Table of Contents

1.0 GENERAL INTRODUCTION

A general perception among resource managers and public alike, is that conifer plantations provide generally poor habitat for most wildlife. Whether this is true for all developmental stages, or just particular phases, is somewhat unclear. The aim of this study, is to identify the habitat parameters affecting songbird diversity in 30-40 year old red pine plantations in eastern Ontario. Stands of this age were selected for investigation, because this is the stage at which songbird diversity and population density appear to be at the lowest levels. It is also the stage at which stand thinning operations are normally undertaken, and thus, there is the potential to enhance songbird habitat quality by modifying the plantation management protocol. Those features found to influence songbird populations have been incorporated into a series of recommendations encompassing forest management objectives at both the stand and regional levels.

Over the past few decades, field studies have indicated serious population declines for many neotropical migrant songbird species (Freemark and Collins 1989; Askins et. al. 1990; Askins, 1993; BBS 1993; Robinson and Wilcove 1995). This decline has been attributed to the reduction and fragmentation of mature forest habitats along the migration routes, and on both wintering and breeding grounds. For many species that normally breed in Canada, tropical and subtropical deforestation is expected to result in the loss of >50% of available wintering habitat by the year 2000 (Diamond 1991). However, there is a general consensus that loss of quality breeding habitat in the U.S. and Canada is the most significant factor in songbird decline (Freemark and Collins 1989; Robinson 1989; Robinson 1992; Robinson and Wilcove 1995). Within the settled areas of Ontario, much of the original forest landscape has been reduced to small isolated woodlots by a century and a half of human settlement (Keddy 1994). There is ample evidence that many songbird species will either not breed in these small fragments, or if they do, their reproductive success may be compromised by "edge effects," such as increased predation, brood parasitism and competition (Kroodsma 1987; Litwin and Smith 1989; Robinson et al. 1995). Management strategies implemented for these remaining fragments, and for regenerating secondary forests, will play a critical role in the population dynamics, as well as long term survival of neotropical migrants.

Historically, wildlife was treated as a by-product of the timber resource, and it wasn't until the early 1900's that this lack of management concern came into question (Leopold 1949). Over the past few decades, Canadians have challenged provincial and federal resource agencies to acknowledge the true value of wildlife, and to manage our forests as multiple resource systems. This includes "recognizing the full range of species diversity and linkages within the ecosystem; perpetuating indigenous species and gene pools; recognizing the full range of values and potentials; perpetuating and restoring inherent diversity; protecting representative biological communities and vulnerable, threatened, and endangered species..." (OMNR 1993). Obviously, a clear understanding of the ecological interactions that underlie forest productivity will be critical to the long-term maintenance of such a resource.

One area that has been of concern to forest managers, is the apparent negative correlation between monotypic conifer stands and songbird diversity (Lack 1939; Moss 1978; Moss 1979; James and Warner 1982; Williams and Marcot 1991). Traditionally, conifers such as red pines, have been established as plantations on abandoned agricultural lands prone to soil erosion. Their hardiness and relatively rapid growth restores stability to light sandy soils, while providing harvestable timber. These plantations can provide favourable economic returns because of their relatively low management costs and shorter harvest cycles when compared to hardwoods (OMNR 1986; OMNR 1989). Plantations established and managed solely for maximum timber yield, however, typically lack the hardwood and herbaceous components found within natural stands. This lack of vegetative complexity has been implicated as the single most important factor affecting songbird diversity and population density, even more so than stand area, geometry or landscape isolation effects (MacArthur et al. 1966; Karr and Freemark 1983; Holmes and Recher 1986; Litwin and Smith 1989; Parker et al, 1994).

Hardwood succession may actually be inhibited by initial plantation management. Pines are typically planted close together to promote tall, straight growth and self-pruning (which reduces the number of knots in the log). As the pine stands mature, much of the under story begins to decline because of increased shading by the canopy. Later, any remaining competitor species may be removed directly (Johnson and Landers 1982; OMNR 1986; OMNR 1989). In both cases the elimination of vegetative layers results in reduced floristic and structural complexity (heterogeneity), and a consequent reduction in niche stratification, (i.e. reduced foraging opportunities on a three-dimensional plane) (MacArthur and MacArthur 1961; MacArthur et al. 1966; MacDonald, 1966; Karr 1968; Karr and Roth 1971; Robinson and Holmes 1982; Robinson and Holmes 1984; Childers et al. 1986). Just as importantly, insect prey diversity declines because of a lack of suitable plant substrates. During this period there is a marked reduction in songbird diversity and density. There is also a marked turnover in species, although some generalists may be capable of maintaining viable populations throughout the stand transitions (Welsh 1987).

Not all songbirds respond negatively to pure, dense, conifer stands, however (Sturman 1968; Holmes et al. 1979; Landres and MacMahon 1980; Rice 1984). Kirtland's warblers *(Dendroica kirtlandii)* nest exclusively in densely stocked jack pine *(Pinus banksiana)* stands that are 6-23 years of age, while red crossbills *(Loxia curvirostra)* forage predominantly on conifer seed crops, an unpredictable resource periodically produced in abundance in older dense stands (Probst 1988; Benkman 1993). Similarly, in the earliest stages of plantation growth, songbird communities may increase in density and richness as young stands develop simple structural complexity, when compared to the prior grassland habitat (Batten and Pomeroy 1969; Currieand Bamford 1982; Childers et al. 1986).

If it is possible to influence habitat quality through appropriate stand management actions, perhaps by enhancing structural heterogeneity, then pine plantations might be used as a conservation tool by resource managers. It has been widely recognized that there is a need for additional forest cover in the highly fragmented landscape of southern Ontario (Geomatics 1993). From a regional perspective, it must be determined whether wildlife would benefit from an overall increase in the area devoted to pine plantations. Similarly, plantations could be used to reconnect or even expand existing woodlot fragments, thus reducing "edge," while expanding the area of forest interior habitat available for nesting songbirds. The results of this study will help to provide a sound basis from which such decisions can be made.

2.0 METHODS

2.1 Study Sites: In 1994, ten red pine and red pine/jack pine plantations were selected from seven sites in eastern Ontario (Table 2.1, Figures 2.1, 2.2). Vegetation communities associated with the study sites were identified by stereoscopic aerial photo analysis and from direct field observations (see Figure 2.3)

Plantation	Location	Area	Aerial Photo	Age
Semi-isolated Sites				
Ashbrook/Simpson/VanWell	Pt. Lot 5, Conc. X Township of Mountain Dundas County	Pr - 18.5 ha Ps - 5 ha	91-4505 18-69	30
Wall	Pt. Lot 12, Conc. VII Oxford Township Mun. of Leeds and Grenville	Pr - 23.5 ha	91-4462 53-179	30-33
Moritz	Pt. Lot 15, Conc. IX Oxford Township Mun. of Leeds and Grenville	Pr - 14 ha	91-4461 53-63	30-31
Bergin	Pt. Lot 15, Conc. IV Oxford Township Mun. of Leeds and Grenville	Pr - 10.3 ha Pj/Pr - 2 ha	91-4464 52-152	30-31
Contiguous Sites				
Stony Swamp Main Plot	Pt. Lot 29-32 Conc.V Nepean Township Mun. of Ottawa-Carleton	Pr - 8.5 ha Pj/Pr -10.3 ha	91-4464 52-152	41-44
Stony Swamp North Plot	Pt. Lot 29-32 Conc.V Nepean Township Mun. of Ottawa-Carleton	Pr - 4.7 ha.	91-4464 52-152	43
Stony Swamp East Plots	Pt. Lot 29-32 Conc.V Nepean Township Mun. of Ottawa-Carleton	1. Pr - 5.3 ha 2. Pr - 7.2 ha	91-4464 52-152	41
Ireton	Pt. Lot 8 Conc.X Lanark Township Lanark County	Pr - 5.0 ha Pr/Pj- 3.2 ha Pr - 12.0 ha.	91-4507 14-158	42-44
Ireton/Stolfa	E 3/4 Lot 6 Conc. IX Lanark Township Lanark County	Pr - 5.5 ha.	91-4506 31-140	44

Table 2.1. Selected plantations used in this study.

Figure 2.1. Forest regions of Ontario. (from Soper and Heimburger, 1982) (☐ - General location of study sites).

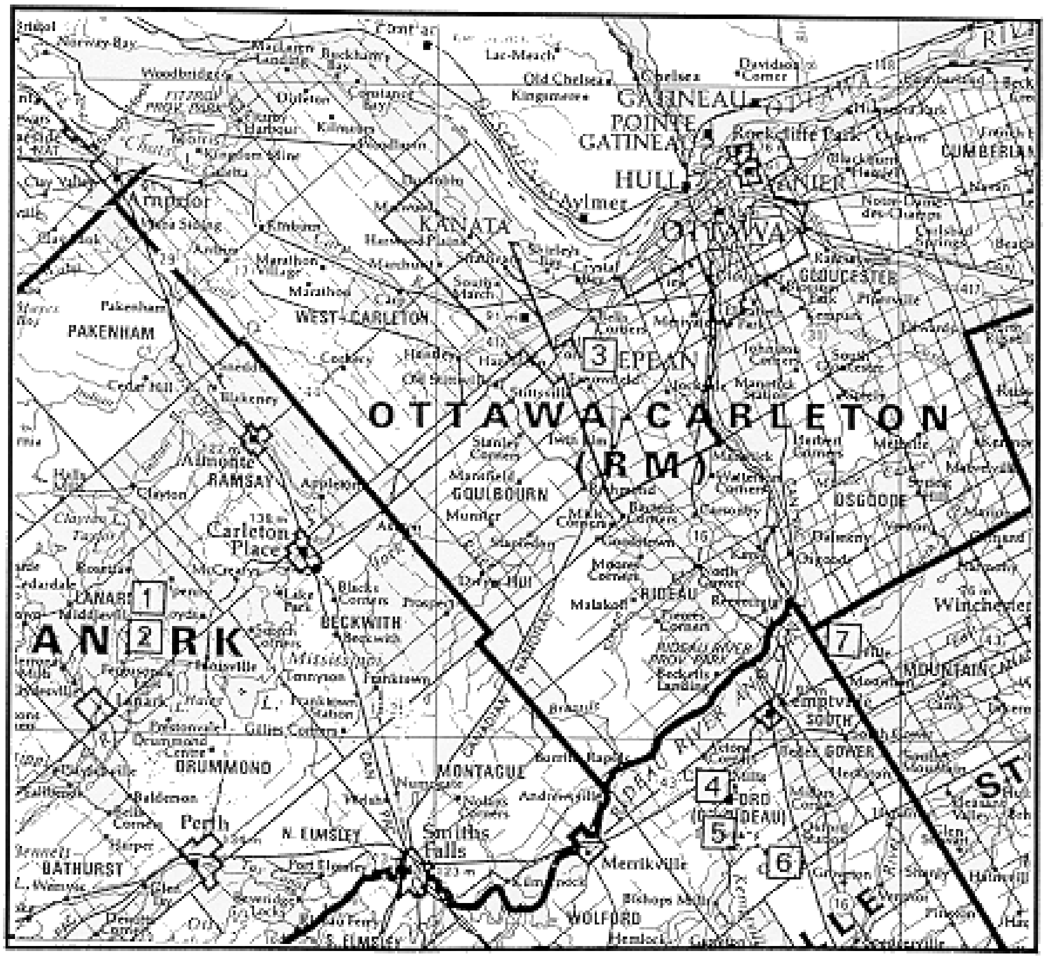
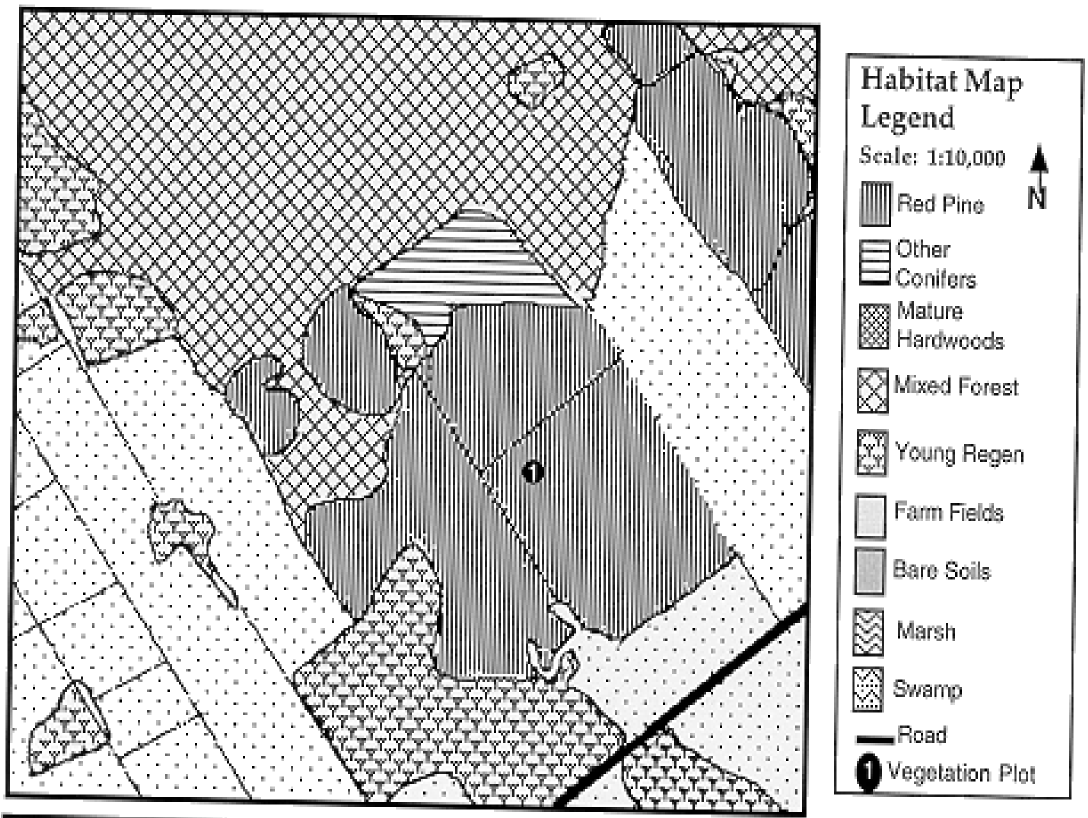


Figure 2.2. Study site locations: 1. Ireton 2. Ireton/Stolfa 3. Stoney Swamp 4. Bergin 5. Wall 6. Moritz 7. Ashbrook/Simpson/VanWell.



Wall Plantation

Location:
Pt. Lot 12, Conc. VII
Oxford Township
Mun. of Leeds and
Grenville

Area: Pr - 23.5 ha

Aerial Photo Ref.:
91-4462 53-179

Age: 30-33 years

Habitat Plot Code:

1. W-95

Figure 2.3. Example of a habitat map and aerial photo of a semi-isolated plantation.

2.2 Data Collection

2.2.1 Species Diversity and Territory Density. In 1994 and 1995, songbird surveys were conducted from the end of April until mid-July, corresponding with the active breeding season for most songbirds found in this region (Cadman et al. 1987; Peck and James 1987). Each of the seven study areas was surveyed between dawn until late morning at least once a week.

Song playback and spot-mapping were used in combination to determine territorial boundaries (Bibby et al. 1992). Territorial males were identified by their behavioural responses to prerecorded song (e.g. directed singing, aggressive posturing). Often males could be lured out to the perimeters of their territories using song playback, however, spot-mapping was deemed to be the more appropriate method for actually determining territorial boundaries within the plantations. This technique relies on repeated observations of males to determine the true extent of their territories (Freemark and Collins 1989; Haila et al. 1989; Bibby et al. 1992). Compared to point counts and linear transects, spot mapping provides more information on breeding, particularly for small areas (Robbins 1978; Tomialojk and Verner 1990).

2.2.2 Reproductive Status. All observations of breeding pairs and nesting activity were recorded throughout the field season. These included: successive observations of female(s) within a male's territory; observations of courtship; observations of nests or nest building behaviours; observations of parents carrying food; and observations of nestlings or fledglings.

2.2.3 Habitat Characterization. Qualitative assessments of the habitats were based on field visits and aerial photo analyses. Habitats were categorized as follows:

Pr - red pine plantations
Ps- scotch pine plantations
Pmix - mixed pine plantations, primarily of red pine/jack pine
OF - old field secessional areas (mixed grasses, shrubs, young trees)
Sw - swamp forest (red maple, birch, cedar, ash) and associated wetland areas
MIX - open canopied areas of mature upland trees species (typically white pine, hard maple, hemlock, ash, birch)
H - mature upland hardwoods (typically of hard maple, oak, ash, birch)

Quantitative habitat measurements of the conifer plantations (Pr and Pmix) were based on guidelines outlined in the Southern Region Ecological Land Classification Forest Plot Sampling Manual (ELC - OMNR 1994). Thirty-two circular sample plots (400 M^2 each) were established within the plantations (several plots were established in adjacent forest habitats for comparison). Plot locations were determined as follows:

i) Areas of peak songbird density were established for each stand from the results of the spot-mapping surveys. Representative plots were established within these areas to ensure that the specific vegetative characteristics of these significant habitats were assessed. In most cases, a simple stratified random approach to plot location would have missed many of these "hot-spots" due to the low density of songbirds occurring within the plantations.

ii) Plots were also established randomly within areas deemed representative of particular plantation conditions. These ranged from pure stands with negligible under story components, to patches of advanced hardwood succession. Sampling intensity was reduced in areas exhibiting obvious uniform growth (e.g. intensively managed sites).

iii) Although extensive sampling of adjacent forest habitats would have provided a useful baseline for habitat quality comparisons, time

constraints prevented the establishment of more than a few plots in these areas.

Once plot locations were established, the specific habitat variables were surveyed as per the ELC guidelines (see Appendix 2 and 3)

2.3 Data Analysis:

2.3.1 Habitat Quality Indices: Songbird habitat quality was determined using a number of indices and comparative assessments. Below are listed the indiceswhich provided the most information pertaining to plantation management criteria:

i) Species Density Diversity In this study, species density was determined from the results of territorial mapping. To provide a comparative measure between stands of different sizes, species density (Sr) was evaluated on a per hectare basis as follows:

$$\mathbf{S_r = S_i/A}$$

where: S_i = total songbird species observed within the community
A = habitat area in hectares

ii) Territory Density. Territorial density was calculated for each of the stands in a manner similar to that for species richness, whereby:

$$\mathbf{T = T_i/ A}$$

where: T_i = total number of territories observed within the stand
A = area of stand in hectares

iii) Breeding Pair Density and % Success. The density of breeding pairs (P) for each stand was determined as above whereby:

$$\mathbf{P= P_i/A}$$

where: P_i = total number of pairs observed within a stand
A = area of the stand in hectares

As a measure of habitat quality, the percentage of territories with breeding pairs was determined from field observations. This is based on a general assumption that territorial quality directly or indirectly affects female mate choice.

iv) Nesting Density and % Success. Next to the successful fledging of young, nesting is perhaps the most valuable measure of territorial quality (Robinson 1989). An effort was made to locate all nests within plantations. Nesting density (N) was calculated for each stand as follows:

$$\mathbf{N = N_i/A}$$

where: N_i = total number of nests observed within the stand
A = area of the stand in hectares

The percentage of territories bearing nests was also determined.

2.3.2 Habitat Plot Data and Assessment of Quality

i) Vegetation Data: The data collected for each of the habitat plots were categorized as follows:

✤Tree Density **(TDEN):** The total number of all trees of ≥9 cm DBH

✤Basal Area **(BASA):** The total basal area calculated in M^2/ha from DBH measurements of all trees of ≥9 cm DBH.

✤Canopy Tree Species Diversity **(TSP):** The number of tree species comprising the canopy layer.

✤DBH Groupings **(A, B, C):** The number of trees in each of three DBH size classes where **A =** ≥9<15 cm, **B =** 15-25 cm and **C =** >25 cm

✤Percent Groundcover **(GC):** The estimated coverage of the herbaceous layer.

✤Canopy Closure **(CC):** The estimated canopy closure (%).

✤Conifer Canopy **(CON):** The estimated percentage of the canopy closure represented by conifer species.

✤Percent Sapling Cover **(SAP):** The total estimated coverage by saplings and tall shrubs (Layers 3 and 4).

✤Percent Seedling Cover **(SEED):** The total estimated coverage by seedlings (Layer 5)

✤Tree Structural Diversity **(TSD):** An index of plot diversity derived from the Foliage Height Diversity index - H' (MacArthur and MacArthur 1961; MacArthur et al. 1966; Litwin and Smith 1989; Parker et al. 1994)

$$\mathbf{H' = -(\sum p_i \, 1n \, p_i)}$$

where, p_i = the proportional coverage by each tree species within a respective height class (Layers 1 to 5)

$\sum(p_i \ \mathrm{In} \ p_i)$ = summation for all species and height classes.

Groundcover (Layer 6) was not included in the analysis because of the variance in seasonal growth that occurred among the plots over the course of the data collection period. Moss and lichen cover (Layer 7), and vegetative debris and exposed rock (Layer 8), were also not included in the analysis.

Frequency distributions were developed for each of the habitat variables to assess normality. Log transformations were conducted for those variables that were significantly skewed from the normal distribution.

ii) Habitat Quality Indices. For each of the habitat plots, the number of songbird species (S), territories (T), breeding pairs (P) and nests (N) associated with each plot were determined using the following criteria:

1. all songbirds whose territories included all or part of the 400 M^2 vegetation plot were included unless their known habitat preference was substantially different from that defined by the plot itself

2. nests were only counted if they were actually located within the boundaries of the plot.

iii) Data Analysis. Simple regressions and ANOVAs were conducted for each of the h@bitat variables. Significant relationships between the various vegetation categories and the songbird habitat quality indices (dependent variables) were assessed at $p < 0.05$ using Fisher's F-test (Zar 1984).

Significant trends were assessed at $0.05 < p < 0.1$.

Multiple regression analyses (stepwise additive regressions) were also conducted to determine the actual combination of independent variables that contributed significantly to habitat quality.

2.3.3 Landscape Effects. Landscape components such as proximity of the study sites to adjacent forest habitats, were not included in the regression analysis because of the lack of appropriate controls; (i.e. wholly isolated stands).

2.3.4 Area Effects. Species-area relationships were developed for each of the three major stand types (pure red pine plantations, pine plantations with advanced hardwood succession and native upland forest). Although there were actually too few stands to statistically validate the results, the trends provide useful information.

3.0 RESULTS

3.1 Comparisons Between Stand Types.

3.1.1 Species Richness. During the two field seasons, 45 species of songbird were observed at the study sites, of which 22 occurred within red pine stands (Appendix 1). Corvids, such as Blue Jays *(Cyanocitta cristata)* and Common Crows *(Corvus americanus),* were excluded from the study, as were non-songbird species such as Ruffed Grouse *(Bonasa umbellatus),* and Greathorned Owls *(Bubo virginiana).* Piscines, including Hairy Woodpeckers *(Dendrocopus villosus),* Downy Woodpeckers *(D.*

pubescens) and Yellowbellied Sapsuckers *(Sphyrapicus varius)* were not included in the diversity analyses, but were noted for their significance as indicators of potential breeding habitat for cavity nesters and of relative insect prey abundance.

Overall, the red pine plantations had the lowest songbird diversity of the seven habitat categories (Figure 3.1). Mean species richness in the red pines was only about 23% of that found within the swamp, mixed forest or mature hardwood stands. The Scotch pine and mixed pine stands were intermediate in richness, as were the old field sites.

At least 4 songbird species were found in each of the eleven red pine stands, while one stand (Ireton) had a maximum of 17 species. The lowest species diversity occurred within the three semi-isolated red pine plantations near Kemptville (Wall, A/S/V, Moritz). Indeed, a significant negative correlation was found between stand area and species richness, although this is likely related to the lack of hardwood regeneration within the larger stands (Figure 3.2).

From a plantation management perspective, maximum species richness within some conifer stands may be indicative of important habitat characteristics. The Ireton/Stolfa red pine stand had a species density value that approached intermediate levels of richness (2.1 spp./ha). Similarly, the Ireton mixed pine stand had a species density value of 5.0 sp./ha, placing it well above the overall mean for the three natural forest stands. Both of these stands were structurally diverse and exhibited substantial hardwood succession.

3.1.2 Territory Density. Boundary locations for species known to have small territories and specific habitat requirements, were usually confined to obvious habitat features. For example, virtually all of the Red-eyed Vireos *(Vireo olivaceus)* observed within the red pines were associated with patches of hardwoods of at least 1 ha in size. In some cases, these patches included nothing more than one or two large oaks or maples surrounded by even-aged saplings. In other cases, the territories of some species were found to extend much farther than expected, particularly within the pure red pine stands. Ovenbird territories, generally about 2 ha in size within mature deciduous habitats (Villard et al. 1991), were found to extend up to 3 ha in some of the red pine stands.

The overall territory density pattern for the individual stands mirrored that of species richness (Figure 3.3). Mean territory density was again lowest in the red pine plantations, and highest in the mixed and hardwood forest habitats. The maximum territory density for a red pine stand was 3.3 terr./ha, which occurred at the 5.5 ha Ireton/Stolfa East site, a highly interspersed plantation surrounded by a complex of other habitat types. Similarly, the 1.2 ha Ireton mixed pine stand had a territory density of 6.2 terr./ha, which was above the mean for the mixed and hardwood forest habitats. In the latter case, the majority of the territories extended beyond the plantation borders and into adjacent forests.

The lowest territory densities (0.6 terr./ha) were observed in two of the three semi-isolated plantations near Kemptville. This was an order of magnitude lower than the mean for the mixed and hardwood forest habitats (6.1 terr./ha). Territory densities were also low (1.0 terr./ha) in the third semi-isolated plantation, and in several monotypic contiguous stands at Stony Swamp.

3.1.3 Percent of Territories with Breeding Pairs . The percentage of territories for which breeding pairs were confirmed was similar across stand types, and averaged between 75% and 88%. Individually, the red pine stands ranged from a low of 76% in the Ireton/Stolfa East stand, to 100% in the north and east Stony Swamp plantations. No significant difference in mean value was found between the three categories of pine plantation.

3.1.4 Nesting Density. The percentage of territories with active nests was assessed for the

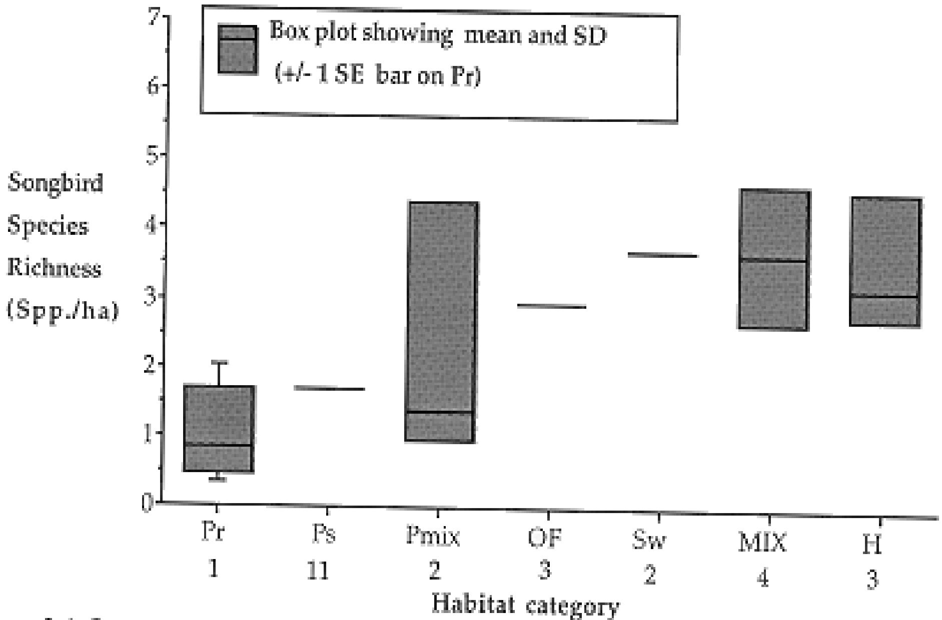


Figure 3.1 Species richness comparisons between stand types indicating generally lower songbird diversity within red pine stands compared to other habitat types, and relatively higher diversity among the natural forest stands. (Pr - red pine plantations; Ps - Scotch pine plantations; Pmix -mixed pine plantations (generally jack pine/red pine); OF - old field areas; Sw - swamp forest and wetland areas; MIX - mature mixed upland forest (conifer/hardwoods); H - mature upland hardwood forest)

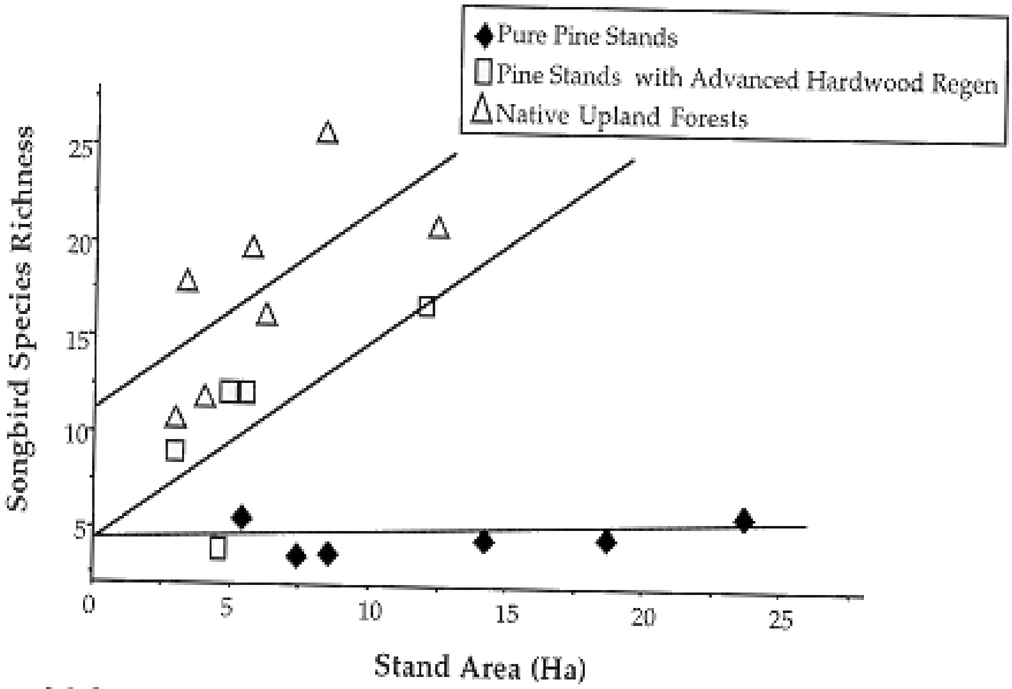


Figure 3.2 Songbird species richness-area relationships for three stand types indicating poor species-area response for the pure red pine stands.

pine plantations only. Nests were found in less than half of the territories within the red pine stands, but in several instances, the missing nests were located in the portions extending into adjacent habitats. The mean density of nests within the red pines was less than half that for the mixed pine stands.

3.2 Comparisons Between Plantations.

3.2.1 Songbird Habitat Quality. Overall, regression analyses provided clear evidence that structural diversity, canopy diversity and sapling coverage were all positively associated with the four measures of songbird habitat quality (see Figure 3.4). Stands with high values of these three components were typically open canopied with substantial intermediate and under story growth. Similarly, Class II tree density (9-25 cm DBH)), overall tree density (all trees >9 cm DBH), total basal area, and canopy closure were all negatively associated with songbird habitat quality (see Figure 3.5). Stands that had high values of these variables were best represented by dense, monotypic plantations with minimal hardwood succession.

Based on regression analyses of each of the habitat quality indices, an optimal stand habitat was designed (from a songbird perspective). This design has been incorporated into the management recommendations (section 4.0)

3.2.2 Stepwise Regression Analysis. All seven of the significantly associated habitat variables were incorporated into an additive stepwise regression analysis, from which multivariate regression equations were developed (Statview 1993). The resulting equations are as follows:

Species Diversity: **y_s = 10.776 + 3.2961ogTSP - 5.3481ogB** (r^2 = .59)

No. of Territories: **y_t = 13.801 + 4.971ogTSP - 7.4671ogB** (r^2 = .57)

No. of Breeding Pairs: **y_p = 16.767 + 7.6871ogTSP - 8.3981ogTDEN** (r^2=.59)

No. of Nests: **Y_n = 6.389 + 2.4061ogTSP - 3.5951ogB** (r^2 = .43)

These equations provide strong support that songbird habitat quality is most affected by interactions between canopy diversity (TSP) and tree density (TDEN and B). In management terms, the best plantation habitats are provided by those stands with the greatest number of tree species in the canopy, and with fairly open structure. Lower tree density corresponds with greater light penetration and an overall increase in the vegetative layering.

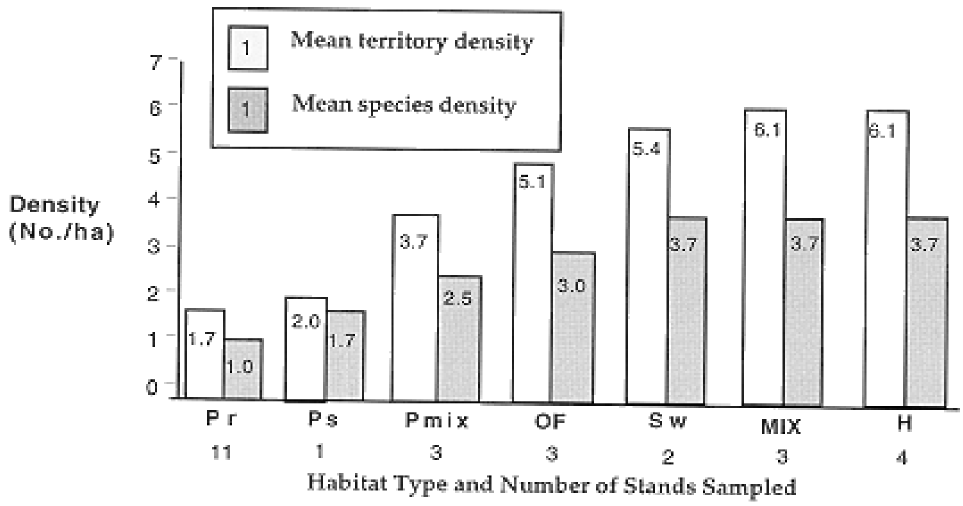


Figure 3.3 Songbird species and territory density comparisons between stand types, indicating generally poor habitat value offered by the red pine plantations on a landscpe basis (Pr - red pine plantations; Ps - Scotch pine plantations; Pmix -mixed pine plantations (generally jack pine/red pine); OF - old field areas; Sw - swamp forest and wetland areas; MIX - mature mixed upland forest (conifer/hardwoods); H - mature upland hardwood forest)

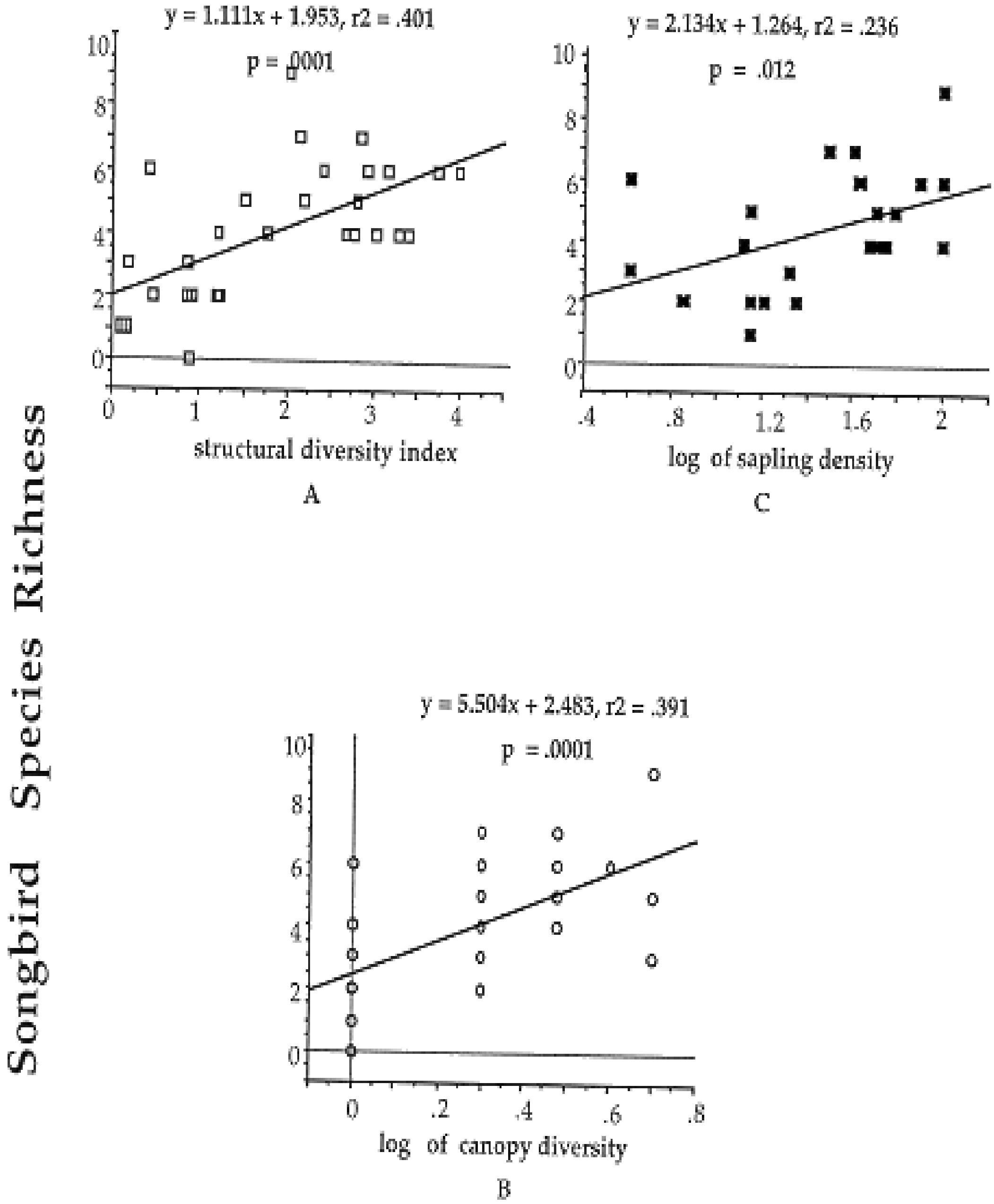


Figure 3.4 Example of linear regression lines and scattergrams for the 3 habitat plot variables positively associated with songbird habitat quality (in this case, songbird species richness).

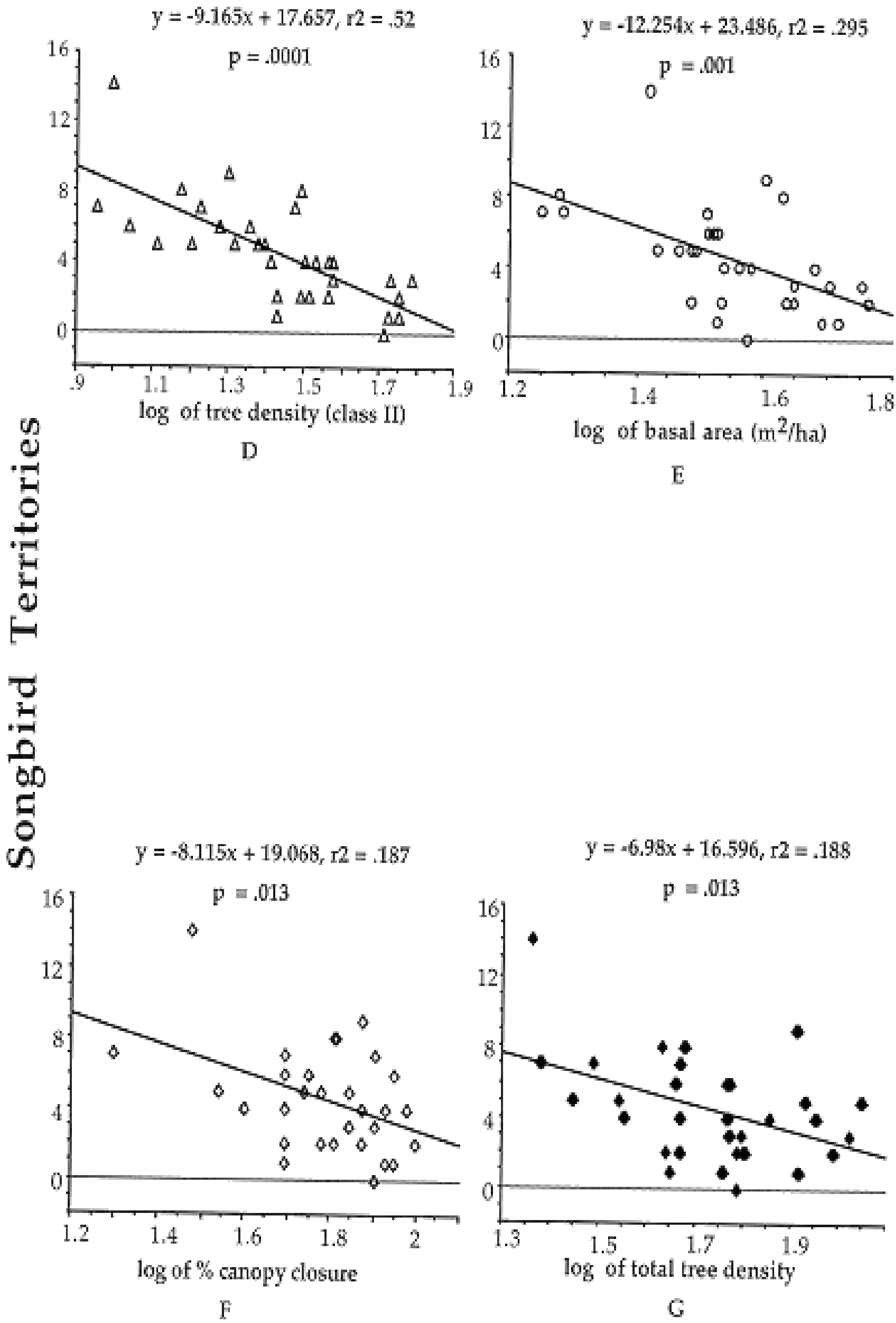


Figure 3.5 Example of linear regression lines and scattergrams for the 3 habitat plot variables negatively associated with songbird habitat quality (in this case, territory density).

4.0 DISCUSSION AND MANAGEMENT RECOMMENDATIONS.

4.1. Overview Wildlife diversity is now recognized not only as an important natural resource, but as a key indicator of ecosystem integrity. To that end, resource managers have a responsibility to ensure that wildlife diversity is not eroded by inappropriate forest management practices. At the stand level, the suite of habitat features found in the most diverse plantations in this study can serve as a basis for maintaining, and even enhancing, songbird diversity. At the landscape level, conifer plantations may provide additional forest habitat, serve as linkages between existing woodlots, or perhaps provide unique habitat features for less common songbirds. Although wildlife values have traditionally been overshadowed by other priorities (e.g. soil stabilization and timber production), there is a precedence for incorporating significant habitat features into the management protocol. A recent initiative on the part of the OMNR, is to promote the restoration of woodlands on private and public lands, in part by encouraging hardwood succession within conifer plantations (Geomatics 1994). This initiative fits in well with the results of this study, in which hardwood succession was found to be critically linked to songbird diversity and reproduction. As temporary shelters for developing structurally diverse hardwood forests, conifer plantations can serve as useful conservation tools for the restoration of neotropical migrant songbird populations.

This study investigated songbird diversity and reproductive status in eleven managed red pine stands in the 30-40 year age class (mid-rotation). Red pine plantations are generally characterized as dense monotypic forests with limited undergrowth. The results support the established view that pure plantations provide generally poor breeding habitat for most songbirds, however, several factors can improve habitat quality significantly. For the 30-40 year age class, poor quality habitat (as measured by low species diversity, territories, breeding pairs and nests) was primarily related to low structural heterogeneity, although species-specific habitat requirements and landscape factors, such as proximity to source habitats, also played important roles.

4.2. Importance of Hardwood Succession. On a per stand basis, habitat quality was considerably lower in the red pine plantations than in any of the other six habitat categories. On average, stands of pure red pine with little or no hardwood regeneration exhibited 27% of the songbird diversity found in the natural forest habitats. Indeed, most of the songbirds observed tended to be associated specifically with areas of advanced hardwood growth. Habitat quality decreased linearly with increasing canopy cover, basal area and tree density. These variables are all negatively correlated with hardwood regeneration and therefore, with structural heterogeneity. Alternatively, habitat quality increased linearly with increasing structural and floristic diversity.

An examination of species occurrences and territorial densities showed an interesting trend in habitat occupancy as the stands gained structural complexity. Habitat generalises, such as the Ovenbird, were capable of establishing territories and successfully nesting in relatively pure stands (although a minimal level of herbaceous or hardwood growth was still necessary for foraging). Robins and Black-capped Chickadees were also prevalent in stands with minimal regeneration, but this can be attributed to their larger home ranges, enabling them to forage beyond the periphery of the generally small plantations. As hardwood succession progressed, other species became more common, including Rose-breasted Grosbeaks, Yellow-rumped Warblers, and Hermit Thrushes. If the regression analyses accurately reflect songbird responses to increasing structural diversity, it might be expected that species richness and territorial density would continue to increase linearly. This appears to be borne out by examining the higher average habitat quality found within the mixed pine stands. Hardwood succession was likely more advanced in these plantations because of lower tree density and sparser canopy cover, which could provide better lighting conditions for under story growth. In some mixed pine stands, species richness, and territorial densities approached levels found within the hardwood and mixed upland forest habitats. It is conceivable that, given time, these stands would take on additional characteristics of the natural forests; i.e. tall remnant pines surrounded by hardwoods of varying sizes and ages.

Habitat quality was found to be further affected by the type and form of hardwood succession occurring within the plantations. Songbird species diversity and breeding densities were highest in patches of hardwoods > 1.0 ha in size, particularly where structural layering was maximized; e.g. numerous foliage layers. Many of the deciduous adapted species, such as Red-eyed Vireos, would not venture beyond the areas of hardwood growth, unless specifically responding to song playbacks. Smaller hardwood patches tended to be occupied only if they were located near other patches, or near the periphery of adjacent natural stands. Finally, plantations with young, uniform growth had generally low breeding densities.

Canopy diversity was positively associated with all four of the habitat quality indices, as indicated by both simple and stepwise regression analyses. In general, habitat selection by songbirds is related to the foraging substrates and nesting sites provided by a variety of mature deciduous trees. Alternatively, the presence of insect prey on particular tree species can contribute to the diversity and abundance of songbirds. For example, spruce budworm outbreaks in the extensive spruce forests of northern Ontario and the northeastern U.S., were found to contribute significantly to the diversity and abundance of foraging songbirds (Crawford and Titterington 1979; Morse, 1980; Welsh 1980; Crawford et al. 1983). Similarly, the presence of certain herbaceous species, such as spring wildflowers, can influence prey availability within a stand (e.g. butterflies, bees, beetles etc.).

From the regression analyses, optimal songbird habitat can be defined within the context of the plantations examined. It should be kept in mind that the plantations with the greatest songbird diversity and breeding densities still fell short of the habitat quality provided by natural upland stands. As the plot analyses were primarily confined to the plantations, the following stand design cannot be transferred to upland forest types without further investigation. However, it is reasonable to expect that the same principles regarding structural diversity apply.

Therefore, within the context of a mid-rotation conifer plantation, a stand design for optimizing songbird habitat might have 100% sapling coverage (layers 3 and 4), corresponding to approximately 50% canopy closure. Basal area would be about 18 m2/ha. with an overall density of 560 trees/ha. (of >9 cm. DBH) of which 250 trees/ha. would be of class 11 size (DBH >9<25 cm.). The canopy would consist of at least 5 equally represented tree species (of which most would be hardwoods). Multiple regression analyses have provided an indication that of the 7 habitat variables examined, canopy diversity (+ve) and class 11 tree density (-ve) have the most influence on songbirds. From a plantation management perspective, it may be useful to focus on these two elements in order to improve songbird habitat quality.

Recommendation 1

That the optimal plantation design for 30-40 year old red pine stands described above, be considered as a starting point for resource managers wishing to manage existing conifer plantations for wildlife. It is recognized that the values as outlined, may run counter to economically viable timber production, but it should also be recognized that wildlife, such as songbirds, may have different needs.

The primary finding of this study, has been that advanced hardwood succession within red pine plantations is the most crucial factor affecting habitat quality. This observation is supported by numerous studies involving a variety of stand management practices (Capen 1979; Dickson and Segelquist 1979; Crawford and Frank 1987; Brawn and Balda 1988; Litwin and Smith 1989). Light penetration to the stand floor appears to be the most limiting factor preventing hardwood seed germination (OMNR 1986; OMNR 1989; Elliott 1994). Stand thinning is the most frequent recommendation for increasing light levels and thus, hardwood growth, although low intensity fires have been suggested for removing the slash overburden (Austin and Perry 1979; Brawn and Balda 1988). Furthermore, snags and perches provided by the hardwood trees may accelerate ecological succession by promoting active seed distribution by birds (McClanahan and Wolfe 1993).

Recommendation 2

That protection and incorporation of significant habitat features such as hardwood fencerows, remnant mature trees, vernal pools, snags, etc. should be considered a priority during the initial phases of plantation development. Remnant hardwood growth will eventually serve as a potential seed source for additional succession, while providing beneficial breeding sites for songbirds. Furthermore, these features should be protected during subsequent thinning or harvesting operations.

Recommendation 3

That all red pine plantations be thinned according to established cutting schedules (Elliott 1994; OMNR 1989). This is recommended as a means of promoting hardwood succession, in addition to improving the quality of harvestable timber. Typically, this form of stand management involves row removal or thinning at 15 -40 years of age followed by successive commercial cuts every 5-25 years depending on site conditions. A stand design that would optimize songbird habitat might have 100% sapling coverage (layers 3 and 4), with approximately 50% canopy closure. Basal area would be about 18 m^2/ha with an overall density of 560 trees/ha (of ≥9 cm. DBH) of which 250 trees/ha would be o class II size (DBH >9<25 cm.). The canopy would consist of at least 5 equally represented tree species (of which most would be hardwoods). It should be noted that landowners would have to balance timber and wildlife values in deciding whether this design would be appropriate.

Recommendation 4

That wherever possible, plantations should be established near existing hardwood seed sources (e.g., hardwood fencerows, swampy areas, adjacent upland stands) to promote hardwood *succession. These areas should be thinned early to promote secessional growth. Hardwood succession should be monitored and additional thinning undertaken if necessary to increase the size of the patch. Plantation areas downwind of hardwood seed sources are prime locations for encouraging hardwood regeneration.*

Recommendation 5

That hardwood succession be promoted in plantations isolated from adjacent natural forest stands. Direct seeding or transplanting of hardwoods into the plantation will likely be required , at least until natural regeneration occurs. Tree shelters such as Tubex®, or Quill® (have been shown to aid in their establishment (OMNR 1994). From a landowner perspective, the development of a hardwood stand within the shelter of a conifer plantation will be substantially more cost-effective than attempting to establish a hardwood plantation directly on open lands.

Recommendation 6

That patches of hardwoods be promoted within the plantations, rather than thin, uniform growth. throughout. In this study, hardwood patches of 1.0 ha. or larger were most likely to attract a wide diversity of songbirds. Alternatively, smaller patches in close proximity to each other, or to adjacent natural stands can be created. These patches may be developed over a number of years by thinning the surrounding red pines to promote natural seeding. Alternatively, small clearings may be cut within the plantations, and hardwoods seeded or transplanted directly (see Recommendation 4). A balance of heavier thinning in areas of hardwood advance in combination with regular thinning in other areas, will help landowners balance timber and wildlife objectives.

Recommendation 7

That jack pines, or jack pine/red pine mixes, be considered on sites with poorer quality, shallow soils. These stands promote hardwood succession more rapidly because of a generally sparser canopy and greater light penetration. These stands were found to have substantially higher songbird diversity than pure stands alone.

4.3 Promotion of Special Features. Species diversity and breeding activities were further influenced by the presence or absence of unique habitat features. Northern Waterthrushes *(Seirus noveboracensis)* were invariably associated with shallow vernal pools located within low-lying patches of black ash, birch and red maple. Another habitat feature associated with stand diversity was the presence of exposed ridges of junipers *(juniperus virginiana),* hawthorns *(Crataegus spp.)* and cedars, which provided nesting sites for White-throated Sparrows *(Zonotrichia albicollis).* Alternatively, some species either rarely nested within the plantations, or did not occur there at all because of a lack of particular habitat features. For example, Pine Warblers *(Dendroica pinus)* were not as numerous as expected in the red pine stands. This appeared to be related to the absence of distinctively tall pines. On several occasions, pine warblers were observed nesting in white pines that were substantially taller than the surrounding red pines. This is apparently a nesting preference specific to the Pine Warbler (Cadman et al. 1987). Snags (dead standing timber) and tree cavities, were other important habitat elements lacking from within the red pine stands. This appeared to be related to specific qualities of the red pines themselves, rather than to the age of the stand or the management process. Once dead, red pines quickly fall and rapidly decompose, instead of remaining upright for many years as do white pines, cedars and hemlocks *(Tsuga canadensis).* This lack of standing dead timber reduces the incidence of insect prey for foraging songbirds such as

Woodpeckers, Chickadees, Solitary Vireos *(Vireo solitarius),* Black and White Warblers *(Mniotilta varia)* and Nuthatches *(Sitta spp.)* (Robinson and Holmes 1982; Cadman et al. 1987). For example, in the mature southern pine forests of the south-eastern U.S., Red-cockaded Woodpeckers *(Picoides borealis) are* believed to be endangered because of the reduction in foraging habitat and available nesting cavities (Kelly et al. 1994). Fewer foraging woodpeckers also limits the number of excavated cavities suitable as nest sites for other species. In the Great Lakes- St. Lawrence forests of Ontario, there are 284 species of vertebrate fauna, of which 15% (43 spp.) are partially dependent on cavities (Anderson and Rice, 1993). For conifer plantations, the presence of mature hardwoods contributes to the availability of these habitat features, and therefore, to greater faunal diversity. Some authors suggest that managers take direct action to create these features within managed stands. For example, by incorporating nest boxes into the stands as a means of promoting cavity nesting songbirds. This has been shown to be effective for young stands during the initiation phase (Oelke 1967). However, in mature stands, the effectiveness of artificial nest boxes is questionable (Norris 1994).

Recommendation 8

That snags and tree cavities be promoted and maintained throughout the life of the stand. This can be accomplished by encouraging hardwood succession, retaining existing old growth features, and allowing a portion of the stand to reach old age (although red pines may be inadequate in this regard). Nest boxes are not recommended for mature stands, but may be useful during the early stages of stand development. It is unlikely that such features can be created from the young developing conifers, therefore the <u>retention</u> of existing old growth features during stand initiation is critical.

4.4 Landscape Context. Landscape context appears to be another important determinant of overall species richness. The three plantations with the lowest songbird diversity lay within agricultural areas, and were relatively isolated from other upland forest habitats. This isolation may be a determinant of overall habitat occupancy, as per the principles of island biogeography (MacArthur and Wilson 1967). There may also be limitations to effective colonization <u>within</u> the larger plantations because of the relative isolation of hardwood patches. Indeed, for the relatively pure stands, species richness did not increase with area as it did for the stands with higher levels of structural diversity. However, the impacts of stand isolation and size are related to the effective search area of a given songbird species (Hunter 1987). In this study, none of the plantations were larger than 23 ha, and none lay farther than 1 km from other upland forests, well within the visual range of most songbirds searching for breeding habitat. The species impoverishment of the larger isolated stands in this study is therefore, most likely related specifically to the lack of hardwoods.

For structurally complex stands, landscape context was found to be an important factor in determining habitat quality, but in an indirect manner. For those conifer plantations located within a matrix of upland forests and old fields, the inadequacy of the habitat was diminished by the degree of hardwood regeneration, which is inherently related to the proximity of hardwood seed sources. Songbirds normally associated with deciduous forests, such as Red-eyed Vireos, Rose-breasted Grosbeaks, and Veerys *(Catharus fuscesens),* established territories that overlapped both habitat types, thus boosting species richness and territorial density. These species were typically absent from the pure red pines, but were observed in isolated patches of hardwood regeneration, and along mature hardwood fencerows extending in from the adjacent forests. Pure pine stands therefore lack the habitat features desired by most breeding songbirds.

In an agricultural or suburban landscape, the availability of upland forests of any type may be a limiting factor in the recovery of declining populations of some neotropical migrants. A 32 year survey of hemlock/hardwood forests in a suburban setting in the northeastern U.S., showed that the recovery of a number of migrants was correlated to nearby reforestation projects (Askins and Philbrick 1987). In such a landscape, large red pine plantations may provide useful breeding habitats for a limited number of songbirds. Similarly, studies of songbird movements between breeding habitats have indicated the importance of wooded corridors, such as those provided by shelterbelts (Haas 1994). However, it is important to undertake additional studies in this regard, to determine if such populations are sustainable. Small isolated woodlots may act as "ecological traps" that attract migrant neotropical dispensers but eventually lead to decreased reproductive success from high levels of predation and parasitism (Robinson 1989).

Recommendation 9

That, wherever possible, red pine stands be initiated adjacent to other upland forest habitats, and that hardwood succession be promoted within the plantations to encourage songbird residency.

Recommendation 10

That longer term studies in reproductive success be undertaken for songbirds breeding within isolated red pine plantations. The results of these studies may provide support for initiating conifer plantations on non-forested lands in order to increase available habitat .

4.5 Plantation Shape. A traditional view among resource managers has been that edge habitats (i.e. peripheral areas of shrubby, secessional growth) are generally beneficial for increasing wildlife diversity and density, primarily through increased habitat interspersion and vegetative complexity (Leopold 1933; Odum 1971; Gates and Gysel 1978). This concept is now viewed as a potentially disruptive management objective in terms of maintaining the integrity of the forest ecosystem. Populations of some migrant songbird species have been found to be declining largely because of the negative influences of brood parasitism and nest predation. These so called "edge effects" tend to occur at much higher frequencies in small fragmented woodlots, and along forest peripheries (Brittingham and Temple 1983; Wilcove et al. 1986; Temple 1986; Yahner and Scott 1988). In the northeastern U.S., nest predation by both avian and mammalian predators was significantly higher in edge habitats than in forest interiors (Roth and Johnson 1993). A critical review by Paton (1994) showed convincing evidence that edge effects may extend up to 50 m into the forest. He suggested that edge effects might even occur around large forest clearings greater than three canopy tree heights in width.

Recommendation 11

That the development of edge habitats be minimized by reducing the exposed perimeter of the *plantation. Within an agricultural landscape, long and narrow, or complex irregular designs should be avoided* <u>*unless*</u> *the perimeter is contiguous with other forest stands (particularly mature upland forest). In this case, the perimeter should be maximized to encourage hardwood succession.*

4.6 Plantation Size. The suitability of a forest habitat varies with the home range size and specific requirements of a given bird species. Overall diversity then, may depend on the scale at which a given habitat is viewed (Hunter 1987). Although plantation size was not adequately assessed in this study, it may be an important determinant of overall diversity. The reduction in breeding habitat through forest fragmentation and loss has been identified as one of the most significant causes of songbird decline in North America (Litwin and Smith 1989; Robinson 1989; Kelly et al. 1994; Opdam et al. 1995). In Pennsylvania, Porneluzi et al. (1993) found a 20 fold decline in ovenbird reproductive success between large hardwood forest fragments (>10000 ha) and smaller fragments (9-183 ha). Robbins et al. (1989) found that for large, undisturbed forests, area was the best predictor of species abundance over any other habitat variable, and therefore should be the first consideration for forest management. If this is not possible, then the authors suggest that managers first identify the specific habitat needs of area-sensitive or rare species before attempting to increase overall diversity. If large contiguous forests are unavailable they recommend managing smaller units in close proximity to larger forests (see Recommendation 11).

Recommendation 12

That the effects of plantation size be further investigated to determine if diversity and overall breeding success are influenced by stand area, particularly for area sensitive songbirds.

4.7 Plantation Age. Plantation age has been shown to play an important role in determining not only songbird diversity and density, but also the specific songbird community that might be expected to occur. For example, during the first 10 years or so (stand initiation phase), songbirds adapted to open field or edge type habitats, appear to do well (Currie and Bamford 1982; Childers et al. 1986). As canopy cover increases over the next 10-15 years, under story vegetation is shaded out and habitat structure declines. *In the absence of managed stand thinning*, this period of under story exclusion may extend for the next 50 years or more. Only a few generalist species are capable of successfully using plantations in this state. However, if the stand is allowed to grow to maturity and beyond, the canopy will begin to open up as trees age and die. Songbird diversity will again increase as structural complexity returns (Adams and Morrison 1993). For stands >100 years of age, some studies have found species diversity to be 50% greater than those in the 26-53 year age class (Currie and Bamford 1982).

Recommendation 13

That some pine stands (or portions thereof) be allowed to complete their natural life span (beyond marketable age). This will increase the representation of an important landscape element in eastern Ontario. However, in the case of red pines, it may be difficult to maintain stands into old age without loss to windfall and ice damage.

4.8 Plantation Age Structure. An uneven age structure within a natural forest stand increases the structural heterogeneity of the habitat and provides increased three-dimensional foraging opportunities for songbirds. However, for the conifer plantations, stand management directed toward the creation of multiple levels of uneven-aged pines will likely not increase habitat value, as there is usually not a corresponding increase in insect abundance (except for perhaps, pest outbreaks). Based on the results of this study, it is primarily hardwood succession that is required to develop the heterogeneous broadleaf structure that will lead to greater prey density and diversity. Furthermore, management directed toward the promotion of conifer regeneration is likely to counteract hardwood succession through competition for light and nutrients.

Recommendation 14

That, for the eastern Ontario region, the creation of an uneven age structure within the conifer plantations be directed toward hardwood succession and not to conifers. Although this may run counter to the objectives of softwood timber production, resource managers must consider the needs of wildlife as well.

4.9 Soils (See Table Al). The majority of the red pine stands sampled in this study were located on light sandy soils, typical of the site conditions normally chosen for these plantations. However, as a species, red pines grow best on deep coarse loams, as do most marketable hardwoods. There is potential then, for the faster growing red pines to serve as shelterwoods for the more valuable, shade tolerant hardwoods on these soil types (OMNR 1989).

Recommendation 15

That red pine plantations be investigated as shelterwoods for the growth of marketable hardwood timber on appropriate soils. This could serve as an important landscape management tool, in addition to the promotion of high quality timber. Hardwood succession within red pine stands initiated between existing forest fragments could eventually increase the overall size of available breeding habitat (an important consideration for area-sensitive species). Similarly, conifer plantations could be used to expand the size of individual woodlots, or to reduce irregularities in the perimeter (thus reducing edge). Alternatively, poor quality shallow soils can support jack pine, but not more valuable timber species. In this study, mixed jack pine/red pine stands were found to have greater levels of hardwood succession than pure red pine stands, with correspondingly higher songbird diversity. If managed strictly to accelerate hardwood succession, the development of such plantations might provide useful wildlife habitat on abandoned farmlands.

Recommendation 16

That jack pine or jack pine/red pine plantations be investigated as a means of promoting the regeneration of hardwood forests (and therefore songbird habitat) on abandoned lands of poor quality soils.

4.10 Songbird Species of Management Concern. The recovery of species diversity within the forests of Ontario has been identified as an important management objective for resource managers (OMNR 1993). As has been indicated throughout this paper, many neotropical migrant songbirds are in particular need of targeted management action. The availability and quality of breeding habitats have been reduced by forest fragmentation, deterioration, and outright loss. It is important to recognize, however, that boosting overall diversity without first identifying and ranking the needs of individual species may be the wrong approach to restoring the integrity of the forest ecosystem. For example, populations of habitat sensitive songbirds may be negatively affected by alterations to the size of the plantation, or by management operations such as thinning or harvesting. Solitary vireos, a provincially significant songbird species, were observed nesting in several mixed pine stands, while hermit thrushes, a declining area-sensitive migrant, were found nesting in many of the red pine stands.

Recommendation 17

That stand management operations not take place from April to July in order to prevent disruptions to resident breeding songbirds.

Recommendation 18

That large plantations (>75 ha), or plantations occurring within a contiguous forest matrix, be assessed for area-sensitive songbird species before decisions are made to harvest large portions of the stand.

5.0 BIBLIOGRAPHY

Adams, E. M. and M.L. Morrison. 1993. Effects of forest stand structure and composition on red-breasted nuthatches and brown creepers. *J.Wildl. Manage.* 57(3):616-629.

Anderson, H.W. and J.A. Rice. 1993. A tree marking guide for the Tolerant Hardwoods Working Group in Ontario. OMNR Forest Resources Branch.

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Pp. 1-34. In D.M. Power (ed) *Current Ornithology.* Plenum Press, N.Y.

Askins, R.A., J.F. Lynch and R. Greenberg. 1990. Population declines in migratory birds in eastern North America. *Curr. Ornith.* 7:1-57.

Askins, R.A., M.J Philbrick and D.S. Sugeno. 1987. Relationship between the regional abundance of forests and the composition of forest bird communities. *Biol. Conserv.* 39:129-152.

Austin, D.D., and M.L. Perry. 1979. Birds in six communities within a lodgepole pine forest.*J Forestry* 77:584-586.

Breeding Bird Survey (BBS) Canada 1993. Newsletter. Canadian Wildlife Service.

Bamford, R. 1986. Broadleaved edges within conifer forest. The importance to bird life. *Q.J For. 80:115121*.

Batten, L.A., and D.E. Pomeroy. 1969. Effects of re-afforestation on the birds of Rhum, Scotland. *Bird Study* 16:13-16.

Benkman, C. W. 1993. Logging, conifers and the conservation of crossbills. *J. Cons. Biol.* 7(3):473-479

Bibby, C.J., N.D. Burgess and D.A. Hill. 1992. Bird Census Techniques. Academic Press. Toronto.

Brawn, D. and R.P. Balda. 1988. The influences of silvicultural activity on Ponderosa pine forest bird communities in the southwestern United States. Pp. 3-21 *In* J.A. Jackson (ed) Bird Conservation. Vol.3. Univ. Wisconsin Press.

Brittingham, M C. and S. A. Temple. 1983. Have cowbirds caused forest songbirds to decline? *Bioscience*

33(l):31-35.

Cadman, M.D., P.F. Eagles and FM. Helleiner. 1987. Atlas of the Breeding Birds of Ontario. University of Waterloo Press, Waterloo, Ontario.

Capen, D.E. 1979. Management of northern pine forests for nongame birds. Pp. 90-109 In R.M. DeGraaf and K.E. Evans (ed). Management of north central and northeastern forests for nongame birds USDA For. Serv. Gen. Tech.Rept. NC-51

Childers, E. L., T.L. Sharik, and C.S. Adkisson. 1986. Effects of loblolly pine plantations on songbird dynamics in the Virginia Piedmont. *J. Wildl. Manage.* 50(3):406-413.

Crawford, H. S. and R.M. Frank. 1987. Wildlife habitat response to silvicultural practices in spruce-fir forests. *Trans. N. Amer. Wildl. Nat. Res. Conf.* 52:92-100.

Crawford, H.S., and R.W. Titterington. 1979. Effects of silviculture practices on bird communities in upland spruce-fir stands. Pp. 110-119. In R.M. DeGraaf and K.E. Evans (ed). Management of north central and northeastern forests for nongame birds. USDA For. Serv. Gen. Tech.Rept. NC-51

Crawford, H.S. R.W. Titterington and D.T. Jennings. 1983. Bird population and spruce budworm populations .*J Forest.* 81:433-435.

Currie, F.A. and R. Bamford. 1982. The value of retaining small conifer stands beyond normal felling age within forests. *Q. J. For.* 76:153-160.

Diamond, A. W. 1991. Assessment of the risk from tropical deforestation to Canadian songbirds. *Trans N.Am. Wildl. Nat. Res. Conf.* 56:177-194.

Dickson, J. G. and C.A. Segelquist. 1979. Breeding bird populations in pine and pine-hardwood forests in Texas. *J. Wildl. Manage.* 43:549-555.

Elliott, K. A. 1994. Managing succession in conifer plantations. OMNR

Freemark, K. and B. Collins. 1989. Landscape ecology of birds breeding in temperate forest fragments. Pp. 443-454 In J.M. Hagan Ill and D.W. Johnston (eds.) Ecology and Conservation of neotropical Migrant Landbirds. Smithsonian Inst. Washington.

Gates, J.E. and L.W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. *Ecology* 59:871-883

Geomatics International Ltd. 1993. Development of a Strategy for Woodlands Restoration in Eastern Ontario. Eastern Ontario Model Forest (EOMF) Information Report No. 3. Kemptville, Ontario

Haas, C. A. 1994. Dispersal and use of corridors by birds in wooded patches on an agricultural landscape. *Cons. Biol.* 9(4):845-854

Haila, Y., I.K.Hanski, and S. Raivio. 1989. Methodology for studying the minimum habitat requirements of forest birds. Ann. *Zool. Fennici* 26:173-180.

Holmes, R. T. and H.F. Recher. 1986. Determinants of guild structure in forest bird communities: An intercontinental comparison. *Condor* 88:427-439.

Holmes, R. T., J.T. Schultz and R. Nothnagle. 1979. Bird predation on forest insects: an exclosure experiment. *Science* 206:462-463.

Hunter, Malcolm L. 1987. Managing forests for spatial heterogeneity to maintain biological diversity. Trans. N. Am. Wildl Nat Res. Conf. 52:60-69

James, F. C. and N.O. Warner. 1982. Relationships between temperate forest bird communities and vegetation structure. *Ecology* 63:159-171.

Johnson, U.S. and J.A. Landers. 1982. Habitat relationships of summer resident birds in slash pine flatwoods. *J.Wildl. Manage.* 46:416-428.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois. *Condor* 70:348-357.

Karr J. R. and K.E. Freemark. 1983. Habitat selection and environmental gradients: dynamics in the "stable" tropics. *Ecology* 64(6):1481-1494.

Karr, J. R. and R.R. Roth. 1971. Vegetation structure and avian diversity in several New World areas. *Amer. Nat.* 105:423-435.

Keddy, C. 1993. Forest History of Eastern Ontario. Eastern Ontario Model Forest (EOMF). Information Report No. 1. Kemptville, Ontario.

Kelly, J. R., S.M. Pletschet, and D.M. Leslie Jr. 1994. Decline of the red-cockaded woodpecker *(Picoides borealis)* in southeastern Oklahoma. *Am. Mid]. Nat.* 132:275-283.

Kroodsma, R. L. 1987. Edge effects on breeding birds along power-line corridors in east Tennessee. Amer. *Midl. Nat.* 118(2): 275-283.

Lack, D. 1939. Further changes in the Breckland avifauna caused by afforestation. *J Anim. Ecol.* 8:227285.

Landres P.B. and J.A. MacMahon. 1980. Guilds and community organization analysis of an oak woodland avifauna in Sonora Mexico. *Auk* 97:351-365.

Leopold, A. 1933. Game Management. Charles Scribner and Sons, New York.

Leopold, A. 1949. A Sand County Almanac. Oxford Univ. Press. New York.

Litwin, T. S. and C. R. Smith. 1989. Factors influencing the decline of neotropical migrants in a northeastern forest: Isolation, fragmentation, or mosaic effects? Pp. 483-496 In J.M. Hagan III and D.W. Johnston (eds.) Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Inst. Washington.

MacArthur, R. H. and MacArthur, J.W. 1961. On bird species diversity. *Ecology* 39:599-619.

MacArthur, R. H. Recher, and M. Cody. 1966. On the relation between habitat selection and species diversity. *Amer. Nat.* 100(913):319-332

MacArthur, R. H. and E.O. Wilson. 1967. The Theory of Island biogeography. Princeton University Press. Princeton, New Jersey.

MacDonald, J.E. 1966. A bird census in red pine plantations and mixed stands in Kirkwood township, Ontario. *Can. Field Nat.* 79:21-25.

McClanahan T.R. and R.W. Wolfe. 1993. Acceleration of forest succession in a fragmented landscape: the role of birds and perches. *J. Cons. Biol.* 7(2):279-288.

Moss, D. 1978. Songbird populations in forestry plantations. *Q. J. For.* 72:5-14.

Moss, D. 1979. The effects on song-bird populations of upland afforestation with spruce. *Forestry* 52:129-150.

Morse, D., H. 1980. Foraging and coexistence of spruce-wood warblers. *Living Bird* 18:7-25.

Norris, T., 1994. Nest box research project. OMNR Kemptville Plantations. Personal communication.

Odum, E. 1971. Fundamentals of Ecology. Saunders Press, Philadelphia, Penn.

Oelke, H. 1967. Pine forest of the southern Canadian Shield. Aud. Field Notes 21:619-620.

OMNR 1986. Managing Red Pine Plantations. Oueen's Printer for Ontario.

OMNR 1989. A Silvicultural Guide for the White Pine and Red Pine Working Groups in Ontario. Queen's Printer for Ontario.

OMNR 1994. Southern Region Ecological Land Classification Field Manual. (Draft) Science and Technology Transfer Unit. Kemptville.

OMNR 1994. Tree shelters help hardwood trees grow faster. Extension Notes. Oueen's Printer for Ontario.

Oelke, H. 1967. Pine forest of the southern Canadian Shield. *Aud. Field Notes* 21:619-620.

Opdam, P., R. Foppen, R. Reijnen, and A. Schotnam. 1995. The landscape ecological approach in bird conservation: integrating the metapopulation concept into spatial planning. *Ibis* 137:S139-S146.

Parker, G.R., D.G. Kimball and B. Dalzell. 1994. Bird communities in selected spruce and pine plantations in New Brunswick. *Can. Field Nat. 108(l):* 1-9.

Paton, P. W. 1994. The effect of edge on avian nest success: How strong is the evidence? *Conserv. Biol.* 8(l):17-26.

Peck, G. K. and R.D. James. 1987. Breeding Birds of Ontario. Nidiology and Distribution. Vol. 2, Passerines. Royal Ontario Museum. Toronto.

Plosz, C. 1994. Bird species richness in managed coniferous woodlots in southern Ontario. MSc Thesis, University of Guelph. Guelph, Ont.

Porneluzi, P., J.C. Bednarz, L.J. Goodrich, N. Zawada and J. Hoover. 1993. Reproductive performance of territorial ovenbirds occupying forest fragments and a contiguous forest in Pennsylvania. *J. Cons. Biol.* 7(3):618-622.

Probst, J.R. 1988. Kirtland's warbler breeding biology and habitat management. Pp 28-35 In: T.W. Hoekstra and J.Cap (ed.) IntegratinV. forest Management for wildlife and Fi-,h. 1 JSDA North Central For. Exp. Stn NC-122 63 pp.

Rice, J., B.W. Anderson, and R.D. Ohmart. 1984. Comparison of the importance of different habitat attributes to avian community organization. *J.Wildl. Manage.* 48(3):895-911.

Robbins, C.S. 1978. Census techniques for forest birds. Pp 142-163 In R.M. DeGraaf, (tech coord.) Proceedings of the Workshop management of southern forests for nongame birds Atlanta Ga.

Robbins, C.S. D.K Dawson and B.A. Dowell. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic States. *Wildl. Monogr. 103:1-34.*

Robinson, S. K. 1989. Population dynamics of breeding neotropical migrants in a fragmented Illinois landscape. Pp. 408-418 In J.M. Hagan III and D.W. Johnston (eds.) Ecology and Conservation of Neotropical Migrant Landbirds.-Smithsonian Inst. Washington.

Robinson, S. K. 1992. The breeding season. Pp 405-407. In J.M. Hagan and D.W. Johnston (eds.). Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Inst. Washington.

Robinson, S. K. and R.T. Holmes. 1982. Foraging behaviour of forest birds: The relationships among search tactics, diet and habitat structure. *Ecology* 63(6):1918-1931.
Robinson, S., and R.T. Holmes. 1984. Effects of plant species and foliage structure on the foraging behaviour of forest birds. *Auk* 101:672-684.

Robinson, S. K, F.R. Thompson III, T.M. Donovan, D.R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. *Science* 267:1987-1990.

Robinson, S., and D.S. Wilcove. 1995 Forest fragmentation in the temperate zone and its effects on migratory songbirds. *Bird Cons. Int'l.* 4(2/3):233-249.

Roth, R. R. and **K.** Johnson. 1993. Long-term dynamics of a wood thrush population breeding in a forest fragment. Auk 110(l):37-48.

Sturman, W.A. 1968. Description and analysis of breeding habitats of the chickadees Parus atricapillus and P. rufescens. *Ecology* 49:418-431.

Temple, S. A. 1986. Predicting impacts of habitat fragmentation on forest birds. A comparison of two models. Pp. 301-304 In J.A. Verner, M.L. Morrison, and C.J. Ralph (eds.) Wildlife 2000. Modelling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison.

Tomialojk, L.K. and J. Verner. 1990. Do point counting and spot-mapping produce equivalent estimates of bird densities? *Auk* 107:447-450.

Welsh, D.A. 1980. The impact of forest cutting on boreal bird populations. *Am. Birds* 34(l):84-94.

Welsh, D.A. 1987. The influence of forest harvesting on mixed coniferous-deciduous boreal bird communities in Ontario, Canada. *Acta Oecol.* 8:247-252.

Wiens, J. A. 1989. The Ecology of Bird Communities. Vol. 1. Foundations and Patterns. Cambridge Univ.Press, New York.

Wilcove, D.S., C.H. McClellan and A.P. Dobson. 1986. Habitat fragmentation in the temperate zone. Pp. 237-256 In M.E. Soulé (ed.) Conservation biology: the science of scarcity and diversity. Sinauer Assoc. Sunderland MA.

Williams, B.and B. G. Marcot. 1991. Uses of biodiversity indicators for analysing and managing forest landscapes. *Trans. N.Am. Wildl. Nat. Res. Conf.* 56:613-627.

Yahner, R. H. and D.P. Scott. 1988. Effects of forest fragmentation and depredation of artificial nests. *Wildl. Manage.* 52:158-161.

Zar, J. H. 1984. Biostatistical Analysis (2nd Ed.) Prentice-Hall Inc. New Jersey

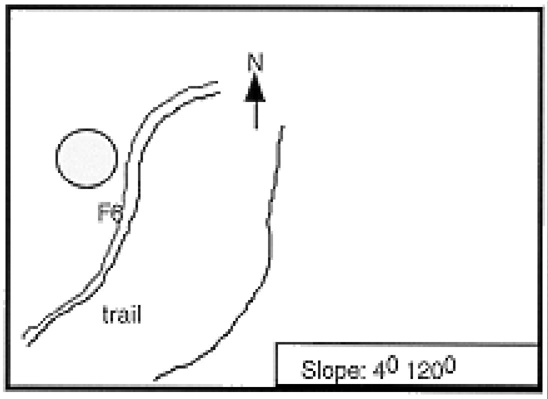
APPENDIX 1. Bird Species Observed at Study Sites

Species Name	Common Name	Species Name	Common Name
Agelaius phoenicus	Red-winged blackbird	*Sphyrapicus varius*	Yellow-bellied sapsucke
Bombycilla cedrorum	Cedar waxwing	*Spizella passerina*	Chipping sparrow
Bonasa umbellatus	Ruffed grouse	*Troglodytes troglodytes*	Winter wren
Cardinalis cardinalis	Northern cardinal	*Turdus migratorius*	American robin
Carduelis tristis	American goldfinch	*Vermivora ruficapilla*	Nashville warbler
Carpodacus purpureus	Purple finch	*Vireo olivaceus*	Red-eyed vireo
Catharus fucescens	Veery	*Vireo solitarius*	Solitary vireo
Catharus guttatus	Hermit Thrush	*Zonotrichia albicollis*	White-thr. sparrow
Certhia americana	Brown creeper		
Contopus virens	Eastern Wood Pewee		
Dendrocopus pubescens	Downy woodpecker		
Dendrocopus villosus	Hairy woodpecker		
Dendroica caerulescens	Black-throated blue warbler		
Dendroica coronata	Yellow-rumped warbler		
Dendroica fusca	Blackburnian warbler		
Dendroica magnolia	Magnolia warbler		
Dendroica pensylvanica	Chestnut-sided warbler		
Dendroica petechia	Yellow warbler		
Dendroica pinus	Pine warbler		
Dendroica virens	Black-throated green warbler		
Empidonax minimus	Least flycatcher		
Empidonax traillii	Willow flycatcher		
Geothlypis trichas	Common yellowthroat		
Hylocichla mustelina	Wood thrush		
Melospiza georgiana	Swamp sparrow		
Melospiza melodia	Song sparrow		
Mniotilta varia	Black and white warbler		
Molothrus ater	Brown-headed cowbird		
Myiarchus crinitus	Great crested flycatcher		
Oporornis philadelphia	Mourning warbler		
Parus atricapillus	Black-capped chickadee		
Passerina cyanea	Indigo bunting		
Pheuticus ludovicianus	Rose-breasted grosbeak		
Piranga olivacea	Scarlet tanager		
Regulus calendula	Ruby-crowned kinglet		
Regulus satrapa	Golden-crowned kinglet		
Sayornis phoebe	Eastern phoebe		
Seirus aurocapillus	Ovenbird		
Seirus noveboracensis	Northern waterthrush		
Setophaga ruticilla	American redstart		
Sitta canadensis	Red-breasted nuthatch		
Sitta carolinensis	White-breasted nuthatch		

Appendix 2. Sample Habitat Plot Data

Site: Ireton/Stolfa West Stand
Plot No.3

Location and Notes



Percent Cover by Layer

Layer Code	Species	Percent
Moss/Lichen(7)		5
Herb(6)	Grass/Carex	6
	Helleborine	t
	Solidago	t
Regen(4)	Mh	1
Saplings(3)	Mh	10
	Hh	10
Understory(2)	Apple	5
Dominant (1)	Pr	80

Total Basal Area (m^2/ha)

Species	Basal Area(m2/ha)
Pr	48.2
Hh	3.22
Mh	2.75
Apple	1.54
Dead	1.1
TOTAL	56.81

Dominant Tree Height/Age

Species	DBH	Age	Height (m)
Pr	22.5	40	15.3

PLOT SUMMARY

Dominant Tree Species: Red Pine
Total Basal Area: 56.81m^2/ha

Layer Code	1	2	3	4	5	6	7
Percent Coverage	80	5	20	1	---	6	5
No. of Species	1	1	2	1	---	3	>2

Appendix 3. Soils Analysis

Site	Texture Group	Depth to Mottles (cm)	Carbonates
Moritz	Sandy	>150	none
Wall	Sandy	>150	none
Bergin	Sandy	>150	none
Stony Swamp-1	Shallow	none	none
Stony Swamp-2	Sandy	>150	none
Stony Swamp-3	Shallow	none	none
Ireton-Main	Coarse Loamy	none	none
Ireton-East	Coarse Loamy	100-150	none
Ireton/Stolfa	Coarse Loamy	100-150	none

General Site Descriptions:

1. Moritz, Wall, Stony Swamp-2 and Ireton-East sites were all pure stands of managed red pines.

2. Bergin and Stony Swamp-1 sites were of a jack pine/red pine mix with advanced hardwood succession.

3. Stony Swamp-3 and the two remaining Ireton sites were all of red pine with advanced hardwood succession.