AVIAN RESPONSES TO RESIDUAL TREE RETENTION IN MANAGED PINE FORESTS OF THE LAKE STATES REGION

by

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ABSTRACT

Ecologically sustainable forest management has been recommended as an alternative to traditional timber harvest practices as a way to balance economic objectives while maintaining composition and structure of wildlife habitats. Retention of live trees after even-aged timber harvest, commonly referred to as green tree retention (GTR), is increasingly recommended as a method to maintain and develop habitat structural complexity within regenerating clearcuts. Although GTR is commonly applied throughout North America, responses of wildlife species and communities to GTR in the Lake States region remains poorly understood. This study sought to determine if avian species and communities responded to differing levels of green tree retention within stands of red pine *(Pinus resinosa)* and jack pine *(Pinus banksiana)* in Wisconsin and Minnesota.

We compared avian species and communities two years before and two years after retention of varying levels of GTR in 24 managed forest stands in Minnesota and Wisconsin: 12 jack pine stands in Minnesota and 12 red pine stands in Wisconsin. Each stand was ≥ 10 hectares. Stands were monitored using 50-m fixed-radius point counts at three separate visits between May and July of each year before (2008 and 2009) and after harvest (2010 and 2011). Four treatment levels were randomly assigned to stands: reference (100% stand area), high retention (7% stand area), low retention (2.5% stand area), and clearcut (0% stand area). Intermediate treatments consisted of 2-3 patches of overstory trees with diameters reflective of the larger stand.

We adjusted raw counts for species and groups using time-of-removal analysis, and tested for differences in species richness, total abundance, diversity, and corrected

abundance among treatments over time using a repeated measures analysis of variance. We also examined avian-habitat relationships using stepwise linear regressions of stand and patch-level habitat characteristics to quantify predictors of variation in avian abundance.

We found no difference among treatments or years in avian diversity for either stand type. Richness and total abundance increased with retention level, but did not significantly differ between 2.5% and 7% retention. Richness was significantly greater in jack pine reference stands than clearcut stands in 2010, and lower in post-harvest clearcut and 2.5% retention stands than pre-harvest stands in both red pine and jack pine forest types. Total abundance was significantly greater in jack pine reference stands than all harvested treatments in 2010, and lower in post-harvest clearcut (2010 and 2011) and 2.5% (2011) stands in both forest types. Four of 10 species groups and 9 of 22 species exhibited significant interactions among treatment or years. However, no species or group responded to levels of retention. Instead, responses were most often related to extremes (harvested vs. unharvested stands).

Overall, individual species and groups were influenced by variation in stand and patch characteristics not explicitly tied to level of aggregate retention. For example, abundances of long-distance migrants and early successional species were often associated with variables resulting from harvest and subsequent succession (e.g., shrub stem count and percentage of woody debris). However, many individual species and groups were associated with stand and patch-level variables tied to retention level. For instance, ovenbirds (*Seiurus aurocapilla*) and hermit thrushes (*Catharus guttatus*) were positively associated with greater basal area and patches per stand, respectively,

reflecting these species' association with mature forests. We suggest that levels and quality of retention evaluated were not effective for maintaining forest species in recently harvested red pine or jack pine stands, and recommend that managers consider higher levels and more complex features of retention to support avian biodiversity.

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INTRODUCTION

Managers of public and private forests are challenged to integrate wood production with other resource objectives, including maintenance of biological diversity (Moore and Allen 1999, Loehle et al. 2002, Verschuyl et al. 2011). Ecologically-based forestry has been proposed as a means of designing harvest and silvicultural treatments that maintain biodiversity by more closely imitating natural processes of forest disturbance and succession than traditional forestry practices (Hansen et al. 1991, Hunter 1999, Franklin et al. 1997). Among the central tenets of this approach is retention of horizontal and vertical distribution of live and dead vegetation (i.e., structure) during and after timber harvest (Franklin et al. 2002, Rosenvald and Lõhmus 2008, Verschuyl et al. 2008). Vertical and horizontal structural complexity promotes forest biodiversity by creating a variety of microclimates and microhabitats that provide food and shelter for a wide array of species (MacArthur and MacArthur 1961, Hunter 1999, Verschuyl et al. 2008). Managed forests often have less structural and biological diversity than naturally disturbed forests (Hansen et al. 1991, Moore and Allen 1999). Therefore, maintenance of biodiversity within managed forests necessitates retention of live trees of various sizes, snags and downed woody debris, and multiple canopy layers (Verschuyl et al. 2008).

At the stand level, effects of forest management on biological diversity from high-intensity forestry practices such as clearcutting are a concern. Clearcutting and other intensive silvicultural practices are compatible with some wildlife species (e.g., Moore and Allen 1999, Franklin et al. 2002, DeGraaf and Yamasaki 2003), and may be particularly beneficial for some migratory songbird species that have declined because of early-successional habitat loss (Hunter et al. 2001, Askins et al. 2007, Otto and Roloff

2012). However, reductions in stand structural diversity after clearcutting also have been implicated in the decline of numerous mature forest species (Thompson et al. 1992, Thompson et al. 2003, Hocking et al. 2013). Traditional clearcutting removes essentially all live and dead overstory trees from a stand, thereby leaving the site devoid of existing snags or potential snag recruitment trees (Franklin et al. 2002, Vershuyl et al. 2008). Post-harvest site preparation further reduces structural complexity of the regenerating stand by removing or reducing understory vegetation and also disturbing residual downed woody debris (Franklin et al. 2002, Thompson et al. 2003). Subsequent thinning of the regenerating stand often removes competing vegetation and damaged, defective, or dead crop trees (Franklin et al. 2007). The short harvest rotations commonly used in conjunction with clearcutting prevent development of large-diameter trees, snag and woody debris recruitment, and occurrence of defective live trees with characteristics used by many wildlife species (Duvall and Grigal 1999, Franklin et al. 2007). Collectively, these practices typically reduce forest structural complexity and biological diversity across all seral stages (Verschuyl et al. 2008).

To mitigate negative effects of clearcutting on forest biodiversity and more closely approximate results of natural disturbances, logging prescriptions increasingly include retention of live (i.e., green) residual trees within harvested stands (Aubry et al. 2004, Gilmore and Palik 2006, Rosenvald and Lõhmus 2008). In principle, green-tree retention (GTR) prescriptions are employed to enhance structural complexity of the regenerating stand, supply recruitment trees for future snags and woody debris, provide refugia for mature-forest wildlife, and to facilitate dispersal across clearcuts (Franklin et al. 1997, Rosenvald and Lõhmus 2008). Retained trees can be dispersed, either

uniformly or opportunistically throughout the stand, or aggregated in patches of varying sizes (Atwell et al. 2008, Rosenvald and Lõhmus 2008). The quantity and spatial distribution of GTR have been predicted to significantly influence future forest composition, structural complexity, and biodiversity by altering stand-level resource availability and patterns of succession (Franklin et al. 1997, Atwell et al. 2008).

Although supported in theory, only recently have biodiversity responses to GTR been investigated (Atwell et al. 2008, Rosenvald and Lõhmus 2008, Otto and Roloff 2012). To date, results of GTR studies have been equivocal, with some studies indicating positive responses of specific wildlife taxa (e.g., songbirds) to GTR (Tittler et al. 2001, Atwell et al. 2008, Söderström 2009) whereas other studies showed no effect (Schiek and Song 2006, Rosenvald and Lõhmus 2008, Otto and Roloff 2012). Regardless, public and private management organizations have increasingly integrated explicit GTR prescriptions into forest practice regulations, voluntary best management practices, and sustainable forestry certification programs (Rochelle 2008, Otto and Roloff 2012, Sustainable Forestry Initiative 2013, Forest Stewardship Council 2013). At least 14 U.S. states now include specific retention regulations or voluntary guidelines as part of timber harvest planning (Patton-Mallory et al. 2011). Regionally, the Wisconsin Department of Natural Resources (WNDR) recommended that 5–15% of stand area be retained in dispersed trees or patches within harvest units subjected to even-aged management (WDNR 2003), and the Michigan Department of Natural Resources (MIDNR) recommended 3–10% retention on state lands (Bielecki et al. 2006). The Minnesota Department of Natural Resources (MNDNR) recommends ≥ 5% retention in patches or 15–30 dispersed trees/ha (MNDNR 2006). Although wildlife are expected to respond

positively to these prescriptions, with few exceptions (e.g., Otto and Roloff 2012) wildlife responses to these management prescriptions have been little studied.

Evaluating effectiveness of these retention guidelines can help forest managers determine whether recommended prescriptions are sufficient for maintaining biodiversity. Consequently, our first objective was to determine if species and communities of passerine birds responded to differing levels of aggregate tree retention within stands of red pine (*Pinus resinosa*) and jack pine (*Pinus banksiana*) in Wisconsin and Minnesota. To achieve this objective, we compared richness, abundance, community similarity, and diversity of passerine birds sampled in two years before until two years after harvest retention of contrasting levels of aggregated overstory trees. We hypothesized that avian biodiversity would increase with level of aggregate retention. Secondly, we recognized that aside from different levels of retention, avian-habitat relationships may depend on underlying structural attributes of stands. Therefore, our second objective was to quantify avian-habitat relationships within post-harvest stands, using both stand and patch-level habitat characteristics to identify predictors of avian abundance. Our hypothesis was that abundance would be most influenced by variables representing vertical structure (e.g., basal area of trees and trees/hectare) of forest stands.

METHODS

Study Area

Our study was conducted on managed forestlands near Tomahawk, WI in Oneida County and near Brainerd, MN in Cass, Morrison and Wadena Counties. Both areas are within the Laurentian Mixed Forest Province, which encompasses northeastern Minnesota, northern Wisconsin, northern Michigan, and southern Ontario (MDNR 2006).

The climate in this region is characterized by substantial temperature extremes and fluctuations, with lows below −45°C and highs up to 43°C (Barrett 1995). Long, cold winters and short, cool summers are common throughout both study areas (Barrett 1995). Mean annual temperatures near Brainerd range from 16 to 21°C in summer and from −17 to −5°C in winter, with a mean annual precipitation of 70.4 cm and a mean annual snowfall of 118.9 cm (MRCC 2000). Mean annual temperatures near Tomahawk range from 16 to 21°C in summer and from −14 to −4°C in winter, with a mean annual precipitation of 81 cm and a mean annual snowfall of 103.9 cm (MRCC 2000).

The Minnesota study area is located within the Pine Moraines and Outwash Plains ecosystem, which is characterized by steep, sandy moraines surrounded by outwash (USGS 2006). Forest types in this region include jack pine barrens, mixed white pine and red pine forest, and mixed paper birch and trembling aspen forest (USGS 2006). In outwash plains, soils are predominantly excessively or well-drained soils classified as Psamments and Aquents (USGS 2006). On moraines, soils are primarily sands and sandy loams classified as Boralfs (USGS 2006).

The Wisconsin study area is located within the Lac Vieux Desert Outwash Plain ecosystem, which is characterized by pitted outwash plains and kettle lakes (USGS 2006). Forest types in this region include jack pine barrens, mixed white pine and red pine forest, conifer swamps, and bogs (USGS 2006). Soils in this region are predominantly acidic sands classified as mostly Spodic Udipsamments on upper slopes, Entic Haplorthods in depressions and Spodosols in areas with stable vegetation (USGS 2006).

Experimental Design

This project was a four-year before-after-control-impact (BACI) study (Smith 2002) consisting of a randomized block design involving 4 treatments representing varying levels of aggregate overstory retention. Each treatment had 6 replicates, with three replicates each in Wisconsin and Minnesota. Treatments were designated as follows: 1) 100% retention, or reference "treatments," that remained unharvested throughout the study, 2) 7% retention, representing approximately 22 trees/ha and a median level of retention recommended by WI and MN state voluntary retention guidelines, 3) 2.5% retention, representing retention levels (2–12trees/ha) commonly applied by commercial forest managers in the region, and 4) 0% retention, representing traditional clearcut harvests. Pre-treatment data were collected in 2008 and 2009 (Veverka 2011) to provide a baseline for comparison with post-treatment data reported here. Comparison of pre- and post-treatment data on the same sites with simultaneous "controls" (BACI design) potentially allows for powerful tests of treatment effects in a varying environment (Steward-Oaten et al. 1986).

Site Selection

Of 24 study sites selected in late winter and early spring of 2008, 12 were jack pine stands near Brainerd, MN and 12 were red pine stands near Tomahawk, WI. All stands were ≥10 ha and at rotation age (48–62 years for jack pine and 58–74 years for red pine). Stands were selected to be as homogenous as possible within each study area with respect to stand age, composition, structure, soils, and management histories. Red pine stands all originated from previous planting of seedlings and in most cases had been row-thinned. Jack pine stands originated from natural fires and had not been thinned.

Random Treatment Designation

In August 2009, 24 study sites were randomly assigned to one of four treatments representing a range of post-harvest overstory retention percentage (100%, 7%, 2.5% or 0%). In late summer and early fall 2009, locations and boundaries of retention patches were marked within 2.5% and 7% retention treatments. Treatment implementation began in early fall 2009 and was completed by late spring 2010.

Bird Community Sampling

We used a fixed-radius point-count method (Ralph et al. 1995, Howe et al. 1997) to quantify richness and abundance of breeding passerine birds (Robbins 1991) within each stand. Point-count stations were stratified throughout each stand, with three 50-m radius point counts per 10-ha. Each point count was located ≥ 50 m from the stand edge to minimize detection of birds associated with adjacent habitat types, and ≥ 100 m apart to avoid multiple detections of individual birds (Ralph et al. 1995, Howe et al. 1997).

Each point-count location was surveyed three times from late-May to mid-July in both pre-treatment and post-treatment years (2008–2011) to minimize detection of non-breeding birds and to account for seasonal variation in bird activity. Each point count lasted 10-min and surveys were conducted within a 5-hr period beginning at sunrise. Observers were rotated among sites to minimize observer bias. Surveys were not conducted during periods of heavy rain, fog, or high winds (i.e., Beaufort >3), as these conditions decrease detectability of birds (Ralph et al. 1995).

Species, age (adult or juvenile), and sex (if known) of all birds heard or seen within each point count were recorded. Each 10-min observation was separated into

three intervals (0–3 min, 3–5 min, or 5–10 min) and initial detections of all individuals were recorded within these intervals. Distance to each bird was measured using a rangefinder. Birds detected flying over point counts during surveys, or those that were detected walking between point-counts were recorded separately.

Stand-level Habitat Sampling

Stand-level habitat variables were measured at each point count within all 24 stands in both pre- and post-treatment years. Pre-treatment vegetation surveys were conducted during the summers of 2008 and 2009 (Veverka 2011), and post-treatment surveys were conducted in the summer of 2011. Four, 0.04-ha vegetation plots were established at each point count: 1 at the center of the point count, and the other three located 30.6 m from the center at 0°, 120° and 270° (Titler et al. 2001, Machtans and Latour 2003).

At the center of each 0.04 ha vegetation plot, we measured canopy closure with a spherical densitometer, and averaged readings from each cardinal direction (Lemmon 1956). Percent ground cover was measured at the center of each plot using a 1-m^2 Daubenmire frame to estimate percent cover of herbaceous, woody debris, leaf litter, and bare soil (Daubenmire 1959, Hetzel and Leberg 2006). Visual obscurity was measured using a 2.5 x 150 cm cover pole (Robel et al. 1970) marked in 10-cm increments, placed at the center of each plot, and read from each cardinal direction. The total number of sections that were ≥ 75% obscured at eye level and 10 m from plot center were recorded.

Diameter at breast height (dbh) was measured for all trees (> 8 cm dbh), poles (3–8 cm dbh), saplings (< 3 cm dbh, > 2 m in height), and snags at each vegetation plot

using a metric dbh tape. Height of all snags and the 5 tallest stems in each tree diameter class per plot were measured using either a cover pole or clinometer (Heltzel and Leberg 2006). Canopy stature of all trees was recorded as dominant (≥ 5 m above canopy), suppressed (≤ 5 m below canopy), or subcanopy (below canopy level). The number of cavities per snag was counted, and each snag was identified either to species or as conifer or hardwood if species was unknown. Snag decay was classified as described by Thomas et al. (1979). Diameter and length were measured for all downed woody debris (DWD) > 8 cm in diameter and > 50 cm in length that intersected a north-south transect within each plot using a tape measure. Decay classes for DWD were determined as described by Bartels et al. (1985).

Two random quadrants were selected in each vegetation plot. In each random quadrant, stems of all shrubs ≤ 2 m tall were counted. Shrub height was also measured using a cover pole at 5 random locations within each quadrant. Measurements of four vegetation plots were averaged for each point count, and then averaged to estimate stand-level habitat characteristics.

Retention Patch Characterization

Retention patches in each 2.5% and 7% retention treatment unit were characterized during summer 2011. The number of patches per stand was counted for both treatments. Minimum distance between patches, minimum distance between each patch and stand edge, perimeter of each patch, and patch area were estimated using the Measure tool in ArcGIS 10 (ESRI 2011).

At the center of each patch, we measured canopy closure using a spherical densitometer, and averaged readings from each cardinal direction (Lemmon 1956). The total number of all standing and down (blown over post-harvest) trees, and the total of number of snags in each patch were counted. Snag height was measured using either a cover pole or clinometer, and dbh was measured using a metric dbh tape. Each snag was identified to species, or as conifer or hardwood if species was unknown. Decay classes for snags were characterized as described by Thomas et al. (1979). Height and dbh of 10 randomly selected trees was measured using a clinometer and diameter tape.

Data Analyses

Habitat Characteristics—Prior to data analysis, redundant stand and patch-level habitat metrics (*Spearman's* $\rho \geq 0.7$) were screened and eliminated, while retaining 20 stand and 20 patch-level variables for further analysis (Table 1). Determining which variables to eliminate was based on ease of measurement and applicability to forest management. We used Mann-Whitney U-tests to compare pre-treatment differences between red pine and jack pine habitat characteristics. Scatterplots, residual plots (Anderson-Darling tests $P < 0.05$), and histograms were used to ensure variables met assumptions of analyses (i.e., colinearity, normality, linearity). Post-treatment habitat metrics were log (volume of downed woody debris, stem count, average snag height, and minimum distance between patches), power (basal area of trees, pole height, basal area of conifer and hardwood snags), or arcsine (canopy closure and percent ground cover of soil, leaf litter, herbaceous matter, and woody debris) transformed to approximate normality when necessary (Zar 1999, Quinn and Keough 2002). One-way analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) tests were used to

compare post-treatment stand-level habitat characteristics among retention treatments (100%, 7%, 2.5%, and 0%). Patch-level habitat metrics were compared between 2.5% and 7% retention treatments using Student's t-tests.

Detection probability—To account for potential differences in detection probability within point-count data, counts were adjusted using a time-of-removal model (Farnsworth et al. 2002, Thompson et al. 2002, Reidy et al. 2011) with the Huggins closed-capture option (Huggins 1989) in Program MARK (White and Burnham 1999). This approach incorporates two components of detection: (1) the probability that a bird is available (sings or exhibits another detectable cue) to be detected, and (2) the probability that the bird is detected, given it is available (McCallum 2005). We combined the first two time intervals (1–3 and 3–5 minutes) into two equal intervals (1–5 and 5–10 minutes) to simplify application of the removal model (Farnsworth et al. 2002). Corrected abundance was estimated based on the probability of each individual being detected during each time interval, with the understanding that once an individual is detected, it is removed from the population (Farnsworth et al. 2002, Thompson and La Sorte 2008). We generated a detection history for each individual at each point count visit over all four years (2008–2011). Detection histories for a single individual at a visit were recorded as either 0,1 or 1,0, where "1" represents a positive detection and "0" represents a non-detection (Otto and Roloff 2012). We organized our detection histories into 5 groups according to differences in habitat that may have influenced detection: pre-harvest jack pine, pre-harvest red pine, post-harvest jack pine reference (100% retention), post-harvest red pine reference (100% retention), and all post-harvest cut treatments (0%, 2.5%, and 7% retention for both jack pine and red pine stands), and constructed six models based on

these potential differences (no difference in detection between groups (constant), difference in detection between all groups (full), pre-treatment vs. post-treatment, harvested vs. unharvested, unharvested jack pine vs. unharvested red pine vs. all harvested, pre-treatment vs. post-treatment unharvested vs. post-treatment harvested). We compared models using Akaike's Information Criterion corrected for small sample size (AIC_c, Burnham and Anderson 2002). Because of high model uncertainty, we model-averaged parameter estimates in MARK (Burnham and Anderson 2002). This resulted in an individual detection estimate for a 5-min interval for each species by detection group. This detection estimate was used to calculate a detection probability for each species using the two time intervals:

$$p = 1 - (1 - p_1)(1 - p_2)$$

where detection probability, *p*, is defined as the probability that an individual is detected during point-count visit (p_1 = estimate for first time interval and p_2 = estimate for second time interval). We tallied the maximum raw abundance count for each species over all three visits for each point count, and used p for each species by detection group to calculate a corrected abundance:

$$N = \frac{C}{p}$$

Where N is defined as the number of individuals present in an area, C is the sample count, and p is the detection estimate (McCallum 2005). These corrected counts were then averaged by stand for each of the four years.

Avian Metrics—Raw counts of all birds were summed over visits each year for each point count station and averaged by stand to obtain a measure of total abundance. Flyovers and birds detected between point counts were excluded from analyses to avoid double-counting individuals. Species richness was derived using the maximum count of all species over the 3 visits for each point count station per year, and averaged by stand. We also compared community composition between post-harvest treatment groups, and between pre-harvest and post-harvest stands within each treatment group using the Sørensen coefficient of similarity (Sørensen 1948). This measure indicates the degree of overlap in species composition, and was based on the number of species common to treatments in a pairwise comparison (Franzreb and Ohmart 1978). A Shannon-Wiener index of diversity was calculated to reflect both species richness and evenness of distribution among species present (Krebs 1989, Nur et al. 1999). We chose twenty-two species for individual species analyses. This sample included the seventeen most common species across all treatments in both pre- and post-harvest years. Five additional species were added to have sufficient representation for assemblages: 3 migratory strategies (long distance, short distance, and resident), 3 habitat-use strategies (mature forest, early successional, and generalist), and 4 nesting habitat types (below canopy, canopy, cavity, and generalist) (Robbins 1991, Rodewald and Yahner 2000, Cutright et al. 2006, Veverka 2011; Appendix A). Corrected counts were summed for all species in each group to estimate corrected abundance for each group in each stand each year.

Treatment Effects—Species richness, total abundance, diversity, corrected abundance of groups, and corrected abundance of individual species were compared among treatments using repeated measures ANOVA (SPSS 2012). The interaction

between treatment and time was of greater interest than treatment or time as main effects (Hanowski et al. 2003). Treatment was the between-subject factor, and Year was the within-subject factor and repeated measure (Hanowski et al. 2003, Wilkerson et al. 2009). A significant interaction between Treatment and Year indicated that retention levels differed significantly from pre-treatment to post-treatment years ($P = \leq 0.05$). For a significant interaction, Tukey's HSD was used to test for differences among treatments within years ($P = \leq 0.05$, Wilkerson et al. 2009). Bonferroni-adjusted multiple t-tests were used to compare years within treatments, to adjust for a large number of comparisons ($P = \leq 0.05$, Wilkerson et al. 2009).

Habitat Relationships—Stepwise multiple regression was used to determine if corrected abundance of post-harvest species and groups was significantly related to stand and patch-level habitat characteristics (SPSS 2012). Stepwise regression was used over other methods because we were primarily interested in identifying post-harvest variables that influenced abundance, rather than building a priori predictive models (St-Laurent et al. 2008). Avian metrics were log-transformed to approximate normality. We tested for differences in corrected abundance of species (n = 22) and groups (n = 10) within stands between years (2010 vs. 2011) using Student's t-tests ($P \leq 0.05$). If variables did not differ significantly between years ($P > 0.05$), abundance was averaged over years. Individual variables were allowed to enter the model if $P < 0.10$, but were removed from the model if $P > 0.15$.

RESULTS

Habitat Differences between Treatments

Several stand-level habitat characteristics were altered by timber harvest and retention treatments. Red pine and jack pine stands differed significantly in habitat metrics, so red pine and jack pine sites were analyzed separately. For both jack pine and red pine stands, leaf litter, overstory basal area, and pole heights were significantly greater in reference treatments than in harvested treatments (Tables 2 and 3). Conversely, woody debris ground cover was significantly greater in harvested treatments within red pine stands and in 2.5% retention treatments within jack pine stands than reference treatments (Tables 2 and 3). In jack pine stands, volume of downed woody debris was significantly higher in reference treatments than 0% retention treatments (Table 2). Amount of bare soil within jack pine stands was highest within 0% and 7% retention treatments and lowest within 2.5% retention and reference treatments (Table 2).

Of 12 patch-level habitat variables retained for analysis, only two varied significantly between 2.5% and 7% retention treatments (Tables 4 and 5). Within jack pine and red pine stands, trees per hectare and patch area were significantly greater at 7% retention sites than at 2.5% retention sites (Tables 4 and 5).

Avian Community Composition

Sixty-one species and 3,057 individuals were detected during pre-harvest years (2008–2009), whereas only 58 species and 1,376 individuals were detected during post-harvest years (2010–2011) (Appendix A). More species were detected in jack pine stands ($n_{pre} = 56$, $n_{post} = 51$) than red pine stands ($n_{pre} = 50$, $n_{post} = 49$) before and after harvest. The 5 most common species before harvest were the ovenbird (*Seirus aurocapilla*), pine

warbler (*Dendroica pinus*), eastern wood-pewee (*Contopus virens*), least flycatcher (*Empidonax minimus*), and black-capped chickadee (*Poecile atricapillus*). The 5 most common species after harvest were the song sparrow (*Melospiza melodia*), American robin (Turdus migratorius), ovenbird, chipping sparrow (*Spizella passerine*), and black-capped chickadee. Species richness ranged 41–50 species in pre-harvest years and 37–42 species in post-harvest years.

Avian Differences between Treatments

Species composition differed most between 0% and 100% treatments for both jack pine ($CC_s = 0.50$) and red pine ($CC_s = 0.57$) stands (Table 6). Diversity did not differ significantly among treatments for either red pine or jack pine stands (Appendices B and C). Total abundance and richness exhibited a significant Treatment X Year interaction in the repeated measures ANOVA for jack pine and red pine stands (Appendices B and C). Richness and abundance both increased from 0% to 100% retention for both stand types in 2010 (Tables 7 and 8). However, richness and abundance only differed significantly between 0% and 100% retention treatments, with both richness and total abundance being significantly higher in reference treatments than harvested treatments (Tables 7 and 8).

Of ten assemblages tested for response of retention treatment over time, only four exhibited a significant Treatment X Year interaction for both jack pine and red pine stands (Appendices B and C). Abundance of long-distance migrants, mature forest species, and below canopy nesters was higher in both jack pine (99-154%) and red pine (89-160%) stands before harvest than after harvest (Tables 7 and 8). Conversely, abundance of generalist nesters increased after harvest in both jack pine (56%) and red

pine (108%) stands (Tables 7 and 8). In jack pine stands, long-distance migrants decreased 77% and mature forest species decreased 74% after harvest for all three harvested retention treatments. Additionally, harvested retention treatments had lower abundance of mature forest species (76%) and long-distance migrants (75%) when compared with reference stands of jack pine in 2010 (Table 7). Mature forest species abundance in red pine stands was significantly greater (792%) before harvest than after harvest within the 0% treatment group, and 13 times more abundant in reference than clearcut treatments in 2011 (Table 7). Abundance of below-canopy nesters was significantly lower after harvest in 2.5% retention stands of red pine, and both 0% and 7% retention stands of jack pine (Tables 7 and 8). In 2010, abundance of below canopy nesters was double that in 0% and 2.5% retention stands of red pine, but did not differ between 7% retention stands and reference treatments (Table 8). Generalist nesting species were 10 times higher in 2.5% retention stands than in reference stands of both jack pine and red pine, and significantly higher in 0% ($\bar{x}$ = 0.855) and 2.5% ($\bar{x}$ = 1.575) retention stands than in reference ($\bar{x}$ = 0.703) stands of jack pine (Tables 7 and 8). Assemblage abundance of no groups differed between intermediate retention stands (2.5% and 7%).

Six of 22 species exhibited a significant response of retention treatment over time in both jack pine and red pine stands (Appendices B and C). Ovenbird abundance was more than three times higher before harvest ($\bar{x}$ = 1.41) than after harvest ($\bar{x}$ = 0.42), and 2 times higher in reference stands ($\bar{x}$ = 1.54) than harvested stands ($\bar{x}$ = 0.706; Tables 7 and 8). However, ovenbirds did not differ significantly in abundance among harvested red pine or jack pine stands (Tables 7 and 8). Similarly, hermit thrushes (*Catharus guttatus*)

were higher in abundance before harvest ($\bar{x}$ = 0.572) than after harvest ($\bar{x}$ = 0.381) and in reference stands ($\bar{x}$ = 0.895) than harvested ($\bar{x}$ = 0.209) stands of both red pine and jack pine (Tables 7 and 8). Hermit thrushes were not detected in 2011 in any harvested red pine stands (Table 8). In 2010, hermit thrush abundance was significantly higher in reference stands of jack pine than all harvested stands (Table 7). Another forest dependent species, the red-eyed vireo (*Vireo olivaceus*), declined in abundance in 7% treatment stands of red pine from 2009 to 2011 (Table 8). Conversely, few song sparrows were detected before harvest and none were detected after harvest in reference stands (Tables 7 and 8). Most song sparrows were detected in 2.5% treatment stands of jack pine and red pine (Tables 7 and 8). Two early-successional species, the pine warbler and American redstart (*Setophaa ruticilla*), were detected more frequently before harvest ($\bar{x}$ = 0.39 and 1.06, respectively) than after harvest ($\bar{x}$ = 0.043 and 0.039, respectively) in jack pine stands (Table 7). Pine warblers were significantly more abundant before harvest (2008) than after harvest (2010 and 2011) in jack pine stands with 7% retention (Table 7). American redstarts differed significantly in abundance between pre- and post-harvest years within 0%, 2.5%, and 7% retention levels in jack pine stands (Table 7). We detected no dark-eyed juncos (*Junco hyemalis*) in jack pine clearcuts or 2.5% retention stands (Table 7). Brown-headed cowbirds (*Molothrus ater*) and veeries (*Catharus fuscescens*) both exhibited a significant Treatment X Year interaction for red pine stands, but did not differ between years within treatments, or between treatments within years (Table 8).

Avian-Habitat Relationships

Eleven of 20 stand-level habitat variables were significantly correlated with abundance of 1 of 10 groups and 22 species in red pine stands, and 7 groups and 17 species in jack pine stands (Tables 9 and 10). Shrub stem count was the most common predictor of group and species abundance in red pine stands, followed by basal area of conifer snags, basal area of trees, and amount of downed woody debris (Table 10). Similarly, groups and species abundance in jack pine stands was most often related to shrub stem count, percent of woody debris ground cover, and amount of downed woody debris (Table 9).

Pole height was positively associated with long-distance migrants, mature forest species, and below canopy nesters in both red pine and jack pine stands (Tables 9 and 10). Mature forest species decreased as basal area of conifer snags increased in both jack pine and red pine stands (Table 9 and 10). Long-distance migrants and mature forest species in jack pine stands, and early-successional species and canopy nesters in red pine stands were positively associated with basal area of trees (Tables 9 and 10). Cavity nesting species in jack pine stands increased with the percentage of woody debris ground cover in 2010 (Table 9).

Abundance of 12 species was positively associated with shrub stem count, including eastern wood-pewee, pine warbler, black-capped chickadee, song sparrow, American robin, chestnut-sided warbler (*Setophaga pensylvanica*), red-eyed vireo, eastern towhee (*Pipilo erythrophthalmus*), American redstart, Nashville warbler (*Oreothlypis ruficapilla*), and indigo bunting (*Passerina cyanea*) in red pine stands, and chipping sparrow, pine warbler, black-capped chickadee, and eastern towhee in jack pine

stands (Tables 9 and 10). Ovenbird abundance increased with basal area of trees in jack pine stands and height of poles in red pine stands (Tables 9 and 10). Abundance of five other species were associated with basal area, either positively (eastern wood-pewees, pine warblers, American robins (2010), and chestnut-sided warblers in red pine stands) or negatively (pine warbler and song sparrow in jack pine stands) (Tables 9 and 10). Hermit thrush abundance was only positively associated with pole height in jack pine stands, and negatively associated with basal area of conifer snags in both red pine and jack pine stands, and percent of woody debris ground cover and stand area in red pine stands (Tables 9 and 10).

Abundance of 6 groups and 19 species in red pine stands, and 8 groups and 15 species in jack pine stands were correlated significantly with at least 1 of 12 patch-level habitat variables (Tables 11 and 12). Overall, patch area was the most common predictor of group and species abundance, along with tree height in jack pine stands and basal area of trees in red pine stands.

In jack pine stands, long-distance migrants and mature forest birds increased as distance between patches and stand edge decreased (Table 11). In contrast, canopy nesters in both red pine (2011) and jack pine stands increased as distance between patches and stand edge increased (Tables 11 and 12). Patch area was positively associated with short distance migrants (2010), early successional species, and generalist nesting species in red pine stands, and negatively associated with canopy nesters in jack pine stands (Tables 11 and 12). Below canopy nesters in jack pine stands decreased with tree height, whereas cavity nesters in jack pine stands (2011) increased with tree height (Tables 11 and 12).

Abundance of chipping sparrows (2011), eastern wood pewees, American redstarts, and Nashville warblers in jack pine stands was positively associated with minimum distance between patches, but negatively associated with abundance of chipping sparrow (2011) in red pine stands (Tables 11 and 12). Patch area was positively related to chipping sparrow abundance (2011) in jack pine stands, and pine warbler, American robin (2010), chestnut-sided warbler, eastern towhee, and Nashville warbler abundance in red pine stands (Tables 11 and 12). Abundance of blue jays (*Cyanocitta cristata*), scarlet tanagers (*Piranga olivacea*), and eastern towhees (2011) in jack pine stands decreased with increased patch area (Table 11). In jack pine stands, tree height was positively related to abundance of black-capped chickadees (2011), red-breasted nuthatches (*Sitta canadensis*), and scarlet tanagers, but negatively related to Nashville warblers, hermit thrushes, and song sparrows (Table 11). Basal area of trees was positively associated with abundance of black-capped chickadees, red-eyed vireos, American redstarts, and indigo buntings in red pine stands, and American robins (2011) and American goldfinches (*Spinus tristis*) in jack pine stands (Tables 11 and 12).

DISCUSSION

Residual tree retention prescriptions are increasingly employed as a means to alleviate negative impacts of traditional clearcutting on forest biodiversity, while continuing to meet silvicultural objectives of managed forests (Rosenvald and Lõhmus 2008, Verschuyl et al. 2011). These prescriptions are required by sustainable forestry certification programs and recommended by state voluntary guidelines, but responses of wildlife to specific retention levels remains poorly quantified (Aubry et al. 2004, Gilmore and Palik 2006). Our findings contradict recent studies that noted positive responses of

avian communities to residual retention (e.g., Atwell et al. 2008, Söderström 2009). We expected avian metrics to increase concomitantly with retention levels, based on results of previous research (reviewed in Rosenvald and Lõhmus 2008), which was generally the trend when evaluating overall richness and abundance. However, we did not find that avian groups or individual species responded to specific levels of retention. Instead, avian species and groups responded to the extremes among treatments (e.g., harvested vs. unharvested stands). Our results were consistent between cover types and similar to recent studies evaluating comparable levels of retention (e.g., Otto and Roloff 2012). With the exception of red-eyed vireos, Otto and Roloff (2012) found no evidence of an increased response with level of retention, rather, songbird occupancy was associated with age since harvest (1-15 years).

Mature forest species in both red pine and jack pine stands were far less abundant after harvest, except for reference stands, which indicates that levels of retention we examined were not sufficient for maintaining populations of mature forest obligates (Otto and Roloff 2012). Ovenbirds were the most abundant mature forest species, and responded most negatively to harvest. As expected, ovenbirds depended on forests and forest interior habitat (Lambert and Hannon, 2000). Correspondingly, we found that ovenbirds were associated with basal area of trees and height of poles in jack pine and red pine stands. Hermit thrushes, similarly, were more abundant in reference stands than harvested stands in 2010. Although recent research has shown that red-eyed vireos may respond positively to retention (Otto and Roloff 2012), our results were conflicting. Abundance of this species was comparable to pre-harvest in some post-harvest stands but detections were too variable among treatment groups for inference. Similarly, other

forest-associated species (least flycatcher, scarlet tanager, veery) did not respond significantly to harvest, likely because these species had fewer detections.

Habitat variables representing understory structure (e.g., pole height and shrub density) are known to influence ground nesting songbirds (Howe et al. 1997, Veverka 2011). Below canopy nesters were more abundant in pre-harvest than post-harvest stands, likely because of their association with understory structure, which was greater in pre-harvest stands. In contrast, abundance of generalist nesting species increased after harvest and were absent from reference stands, except jack pine stands in 2010. The latter may be indicative of their variable nesting requirements, because jack pine forests provide more structural and compositional complexity than red pine plantations (Howe et al. 1997). Additionally, song sparrows and eastern towhees, both habitat generalists, were far more abundant after harvest. Song sparrows have been categorized as early successional species that respond positively to canopy removal (Hanowski et al. 2003). Further, we found that song sparrows increased as basal area decreased in jack pine stands, which supports other studies that suggest harvesting mimics natural disturbance, incorporating a crucial early-successional component in an otherwise contiguous even-aged forest landscape (e.g., Rodewald and Yahner 2000).

Long distance migrants are of increasing concern to forest managers, because loss of habitat has been a cause of decline in recent years (Chambers et al. 1999). Most of the 22 species we analyzed fell within this assemblage, and decreased in abundance after harvest in both red pine and jack pine stands. Although some species we detected (Nashville warbler, chestnut-sided warbler, and indigo bunting) are known to be associated with early successional characteristics, they did not positively respond to

retention levels in either stand type. This may be a result of the short-term length of our study, because bird species generally increase as succession progresses, with shrubs, tree canopy, and bark surface becoming more prominent parts of forest ecosystems (Howe et al. 1997). Furthermore, this group is associated with presence or volume of vegetative strata (Thompson et al. 1993). Because several of our habitat variables were reduced after harvest (e.g., pole height, shrub stem count, basal area of trees), a decrease in abundance of species dependent on these factors was expected. Conversely, two long distance migrants, chestnut-sided warbler and Nashville warbler, increased since pre-settlement times as a result of forestry practices (Morse 1989). However, these species are generally more strongly associated with hardwood forests (Howe et al. 1997).

As expected, groups and species of birds were often associated with stand and patch-level variables related to vertical structure (e.g., basal area of trees and snags, tree height, patch area) (Veverka 2011). However, individual species and groups also related to variation in stand and patch characteristics not explicitly tied to level of aggregate retention. For example, abundances were often predicted best by variables resulting from harvest and subsequent succession (e.g., shrub stem count, pole height, percentage of woody debris ground cover). Cavity nesting birds in 2010 jack pine stands were positively associated with percentage of woody debris ground cover, likely a response to foraging conditions (Bull 2002). Additionally, long-distance migrants and mature forest birds increased with decreasing distance between patch and stand edge, whereas canopy nesting birds responded positively. One explanation for the latter is that distance may have been too small to limit movement by canopy nesting birds, as well as additional species that were not influenced in either direction by distance between patch and stand

edge (Linden et al. 2012). Variation in habitat associations supports previous findings that avian metrics are tied to increasing structural and compositional complexity (Veverka 2011).

Our study had several limitations in the context of understanding avian responses to levels of retention. First, our analysis may have lacked power to detect a difference in avian abundance between treatments due to a relatively small sample size and low mean species estimates, which has been a common problem in similar studies (St-Laurent 2008, Otto and Roloff 2012). The original design combined 12 jack pine and 12 red pine stands, for a total of 24 experimental units. However, because initial tests confirmed multiple differences between the two stand types, we were not able to justify combining stands for further analyses. Future research would benefit from an increase in the number of equivalent replicates. Secondly, bird species may not recognize levels of retention we implemented to be functionally different from each other or from traditional clearcuts. This may be a result of relatively low levels of retention, which is consistent with previous studies (e.g., Tittler et al. 2001, Otto and Roloff 2012). Although 7% retention seemed to approach abundance levels of unharvested stands in some instances (e.g., below canopy nesters in 2010 red pine stands), we found no statistical support to infer that this level effectively supports avian biodiversity comparable with mature forests. Other studies reported distinct avian communities or higher abundances associated with higher levels of GTR (e.g., Atwell et al. 2008, Söderström 2009) evaluated higher levels (e.g., 25%) of retention. Specifically, Tittler et al. (2001) described the importance of identifying the inflection point in bird abundance vs. residual trees, or the point at which the abundance of birds reaches that of unharvested stands. Identifying this critical point

will require tests of wildlife responses to increasing levels of retention beyond the scope of this project.

Although aggregate retention positively affects forest biodiversity, and is the most common and operationally desirable approach, responses to GTR may differ with dispersed retention (Rosenvald and Lõhmus 2008). Responses also may take longer than our two-year post-sampling period. Initial response to harvest may be attributed to forest dependent species returning to the same plot after harvest, which was consistent with our results of higher abundance in treatment stands in 2010 vs. 2011 (Hanowski et al. 2003). This indicates that abundance we observed may decrease further over time if retention levels are not sufficient to support biodiversity comparable with mature forests. Conversely, abundance and richness in harvested treatments exceeded unharvested controls three years after harvest in northern Minnesota (Atwell et al. 2008). These differing results demonstrate the need for longer-term studies to better understand persisting effects of retention treatments (i.e., long-term structural enrichment), which may be more crucial than temporary impacts on forest biodiversity (Rosenvald and Lõhmus 2008). Additionally, retention patches may have lacked structural complexity necessary for supporting avian communities (Verschuyl et al. 2008). Retention patches in both red pine and jack pine stands consisted of healthy, rotation age trees with diameters reflective of the pre-harvest stand. Large diameter legacy trees, defective and diseased trees, and snags, all known to be particularly valuable for birds and other wildlife (Hansen et al. 1991, Franklin et al. 2007, St-Laurent et al. 2008, Verschuyl et al. 2008), had been largely eliminated from these stands during previous rotations and thinning treatments. The types and quality of retention may be of equal or greater

importance than the area retained if structural diversity within clearcuts is the goal of green tree retention.

Managing for multiple species presents a challenging task for forest managers, as no single prescription of retention will influence all species in the same way, nor will it provide a panacea for maintaining biodiversity. We recommend a mixture of management objectives, including (1) maintaining unharvested reserves to support mature forest species, (2) retaining greater quantities of trees within harvested stands, and (3) taking into account structural complexity of retention rather than quantity of retention alone. Additionally, further research incorporating higher levels of retention, and importance of quality vs. quantity of retention is warranted.

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Table 1. Stand-level habitat variables measured at each of 24 stands and patch-level habitat variables measured at each of 12 (2.5% and 7.0%) stands included in stepwise multiple regressions explaining post-retention bird habitat relationships, as well as analysis of variance and t-tests to determine differences between treatments.

Variable	Units	Sample Area[a]	Description
Stand_Area	ha	S	Stand area
Shrub_Ht	m	S	Shrub height
GC_S	%	S	Ground cover: soil
GC_L	%	S	Ground cover: litter
GC_H	%	S	Ground cover: herbaceous
GC_WD	%	S	Ground cover: woody debris
BA_Tree	m^2	S,P	Basal area of trees
BA_Pole	m^2	S	Basal area of poles
BA_Sapp	m^2	S	Basal area of saplings
VO	%	S	Visual obscurity
CC	%	S,P	Canopy closure
Stem_Count	none	S	Shrub stem count
Vcm^3	cm^3	S	Downed woody debris (DWD) volume
DWD_Decay	none	S	DWD decay class
Tree_Ht	m	S,P	Tree height
Pole_Ht	m	S	Pole height
Sapp_Ht	m	S	Sapling height
Snag_Ht	m	S,P	Snag height
SnagCon_BA	m^2	S	Basal area of conifer snags
SnagHW_BA	m^2	S	Basal area of hardwood snags
Patches/Stand	none	P	Number of patches per stand
Water(Y/N)	none	P	Presence/absence of water feature
MinDist_Patch	m	P	Minimum distance between patches
MinDist_Edge	m	P	Minimum distance between patch and edge
Patch_Perim	m	P	Average patch perimeter
Patch_Area	ha	P	Sum of patch area per stand
Trees/Stand	none	P	Total number of trees per stand
Trees/Patch	none	P	Average number of trees per patch
Trees/ha	ha	P	Trees per hectare
Snags/Stand	none	P	Total number of snags per stand

[a]An S indicates variables that were measured at the stand-level (24 pre and post-retention stands), and P indicates variables that were measured at the patch level (12 post-retention stands)

Table 1 (cont'd). Stand-level habitat variables measured at each of 24 stands and patch-level habitat variables measured at each of 12 (2.5% and 7.0%) stands included in stepwise multiple regressions explaining post-retention bird habitat relationships, as well as analysis of variance and t-tests to determine differences between treatments.

Variable	Units	Sample Area[a]	Description
Blowdown/Stand	none	P	Total number of blowdown trees per stand
Proport_Blowdown	none	P	Proportion of blowdown per patch
Tree_Dbh	cm	P	Average dbh of trees
Snag_Dbh	cm	P	Average dbh of snags
Snag_Decay	none	P	Median snag decay
BA_Snag	m^2	P	Basal area of all snags

[a]An S indicates variables that were measured at the stand-level (24 pre and post-retention stands), and P indicates variables that were measured at the patch level (12 post-retention stands).

Table 2. Mean (SE) of stand-level habitat variables measured in 0% (n = 3), 2.5% (n = 3), 7.0% (n = 3), and reference (n = 3) plots within post-retention stands of jack pine (Minnesota), 2010-2011. Non-transformed data are presented.

Variable	0% retention	2.5% retention	7.0% retention	Reference	F	P
Stand_Area	118236(21033)	146226(24514)	177117(23647)	142234(25391)	1.04	0.43
GC_S	23.26(7.41) A	5.88(0.83) B	25.65(5.22) A	0.20(0.10) B	11.30	0.00
GC_L	31.00(10.40) A	9.64(3.23) A	22.69(5.83) A	85.98(4.84) B	19.19	0.00
GC_H	34.90(16.30)	67.58(3.29)	38.35(8.90)	30.85(8.57)	2.17	0.17
GC_WD	10.61(1.52) AB	16.89(1.96) A	13.31(3.36) AB	4.06(1.64) B	3.93	0.05
BA_Tree	0.008(0.005) A	0.036(0.018) A	0.082(0.044) A	0.895(0.136) B	13.44	0.00
Stem_Count	40.30(25.10)	156.80(57.20)	30.20(16.50)	106.17(2.42)	3.38	0.08
Vcm^3	19573(2713) A	61704(24416) AB	56401(29155) AB	266792(88813)	4.49	0.04
Pole_Ht	0.27(0.15) A	0.39(0.16) A	0.46(0.08) A	5.74(0.57) B	23.94	0.00
SnagCon_BA	0.009(0.003) A	0.009(0.005) A	0.016(0.004) A	0.338(0.050) B	56.21	0.00
SnagHW_BA	0.000(0.000)	0.006(0.004)	0.001(0.001)	0.003(0.003)	0.90	0.48

Note: Different letters within rows indicate significant differences among treatments ($P \leq 0.05$)

Table 3. Mean (SE) of stand-level habitat variables measured in 0% (n = 3), 2.5% (n = 3), 7.0% (n = 3), and reference (n = 3) plots within post-retention stands of red pine (Wisconsin), 2010-2011. Non-transformed data are presented.

Variable	0% retention	2.5% retention	7.0% retention	Reference	F	P
Stand_Area	177387(50483)	141640(32338)	166730(17751)	158367(9649)	0.23	0.88
GC_S	5.28(2.28)	0.667(0.397)	0.514(0.301)	1.300(0.813)	3.15	0.09
GC_L	34.28(8.16) A	49.78(5.33) A	45.16(3.27) A	93.14(3.42) B	21.97	0.00
GC_H	31.08(9.85)	22.64(4.20)	22.70(10.50)	19.49(5.26)	0.31	0.82
GC_WD	29.36(5.44) A	26.76(2.97) A	31.16(7.68) A	1.88(1.13) B	9.88	0.01
BA_Tree	0.000(0.000) A	0.082(0.009) B	0.108(0.031) B	0.905(0.145) C	108.56	0.00
Stem_Count	49.90(18.00)	36.00(15.00)	96.50(59.40)	36.40(10.20)	0.15	0.92
Vcm^3	40188(16836)	21455(1061)	62579(25326)	18048(15743)	2.27	0.16
Pole_Ht	0.75(0.55) A	0.76(0.47) A	0.31(0.19) A	4.98(0.45) B	10.80	0.00
SnagCon_BA	0.002(0.002)	0.007(0.004)	0.002(0.000)	0.025(0.020)	1.01	0.44
SnagHW_BA	0.000(0.000)	0.000(0.000)	0.001(0.000)	0.000(0.000)	0.51	0.69

Note: Different letters within rows indicate significant differences among treatments ($P \leq 0.05$)

Table 4. Mean (SE) of patch-level habitat variables measured in 2.5% (n = 3) and 7.0% (n = 3) plots within post-retention stands of jack pine (Minnesota), 2010-2011. Non-transformed data are presented.

Variable[a]	2.5% retention	7.0% retention	t	P
Patches/Stand	2.00(0.00)	2.67(0.33)	-2.00	0.12
MinDist_Patch	156.70(33.00)	89.30(34.60)	1.41	0.23
MinDist_Edge	94.80(16.50)	72.50(11.70)	1.10	0.33
CC	15.42(2.99)	11.84(0.23)	-1.24	0.28
Patch_Area*	0.24(0.12)	1.36(0.28)	-3.64	0.02
Trees/ha*	0.001(0.000)	0.003(0.000)	-4.73	0.01
Proport_Blowdown	0.095(0.030)	0.036(0.010)	1.83	0.14
Tree_Ht	36.37(1.92)	37.87(0.86)	-0.71	0.52
Tree_Dbh	20.90(0.63)	19.29(0.32)	2.29	0.08
BA_Tree	0.034(0.002)	0.029(0.001)	2.15	0.09
Snag_Ht	11.41(1.67)	9.98(0.26)	0.80	0.47
Snag_Dbh	16.75(2.22)	14.23(0.60)	1.09	0.33

[a]Variables marked with * indicate a significant difference among treatments ($P \leq 0.05$)

Table 5. Mean (SE) of patch-level habitat variables measured in 2.5% (n = 3) and 7.0% (n = 3) plots within post-retention stands of red pine (Wisconsin), 2010-2011. Non-transformed data are presented.

Variable[a]	2.5% retention	7.0% retention	t	P
Patches/Stand	2.00(0.00)	2.00(0.00)	-	-
MinDist_Patch	172.00(122.00)	48.67(4.10)	0.99	0.38
MinDist_Edge	83.50(28.80)	103.20(27.00)	-0.50	0.65
CC	16.21(0.94)	15.46(1.67)	-0.42	0.69
Patch_Area*	0.19(0.05)	0.88(0.19)	-3.43	0.03
Trees/ha*	0.001(0.000)	0.002(0.000)	-14.22	0.00
Proport_Blowdown	0.038(0.016)	0.024(0.005)	0.79	0.47
Tree_Ht	38.63(2.13)	39.80(0.36)	-0.54	0.62
Tree_Dbh	30.12(0.32)	29.36(3.19)	0.24	0.83
BA_Tree	0.071(0.002)	0.069(0.016)	0.12	0.91
Snag_Ht	8.89(0.93)	6.18(1.52)	1.52	0.20
Snag_Dbh	15.28(1.84)	14.52(1.82)	0.29	0.79

[a]Variables marked with * indicate a significant difference among treatments ($P \leq 0.05$)

Table 6. Sørensen coefficients of community similarity (Cc_s) for avian communities among green tree retention treatments implemented within stands of red pine (Wisconsin) and jack pine (Minnesota), 2010-2011.

	Retention Treatment		
	0%	2.5%	7%
Minnesota			
2.5%	0.6875		
7%	0.6779	0.7397	
100%	0.5000	0.6285	0.7384
Wisconsin			
2.5%	0.6956		
7%	0.6984	0.6557	
100%	0.5769	0.6000	0.6567

Table 7. Mean differences in corrected avian abundance (± 1 SE) among green tree retention treatments in pre-treatment (2008-2009) and post-treatment (2010-2011) years for jack pine stands (Minnesota).[a]

	Pre-treatment		Post-treatment	
Species or group	2008	2009	2010	2011
Richness				
0% retention	8.44 (0.44) a	13.47 (0.88) ABb	4.97 (0.50) Ac	2.53 (0.37) c
2.5% retention	10.31 (1.10) ab	14.67 (0.99) Aa	6.91 (1.42) ABbc	3.64 (0.82) c
7.0% retention	12.83 (0.44) a	10.48 (0.39) Bab	7.74 (1.16) ABb	3.61 (0.77) c
Reference	8.72 (3.38) ab	10.61 (0.77) Ba	9.92 (0.65) Ba	4.01 (0.80) b
Total Abundance				
0% retention	13.06 (0.64) a	20.25 (1.42) ABb	5.78 (0.59) Ac	2.92 (0.43) c
2.5% retention	13.80 (1.22) a	25.96 (2.85) Ab	9.26 (1.07) Aac	5.42 (0.76) c
7.0% retention	18.96 (0.42) a	16.35 (1.45) Ba	10.61 (1.31) Ab	4.53 (0.79) c
Reference	13.07 (2.71) ab	19.19 (1.54) ABa	16.29 (1.32) Ba	6.33 (1.20) b
Diversity				
0% retention	2.45 (0.04)	2.83 (0.05)	2.13 (0.18)	1.83 (0.13)
2.5% retention	2.85 (0.09)	3.02 (0.07)	2.37 (0.27)	2.22 (0.20)
7.0% retention	3.02 (0.11)	2.76 (0.03)	2.59 (0.22)	2.11 (0.28)
Reference	2.51 (0.25)	2.67 (0.19)	2.51 (0.10)	1.71 (0.26)

[a]Treatment means with different upper case letters among rows indicate significant differences among retention treatments within a year based on Tukey's honestly significant difference. Treatment means with different lowercase letters across columns indicate significant differences between years within a treatment based on Bonferroni-adjusted multiple t-tests.

[b]Habitat group: MF (mature forest), ES (early successional), or G (generalist); migratory group: SD (short distance), LD (long distance), or R (resident); nesting group: BC (below canopy), CN (canopy), CV (cavity), or GN (generalist).

Table 7 (cont'd). Mean differences in corrected avian abundance (± 1 SE) among green tree retention treatments in pre-treatment (2008-2009) and post-treatment (2010-2011) years for jack pine stands (Minnesota).[a]

	Pre-treatment		Post-treatment	
Species or group	2008	2009	2010	2011
Long distance				
0% retention	6.75 (0.29) a	9.77 (0.54) a	1.96 (0.90) Ab	1.68 (0.86) b
2.5% retention	6.45 (0.67) a	10.85 (0.52) b	1.93 (0.94) Ac	1.66 (0.38) c
7.0% retention	7.93 (0.46) a	6.39 (0.78) a	2.46 (0.37) Ab	1.35 (0.44) b
Reference	5.51 (0.69)	8.77 (1.79)	8.33 (0.48) B	5.17 (1.93)
Short distance				
0% retention	1.12 (0.60)	3.27 (0.42)	4.38 (0.19)	1.37 (0.82)
2.5% retention	2.00 (0.13)	1.98 (0.39)	6.67 (0.63)	2.81 (0.33)
7.0% retention	3.67 (0.82)	3.89 (0.69)	6.04 (0.24)	1.77 (0.67)
Reference	2.18 (1.36)	3.20 (0.62)	4.65 (1.70)	0.90 (0.53)
Resident				
0% retention	0.98 (0.50)	2.44 (0.80)	1.30 (0.80)	0.40 (0.40)
2.5% retention	1.44 (0.67)	2.03 (0.38)	6.42 (0.95)	0.23 (0.23)
7.0% retention	1.58 (0.62)	1.65 (0.17)	6.12 (3.10)	2.42 (2.42)
Reference	1.21 (0.30)	1.55 (0.09)	3.30 (0.66)	0.61 (0.31)

Mature forest				
0% retention	3.37 (0.74) ab	5.63 (0.58) b	1.41 (0.94) Ac	0.69 (0.44) c
2.5% retention	3.82 (0.29) a	6.76 (0.42) b	1.76 (0.79) Aac	0.52 (0.42) c
7.0% retention	4.27 (0.27) a	3.66 (1.07) a	1.92 (0.22) Aab	0.77 (0.16) b
Reference	3.55 (0.67)	5.84 (0.72)	7.02 (0.90) B	4.45 (1.67)
Early successional				
0% retention	2.92 (0.74)	4.62 (0.60)	1.55 (0.04)	1.46 (0.66)
2.5% retention	3.29 (0.51)	4.58 (0.41)	1.44 (0.48)	1.39 (0.39)
7.0% retention	4.54 (0.60)	3.40 (0.59)	1.25 (0.18)	0.78 (0.45)
Reference	2.91 (0.64)	2.64 (0.93)	1.65 (0.26)	0.96 (0.12)
Generalist (habitat)				
0% retention	2.66 (0.69)	5.24 (0.87)	4.68 (0.81)	1.28 (0.28)
2.5% retention	2.78 (0.52)	3.51 (0.27)	11.84 (1.24)	2.80 (0.23)
7.0% retention	4.38 (0.19)	4.88 (0.46)	11.45 (2.97)	3.98 (1.88)
Reference	2.45 (1.14)	5.05 (0.69)	7.61 (1.80)	1.26 (0.57)
Below canopy				
0% retention	5.87 (0.73) ab	8.95 (1.56) a	3.79 (0.85) ab	2.27 (0.96) b
2.5% retention	5.43 (0.17) ab	7.98 (0.93) a	3.15 (1.26) b	2.34 (0.72) b
7.0% retention	6.56 (0.16) a	6.27 (0.35) a	3.94 (0.34) b	1.64 (0.44) c
Reference	5.26 (0.82)	7.64 (1.70)	7.03 (0.85)	2.92 (0.17)

Canopy				
0% retention	1.97 (0.82)	3.90 (1.25)	1.98 (0.69)	0.14 (0.14)
2.5% retention	3.01 (0.30)	4.64 (0.46)	5.25 (0.32)	0.75 (0.24)
7.0% retention	4.55 (0.21)	2.19 (0.13)	5.30 (2.62)	2.93 (2.16)
Reference	2.22 (0.80)	3.80 (1.17)	6.14 (1.06)	3.61 (2.27)
Cavity				
0% retention	0.81 (0.60)	1.61 (0.36)	0.40 (0.40)	0.40 (0.40)
2.5% retention	1.04 (0.23)	1.33 (0.07)	3.04 (0.94)	0.23 (0.23)
7.0% retention	1.07 (0.56)	1.55 (0.26)	2.74 (1.41)	0.00 (0.00)
Reference	0.99 (0.27)	0.67 (0.15)	2.14 (0.47)	0.14 (0.14)
Generalist (nesting)				
0% retention	0.29 (0.15)	1.03 (0.29) AB	1.47 (0.32) A	0.63 (0.43)
2.5% retention	0.41 (0.08) a	0.91 (0.07) Aa	3.60 (0.46) Bb	1.38 (0.09) a
7.0% retention	1.01 (0.19) ab	1.92 (0.30) Bab	2.63 (0.29) ABa	0.98 (0.49) b
Reference	0.44 (0.44)	1.41 (0.08) AB	0.96 (0.65) A	0.00 (0.00)

[a]Treatment means with different upper case letters among rows indicate significant differences among retention treatments within a year based on Tukey's honestly significant difference. Treatment means with different lowercase letters across columns indicate significant differences between years within a treatment based on Bonferroni-adjusted multiple t-tests.

[b]Habitat group: MF (mature forest), ES (early successional), or G (generalist); migratory group: SD (short distance), LD (long distance), or R (resident); nesting group: BC (below canopy), CN (canopy), CV (cavity), or GN (generalist).

Table 7 (cont'd). Mean differences in corrected avian abundance (± 1 SE) among green tree retention treatments in pre-treatment (2008-2009) and post-treatment (2010-2011) years for jack pine stands (Minnesota).[a]

	Pre-treatment		Post-treatment	
Species or group	2008	2009	2010	2011
Ovenbird				
0% retention	1.43 (0.05) a	0.80 (0.12) b	0.18 (0.18) Ac	0.00 (0.00) Ac
2.5% retention	1.38 (0.18) a	1.65 (0.43) a	0.14 (0.14) Ab	0.00 (0.00) Ab
7.0% retention	1.03 (0.39)	1.00 (0.18)	0.31 (0.21) A	0.00 (0.00) A
Reference	1.81 (0.15)	2.53 (0.75)	2.14 (0.43) B	1.31 (0.57) B
Chipping Sparrow				
0% retention	0.21 (0.11)	1.02 (0.26)	0.80 (0.40)	0.31 (0.18)
2.5% retention	0.41 (0.13)	0.29 (0.29)	0.45 (0.28)	0.00 (0.00)
7.0% retention	0.50 (0.19)	0.48 (0.32)	0.80 (0.05)	0.28 (0.17)
Reference	0.51 (0.51)	0.00 (0.00)	0.48 (0.06)	0.00 (0.00)
Eastern Wood-Pewee				
0% retention	0.69 (0.22)	1.09 (0.46)	0.00 (0.00)	0.00 (0.00)
2.5% retention	0.57 (0.09)	1.02 (0.40)	0.00 (0.00)	0.12 (0.12)
7.0% retention	1.02 (0.09)	0.49 (0.18)	0.54 (0.28)	0.07 (0.07)
Reference	0.55 (0.28)	1.22 (0.46)	0.81 (0.50)	0.15 (0.15)
Pine Warbler				
0% retention	0.00 (0.00) A	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2.5% retention	0.32 (0.22) AB	0.64 (0.15)	0.00 (0.00)	0.00 (0.00)
7.0% retention	0.85 (0.16) Ba	0.32 (0.22) ab	0.00 (0.00) b	0.00 (0.00) b

Reference	0.56 (0.14) AB	0.43 (0.12)	0.09 (0.09)	0.25 (0.13)
Black-capped Chickadee				
0% retention	0.81 (0.60)	1.25 (0.48)	0.40 (0.40)	0.40 (0.40)
2.5% retention	0.68 (0.12)	0.73 (0.10)	2.97 (0.92)	0.23 (0.23)
7.0% retention	0.80 (0.40)	1.19 (0.23)	2.74 (1.41)	0.00 (0.00)
Reference	0.56 (0.28)	0.18 (0.18)	1.54 (0.38)	0.00 (0.00)
Song Sparrow				
0% retention	0.00 (0.00) a	0.00 (0.00) a	1.11 (0.25) Ab	0.36 (0.19) ABab
2.5% retention	0.00 (0.00) a	0.00 (0.00) a	1.52 (0.25) Ab	1.38 (0.09) Ab
7.0% retention	0.08 (0.08)	0.00 (0.00)	1.32 (0.17) A	0.54 (0.54) AB
Reference	0.00 (0.00)	0.00 (0.00)	0.00 (0.00) B	0.00 (0.00) B
American Robin				
0% retention	0.16 (0.16)	0.00 (0.00)	1.08 (0.22)	0.14 (0.14)
2.5% retention	0.65 (0.12)	0.00 (0.00)	1.41 (0.29)	0.46 (0.20)
7.0% retention	0.48 (0.06)	0.12 (0.12)	0.93 (0.19)	0.09 (0.09)
Reference	0.22 (0.11)	0.09 (0.09)	1.99 (0.75)	0.23 (0.23)
Least Flycatcher				
0% retention	0.96 (0.52)	1.52 (0.73)	0.00 (0.00)	0.00 (0.00)
2.5% retention	0.26 (0.13)	1.32 (0.35)	0.20 (0.20)	0.07 (0.07)
7.0% retention	0.81 (0.27)	0.80 (0.41)	0.24 (0.12)	0.23 (0.15)
Reference	0.07 (0.07)	0.68 (0.44)	2.09 (0.59)	2.23 (2.23)

Hermit Thrush				
0% retention	0.22 (0.11)	0.65 (0.33)	0.35 (0.35) A	0.16 (0.16)
2.5% retention	0.64 (0.15) a	0.82 (0.19) a	0.44 (0.08) Aab	0.00 (0.00) b
7.0% retention	0.34 (0.22)	0.61 (0.41)	0.27 (0.14) A	0.34 (0.17)
Reference	0.47 (0.24) a	0.49 (0.33) a	1.76 (0.30) Bb	0.09 (0.09) a
Chestnut-sided Warbler				
0% retention	1.05 (0.53)	1.16 (0.41)	0.42 (0.25)	0.40 (0.25)
2.5% retention	1.03 (0.30)	0.92 (0.05)	0.09 (0.09)	0.26 (0.15)
7.0% retention	0.65 (0.46)	0.22 (0.12)	0.00 (0.00)	0.19 (0.09)
Reference	0.39 (0.28)	0.00 (0.00)	0.18 (0.18)	0.28 (0.28)
Brown-headed Cowbird				
0% retention	0.30 (0.15)	1.03 (0.30)	0.36 (0.36)	0.27 (0.27)
2.5% retention	0.41 (0.08)	0.91 (0.08)	2.07 (0.50)	0.00 (0.00)
7.0% retention	0.93 (0.20)	1.92 (0.30)	1.32 (0.16)	0.43 (0.43)
Reference	0.44 (0.44)	1.41 (0.09)	0.96 (0.66)	0.00 (0.00)
Red-eyed Vireo				
0% retention	0.63 (0.14)	0.99 (0.46)	0.00 (0.00)	0.19 (0.19)
2.5% retention	0.72 (0.19)	1.50 (0.38)	0.15 (0.15)	0.00 (0.00)
7.0% retention	0.34 (0.19)	0.29 (0.29)	0.15 (0.15)	0.08 (0.08)
Reference	0.52 (0.08)	1.17 (0.38)	0.50 (0.36)	0.33 (0.18)

Eastern Towhee				
0% retention	0.45 (0.33)	0.30 (0.16)	0.83 (0.08)	0.11 (0.11)
2.5% retention	0.00 (0.00)	0.15 (0.07)	0.48 (0.27)	0.60 (0.11)
7.0% retention	0.43 (0.12)	0.86 (0.49)	1.11 (0.43)	0.33 (0.17)
Reference	0.36 (0.36)	0.49 (0.32)	1.14 (0.40)	0.15 (0.15)
American Redstart				
0% retention	1.09 (0.28) ABa	1.09 (0.28) a	0.00 (0.00) b	0.00 (0.00) b
2.5% retention	0.88 (0.27) ABab	1.65 (0.50) b	0.00 (0.00) a	0.00 (0.00) a
7.0% retention	1.72 (0.09) Aa	1.16 (0.22) a	0.00 (0.00) b	0.21 (0.21) b
Reference	0.31 (0.31) B	0.60 (0.29)	0.10 (0.10)	0.00 (0.00)
Dark-eyed Junco				
0% retention	0.09 (0.09) a	0.74 (0.21) ABb	0.00 (0.00) a	0.00 (0.00) a
2.5% retention	0.07 (0.73)	0.00 (0.00) A	0.00 (0.00)	0.00 (0.00)
7.0% retention	0.12 (0.12)	0.18 (0.18) AB	0.11 (0.11)	0.11 (0.11)
Reference	0.09 (0.91)	0.77 (0.17) B	0.00 (0.00)	0.27 (0.27)
Nashville Warbler				
0% retention	0.45 (0.45)	0.58 (0.41)	0.12 (0.12)	0.16 (0.16)
2.5% retention	0.15 (0.15)	0.48 (0.32)	0.09 (0.09)	0.42 (0.30)
7.0% retention	0.27 (0.27)	0.86 (0.34)	0.00 (0.00)	0.09 (0.09)
Reference	0.73 (0.36)	1.11 (0.54)	0.21 (0.11)	0.30 (0.16)

Blue Jay				
0% retention	0.17 (0.17)	0.83 (0.44)	0.91 (0.91)	0.00 (0.00)
2.5% retention	0.40 (0.20)	0.70 (0.36)	3.38 (0.64)	0.00 (0.00)
7.0% retention	0.52 (0.13)	0.09 (0.09)	3.38 (1.89)	2.42 (2.42)
Reference	0.23 (0.11)	0.88 (0.88)	1.16 (0.65)	0.46 (0.25)
Red-breasted Nuthatch				
0% retention	0.00 (0.00)	0.36 (0.23)	0.00 (0.00)	0.00 (0.00)
2.5% retention	0.36 (0.20)	0.60 (0.17)	0.07 (0.07)	0.00 (0.00)
7.0% retention	0.28 (0.17)	0.36 (0.23)	0.00 (0.00)	0.00 (0.00)
Reference	0.43 (0.22)	0.50 (0.19)	0.60 (0.37)	0.14 (0.14)
Veery				
0% retention	0.12 (0.12)	1.20 (0.09)	0.89 (0.47)	0.35 (0.35)
2.5% retention	0.00 (0.00)	0.52 (0.27)	0.56 (0.31)	0.35 (0.35)
7.0% retention	0.88 (0.42)	0.59 (0.26)	0.74 (0.46)	0.00 (0.00)
Reference	0.07 (0.07)	0.49 (0.14)	0.53 (0.09)	0.20 (0.11)
Scarlet Tanager				
0% retention	0.00 (0.00)	0.45 (0.26)	0.00 (0.00)	0.00 (0.00)
2.5% retention	0.81 (0.31)	0.97 (0.45)	0.26 (0.14)	0.09 (0.09)
7.0% retention	0.87 (0.26)	0.35 (0.05)	0.20 (0.20)	0.12 (0.12)
Reference	0.60 (0.40)	0.48 (0.32)	0.00 (0.00)	0.30 (0.16)

American Goldfinch				
0% retention	0.00 (0.00)	0.18 (0.18)	0.20 (0.20)	0.15 (0.15)
2.5% retention	0.14 (0.14)	0.00 (0.00)	0.74 (0.56)	0.37 (0.37)
7.0% retention	0.29 (0.29)	0.00 (0.00)	0.45 (0.23)	0.00 (0.00)
Reference	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Indigo Bunting				
0% retention	0.09 (0.09)	0.23 (0.12)	0.00 (0.00)	0.43 (0.43)
2.5% retention	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.34 (0.17)
7.0% retention	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Reference	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

[a]Treatment means with different upper case letters among rows indicate significant differences among retention treatments within a year based on Tukey's honestly significant difference. Treatment means with different lowercase letters across columns indicate significant differences between years within a treatment based on Bonferroni-adjusted multiple t-tests.

[b]Habitat group: MF (mature forest), ES (early successional), or G (generalist); migratory group: SD (short distance), LD (long distance), or R (resident); nesting group: BC (below canopy), CN (canopy), CV (cavity), or GN (generalist).

Table 8. Mean differences in corrected avian abundance (± 1 SE) among green tree retention treatments in pre-treatment (2008-2009) and post-treatment (2010-2011) years for red pine stands (Wisconsin).[a]

	Pre-treatment		Post-treatment	
Species or group	2008	2009	2010	2011
Richness				
0% retention	7.29 (0.66) a	9.84 (0.39) a	3.18 (0.74) b	2.44 (0.46) b
2.5% retention	7.38 (0.45) a	5.58 (0.34) ab	4.14 (0.72) b	1.64 (0.07) c
7.0% retention	8.79 (1.36)	9.42 (1.98)	6.08 (2.03)	3.29 (0.81)
Reference	7.97 (0.39) a	6.10 (0.26) ab	7.52 (1.05) a	3.42 (0.91) b
Total Abundance				
0% retention	12.58 (1.62) a	16.56 (1.71) a	5.13 (1.04) b	3.56 (0.18) b
2.5% retention	10.36 (0.83) a	8.67 (0.77) ab	5.89 (0.95) bc	2.52 (0.24) c
7.0% retention	13.26 (2.07)	17.02 (4.18)	8.99 (2.84)	4.26 (1.08)
Reference	11.37 (0.62) a	9.78 (0.99) ab	11.01 (1.77) a	4.20 (1.00) b
Diversity				
0% retention	2.15 (0.04)	2.65 (0.03)	1.42 (0.25)	1.52 (0.32)
2.5% retention	2.43 (0.18)	2.25 (0.19)	1.83 (0.14)	1.58 (0.06)
7.0% retention	2.58 (0.15)	2.61 (0.18)	2.36 (0.31)	1.86 (0.24)
Reference	2.61 (0.14)	2.38 (0.05)	2.42 (0.17)	1.80 (0.26)

[a]Treatment means with different upper case letters among rows indicate significant differences among retention treatments within a year based on Tukey's honestly significant difference. Treatment means with different lowercase letters across columns indicate significant differences between years within a treatment based on Bonferroni-adjusted multiple t-tests.

[b]Habitat group: MF (mature forest), ES (early successional), or G (generalist); migratory group: SD (short distance), LD (long distance), or R (resident); nesting group: BC (below canopy), CN (canopy), CV (cavity), or GN (generalist).

Table 8 (cont'd). Mean differences in corrected avian abundance (± 1 SE) among green tree retention treatments in pre-treatment (2008-2009) and post-treatment (2010-2011) years for red pine stands (Wisconsin).[a]

	Pre-treatment	Post-treatment		
Species or group	2008	2009	2010	2011
Long distance				
0% retention	4.22 (0.36) ab	6.93 (0.73) a	1.00 (0.89) b	0.99 (0.59) ABb
2.5% retention	3.66 (0.31) a	3.10 (0.79) ab	0.87 (0.65) bc	0.23 (0.23) Ac
7.0% retention	4.18 (1.01)	6.83 (1.96)	2.11 (0.90)	0.94 (0.30) AB
Reference	3.42 (0.76)	2.85 (0.83)	4.81 (1.37)	2.63 (0.76) B
Short distance				
0% retention	2.76 (0.51)	5.48 (0.55)	3.18 (0.45)	2.51 (0.13)
2.5% retention	2.90 (0.73)	4.38 (0.45)	3.78 (0.19)	1.55 (0.05)
7.0% retention	5.46 (0.33)	4.78 (0.80)	5.00 (0.78)	3.03 (0.90)
Reference	2.77 (0.08)	3.62 (0.97)	3.16 (0.54)	0.87 (0.08)
Resident				
0% retention	1.48 (0.14)	2.02 (0.09)	1.44 (1.11)	1.21 (1.21)
2.5% retention	0.84 (0.65)	1.14 (0.24)	3.29 (2.08)	1.60 (1.07)
7.0% retention	1.56 (0.20)	1.51 (0.27)	5.04 (2.88)	0.00 (0.00)
Reference	1.67 (0.42)	2.07 (0.65)	2.22 (0.33)	0.46 (0.28)
Mature forest				
0% retention	3.12 (0.44) a	4.73 (0.06) Aa	0.77 (0.77) b	0.11 (0.11) Ab
2.5% retention	2.16 (0.18)	1.53 (0.59) B	0.87 (0.65)	0.00 (0.00) A
7.0% retention	1.85 (0.13) ab	3.83 (1.12) ABa	0.71 (0.36) b	0.18 (0.18) Ab

Reference	2.23 (0.36)	1.71 (0.21) B	3.98 (1.02)	1.58 (0.24) B
Early successional				
0% retention	2.99 (0.33)	4.34 (1.02)	0.40 (0.21)	1.63 (0.82)
2.5% retention	3.03 (0.44)	3.82 (1.09)	1.03 (0.09)	0.91 (0.17)
7.0% retention	5.37 (1.14)	4.92 (1.39)	3.08 (0.83)	1.29 (0.45)
Reference	2.69 (0.14)	3.58 (0.38)	2.26 (0.87)	1.50 (0.52)
Generalist (habitat)				
0% retention	2.36 (0.54)	5.36 (0.86)	4.46 (0.98)	2.97 (0.76)
2.5% retention	2.21 (0.47)	3.27 (1.54)	6.03 (2.17)	2.47 (0.96)
7.0% retention	3.99 (0.28)	4.36 (1.07)	8.36 (3.43)	2.50 (0.72)
Reference	2.93 (0.66)	3.26 (1.00)	3.95 (0.96)	0.88 (0.35)
Below canopy				
0% retention	4.24 (0.45) ab	6.23 (0.71) a	1.82 (0.69) Ab	1.68 (0.61) b
2.5% retention	3.60 (0.28) a	4.75 (0.60) a	1.80 (0.17) Ab	1.21 (0.15) b
7.0% retention	6.27 (1.16)	6.82 (1.58)	3.55 (0.84) AB	2.12 (0.66)
Reference	3.33 (0.70)	4.11 (0.14)	5.49 (1.12) B	3.11 (0.70)
Canopy				
0% retention	3.13 (0.19)	4.42 (0.58)	1.82 (1.08)	1.45 (1.45)
2.5% retention	2.78 (0.41)	2.62 (0.65)	3.21 (1.28)	1.28 (1.28)
7.0% retention	3.85 (0.24)	4.44 (1.40)	3.95 (2.26)	0.34 (0.23)
Reference	2.90 (0.59)	2.93 (0.40)	3.15 (1.07)	0.61 (0.31)

Cavity				
0% retention	0.91 (0.29)	1.72 (0.39)	0.23 (0.23)	0.00 (0.00)
2.5% retention	0.67 (0.48)	1.02 (0.12)	1.17 (1.17)	0.39 (0.39)
7.0% retention	0.81 (0.21)	1.33 (0.27)	3.59 (1.80)	0.00 (0.00)
Reference	1.44 (0.36)	1.42 (0.47)	1.55 (0.00)	0.23 (0.12)
Generalist (nesting)				
0% retention	0.19 (0.19)	2.06 (0.84)	1.75 (0.25) A	1.58 (0.37)
2.5% retention	0.35 (0.35) ab	0.23 (0.23) a	1.76 (0.41) Ab	0.50 (0.07) ab
7.0% retention	0.28 (0.28)	0.53 (0.27)	1.06 (0.13) AB	1.51 (0.80)
Reference	0.19 (0.19)	0.09 (0.09)	0.00 (0.00) B	0.00 (0.00)

[a]Treatment means with different upper case letters among rows indicate significant differences among retention treatments within a year based on Tukey's honestly significant difference. Treatment means with different lowercase letters across columns indicate significant differences between years within a treatment based on Bonferroni-adjusted multiple t-tests.

[b]Habitat group: MF (mature forest), ES (early successional), or G (generalist); migratory group: SD (short distance), LD (long distance), or R (resident); nesting group: BC (below canopy), CN (canopy), CV (cavity), or GN (generalist).

Table 8 (cont'd). Mean differences in corrected avian abundance (± 1 SE) among green tree retention treatments in pre-treatment (2008-2009) and post-treatment (2010-2011) years for red pine stands (Wisconsin).[a]

	Pre-treatment	Post-treatment		
Species or group	2008	2009	2010	2011
Ovenbird				
0% retention	2.02 (0.23) a	1.82 (0.59) a	0.12 (0.12) Ab	0.00 (0.00) Ab
2.5% retention	0.95 (0.41)	0.98 (0.45)	0.09 (0.09)A	0.00 (0.00) A
7.0% retention	1.31 (0.18) a	1.44 (0.32) a	0.29 (0.19) ABb	0.00 (0.00) Ab
Reference	1.42 (0.19)	1.05 (0.13)	1.21 (0.38) B	0.92 (0.07) B
Chipping Sparrow				
0% retention	0.50 (0.26)	0.60 (0.09)	0.24 (0.24)	0.29 (0.05)
2.5% retention	0.57 (0.13)	0.87 (0.11)	0.73 (0.24)	0.69 (0.16)
7.0% retention	0.63 (0.32)	0.79 (0.14)	0.61 (0.17)	0.53 (0.22)
Reference	0.32 (0.16)	1.16 (0.26)	1.52 (0.71)	0.51 (0.04)
Eastern Wood-Pewee				
0% retention	0.86 (0.25)	0.83 (0.39)	0.07 (0.07)	0.00 (0.00)
2.5% retention	0.64 (0.14)	0.77 (0.60)	0.00 (0.00)	0.00 (0.00)
7.0% retention	0.63 (0.04)	0.78 (0.22)	0.44 (0.22)	0.00 (0.00)
Reference	0.64 (0.33)	0.39 (0.26)	0.53 (0.29)	0.18 (0.18)
Pine Warbler				
0% retention	1.62 (0.24)	1.52 (0.20)	0.00 (0.00)	0.13 (0.13)
2.5% retention	1.08 (0.06)	1.02 (0.28)	0.10 (0.10)	0.00 (0.00)
7.0% retention	1.71 (0.33)	1.14 (0.13)	0.69 (0.38)	0.00 (0.00)

Reference	1.16 (0.35)	1.18 (0.38)	0.44 (0.22)	0.12 (0.12)
Black-capped Chickadee				
0% retention	0.30 (0.15)	0.87 (0.55)	0.23 (0.23)	0.00 (0.00)
2.5% retention	0.14 (0.14)	0.68 (0.27)	1.17 (1.17)	0.40 (0.40)
7.0% retention	0.60 (0.11)	0.86 (0.19)	3.52 (1.77)	0.00 (0.00)
Reference	1.11 (0.40)	0.94 (0.39)	1.54 (0.00)	0.23 (0.11)
Song Sparrow				
0% retention	0.00 (0.00) a	0.60 (0.29) ab	1.75 (0.25) Ab	1.58 (0.37) b
2.5% retention	0.00 (0.00) a	0.00 (0.00) a	1.58 (0.52) Ab	0.50 (0.07) ab
7.0% retention	0.00 (0.00)	0.16 (0.16)	1.06 (0.13) AB	1.29 (0.60)
Reference	0.00 (0.00)	0.00 (0.00)	0.00 (0.00) B	0.00 (0.00)
American Robin				
0% retention	0.08 (0.08)	0.65 (0.31)	0.43 (0.23)	0.00 (0.00)
2.5% retention	0.60 (0.30)	0.56 (0.31)	0.72 (0.07)	0.07 (0.07)
7.0% retention	0.70 (0.23)	0.99 (0.32)	1.29 (0.30)	0.34 (0.23)
Reference	0.47 (0.11)	0.57 (0.20)	0.86 (0.52)	0.09 (0.09)
Least Flycatcher				
0% retention	0.00 (0.00)	1.12 (0.07)	0.11 (0.11)	0.11 (0.11)
2.5% retention	0.29 (0.29)	0.15 (0.08)	0.28 (0.28)	0.00 (0.00)
7.0% retention	0.07 (0.07)	1.26 (0.80)	0.07 (0.07)	0.00 (0.00)
Reference	0.40 (0.23)	0.14 (0.14)	0.55 (0.55)	0.00 (0.00)

Hermit Thrush				
0% retention	0.89 (0.22) ab	1.14 (0.36) a	0.16 (0.16) ab	0.00 (0.00) b
2.5% retention	0.53 (0.15)	0.40 (0.24)	0.51 (0.30)	0.00 (0.00)
7.0% retention	0.40 (0.17)	0.62 (0.09)	0.28 (0.16)	0.00 (0.00)
Reference	0.41 (0.09)	0.52 (0.27)	1.28 (0.72)	0.45 (0.32)
Chestnut-sided Warbler				
0% retention	0.13 (0.13)	0.80 (0.29)	0.00 (0.00)	0.00 (0.00)
2.5% retention	0.40 (0.23)	0.34 (0.18)	0.00 (0.00)	0.11 (0.11)
7.0% retention	1.12 (0.78)	1.98 (1.01)	0.33 (0.09)	0.60 (0.31)
Reference	0.10 (0.10)	0.08 (0.08)	0.29 (0.16)	0.44 (0.31)
Brown-headed Cowbird				
0% retention	0.19 (0.19)	0.15 (0.60)	0.00 (0.00)	0.00 (0.00)
2.5% retention	0.35 (0.35)	0.23 (0.23)	0.18 (0.18)	0.00 (0.00)
7.0% retention	0.28 (0.28)	0.37 (0.25)	0.00 (0.00)	0.21 (0.21)
Reference	0.19 (0.19)	0.09 (0.09)	0.00 (0.00)	0.00 (0.00)
Red-eyed Vireo				
0% retention	0.07 (0.07)	0.65 (0.25) A	0.38 (0.38)	0.00 (0.00)
2.5% retention	0.40 (0.27)	0.00 (0.00) B	0.00 (0.00)	0.00 (0.00)
7.0% retention	0.07 (0.07) ab	0.35 (0.08) ABa	0.76 (0.08) ab	0.00 (0.00) b
Reference	0.00 (0.00)	0.00 (0.00) B	0.47 (0.22)	0.20 (0.20)

Eastern Towhee				
0% retention	0.14 (0.14)	0.07 (0.07)	0.33 (0.17)	0.18 (0.09)
2.5% retention	0.00 (0.00)	0.27 (0.27)	0.00 (0.00)	0.11 (0.11)
7.0% retention	0.29 (0.29)	0.07 (0.07)	0.18 (0.18)	0.54 (0.31)
Reference	0.22 (0.12)	0.07 (0.07)	0.16 (0.08)	0.07 (0.07)
American Redstart				
0% retention	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.29 (0.29)
2.5% retention	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
7.0% retention	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.17 (0.17)
Reference	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Dark-eyed Junco				
0% retention	0.23 (0.23)	0.58 (0.10)	0.43 (0.43)	0.00 (0.00)
2.5% retention	0.32 (0.32)	0.63 (0.63)	0.27 (0.15)	0.18 (0.18)
7.0% retention	0.76 (0.38)	0.95 (0.23)	0.41 (0.29)	0.11 (0.11)
Reference	0.09 (0.09)	0.55 (0.44)	0.18 (0.09)	0.08 (0.08)
Nashville Warbler				
0% retention	0.11 (0.11)	0.57 (0.57)	0.16 (0.16)	0.42 (0.30)
2.5% retention	0.33 (0.17)	0.29 (0.29)	0.00 (0.00)	0.12 (0.12)
7.0% retention	0.30 (0.17)	0.23 (0.23)	0.46 (0.26)	0.00 (0.00)
Reference	0.23 (0.23)	0.46 (0.46)	0.00 (0.00)	0.44 (0.44)

Blue Jay				
0% retention	0.57 (0.18)	0.30 (0.30)	1.21 (1.21)	1.21 (1.21)
2.5% retention	0.17 (0.17)	0.13 (0.13)	2.11 (1.09)	1.21 (1.21)
7.0% retention	0.75 (0.09)	0.18 (0.09)	1.45 (1.45)	0.00 (0.00)
Reference	0.23 (0.11)	0.65 (0.18)	0.67 (0.33)	0.22 (0.22)
Red-breasted Nuthatch				
0% retention	0.61 (0.17)	0.85 (0.40)	0.00 (0.00)	0.00 (0.00)
2.5% retention	0.53 (0.35)	0.33 (0.18)	0.00 (0.00)	0.00 (0.00)
7.0% retention	0.21 (0.12)	0.47 (0.15)	0.07 (0.07)	0.00 (0.00)
Reference	0.34 (0.07)	0.48 (0.37)	0.00 (0.00)	0.00 (0.00)
Veery				
0% retention	0.13 (0.13)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2.5% retention	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
7.0% retention	0.00 (0.00)	0.08 (0.08)	0.00 (0.00)	0.18 (0.18)
Reference	0.00 (0.00)	0.00 (0.00)	0.37 (0.19)	0.00 (0.00)
Scarlet Tanager				
0% retention	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2.5% retention	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
7.0% retention	0.00 (0.00)	0.09 (0.09)	0.00 (0.00)	0.00 (0.00)
Reference	0.00 (0.00)	0.00 (0.00)	0.10 (0.10)	0.00 (0.00)

American Goldfinch				
0% retention	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.18)
2.5% retention	0.00 (0.00)	0.81 (0.81)	0.20 (0.20)	0.00 (0.00)
7.0% retention	1.10 (0.45)	0.32 (0.32)	0.76 (0.09)	0.00 (0.00)
Reference	0.32 (0.16)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Indigo Bunting				
0% retention	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.17 (0.17)
2.5% retention	0.12 (0.12)	0.18 (0.11)	0.00 (0.00)	0.00 (0.00)
7.0% retention	0.29 (0.29)	0.00 (0.00)	0.17 (0.17)	0.00 (0.00)
Reference	0.22 (0.13)	0.22 (0.13)	0.00 (0.00)	0.00 (0.00)

[a]Treatment means with different upper case letters among rows indicate significant differences among retention treatments within a year based on Tukey's honestly significant difference. Treatment means with different lowercase letters across columns indicate significant differences between years within a treatment based on Bonferroni-adjusted multiple t-tests.

[b]Habitat group: MF (mature forest), ES (early successional), or G (generalist); migratory group: SD (short distance), LD (long distance), or R (resident); nesting group: BC (below canopy), CN (canopy), CV (cavity), or GN (generalist).

Table 9. Summary of post-retention bird stand-level habitat relationships within 12 jack pine (Minnesota) stands that varied in level of green tree retention, 2010-2011. Species and groups that were significantly different between years were analyzed separately. Variables are listed in order of inclusion into stepwise regression models.

Species or group	Model R^{2a}	Variable	Relationship	P
Long distance	0.992***	Pole height	+	0.005
		Basal area of conifer snags	-	0.000
		Downed woody debris (DWD) volume	+	0.000
		Ground cover: woody debris	-	0.000
		Basal area of trees	+	0.001
		Ground cover: soil	-	0.027
Short distance 2010	0.379*	Downed woody debris (DWD) volume	-	0.033
Mature forest	0.997***	Pole height	+	0.000
		Basal area of conifer snags	-	0.000
		Downed woody debris (DWD) volume	+	0.000
		Ground cover: woody debris	-	0.000
		Basal area of trees	+	0.000
		Stand area	-	0.025
Generalist (habitat) 2011	0.307(*)	Ground cover: woody debris	+	0.062
Below canopy 2010	0.908**	Pole height	+	0.010
		Shrub stem count	-	0.001

		Ground cover: litter	-	0.075
		Basal area of conifer snags	-	0.081
Cavity 2010	0.638*	Ground cover: soil	-	0.009
		Ground cover: woody debris	+	0.028
Cavity 2011	0.250(*)	Shrub stem count	+	0.098
Generalist (nesting) 2010	0.849***	Ground cover: litter	-	0.000
		Stand area	+	0.007
Generalist (nesting) 2011	0.432*	Ground cover: litter	-	0.020

[a] Model P values: (*)P≤0.10, *P< 0.05, **P<0.01, ***P<0.001

Table 9 (cont'd). Summary of post-retention bird stand-level habitat relationships within 12 jack pine (Minnesota) stands that varied in level of green tree retention, 2010-2011. Species and groups that were significantly different between years were analyzed separately. Variables are listed in order of inclusion into stepwise regression models.

Species or group	Model R^{2a}	Variable	Relationship	P
Ovenbird	0.927***	Basal area of trees	+	0.000
Chipping Sparrow 2010	0.875**	Shrub stem count	-	0.008
		Basal area of hardwood snags	+	0.003
		Ground cover: herbaceous	-	0.007
		Downed woody debris (DWD) volume	-	0.032
Chipping Sparrow 2011	0.912***	Ground cover: soil	+	0.000
		Ground cover: woody debris	-	0.007
		Basal area of hardwood snags	+	0.068
Pine Warbler	0.998***	Basal area of conifer snags	+	0.000
		Basal area of trees	-	0.007
		Shrub stem count	+	0.099
Black-capped Chickadee 2010	0.298(*)	Shrub stem count	+	0.066
Song Sparrow	0.679**	Basal area of trees	-	0.001
American Robin 2010	0.376*	Ground cover: soil	-	0.034
Least Flycatcher	0.564**	Pole height	+	0.005
Hermit Thrush	0.816***	Pole height	+	0.014

		Basal area of conifer snags	-	0.043
Brown-headed Cowbird 2010	0.862***	Ground cover: herbaceous	+	0.000
		Stand area	+	0.000
Red-eyed Vireo	0.572**	Downed woody debris (DWD) volume	+	0.004
Eastern Towhee 2010	0.364*	Shrub stem count	-	0.038
American Redstart	0.383*	Stand area	+	0.032
Nashville Warbler	0.247(*)	Ground cover: soil	-	0.100
Blue Jay	0.393*	Ground cover: woody debris	+	0.029
Red-breasted Nuthatch	0.768***	Downed woody debris (DWD) volume	+	0.000
Scarlet Tanager	0.284(*)	Basal area of hardwood snags	+	0.075
American Goldfinch	0.519**	Ground cover: litter	-	0.008

[a] Model P values: (*)P≤0.10, *P< 0.05, **P<0.01, ***P<0.001

Table 10. Summary of post-retention bird stand-level habitat relationships within 12 red pine (Wisconsin) stands that varied in level of green tree retention, 2010-2011. Species and groups that were significantly different between years were analyzed separately. Variables are listed in order of inclusion into stepwise regression models.

Species or group	Model R^{2a}	Variable	Relationship	P
Long distance	0.787**	Pole height	+	0.001
		Shrub stem count	+	0.013
Short distance 2010	0.848***	Shrub stem count	+	0.000
		Ground cover: herbaceous	-	0.001
Short distance 2011	0.946***	Downed woody debris (DWD) volume	+	0.000
		Basal area of trees	-	0.000
		Ground cover: herbaceous	+	0.044
Resident	0.660**	Stand area	-	0.030
		Shrub stem count	+	0.031
Mature forest	0.861***	Pole height	+	0.000
		Basal area of conifer snags	-	0.075
Early successional	0.716**	Shrub stem count	+	0.002
		Basal area of trees	+	0.020
Generalist (habitat) 2010	0.861**	Shrub stem count	+	0.002
		Stand area	-	0.016
		Basal area of conifer snags	-	0.016

Generalist (habitat) 2011	0.450*	Basal area of trees	-	0.017
Below canopy	0.701**	Pole height	+	0.004
		Shrub stem count	+	0.015
Canopy 2010	0.993***	Shrub stem count	+	0.000
		Downed woody debris (DWD) volume	-	0.000
		Stand area	-	0.000
		Basal area of conifer snags	-	0.000
		Ground cover: soil	-	0.003
		Basal area of trees	+	0.000
Canopy 2011	0.275(*)	Ground cover: soil	+	0.080
Cavity	0.314(*)	Shrub stem count	+	0.058
Generalist (nesting)	0.874***	Basal area of trees	-	0.000
		Downed woody debris (DWD) volume	+	0.057

[a] Model P values: (*)P≤0.10, *P< 0.05, **P<0.01, ***P<0.001

Table 10 (cont'd). Summary of post-retention bird stand-level habitat relationships within 12 red pine (Wisconsin) stands that varied in level of green tree retention, 2010-2011. Species and groups that were significantly different between years were analyzed separately. Variables are listed in order of inclusion into stepwise regression models.

Species or group	Model R^{2a}	Variable	Relationship	P
Ovenbird	0.791***	Pole height	+	0.000
Chipping Sparrow 2010	0.862**	Basal area of conifer snags	+	0.005
		Ground cover: litter	+	0.014
		Downed woody debris (DWD) volume	+	0.042
Eastern Wood-Pewee	0.571*	Basal area of trees	+	0.014
		Shrub stem count	+	0.060
Pine Warbler	0.736**	Shrub stem count	+	0.002
		Basal area of trees	+	0.014
Black-capped Chickadee	0.317(*)	Shrub stem count	+	0.057
Song Sparrow	0.870***	Ground cover: litter	-	0.000
		Shrub stem count	-	0.078
American Robin 2010	0.959***	Basal area of conifer snags	-	0.004
		Ground cover: litter	+	0.008
		Pole height	-	0.002
		Shrub stem count	+	0.002
		Basal area of trees	+	0.082

American Robin 2011	0.553**	Shrub stem count	+	0.006
Least Flycatcher	0.728**	Basal area of hardwood snags	+	0.002
		Downed woody debris (DWD) volume	-	0.009
Hermit Thrush	0.749**	Ground cover: woody debris	-	0.002
		Basal area of conifer snags	-	0.031
		Stand area	-	0.072
Chestnut-sided Warbler	0.815**	Shrub stem count	+	0.001
		Basal area of trees	+	0.006
		Pole height	-	0.037
Brown-headed Cowbird	0.269(*)	Downed woody debris (DWD) volume	+	0.084
Red-eyed Vireo	0.818**	Basal area of conifer snags	+	0.002
		Ground cover: soil	+	0.008
		Shrub stem count	+	0.051
Eastern Towhee	0.904***	Shrub stem count	+	0.000
		Stand area	+	0.003
American Redstart	0.794**	Shrub stem count	+	0.009
		Ground cover: soil	+	0.011
		Ground cover: litter	-	0.039
Dark-eyed Junco	0.374*	Downed woody debris (DWD) volume	+	0.035

Nashville Warbler	0.833**	Ground cover: soil	+	0.001
		Shrub stem count	+	0.010
		Basal area of conifer snags	-	0.033
Blue Jay	0.524*	Ground cover: herbaceous	+	0.033
		Stand area	-	0.099
Red-breasted Nuthatch	0.570**	Downed woody debris (DWD) volume	+	0.005
Veery	0.697**	Ground cover: litter	+	0.002
		Basal area of conifer snags	-	0.022
Scarlet Tanager	0.712*	Ground cover: soil	+	0.040
		Ground cover: litter	+	0.020
		Basal area of conifer snags	-	0.075
American Goldfinch	0.397*	Ground cover: litter	-	0.028
Indigo Bunting	0.851***	Stand area	+	0.000
		Shrub stem count	+	0.000

[a] Model P values: (*)P≤0.10, *P< 0.05, **P<0.01, ***P<0.001

Table 11. Summary of post-retention bird patch-level habitat relationships within 6 jack pine (Minnesota) stands that varied in level of green tree retention, 2010-2011. Species and groups that were significantly different between years were analyzed separately. Variables are listed in order of inclusion into stepwise regression models.

Species or group	Model R^{2a}	Variable	Relationship	P
Long distance	0.912*	Minimum distance between patch and edge	-	0.023
		Canopy Closure	-	0.081
Short distance 2010	0.973**	Snag dbh	+	0.042
		Tree height	-	0.074
Mature forest	0.953*	Minimum distance between patch and edge	-	0.011
		Snag height	+	0.043
Early successional	0.941*	Snag dbh	+	0.015
		Snag height	-	0.076
Below canopy 2010	0.995**	Proportion of blowdown per patch	-	0.006
		Tree height	-	0.016
		Snag height	-	0.056
Canopy	0.989*	Patches per stand	+	0.007
		Patch area	-	0.026
		Minimum distance between patch and edge	+	0.084
Cavity 2011	0.956**	Proportion of blowdown per patch	+	0.008
		Tree height	+	0.078

Generalist (nesting) 2010	0.963**	Trees per hectare	-	0.003
		Basal area of trees	-	0.032

[a] Model P values: (*)P≤0.10, *P< 0.05, **P<0.01, ***P<0.001

Table 11 (cont'd). Summary of post-retention bird patch-level habitat relationships within 6 jack pine (Minnesota) stands that varied in level of green tree retention, 2010-2011. Species and groups that were significantly different between years were analyzed separately. Variables are listed in order of inclusion into stepwise regression models.

Species or group	Model R^{2a}	Variable	Relationship	P
Chipping Sparrow 2010	0.997**	Proportion of blowdown per patch	-	0.002
		Snag height	+	0.009
		Minimum distance between patches	-	0.027
Chipping Sparrow 2011	0.890*	Patch area	+	0.018
		Minimum distance between patches	+	0.081
Eastern Wood-Pewee	0.971**	Patches per stand	+	0.002
		Minimum distance between patches	+	0.033
Black-capped Chickadee 2011	0.956**	Proportion of blowdown per patch	+	0.008
		Tree height	+	0.078
Song Sparrow	0.997**	Patches per stand	-	0.002
		Tree height	-	0.014
		Patch area	+	0.047
American Robin 2011	0.992***	Basal area of trees	+	0.000
Hermit Thrush	0.922*	Patches per stand	+	0.012
		Tree height	-	0.034
Eastern Towhee 2011	0.553 (*)	Patch area	-	0.090

American Redstart	0.997**	Patch area	+	0.002
		Patches per stand	-	0.005
		Minimum distance between patches	+	0.029
Nashville Warbler	0.989**	Minimum distance between patches	+	0.001
		Tree height	-	0.007
Blue Jay	0.981*	Patches per stand	+	0.012
		Minimum distance between patch and edge	+	0.061
		Patch area	-	0.075
Red-breasted Nuthatch	0.956**	Proportion of blowdown per patch	+	0.008
		Tree height	+	0.078
Veery	0.995**	Snag dbh	+	0.010
		Canopy closure	+	0.019
		Minimum distance between patch and edge	-	0.084
Scarlet Tanager	0.993*	Minimum distance between patch and edge	-	0.005
		Patch area	-	0.010
		Tree height	+	0.075
American Goldfinch	0.709*	Basal area of trees	+	0.035
Indigo Bunting	0.599(*)	Trees per hectare	-	0.071

[a] Model P values: (*)P≤0.10, *P< 0.05, **P<0.01, ***P<0.001

Table 12. Summary of post-retention bird patch-level habitat relationships within 6 red pine (Wisconsin) stands that varied in level of green tree retention, 2010-2011. Species and groups that were significantly different between years were analyzed separately. Variables are listed in order of inclusion into stepwise regression models.

Species or group	Model R^{2a}	Variable	Relationship	P
Short distance 2010	0.670*	Patch area	+	0.046
Early successional	0.776*	Patch area	+	0.020
Generalist (habitat) 2010				
Generalist (habitat) 2011	0.999**	Tree height	+	0.001
		Snag dbh	-	0.001
		Snag height	+	0.003
Canopy 2010	0.978**	Proportion of blowdown per patch	-	0.001
		Snag height	+	0.005
Canopy 2011	0.984**	Minimum distance between patch and edge	+	0.017
Cavity	0.884*	Snag dbh	-	0.021
		Basal area of trees	+	0.066
Generalist (nesting)	0.933*	Canopy closure	-	0.008
		Patch area	+	0.067

[a] Model P values: (*)P≤0.10, *P< 0.05, **P<0.01, ***P<0.001

Table 12 (cont'd). Summary of post-retention bird patch-level habitat relationships within 6 red pine (Wisconsin) stands that varied in level of green tree retention, 2010-2011. Species and groups that were significantly different between years were analyzed separately. Variables are listed in order of inclusion into stepwise regression models.

Species or group	Model R^{2a}	Variable	Relationship	P
Chipping Sparrow 2010	0.752*	Proportion of blowdown per patch	+	0.025
Chipping Sparrow 2011	0.999**	Proportion of blowdown per patch	+	0.002
		Canopy closure	-	0.004
		Minimum distance between patches	-	0.010
Pine Warbler	0.840*	Patch area	+	0.010
Black-capped Chickadee	0.886*	Snag dbh	-	0.021
		Basal area of trees	+	0.062
Song Sparrow	0.647(*)	Canopy closure	-	0.054
American Robin 2010	0.807*	Patch area	+	0.015
American Robin 2011	0.990**	Minimum distance between patch and edge	+	0.000
		Proportion of blowdown per patch	-	0.003
Hermit Thrush	0.538(*)	Tree height	-	0.097
Chestnut-sided Warbler	0.640(*)	Patch area	+	0.056
Brown-headed Cowbird	0.596(*)	Proportion of blowdown per patch	+	0.072
Red-eyed Vireo	0.996***	Basal area of trees	+	0.000

		Trees per hectare	+	0.001
Eastern Towhee	0.581(*)	Patch area	+	0.078
American Redstart	0.996***	Basal area of trees	+	0.000
		Trees per hectare	+	0.001
Dark-eyed Junco	0.962**	Snag dbh	-	0.001
Nashville Warbler	0.673*	Patch area	+	0.046
Blue Jay	0.998***	Tree dbh	+	0.000
		Basal area of trees	-	0.000
Veery	0.650(*)	Snag height	-	0.053
American Goldfinch	0.593(*)	Trees per hectare	+	0.073
Indigo Bunting	0.996***	Basal area of trees	+	0.000
		Trees per hectare	+	0.001

[a] Model P values: (*)P≤0.10, *P< 0.05, **P<0.01, ***P<0.001

Appendix A. Common names of all bird species included in overall analyses with 4-letter code, scientific names and species assemblage designations for migratory strategy, habitat use, and nesting habitat.

Code	Common Name	*Scientific Name*	Migratory strategy (MS)[a]	Habitat-use (HU)[b]	Nesting habitat (NH)[c]
AMCR	American Crow	*Corvus brachyrhynchos*	R	G	Cnpy
AMGO	American Goldfinch	*Carduelis tristis*	SD	ES	BC
AMKE	American Kestrel	*Falco sparverius*	SD	ES	Cvty
AMRE	American Redstart	*Setophaga ruticilla*	LD	ES	BC
AMRO	American Robin	*Turdus migratorius*	SD	G	Cnpy
BAOR	Baltimore Oriole	*Icterus galbula*	LD	G	Cnpy
BAWW	Black and White warbler	*Mniotilla varia*	LD	MF	BC
BBWO	Black-backed Woodpecker	*Picoides arcticus*	R	ES	Cvty
BCCH	Black-capped Chickadee	*Poecile atricapillus*	R	G	Cvty
BHCO	Brown-headed Cowbird	*Molothrus ater*	SD	G	GN
BHVI	Blue-headed Vireo	*Vireo solitarius*	SD	ES	BC
BLJA	Blue Jay	*Cyanocitta cristata*	R	G	Cnpy
BRCR	Brown Creeper	*Certhia americana*	R	MF	Cvty
BTNW	Black-throated Green Warbler	*Dendroica virens*	LD	ES	BC
BWHA	Broad-winged Hawk	*Buteo platypterus*	LD	MF	Cnpy
CAWA	Canada Warbler	*Wilsonia canadensis*	LD	MF	BC
CEDW	Cedar Waxwing	*Bombycilla cedrorum*	SD	G	BC
CHSP	Chipping Sparrow	*Spizella passerina*	SD	ES	BC
CORA	Common Raven	*Corvus corax*	R	G	GN
COYE	Common Yellowthroat	*Geothlypis trichas*	LD	ES	BC
CSWA	Chestnut-sided Warbler	*Dendroica pensylvanica*	LD	ES	BC
DEJU	Dark-eyed Junco	*Junco hyemalis*	SD	G	BC
DOWO	Downy Woodpecker	*Picoides pubescens*	R	MF	Cvty
EABL	Eastern Bluebird	*Sialia sialis*	SD	ES	Cvty
EAKI	Eastern Kingbird	*Tyrannus tyrannus*	LD	ES	Cnpy
EAPH	Eastern Phoebe	*Sayornis phoebe*	LD	G	GN
EATO	Eastern Towhee	*Pipilo erythrophthalmus*	SD	G	BC
EAWP	Eastern Wood-Pewee	*Contopus virens*	LD	G	Cnpy
FISP	Field Sparrow	*Spizella pusilla*	SD	ES	BC
GBHE	Great Blue Heron	*Ardea herodias*	SD	G	Cnpy
GCFL	Great-crested Flycatcher	*Myiarchus crinitus*	LD	MF	Cvty
GCKI	Golden-crowned Kinglet	*Regula satrapa*	SD	ES	Cnpy
GRCA	Gray Catbird	*Dumetella carolinensis*	LD	ES	BC
GRSP	Grasshopper Sparrow	*Ammodramus savannarum*	SD	ES	BC
GWWA	Golden-winged warbler	*Vermivora chrysoptera*	LD	ES	BC
HAWO	Hairy Woodpecker	*Picoides villosus*	R	MF	Cvty
HETH	Hermit Thrush	*Catharus guttatus*	LD	MF	BC
HOWR	House Wren	*Troglodytes aedon*	SD	G	Cvty
INBU	Indigo Bunting	*Passerina cyanea*	LD	ES	BC

[a]Long distance migrants (LD), Short distance migrants (SD), Residents (R)

[b]Early successional (ES), Mature forest (MF), Generalist (G)

[c]Below canopy (BC), Canopy (Cnpy), Cavity (Cvty), Generalist (GN)

Appendix A (cont'd). Common names of all bird species included in overall analyses with 4-letter code, scientific names and species assemblage designations for migratory strategy, habitat use, and nesting habitat.

Code	Common Name	*Scientific Name*	Migratory strategy (MS)[a]	Habitat-use (HU)[b]	Nesting habitat (NH)[c]
KILL	Killdeer	*Charadrius vociferus*	SD	ES	BC
LEFL	Least Flycatcher	*Empidonax minimus*	LD	MF	Cnpy
MODO	Mourning Dove	*Zenaida macroura*	SD	G	GN
MOWA	Mourning Warbler	*Oporornis philadelphia*	LD	ES	BC
NOFL	Northern Flicker	*Colaptes auratus*	SD	ES	Cvty
NAWA	Nashville Warbler	*Vermivora ruficapilla*	LD	ES	BC
OVEN	Ovenbird	*Seiurus aurocapilla*	LD	MF	BC
PIWA	Pine Warbler	*Dendroica pinus*	SD	ES	Cnpy
PIWO	Pileated Woodpecker	*Dryocopus pileatus*	R	MF	Cvty
PUFI	Purple Finch	*Carpodacus purpureus*	SD	ES	Cnpy
RBGR	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	LD	G	BC
RBNU	Red-breasted Nuthatch	*Sitta canadensis*	R	ES	Cvty
RBWO	Red-bellied Woodpecker	*Melanerpes carolinus*	R	MF	Cvty
RECR	Red Crossbill	*Loxia curvirostra*	R	ES	Cnpy
REVI	Red-eyed Vireo	*Vireo olivaceus*	LD	MF	BC
RTHU	Ruby-throated Hummingbird	*Archilochus colubris*	LD	G	BC
RUGR	Ruffed Grouse	*Bonasa umbellus*	R	MF	BC
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*	SD	ES	BC
SCTA	Scarlet tanager	*Piranga olivacea*	LD	MF	Cnpy
SOSP	Song Sparrow	*Melospiza melodia*	SD	G	GN
TRES	Tree Swallow	*Tachycineta bicolor*	SD	ES	Cvty
VEER	Veery	*Catharus fuscescens*	LD	MF	BC
VESP	Vesper Sparrow	*Pooecetes gramineus*	SD	ES	BC
WAVI	Warbling Vireo	*Vireo gilvus*	LD	MF	Cnpy
WBNU	White-breasted Nuthatch	*Sitta carolinensis*	R	MF	Cvty
WCSP	White-crowned Sparrow	*Zonotrichia leucophrys*	SD	ES	BC
WITU	Wild Turkey	*Meleagris gallopavo*	R	MF	BC
WTSP	White-throated Sparrow	*Zonotrichia leucophrys*	SD	G	BC
YBSA	Yellow-bellied Sapsucker	*Sphyrapicus varius*	SD	ES	Cvty
YRWA	Yellow-rumped Warbler	*Dendroica coronata*	LD	MF	BC
YTVI	Yellow-throated Vireo	*Vireo flavifrons*	LD	MF	Cnpy
YWAR	Yellow Warbler	*Dendroica petechia*	LD	ES	BC

[a]Long distance migrants (LD), Short distance migrants (SD), Residents (R)

[b]Early successional (ES), Mature forest (MF), Generalist (G)

[c]Below canopy (BC), Canopy (Cnpy), Cavity (Cvty), Generalist (GN)

Appendix B. Repeated measures ANOVA comparing avian richness, diversity, and abundance among four levels of green tree retention (0%, 2.5%, 7%, 100%) in jack pine stands (Minnesota), before (2008-2009) and after (2010-2011) the implementation of retention treatments. Corrected abundance was used for species and groups.

Species or Group and Source	SS	*df*	MS	*F*	*P*
Richness					
Between					
Treatment	16.445	3	5.482	0.815	0.521
Error	53.812	8	6.726		
Within					
Year	523.120	3	174.373	138.546	0.000
Treatment X Year	100.882	9	11.209	8.906	0.000
Error	30.206	24	1.259		
Total Abundance					
Between					
Treatment	80.370	3	26.790	2.889	0.102
Error	74.175	8	9.272		
Within					
Year	1574.598	3	524.866	108.133	0.000
Treatment X Year	330.035	9	36.671	7.555	0.000
Error	116.493	24	4.854		
Diversity					
Between					
Treatment	0.984	3	0.328	1.326	0.332
Error	1.979	8	0.247		
Within*					

Year	5.214	1.948	2.677	42.016	0.000
Treatment X Year	0.743	5.843	0.127	1.996	0.129
Error	0.993	15.581	0.064		
Long distance					
Between					
Treatment	39.622	3	13.207	5.422	0.025
Error	19.416	8	2.427		
Within					
Year	309.210	3	103.070	44.761	0.000
Treatment X Year	118.697	9	13.189	5.727	0.000
Error	55.264	24	2.303		
Short distance					
Between					
Treatment	12.578	3	4.193	1.198	0.371
Error	27.996	8	3.499		
Within					
Year	96.728	3	32.243	30.296	0.000
Treatment X Year	19.467	9	2.163	2.032	0.080
Error	25.542	24	1.064		
Resident					
Between					
Treatment	21.157	3	7.052	2.075	0.182
Error	27.193	8	3.399		
Within					
Year	82.274	3	27.425	7.386	0.001

Treatment X Year	43.693	9	4.855	1.308	0.284
Error	89.112	24	3.713		
Mature forest					
Between					
Treatment	51.069	3	17.023	13.766	0.002
Error	9.983	8	1.237		
Within					
Year	92.903	3	30.968	18.182	0.000
Treatment X Year	62.261	9	6.918	4.062	0.003
Error	40.878	24	1.703		
Early successional					
Between					
Treatment	3.037	3	1.012	0.879	0.492
Error	9.211	8	1.151		
Within					
Year	65.107	3	21.702	29.770	0.000
Treatment X Year	11.926	9	1.325	1.818	0.117
Error	17.496	24	0.729		
Generalist (habitat)					
Between					
Treatment	52.096	3	17.365	2.548	0.129
Error	54.524	8	6.816		
Within*					
Year	310.153	1.663	186.513	32.387	0.000
Treatment X Year	80.030	4.989	16.042	2.786	0.062
Error	76.613	13.303	5.759		

Below canopy					
Between					
Treatment	9.312	3	3.104	0.642	0.609
Error	38.687	8	4.836		
Within					
Year	186.348	3	62.116	41.723	0.000
Treatment X Year	34.521	9	3.836	2.576	0.031
Error	35.730	24	1.489		
Canopy					
Between					
Treatment	27.780	3	9.260	1.304	0.338
Error	56.794	8	7.099		
Within					
Year	50.272	3	16.757	4.928	0.008
Treatment X Year	49.505	9	5.501	1.618	0.166
Error	81.606	24	3.400		
Cavity					
Between					
Treatment	3.031	3	1.010	2.039	0.187
Error	3.964	8	0.495		
Within*					
Year	21.906	1.603	13.662	7.598	0.009
Treatment X Year	11.600	4.810	2.412	1.341	0.308
Error	23.066	12.827	1.798		
Generalist (nesting)					
Between					

Treatment	8.309	3	2.770	5.780	0.021
Error	3.833	8	0.479		
Within*					
Year	19.087	1.874	10.183	23.810	0.000
Treatment X Year	10.110	5.623	1.798	4.204	0.012
Error	6.413	14.996	0.428		
Ovenbird					
Between					
Treatment	15.198	3	5.006	6.465	0.016
Error	6.269	8	0.784		
Within					
Year	11.605	3	3.888	26.826	0.000
Treatment X Year	3.442	9	0.382	2.652	0.027
Error	3.461	24	0.144		
Chipping Sparrow					
Between					
Treatment	1.027	3	0.342	2.180	0.168
Error	1.256	8	0.157		
Within					
Year	1.400	3	0.467	2.809	0.061
Treatment X Year	1.400	9	0.160	0.963	0.493
Error	3.987	24	0.166		
Eastern Wood-Pewee					
Between					
Treatment	0.499	3	0.166	0.609	0.628

Error	2.185	8	0.273		
Within					
Year	5.360	3	1.787	9.609	0.000
Treatment X Year	2.411	9	0.268	1.441	0.226
Error	4.463	24	0.186		
Pine Warbler					
Between					
Treatment	0.793	3	0.264	7.189	0.012
Error	0.294	8	0.037		
Within					
Year	1.497	3	0.499	13.216	0.000
Treatment X Year	1.158	9	0.129	3.408	0.008
Error	0.906	24	0.038		
Black-capped Chickadee					
Between					
Treatment	3.471	3	1.157	2.537	0.130
Error	3.648	8	0.456		
Within					
Year	19.349	3	6.450	7.012	0.002
Treatment X Year	11.967	9	1.330	1.446	0.224
Error	22.075	24	0.920		
Song Sparrow					
Between					
Treatment	3.290	3	1.097	8.542	0.007
Error	1.027	8	0.128		
Within*					

Year	8.140	1.600	5.086	33.732	0.000
Treatment X Year	3.961	4.801	0.825	5.471	0.007
Error	1.931	12.803	0.151		
American Robin					
Between					
Treatment	0.808	3	0.269	0.918	0.474
Error	0.2347	8	0.293		
Within					
Year	12.132	3	4.044	29.942	0.000
Treatment X Year	1.909	9	0.212	1.571	0.181
Error	3.241	24	0.135		
Least Flycatcher					
Between					
Treatment	4.990	3	1.663	1.028	0.430
Error	12.944	8	1.618		
Within					
Year	2.216	3	0.739	0.643	0.595
Treatment X Year	16.954	9	1.884	1.639	0.160
Error	27.585	24	1.149		
Hermit Thrush					
Between					
Treatment	0.917	3	0.306	2.372	0.146
Error	1.030	8	0.129		
Within					
Year	2.302	3	0.767	4.433	0.013
Treatment X Year	4.221	9	0.469	2.709	0.025

Error	4.154	24	0.173		
Chestnut-sided Warbler					
Between					
Treatment	2.406	3	0.802	2.583	0.126
Error	2.483	8	0.310		
Within					
Year	2.762	3	0.921	5.290	0.006
Treatment X Year	1.644	9	0.183	1.050	0.432
Error	4.176	24	0.174		
Brown-headed Cowbird					
Between					
Treatment	2.778	3	0.926	2.626	0.122
Error	2.821	8	0.353		
Within					
Year	10.611	3	3.537	13.272	0.000
Treatment X Year	4.801	9	0.533	2.002	0.084
Error	6.396	24	0.266		
Red-eyed Vireo					
Between					
Treatment	1.277	3	0.426	1.197	0.371
Error	2.844	8	0.355		
Within					
Year	5.353	3	1.784	15.885	0.000
Treatment X Year	1.890	9	0.210	1.870	0.107
Error	2.696	24	0.112		
Eastern Towhee					

Between					
Treatment	0.917	3	0.306	1.133	0.392
Error	2.159	8	0.270		
Within					
Year	2.756	3	0.919	4.866	0.009
Treatment X Year	1.624	9	0.180	0.956	0.498
Error	4.532	24	0.189		
American Redstart					
Between					
Treatment	1.749	3	0.583	2.720	0.115
Error	1.715	8	0.214		
Within					
Year	12.701	3	4.234	35.074	0.000
Treatment X Year	3.120	9	0.347	2.872	0.019
Error	2.897	24	0.121		
Dark-eyed Junco					
Between					
Treatment	0.460	3	0.153	6.130	0.018
Error	0.200	8	0.025		
Within					
Year	1.148	3	0.383	7.436	0.001
Treatment X Year	1.082	9	0.120	2.337	0.047
Error	1.235	24	0.051		
Nashville Warbler					
Between					
Treatment	0.700	3	0.233	0.631	0.616

Error	2.959	8	0.370		
Within					
Year	2.837	3	0.946	4.774	0.010
Treatment X Year	0.861	9	0.096	0.483	0.871
Error	4.753	24	0.198		
Blue Jay					
Between					
Treatment	9.016	3	3.005	1.485	0.290
Error	16.190	8	2.024		
Within*					
Year	25.531	1.999	12.771	3.847	0.043
Treatment X Year	21.006	5.997	3.503	1.055	0.428
Error	53.095	15.992	3.320		
Red-breasted Nuthatch					
Between					
Treatment	0.725	3	0.242	8.449	0.007
Error	0.229	8	0.029		
Within*					
Year	1.099	2.039	0.539	3.587	0.050
Treatment X Year	0.510	6.117	0.083	0.555	0.763
Error	2.451	16.312	0.150		
Veery					
Between					
Treatment	0.838	3	0.279	1.031	0.429
Error	2.169	8	0.271		
Within					

Year	2.349	3	0.783	3.954	0.020
Treatment X Year	2.190	9	0.243	1.229	0.324
Error	4.753	24	0.198		
Scarlet Tanager					
Between					
Treatment	1.100	3	0.367	1.484	0.291
Error	1.976	8	0.247		
Within					
Year	2.382	3	0.794	6.573	0.002
Treatment X Year	1.309	9	0.145	1.204	0.338
Error	2.900	24	0.121		
American Goldfinch					
Between					
Treatment	0.598	3	0.199	2.686	0.117
Error	0.594	8	0.074		
Within*					
Year	0.624	1.613	0.387	1.377	0.281
Treatment X Year	0.823	4.838	0.170	0.606	0.692
Error	3.623	12.901	0.281		
Indigo Bunting					
Between					
Treatment	0.291	3	0.097	1.459	0.297
Error	0.533	8	0.067		
Within*					
Year	0.264	1.135	0.233	2.399	0.155
Treatment X Year	0.305	3.405	0.090	0.924	0.478

Error	0.882	9.081	0.097	

* Indicates a significant Mauchly's test of sphericity, therefore corrected Greenhouse-Geisser values were used.

Appendix C. Repeated measures ANOVA comparing avian richness, diversity, and abundance among four levels of green tree retention (0%, 2.5%, 7%, 100%) in red pine stands (Wisconsin), before (2008-2009) and after (2010-2011) the implementation of retention treatments. Corrected abundance was used for species and groups.

Species or Group and Source	SS	*df*	MS	*F*	*P*
Richness					
Between					
Treatment	31.495	3	10.498	1.586	0.267
Error	52.965	8	6.621		
Within					
Year	215.035	3	71.678	47.186	0.000
Treatment X Year	56.774	9	6.308	4.153	0.003
Error	36.457	24	1.519		
Total Abundance					
Between					
Treatment	99.677	3	33.226	1.696	0.244
Error	156.692	8	19.587		
Within					
Year	656.638	3	218.879	45.279	0.000
Treatment X Year	162.364	9	18.040	3.732	0.005
Error	116.015	24	4.834		
Diversity					
Between					
Treatment	1.522	3	0.507	2.678	0.118
Error	1.515	8	0.189		
Within					

Year	5.035	3	1.678	21.632	0.000
Treatment X Year	1.471	9	0.163	2.106	0.070
Error	1.862	24	0.078		
Long distance					
Between					
Treatment	19.185	3	6.395	1.122	0.396
Error	45.591	8	5.699		
Within					
Year	100.173	3	33.391	27.141	0.000
Treatment X Year	67.517	9	7.502	6.098	0.000
Error	29.526	24	1.230		
Short distance					
Between					
Treatment	24.698	3	8.233	5.447	0.025
Error	12.092	8	1.512		
Within					
Year	41.799	3	13.933	19.059	0.000
Treatment X Year	11.666	9	1.296	1.773	0.127
Error	17.545	24	0.731		
Resident					
Between					
Treatment	1.691	3	0.564	0.155	0.924
Error	29.127	8	3.641		
Within*					
Year	30.693	1.518	20.226	3.144	0.089

Treatment X Year	27.849	4.553	6.117	0.951	0.477
Error	78.091	12.140	6.432		
Mature forest					
Between					
Treatment	11.176	3	3.725	3.937	0.054
Error	7.569	8	0.946		
Within					
Year	41.228	3	13.743	18.083	0.000
Treatment X Year	41.978	9	4.644	6.137	0.000
Error	18.239	24	0.760		
Early successional					
Between					
Treatment	16.231	3	5.410	1.456	0.298
Error	29.726	8	3.716		
Within					
Year	68.295	3	22.765	24.852	0.000
Treatment X Year	14.812	9	1.646	1.797	0.121
Error	21.985	24	0.916		
Generalist (habitat)					
Between					
Treatment	25.869	3	8.623	1.630	0.258
Error	42.328	8	5.291		
Within					
Year	84.596	3	28.199	5.729	0.004
Treatment X Year	31.958	9	3.551	0.721	0.685
Error	118.133	24	4.922		

Below canopy					
Between					
Treatment	22.180	3	7.393	1.525	0.281
Error	38.789	8	4.849		
Within					
Year	79.890	3	26.630	38.194	0.000
Treatment X Year	41.596	9	4.622	6.629	0.000
Error	16.734	24	0.697		
Canopy					
Between					
Treatment	4.093	3	1.364	0.675	0.591
Error	16.176	8	2.022		
Within					
Year	51.536	3	17.179	5.005	0.008
Treatment X Year	15.954	9	1.773	0.516	0.848
Error	82.379	24	3.432		
Cavity					
Between					
Treatment	3.879	3	1.293	0.876	0.493
Error	11.810	8	1.476		
Within*					
Year	15.021	1.426	10.530	5.270	0.032
Treatment X Year	16.220	4.279	3.790	1.897	0.177
Error	22.803	11.412	1.998		
Generalist (nesting)					
Between					

Treatment	10.670	3	3.557	6.314	0.017
Error	4.506	8	0.563		
Within					
Year	5.134	3	1.711	4.983	0.008
Treatment X Year	8.367	9	0.930	2.707	0.025
Error	8.241	24	0.343		
Ovenbird					
Between					
Treatment	2.845	3	0.948	2.454	0.138
Error	3.091	8	0.386		
Within					
Year	13.419	3	4.473	27.299	0.000
Treatment X Year	4.724	9	0.525	3.203	0.011
Error	3.932	24	0.164		
Chipping Sparrow					
Between					
Treatment	1.375	3	0.458	1.973	0.197
Error	1.858	8	0.232		
Within					
Year	1.181	3	0.394	2.169	0.118
Treatment X Year	2.136	9	0.237	1.308	0.284
Error	4.355	24	0.181		
Eastern Wood-Pewee					
Between					
Treatment	0.086	3	0.029	0.094	0.961

Error	2.439	8	0.305		
Within					
Year	3.753	3	1.251	8.806	0.000
Treatment X Year	1.116	9	0.124	0.873	0.562
Error	3.410	24	0.142		
Pine Warbler					
Between					
Treatment	0.778	3	0.259	1.212	0.366
Error	1.712	8	0.214		
Within					
Year	15.549	3	5.183	39.804	0.000
Treatment X Year	1.530	9	0.170	1.306	0.285
Error	3.125	24	0.130		
Black-capped Chickadee					
Between					
Treatment	5.564	3	1.855	1.564	0.272
Error	9.490	8	1.186		
Within*					
Year	13.856	1.443	9.602	4.714	0.041
Treatment X Year	13.674	4.329	3.159	1.551	0.251
Error	23.514	11.544	2.037		
Song Sparrow					
Between					
Treatment	5.966	3	1.989	14.786	0.001
Error	1.076	8	0.134		
Within					

Year	9.835	3	3.278	16.928	0.000
Treatment X Year	5.097	9	0.566	2.924	0.017
Error	4.648	24	0.194		
American Robin					
Between					
Treatment	1.789	3	0.596	2.884	0.103
Error	1.655	8	0.207		
Within					
Year	3.379	3	1.126	6.365	0.002
Treatment X Year	0.573	9	0.064	0.380	0.943
Error	4.247	24	0.177		
Least Flycatcher					
Between					
Treatment	0.219	3	0.073	0.292	0.830
Error	1.998	8	0.250		
Within					
Year	2.667	3	0.889	4.030	0.019
Treatment X Year	3.887	9	0.432	1.958	0.091
Error	5.294	24	0.221		
Hermit Thrush					
Between					
Treatment	0.925	3	0.308	0.643	0.609
Error	3.835	8	0.479		
Within					
Year	2.191	3	0.730	5.730	0.004
Treatment X Year	3.238	9	0.360	2.823	0.020

Error	3.059	24	0.127		
Chestnut-sided Warbler					
Between					
Treatment	5.473	3	1.824	2.005	0.192
Error	7.281	8	0.910		
Within					
Year	2.800	3	0.933	4.430	0.013
Treatment X Year	3.903	9	0.434	2.058	0.076
Error	5.056	24	0.211		
Brown-headed Cowbird					
Between					
Treatment	0.717	3	0.239	1.183	0.375
Error	1.617	8	0.202		
Within					
Year	1.928	3	0.643	4.609	0.011
Treatment X Year	2.999	9	0.333	2.391	0.043
Error	3.346	24	0.139		
Red-eyed Vireo					
Between					
Treatment	0.220	3	0.073	0.654	0.602
Error	0.895	8	0.112		
Within					
Year	0.305	3	0.102	1.671	0.200
Treatment X Year	1.496	9	0.166	2.734	0.024
Error	1.460	24	0.061		
Eastern Towhee					

Between					
Treatment	0.208	3	0.069	0.399	0.757
Error	1.392	8	0.174		
Within					
Year	0.070	3	0.023	0.559	0.647
Treatment X Year	0.597	9	0.066	1.586	0.176
Error	1.004	24	0.042		
American Redstart					
Between					
Treatment	0.044	3	0.015	0.706	0.575
Error	0.166	8	0.021		
Within*					
Year	0.117	1	0.117	1.882	0.207
Treatment X Year	0.132	3	0.044	0.706	0.575
Error	0.499	8	0.062		
Dark-eyed Junco					
Between					
Treatment	0.706	3	0.235	0.608	0.628
Error	3.095	8	0.387		
Within					
Year	2.085	3	0.695	3.550	0.029
Treatment X Year	0.509	9	0.057	0.289	0.971
Error	4.700	24	0.196		
Nashville Warbler					
Between					
Treatment	0.115	3	0.038	0.076	0.971

Error	4.018	8	0.502		
Within					
Year	0.323	3	0.108	0.859	0.476
Treatment X Year	1.045	9	0.116	0.927	0.520
Error	3.009	24	0.125		
Blue Jay					
Between					
Treatment	1.603	3	0.534	0.383	0.768
Error	11.176	8	1.397		
Within*					
Year	7.937	1.930	4.114	1.708	0.214
Treatment X Year	6.511	5.789	1.125	0.467	0.817
Error	37.171	15.436	2.408		
Red-breasted Nuthatch					
Between					
Treatment	0.245	3	0.082	0.859	0.500
Error	0.761	8	0.095		
Within*					
Year	2.715	1.671	1.625	9.145	0.004
Treatment X Year	0.509	5.012	0.102	0.571	0.721
Error	2.375	13.365	0.178		
Veery					
Between					
Treatment	0.058	3	0.019	1.312	0.336
Error	0.118	8	0.015		
Within					

Year	0.038	3	0.013	0.696	0.564
Treatment X Year	0.374	9	0.042	2.299	0.050
Error	0.434	24	0.018		
Scarlet Tanager					
Between					
Treatment	0.007	3	0.002	0.671	0.593
Error	0.027	8	0.003		
Within*					
Year	0.007	1.762	0.004	0.671	0.509
Treatment X Year	0.034	5.284	0.006	1.110	0.400
Error	0.082	14.098	0.006		
American Goldfinch					
Between					
Treatment	1.726	3	0.575	1.710	0.242
Error	2.692	8	0.337		
Within*					
Year	0.485	1.611	0.301	1.052	0.362
Treatment X Year	3.408	4.834	0.705	2.465	0.090
Error	3.688	12.891	0.286		
Indigo Bunting					
Between					
Treatment	0.041	3	0.014	0.214	0.884
Error	0.510	8	0.064		
Within					
Year	0.110	3	0.037	1.257	0.311
Treatment X Year	0.358	9	0.040	1.361	0.259

Error	0.701	24	0.029	

* Indicates a significant Mauchly's test of sphericity, therefore corrected Greenhouse-Geisser values were used.