | | | | | | | | | | | | | |
| GEN | 3 | 0.14 | 0.84 | 0.59 | 0.28 | 0.22 | 0.22 | 0.05 | 0.63 | 0.59 | 0.24 | 0.43 | 0.07 |
| LOW | 11 | 1.67 | 1.61 | 1.48 | 1.36 | 1.61 | 1.27 | 1.51 | 1.53 | 1.08 | 1.63 | 0.89 | 1.13 |
| TREE | 24 | 1.02 | 1.35 | 0.95 | 0.90 | 1.33 | 0.72 | 1.06 | 0.84 | 0.49 | 1.00 | 0.02 | 0.02 |

* Number of species in life-history category.

** Life-history characteristics from Birds of North America species accounts (Gill, Ed.). **Migration Status:** RES - year-round resident, SD = short-distance migrant (winters in N.A.), NTM - neotropical migrant (winters S. of U.S.); **Preferred Forest Type:** DEC - deciduous, CON - coniferous, GEN - generalist, deciduous, coniferous, or mixed; **Nest Placement:** CAV - cavity, GND - ground, SHR - shrub, SAP - sapling, TREE - tree; **Foraging Location:** TREE - trees, LOW - ground &/or shrubs, GEN - generalist, feeds anywhere

**Table 6.** Occurrence and mean abundance (individuals/10ha) of species in Black Sturgeon study area, 1993-1995. Species are sorted in decreasing order of abundance in Control blocks. Zeros have been removed to facilitate interpretation. Numbers of treatment blocks are in parentheses. Species codes are explained in Table 2.

| | | CONTROL | | | PATCH | | | PARTIAL | | | CLEARCUT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *F** | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 |
| **Species** | (/12) | (6) | (10) | (10) | (3) | (3) | (3) | (8) | (10) | (10) | (6) | (10) | (10) |
| OVEN | 11 | 7.08 | 7.43 | 5.81 | 7.29 | 6.33 | 4.33 | 7.50 | 1.49 | 1.50 | 7.29 | 0.10 | |
| REVI | 10 | 5.10 | 5.41 | 4.91 | 5.00 | 6.33 | 4.67 | 7.34 | 3.80 | 1.94 | 6.15 | | |
| SWTH | 10 | 4.58 | 4.37 | 3.82 | 3.75 | 5.00 | 2.00 | 3.52 | 2.44 | 1.16 | 5.31 | | |
| BBWA | 10 | 3.23 | 5.33 | 3.56 | 3.54 | 5.67 | 3.67 | 3.67 | 2.73 | 1.31 | 3.65 | | |
| WIWR | 12 | 2.29 | 1.49 | 2.07 | 1.46 | 2.00 | 1.67 | 1.72 | 1.93 | 1.72 | 2.19 | 0.41 | 0.10 |
| CMWA | 9 | 2.08 | 1.78 | 0.54 | 1.67 | 0.67 | | 1.56 | 1.09 | 0.22 | 1.25 | | |
| YRWA | 11 | 1.98 | 2.52 | 1.88 | 1.67 | 2.00 | 2.33 | 1.88 | 1.66 | 0.74 | 2.40 | 0.11 | |
| YBFL | 10 | 1.88 | 1.37 | 1.33 | 2.71 | 1.67 | 0.67 | 1.41 | 0.42 | 0.56 | 1.77 | | |
| BLWA | 10 | 1.67 | 4.38 | 2.49 | 1.04 | 3.33 | 2.33 | 1.80 | 3.00 | 0.96 | 1.46 | | |
| HETH | 11 | 1.56 | 0.62 | 1.81 | 1.04 | 0.33 | 3.00 | 1.56 | 1.64 | 0.42 | 0.73 | 0.10 | |
| WTSP | 12 | 1.25 | 1.17 | 0.72 | 0.42 | 2.00 | 2.00 | 1.02 | 4.46 | 3.80 | 1.46 | 3.93 | 5.11 |
| MAWA | 11 | 1.25 | 0:91 | 0.81 | 0.21 | 1.00 | 0.33 | 1.09 | 1.20 | 0.20 | 0.94 | | 0.20 |
| CHSP | 12 | 1.15 | 1.70 | 1.28 | 1.04 | 1.00 | 0.67 | 1.09 | 2.24 | 0.62 | 0.42 | 1.56 | 0.86 |
| RBNU | 11 | 1.04 | 1.38 | 2.50 | 1.25 | 0.67 | 1.33 | 0.94 | 0.62 | 1.04 | 1.15 | 0.10 | |
| PUFI | 11 | 1.04 | 1.12 | 0.32 | 0.42 | 1.33 | 0.33 | 0.63 | 1.16 | 0.41 | 0.52 | | 0.21 |
| NAWA | 7 | 0.83 | 0.87 | 0.77 | | 2.33 | | 0.16 | | 0.21 | 0.21 | | |
| GCKI | 10 | 0.73 | 1.64 | 1.84 | 1.04 | 0.33 | 0.67 | 0.94 | 0.31 | 0.32 | 0.42 | | |
| TEWA | 10 | 0.63 | 3.10 | 0.11 | 1.46 | 3.00 | | 0.94 | 0.84 | 0.44 | 1.04 | 0.10 | |
| HAWO | 11 | 0.63 | 0.21 | 0.11 | 1.04 | 0.33 | 0.33 | 0.31 | 0.30 | 0.30 | 0.52 | | 0.10 |
| BRCR | 8 | 0.52 | 0.31 | 0.30 | | 0.33 | | 0.94 | 0.82 | 0.21 | 0.52 | | |
| DOWO | 11 | 0.52 | 0.20 | 0.11 | 0.21 | 0.33 | 0.33 | 0.47 | 0.40 | 0.60 | 0.52 | 0.10 | |
| BCCH | 8 | 0.42 | 0.30 | 0.30 | | | 0.33 | 0.23 | 0.42 | 0.92 | 0.10 | | |
| BHVI | 8 | 0.42 | 0.11 | | 0.21 | 0.33 | | 0.39 | 0.21 | 0.22 | 0.52 | | |

Table 6 (continued).

| | | CONTROL | | | PATCH | | | PARTIAL | | | CLEARCUT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *F** | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 |
| **Species** | (/12) | (6) | (10) | (10) | (3) | (3) | (3) | (8) | (10) | (10) | (6) | (10) | (10) |
| AMRO | 12 | 0.31 | 1.93 | 1.36 | 0.83 | 0.67 | 0.67 | 0.08 | 1.58 | 1.46 | 0.31 | 1.08 | 0.22 |
| RCKI | 7 | 0.21 | 0.56 | 0.21 | | 0.33 | | | 0.11 | 0.11 | 0.10 | | |
| MOWA | 10 | 0.21 | 0.10 | 0.40 | | 0.33 | 0.33 | | 2.00 | 2.60 | 0.31 | 1.40 | 4.73 |
| CAWA | 6 | 0.10 | 0.60 | 0.40 | | | | 0.08 | 0.20 | | 0.10 | | |
| VEER | 6 | 0.10 | 0.60 | 0.30 | | 0.33 | | 0.16 | | | 0.10 | | |
| BBWO | 9 | 0.10 | 0.32 | 0.33 | 0.21 | 0.33 | | 0.31 | 0.50 | 0.60 | 0.73 | | |
| BOCH | 3 | 0.10 | 0.21 | | | | | | | | 0.10 | | |
| NOFL | 7 | 0.10 | 0.11 | | | | | 0.08 | 0.40 | | 0.10 | 0.51 | 0.20 |
| NOPA | 5 | | 0.20 | 0.10 | | 0.67 | | 0.16 | 0.10 | | | | |
| DEJU | 5 | | 0.11 | 0.11 | | 0.33 | | | 0.22 | | | | 0.11 |
| EWPE | 2 | | 0.11 | | | | | 0.16 | | | | | |
| YBSA | 6 | | 0.10 | 0.20 | | 0.33 | | 0.16 | 0.50 | 0.40 | | | |
| TTWO | 2 | | | 0.11 | | 0.67 | | | | | | | |
| CSWA | 4 | | | | | | | | 0.10 | 0.31 | 0.31 | 0.20 | |
| LISP | 3 | | | | | | | | | 0.10 | | 1.73 | 1.33 |
| OVERALL | 12 | 1.39 | 1.51 | 1.28 | 1.70 | 1.62 | 1.60 | 1.36 | 1.22 | 0.85 | 1.33 | 0.82 | 1.20 |

* Number of treatment-year classes species occurred in (out of a possible 12).

**Table 7.** Dominance [rank abundance; based on mean abundance (individuals/10ha)] of species in Black Sturgeon study area, 1993-1995. Species are sorted in order of increasing rank in Control blocks. Ranks <6 are in bold to highlight changes in most abundant species. Numbers of blocks are in parentheses. Species codes are explained in Table 2.

| | CONTROL | | | PATCH | | | PARTIAL | | | CLEARCUT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 |
| Species | (6) | (10) | (10) | (3) | (3) | (3) | (8) | (10) | (10) | (6) | (10) | (10) |
| OVEN | **1** | **1** | **1** | **1** | **1** | **2** | **1** | 12 | **5** | **1** | 10 | 12 |
| REVI | **2** | **2** | **2** | **2** | **1** | **1** | **2** | **2** | **3** | **2** | 15 | 12 |
| SWTH | **3** | **5** | **3** | **3** | **4** | 7 | **4** | **5** | 8 | **3** | 15 | 12 |
| BBWA | **4** | **3** | **4** | **4** | **3** | **3** | **3** | **4** | 7 | **4** | 15 | 12 |
| WIWR | **5** | 12 | 7 | 8 | 8 | 9 | 7 | 8 | **4** | 6 | 7 | 10 |
| CMWA | 6 | 9 | 17 | 6 | 15 | 21 | 8 | 15 | 24 | 10 | 15 | 12 |
| YRWA | 7 | 7 | 8 | 6 | 8 | **5** | **5** | 9 | 12 | **5** | 9 | 12 |
| YBFL | 8 | 14 | 12 | **5** | 11 | 11 | 10 | 21 | 16 | 7 | 15 | 12 |
| BLWA | 9 | **4** | 6 | 11 | **5** | **5** | 6 | **3** | 10 | 8 | 15 | 12 |
| HETH | 10 | 19 | 10 | 11 | 20 | **4** | 8 | 10 | 18 | 14 | 10 | 12 |
| WTSP | 11 | 15 | 16 | 17 | 8 | 7 | 13 | **1** | **1** | 8 | **1** | **1** |
| MAWA | 11 | 17 | 14 | 19 | 13 | 15 | 11 | 13 | 28 | 13 | 15 | 7 |
| CHSP | 13 | 10 | 13 | 11 | 13 | 11 | 11 | 6 | 13 | 21 | **3** | **4** |
| RBNU | 14 | 13 | **5** | 10 | 15 | 10 | 14 | 18 | 9 | 11 | 10 | 12 |
| PUFI | 14 | 16 | 21 | 17 | 12 | 15 | 18 | 14 | 19 | 16 | 15 | 6 |
| NAWA | 16 | 18 | 15 | 23 | 7 | 21 | 24 | 33 | 26 | 26 | 15 | 12 |
| GCKI | 17 | 11 | 9 | 11 | 20 | 11 | 14 | 25 | 21 | 21 | 15 | 12 |
| TEWA | 18 | 6 | 27 | 8 | 6 | 21 | 14 | 16 | 17 | 12 | 10 | 12 |
| HAWO | 18 | 26 | 27 | 11 | 20 | 15 | 21 | 26 | 23 | 16 | 15 | 10 |
| BRCR | 20 | 24 | 22 | 23 | 20 | 21 | 14 | 17 | 26 | 16 | 15 | 12 |
| DOWO | 20 | 28 | 27 | 19 | 20 | 15 | 19 | 23 | 14 | 16 | 10 | 12 |

Table 7 (continued).

| | CONTROL | | | PATCH | | | PARTIAL | | | CLEARCUT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 | 1993 | 1994 | 1995 |
| **Species** | (6) | (10) | (10) | (3) | (3) | (3) | (8) | (10) | (10) | (6) | (10) | (10) |
| BCCH | 22 | 25 | 22 | 23 | 32 | 15 | 23 | 21 | 11 | 27 | 15 | 12 |
| BHVI | 22 | 30 | 33 | 19 | 20 | 21 | 20 | 28 | 24 | 16 | 15 | 12 |
| AMRO | 24 | 8 | 11 | 16 | 15 | 11 | 29 | 11 | 6 | 23 | 5 | 5 |
| RCKI | 25 | 22 | 25 | 23 | 20 | 21 | 32 | 30 | 29 | 27 | 15 | 12 |
| MOWA | 25 | 34 | 18 | 23 | 20 | 15 | 32 | 7 | 2 | 23 | 4 | 2 |
| CAWA | 27 | 20 | 18 | 23 | 32 | 21 | 29 | 29 | 31 | 27 | 15 | 12 |
| VEER | 27 | 20 | 22 | 23 | 20 | 21 | 24 | 33 | 31 | 27 | 15 | 12 |
| BBWO | 27 | 23 | 20 | 19 | 20 | 21 | 21 | 19 | 14 | 14 | 15 | 12 |
| BOCH | 27 | 26 | 33 | 23 | 32 | 21 | 32 | 33 | 31 | 27 | 15 | 12 |
| NOFL | 27 | 30 | 33 | 23 | 32 | 21 | 29 | 23 | 31 | 27 | 6 | 7 |
| NOPA | 32 | 28 | 32 | 23 | 15 | 21 | 24 | 31 | 31 | 33 | 15 | 12 |
| DEJU | 32 | 30 | 27 | 23 | 20 | 21 | 32 | 27 | 31 | 33 | 15 | 9 |
| EWPE | 32 | 30 | 33 | 23 | 32 | 21 | 24 | 33 | 31 | 33 | 15 | 12 |
| YBSA | 32 | 34 | 26 | 23 | 20 | 21 | 24 | 19 | 20 | 33 | 15 | 12 |
| TTWO | 32 | 36 | 27 | 23 | 15 | 21 | 32 | 33 | 31 | 33 | 15 | 12 |
| CSWA | 32 | 36 | 33 | 23 | 32 | 21 | 32 | 31 | 22 | 23 | 8 | 12 |
| LISP | 32 | 36 | 33 | 23 | 32 | 21 | 32 | 33 | 30 | 33 | 2 | 3 |

**Table 8.** Habitat characteristics of treatment blocks (mean ± SD) in Black Sturgeon study area, 1993-1995. Numbers of blocks are in parentheses. Ten 10m-by-10m permanent sample plots (total area = 0.1ha) were sampled per block. Data from Control and Partial treatment blocks were used in multivariate analyses of bird-habitat relationships.

| | CONTROL | | PATCH | | PARTIAL | | CLEARCUT | |
|---|---|---|---|---|---|---|---|---|
| **Habitat** | **1993** | **1994** | **1993** | **1994** | **1993** | **1994** | **1993** | **1994** |
| **Characteristic*** | (4) | (4) | (3) | (0) | (8) | (8) | (6) | (1) |
| **Stem Counts (/0.1ha)** | | | | | | | | |
| Living Coniferous* | 54.0 ± 25.4 | 86.5 ± 39.2 | 45.7 ± 20.3 | n / a | 52.8 ± 9.6 | 18.9 ± 12.3 | 54.7 ± 5.9 | 0.0 |
| Living Deciduous | 73.0 ± 25.7 | 75.8 ± 29.2 | 65.3 ± 15.5 | n / a | 70.9 ± 11.8 | 36.1 ± 11.5 | 62.8 ± 14.0 | 3.0 |
| Living Total | 127.0 ± 26.0 | 162.3 ± 43.3 | 111.0 ± 35.5 | n / a | 123.6 ± 8.6 | 55.0 ± 19.8 | 117.5 ± 17.7 | 3.0 |
| Dead Total* | 40.8 ± 12.1 | 87.5 ± 68.8 | 65.7 ± 35.6 | n / a | 49.0 ± 13.2 | 16.3 ± 12.6 | 61.2 ± 12.6 | 0.0 |
| **Height (m)** | | | | | | | | |
| Living Coniferous | 14.3 ± 0.9 | 13.6 ± 1.4 | 14.9 ± 1.2 | n / a | 14.8 ± 1.0 | 12.9 ± 1.3 | 14.7 ± 1.0 | n / a |
| Living Deciduous | 17.1 ± 0.2 | 16.1 ± 0.6 | 17.0 ± 0.0 | n / a | 16.5 ± 1.1 | 16.9 ± 2.7 | 16.8 ± 0.7 | 17.7 |
| **Basal Area (m^2/ha)** | | | | | | | | |
| Living Coniferous* | 17.5 ± 6.5 | 14.1 ± 3.8 | 12.1 ± 3.9 | n / a | 16.6 ± 5.2 | 2.8 ± 1.2 | 14.6 ± 4.0 | 0.0 |
| Living Deciduous* | 29.6 ± 10.4 | 21.7 ± 7.4 | 21.8 ± 6.3 | n / a | 26.7 ± 8.9 | 10.3 ± 2.9 | 18.8 ± 5.3 | 0.8 |
| Living Total | 47.2 ± 5.3 | 35.8 ± 4.0 | 33.9 ± 10.2 | n / a | 43.3 ± 10.7 | 13.0 ± 2.1 | 33.3 ± 6.4 | 0.8 |
| **Percent Canopy Cover** | | | | | | | | |
| ***Permanent Sampling Plots*** | | | | | | | | |
| Trembling Aspen | 49.8 ± 25.7 | n / a | 51.7 ± 4.2 | n / a | 55.9 ± 12.2 | n / a | 47.2 ± 7.2 | n / a |
| White Birch | 11.8 ± 12.2 | n / a | 16.0 ± 5.3 | n / a | 8.6 ± 5.6 | n / a | 16.3 ± 8.2 | n / a |
| **Deciduous** | **61.5 ± 23.4** | n / a | **67.7 ± 8.1** | n / a | **64.5 ± 9.4** | n / a | **63.5 ± 6.5** | n / a |
| Balsam Fir | 13.8 ± 8.4 | n / a | 13.7 ± 11.2 | n / a | 12.8 ± 5.1 | n / a | 14.5 ± 7.8 | n / a |
| Jack Pine | 7.5 ± 9.0 | n / a | 2.3 ± 1.5 | n / a | 1.9 ± 2.7 | n / a | 4.0 ± 6.6 | n / a |
| Black Spruce | 9.0 ± 15.4 | n / a | 9.3 ± 12.1 | n / a | 3.9 ± 4.5 | n / a | 2.5 ± 1.9 | n / a |
| White Spruce | 8.3 ± 6.4 | n / a | 7.0 ± 6.2 | n / a | 17.0 ± 11.5 | n / a | 15.5 ± 13.1 | n / a |
| **Coniferous** | **38.5 ± 23.4** | n / a | **32.3 ± 8.1** | n / a | **35.5 ± 9.4** | n / a | **36.5 ± 6.5** | n / a |
| ***Canopy Photos**** | 91.9 ± 2.2 | 88.9 ± 4.0 | 90.5 ± 3.8 | 74.0 ± 1.8 | 90.7 ± 4.6 | 69.3 ± 2.5 | 90.3 ± 4.0 | 11.1 ± 0.8 |

* Variables with asterisks were used in multivariate analyses of bird-habitat relationships.

** Hemispherical photographs of canopy taken at subset of stations; 1994 sample sizes: Control, 3; Patch, 3; Partial, 8; Clearcut, 2.

**Table 9.** Summary of results from NMDS ordination of species and habitat data in Black Sturgeon study area, 1993-1994. Species codes are explained in Table 2.

| | *n* | | | | | | $R^{2*}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Ordination**** | **Species***** | **Blocks** | **Deleted Species** | **Dimensions** | **Final Stress** | **Final Instability** | **Ais 1** | **Ais 2** | **Ais 3** | **Total** |
| Pre-harvest | 30 | 12 | BOCH, CSWA, DEJU, LISP, MOWA, NOFL, RCKI, TTWO | 2 | 5.181 | 0.00001 | 0.507 | 0.343 | --- | 0.850 |
| Pre-/Post-Harvest | 31 | 24 | BOCH, CSWA, DEJU, EWPE, LISP, RCKI, TTWO | 3 | 11.493 | 0.00001 | 0.495 | 0.203 | 0.172 | 0.871 |

* for correlations between ordination distance and distance in original data

** Pre-harvest: 1993 data from 12 blocks (4 Control, 8 Partial cuts); Pre-/Post-Harvest: 1993 & 1994 data from same 12 blocks

*** Out of 38 species used in NPMANOVA ananlyses (see Table 2).

**Table 10.** FEC vegetation types at bird point count stations in treatment Stands 1 to 3 and Reference Stand 4 at Black Sturgeon research site.

| TYPE* | DESCRIPTION | STATIONS (n=97) |
|---|---|---|
| 7 | TREM ASPEN-BALSAM FIR/BALS FIR SHRUB | 31 |
| 6 | TREM ASPEN (WH BIRCH)-BALSAM FIR/MO MAPLE | 22 |
| 9 | TREM ASPEN MIXEDWOOD | 16 |
| 10 | TREM ASPEN - BL SPRUCE - J PINE/LOW SHRUB | 11 |
| 8 | TREM ASPEN (WH BIRCH)/MOUNTAIN MAPLE | 6 |
| 11 | TREM ASPEN - CONIFER/BLUEBERRY/FEATHERMOSS | 5 |
| 20 | BLACK SPRUCE MIXEDWOOD/FEATHERMOSS | 3 |
| 19 | BLACK SPRUCE MIXEDWOOD/HERB RICH | 2 |
| 17 | JACK PINE MIXEDWOOD/SHRUB RICH | 1 |
| 5 | ASPEN HARDWOOD | 1 |

* Forest Ecosystem Classification system vegetation type, following Sims et al. 1989.

**Appendix 1.** Abundance per point count of all identified and unidentified woodpeckers combined (WOODZ) in Black Sturgeon study area, 1993-1995.

| TREATMENT | 1993 | 1994 | 1995 |
|---|---|---|---|
| PREHARV* | 0.614 | | |
| CONTROL | | 0.320 | 0.320 |
| PATCH | | 0.600 | 0.067 |
| PARTIAL | | 0.440 | 0.380 |
| CLEARCUT | | 0.120 | 0.040 |
| REF | 0.500 | 0.400 | 0.325 |

* data for Stands 1-3 combined in 1993

**Appendix 2.** Mean abundance (individuals/10ha) by species for Reference stand (Stand 4) in Black Sturgeon study area, 1993-1995. Zeros have been removed to facilitate interpretation. Species are assorted in alphabetical order by 4-letter code; codes are explained in Table 2.

| Species | 1993 | 1994 | 1995 | Species | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|
| AMCR | 0.347 | 0.313 | 0.319 | HETH | 1.438 | 0.503 | 1.274 |
| AMGO | | | | LEFL | | 3.500 | 2.851 |
| AMKE | | | | LISP | | | |
| AMRE | | | | MAWA | 1.788 | 1.250 | 1.483 |
| AMRO | 0.868 | 0.590 | 0.573 | MERL | | | |
| BAWW | | | | MOWA | 0.590 | 0.146 | 0.424 |
| BBWA | 2.694 | 2.823 | 1.344 | NAWA | 0.590 | 0.580 | 0.868 |
| BBWO | 0.382 | 0.208 | | NOFL | 0.233 | 0.139 | 0.069 |
| BCCH | 0.448 | 0.250 | 0.545 | NOPA | 0.035 | 0.035 | 0.035 |
| BHVI | 0.365 | 0.069 | | OVEN | 9.028 | 8.747 | 5.788 |
| BLJA | 0.201 | 0.417 | 0.111 | PHVI | | | |
| BLWA | 0.972 | 1.924 | 0.833 | PISI | | 0.486 | 0.174 |
| BOCH | 0.069 | | | PIWO | 0.139 | 0.250 | 0.052 |
| BRCR | 0.250 | 0.563 | 0.347 | PUFI | 0.712 | 0.597 | 0.069 |
| BTBW | | | | RBGR | 0.069 | | |
| BTNW | | | | RBNU | 0.250 | 0.632 | 0.528 |
| BWHA | 0.042 | 0.208 | 0.278 | RCKI | 0.667 | 0.035 | 0.111 |
| CAWA | 0.069 | | 0.069 | RECR | | | 0.069 |
| CCSP | | | | REVI | 5.462 | 4.194 | 4.056 |
| CEDW | 0.278 | 0.042 | 0.069 | RUGR | 0.069 | | 0.087 |
| CHSP | 1.510 | 0.528 | 0.139 | SCTA | | | |
| CMWA | 0.681 | 0.441 | 0.069 | SSHA | | | |
| CORA | | 0.139 | 0.139 | SWTH | 2.431 | 2.625 | 1.969 |
| COYE | 0.069 | | | TEWA | 0.910 | 1.618 | 0.451 |
| CSWA | | 0.069 | 0.069 | TTWO | 0.052 | 0.104 | |
| DEJU | | 0.156 | | VEER | 1.160 | 0.993 | 0.882 |
| DOWO | 0.382 | 0.316 | 0.163 | WIWR | 0.493 | 1.042 | 1.531 |
| EVGR | 0.486 | 0.451 | 0.208 | WTSP | 1.997 | 1.566 | 1.896 |
| EWPE | 0.035 | | 0.431 | WWCR | | 0.208 | |
| GCKI | 0.278 | 0.521 | 0.417 | YBFL | 4.156 | 0.469 | 0.396 |
| GRCA | | | | YBSA | | | |
| GRJA | 0.208 | 0.208 | 0.174 | YRWA | 1.038 | 1.003 | 0.858 |
| HAWO | 0.250 | 0.069 | 0.069 | WOODZ* | 1.205 | 0.948 | 0.771 |
| **Total Species Richness** | | | | | **45** | **45** | **44** |

* WOODZ is all identified and unidentified woodpeckers combined, and is included as an index of woodpecker abundance. It is not included in total species richness.

**Appendix 3.** Comparison of p-values reported by Kruskal-Wallis ANOVA by ranks tests between treatments within the first year post harvest (1994). Species with significant differences between treatments are in bold (Bonferonni adjusted significance level).

| Species | Species Code | Kruskal-Wallis p-value | Treatment Differences ++ Clear Cut | Partial Cut | Control |
|---|---|---|---|---|---|
| American Robin | AMRO | 0.5266 | | | |
| **Bay-breasted Warbler** | **BBWA **** | **< 0.0001** | a,b | a | b |
| Black-backed Woodpecker | BBWO | 0.1053 | | | |
| Black-capped Chickadee | BCCH | 0.0875 | | | |
| Blue-headed Vireo | BHVI | 0.3546 | | | |
| **Blackburnian Warbler** | **BLWA *** | **0.0017** | a,b | a | b |
| Boreal Chickadee | BOCH | 0.1263 | | | |
| Brown Creeper | BRCR | 0.0125 | | | |
| Canada Warbler | CAWA | 0.3428 | | | |
| Chipping Sparrow | CHSP | 0.4901 | | | |
| Cape May Warbler | CMWA | 0.0061 | | | |
| Chestnut-sided Warbler | CSWA | 0.3416 | | | |
| Dark-eyed Junco | DEJU | 0.5951 | | | |
| Downy Woodpecker | DOWO | 0.4148 | | | |
| Eastern Wood-Peewee | EWPE | 0.3679 | | | |
| **Golden-crowned Kinglet** | **GCKI *** | **0.0022** | a | | a |
| Hairy Woodpecker | HAWO | 0.2116 | | | |
| Hermit Thrush | HETH | 0.0655 | | | |
| **Lincoln's Sparrow** | **LISP *** | **0.002** | a,b | a | b |
| Magnolia Warbler | MAWA | 0.0267 | | | |
| Mourning Warbler | MOWA | 0.0083 | | | |
| Nashville Warbler | NAWA | 0.0118 | | | |
| Northern Flicker | NOFL | 0.3098 | | | |
| Northern Parula | NOPA | 0.5951 | | | |
| **Ovenbird** | **OVEN **** | **< 0.0001** | a | b | a,b |
| Purple Finch | PUFI | 0.0033 | | | |
| Red-breasted Nuthatch | RBNU | 0.0038 | | | |
| Ruby-crowned Kinglet | RCKI | 0.1279 | | | |
| **Red-eyed Vireo** | **REVI **** | **0.0001** | a,b | a | b |
| **Swainson's Thrush** | **SWTH **** | **< 0.0001** | a | b | a,b |
| **Tennessee Warbler** | **TEWA **** | **0.0007** | a | | a |
| Three-toed Woodpecker | TTWO | 1.0 | | | |
| Veery | VEER | 0.1263 | | | |
| **Winter Wren** | **WIWR **** | **0.0006** | a | a | |
| **White-throated Sparrow** | **WTSP *** | **0.0014** | a | b | a,b |
| Yellow-bellied Flycatcher | YBFL | 0.0108 | | | |
| Yellow-bellied Sapsucker | YBSA | 0.3177 | | | |
| **Yellow-rumped Warbler** | **YRWA *** | **0.0018** | a | | a |

** indicates significance at alpha = 0.05
* indicates significance at alpha = 0.1
++ columns indicate significant differences between treatments according to post-hoc multiple comparisons

**Appendix 4.** Comparison of p-values reported by Kruskal-Wallis ANOVA by ranks tests between treatments within the second year post harvest (1995). Species with significant differences between treatments are in bold (Bonferonni adjusted significance level).

| Species | Species Code | Kruskal-Wallis p-value | Treatment Differences ++ Clear Cut | Partial Cut | Control |
|---|---|---|---|---|---|
| American Robin | AMRO | 0.0204 | | | |
| **Bay-breasted Warbler** | **BBWA** ** | **0.0001** | a | b | a,b |
| Black-backed Woodpecker | BBWO | 0.1071 | | | |
| Black-capped Chickadee | BCCH | 0.0262 | | | |
| Blue-headed Vireo | BHVI | 0.3679 | | | |
| **Blackburnian Warbler** | **BLWA** ** | **0.0005** | a | | a |
| Boreal Chickadee | BOCH | 1.000 | | | |
| Brown Creeper | BRCR | 0.3296 | | | |
| Canada Warbler | CAWA | 0.3679 | | | |
| Chipping Sparrow | CHSP | 0.2427 | | | |
| Cape May Warbler | CMWA | 0.0917 | | | |
| Chestnut-sided Warbler | CSWA | 0.7351 | | | |
| Dark-eyed Junco | DEJU | 0.5958 | | | |
| Downy Woodpecker | DOWO | 0.0193 | | | |
| Eastern Wood-Peewee | EWPE | 1.000 | | | |
| **Golden-crowned Kinglet** | **GCKI** * | **0.0063** | a | | a |
| Hairy Woodpecker | HAWO | 0.7351 | | | |
| Hermit Thrush | HETH | 0.0046 | | | |
| **Lincoln's Sparrow** | **LISP** ** | **0.0001** | a,b | a | b |
| Magnolia Warbler | MAWA | 0.1066 | | | |
| **Mourning Warbler** | **MOWA** ** | **0.0005** | a | | a |
| Nashville Warbler | NAWA | 0.0781 | | | |
| Northern Flicker | NOFL | 0.126 | | | |
| Northern Parula | NOPA | 0.3679 | | | |
| **Ovenbird** | **OVEN** ** | **0.0000** | a | b | a,b |
| Purple Finch | PUFI | 0.806 | | | |
| **Red-breasted Nuthatch** | **RBNU** ** | **0.0001** | a | | a |
| Ruby-crowned Kinglet | RCKI | 0.3546 | | | |
| **Red-eyed Vireo** | **REVI** ** | **0.0001** | a | | a |
| **Swainson's Thrush** | **SWTH** ** | **0.0000** | a | b | a,b |
| Tennessee Warbler | TEWA | 0.3301 | | | |
| Three-toed Woodpecker | TTWO | 0.3679 | | | |
| Veery | VEER | 0.1263 | | | |
| **Winter Wren** | **WIWR** ** | **0.001** | a,b | a | b |
| **White-throated Sparrow** | **WTSP** ** | **0.0012** | a | b | a,b |
| Yellow-bellied Flycatcher | YBFL | 0.0121 | | | |
| Yellow-bellied Sapsucker | YBSA | 0.1893 | | | |
| **Yellow-rumped Warbler** | **YRWA** * | **0.0014** | a | | a |

** indicates significance at alpha = 0.05

* indicates significance at alpha = 0.1

++ columns indicate significant differences between treatments according to post-hoc multiple comparisons

**Appendix 5.** Comparison of p-values reported by Kruskal-Wallis ANOVA by ranks tests between years within Clear Cut Treatments. Species with significant differences between years are in bold (Bonferonni adjusted significance level).

| Species | Species Code | Kruskal-Wallis p-value | Treatment Differences ++ | | |
|---|---|---|---|---|---|
| | | | Clear Cut | Partial Cut | Control |
| American Robin | AMRO | 0.3007 | | | |
| **Bay-breasted Warbler** | **BBWA **** | **0.0003** | a,b | a | b |
| **Black-backed Woodpecker** | **BBWO *** | **0.0016** | a,b | a | b |
| Black-capped Chickadee | BCCH | 0.3679 | | | |
| Blue-headed Vireo | BHVI | 0.0082 | | | |
| **Blackburnian Warbler** | **BLWA **** | **0.0003** | a,b | a | b |
| Boreal Chickadee | BOCH | 0.3679 | | | |
| Brown Creeper | BRCR | 0.0082 | | | |
| Canada Warbler | CAWA | 0.3679 | | | |
| Chipping Sparrow | CHSP | 0.0664 | | | |
| Cape May Warbler | CMWA | 0.0085 | | | |
| Chestnut-sided Warbler | CSWA | 0.3033 | | | |
| Dark-eyed Junco | DEJU | 1.00 | | | |
| Downy Woodpecker | DOWO | 0.0467 | | | |
| Eastern Wood-Peewee | EWPE | 1.00 | | | |
| Golden-crowned Kinglet | GCKI | 0.0342 | | | |
| Hairy Woodpecker | HAWO | 0.0467 | | | |
| Hermit Thrush | HETH | 0.0131 | | | |
| Lincoln's Sparrow | LISP | 0.0047 | | | |
| Magnolia Warbler | MAWA | 0.0585 | | | |
| Mourning Warbler | MOWA | 0.0059 | | | |
| Nashville Warbler | NAWA | 0.1194 | | | |
| Northern Flicker | NOFL | 0.3284 | | | |
| Northern Parula | NOPA | 1.00 | | | |
| **Ovenbird** | **OVEN **** | **0.0006** | a,b | a | b |
| Purple Finch | PUFI | 0.1119 | | | |
| **Red-breasted Nuthatch** | **RBNU *** | **0.0017** | a,b | a | b |
| Ruby-crowned Kinglet | RCKI | 0.3679 | | | |
| **Red-eyed Vireo** | **REVI **** | **0.0003** | a,b | a | b |
| **Swainson's Thrush** | **SWTH **** | **0.0003** | a,b | a | b |
| Tennessee Warbler | TEWA | 0.0287 | | | |
| Three-toed Woodpecker | TTWO | 1.00 | | | |
| Veery | VEER | 0.3679 | | | |
| Winter Wren | WIWR | 0.005 | | | |
| White-throated Sparrow | WTSP | 0.0709 | | | |
| **Yellow-bellied Flycatcher** | **YBFL **** | **0.0003** | a,b | a | b |
| Yellow-bellied Sapsucker | YBSA | 1.00 | | | |
| **Yellow-rumped Warbler** | **YRWA **** | **0.0003** | a,b | a | b |

** indicates significance at alpha = 0.05

* indicates significance at alpha = 0.1

++ columns indicate significant differences between treatments according to post-hoc multiple comparisons

**Appendix 6.** Comparison of p-values reported by Kruskal-Wallis ANOVA by ranks tests between years within Partial Cut Treatments. Species with significant differences between years are in bold (Bonferonni adjusted significance level).

| Species | Species Code | Kruskal-Wallis p-value | Treatment Differences ++ Clear Cut | Partial Cut | Control |
|---|---|---|---|---|---|
| American Robin | AMRO | 0.0038 | | | |
| **Bay-breasted Warbler** | **BBWA **** | **0.0006** | a | | a |
| Black-backed Woodpecker | BBWO | 0.6404 | | | |
| Black-capped Chickadee | BCCH | 0.5653 | | | |
| Blue-headed Vireo | BHVI | 0.0534 | | | |
| Blackburnian Warbler | BLWA | 0.0331 | | | |
| Boreal Chickadee | BOCH | 1.00 | | | |
| Brown Creeper | BRCR | 0.3029 | | | |
| Canada Warbler | CAWA | 0.5919 | | | |
| Chipping Sparrow | CHSP | 0.0302 | | | |
| Cape May Warbler | CMWA | 0.0031 | | | |
| Chestnut-sided Warbler | CSWA | 0.5919 | | | |
| Dark-eyed Junco | DEJU | 1.00 | | | |
| Downy Woodpecker | DOWO | 0.5284 | | | |
| Eastern Wood-Peewee | EWPE | 0.12 | | | |
| Golden-crowned Kinglet | GCKI | 0.0063 | | | |
| Hairy Woodpecker | HAWO | 0.9369 | | | |
| Hermit Thrush | HETH | 0.0942 | | | |
| Lincoln's Sparrow | LISP | 0.3679 | | | |
| Magnolia Warbler | MAWA | 0.0501 | | | |
| **Mourning Warbler** | **MOWA **** | **0.0002** | a,b | a | b |
| Nashville Warbler | NAWA | 0.5919 | | | |
| Northern Flicker | NOFL | 0.302 | | | |
| Northern Parula | NOPA | 0.37 | | | |
| **Ovenbird** | **OVEN **** | **0.0003** | a,b | a | b |
| Purple Finch | PUFI | 0.4653 | | | |
| Red-breasted Nuthatch | RBNU | 0.4103 | | | |
| Ruby-crowned Kinglet | RCKI | 1.00 | | | |
| Red-eyed Vireo | REVI | 0.0082 | | | |
| **Swainson's Thrush** | **SWTH **** | **0.0004** | a | | a |
| Tennessee Warbler | TEWA | 0.888 | | | |
| Three-toed Woodpecker | TTWO | 1.00 | | | |
| Veery | VEER | 0.1236 | | | |
| Winter Wren | WIWR | 0.6186 | | | |
| **White-throated Sparrow** | **WTSP **** | **0.0006** | a,b | a | b |
| Yellow-bellied Flycatcher | YBFL | 0.0059 | | | |
| Yellow-bellied Sapsucker | YBSA | 0.7423 | | | |
| Yellow-rumped Warbler | YRWA | 0.0058 | | | |

** indicates significance at alpha = 0.05

* indicates significance at alpha = 0.1

++ columns indicate significant differences between treatments according to post-hoc multiple comparisons