IMPACT OF FOREST SUCCESSION ON SHRUBLAND-DEPENDENT BIRDS IN ASPEN FORESTS MANAGED WITH TRADITIONAL AND ALTERNATIVE CLEARCUTTING SYSTEMS IN NORTHERN WISCONSIN

By

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Chapter I

Introduction

Over the last 10 years, researchers identified negative population trends for many avian species associated with early seral stages of forest succession (Askins 1993). Of 12 shrubland specialists from the eastern United States, 6 bird species declined significantly between 1966 and 1991 (Askins 1993). Of 15 early successional specialists found in New England, 9 species declined (8 significantly) while only 1 species increased significantly between 1966 and 1988; 13 species declined (7 significantly) and 0 species increased during the final 6 years of their analysis of Breeding Bird Survey route data (Witham and Hunter 1989). These investigations indicated a general negative population trend for early successional specialists that appeared to worsen toward the end of the twentieth century.

Due to these declining population trends and other factors, the U. S. Fish and Wildlife Service (FWS; 1999) Region 3 identified 4 shrubland specialists, the American Woodcock (*Scolopax minor*), Golden-winged Warbler (*Vermivora chrysoptera*), Kirtland's Warbler (*Dendroica kirtlandii*), and Loggerhead Shrike (*Lanius ludovicianus*), among the 33 species of highest conservation priority in the Great Lakes States. Partners in Flight (unpublished data) listed the Golden-winged Warbler as 1 of 2 species of highest management concern in the Boreal/Northern Hardwoods Transition Zone of the Upper Great Lakes Region. With the population

declining by nearly 8% per year in parts of the breeding range (Cornell Laboratory of Ornithology 2000), the FWS initiated a status assessment of the Golden-winged Warbler for possible listing under the Endangered Species Act.

Biologists believe the decline of early successional bird populations relates to several factors. First, research suggests these species have a narrower niche breadth relative to species associated with mature forests (King and DeGraaf 2000). This evidence supports speculation of high specialization for many species associated with transitory shrub habitats (Askins 1993). Second, Brown-headed Cowbird (*Molothrus ater*) parasitism is common for some species specializing in early successional habitats (Confer 1992), while other research suggests this is a minor problem in forested landscapes (Hanski et al. 1996, Flaspohler et al. 2001). Finally, the maturation of eastern deciduous forests likely plays a significant role in the loss of suitable breeding habitat and the decline of these species (Askins 1993, Litvaitis 1993, Witham and Hunter 1993, Straw et al. 1994, Hagan 1995).

In northern Wisconsin, aspen-birch (*Populus* spp. and *Betula papyrifera*) forest is the most common early successional community; however between 1936 and 1996, aspen forest declined from 5.2 million acres to 3.2 million acres statewide. The 40% loss of aspen has been attributed to the transition of aspen forest to northern hardwood forest (Wisconsin Department of Natural Resources 1997) and corresponds to the period of decline for many early successional-dependent birds.

To better understand the impact of forest maturation on shrubland bird populations, I explored the relationship between population densities of 2 bird species

and habitat quality as affected by spatial and temporal dimensions of forest succession. Golden-winged Warblers are associated with open shrublands and are most affected by temporal changes in forest structure (Confer 1992). To identify the stages of forest succession associated with high population densities, I examined territorial male densities and the pattern of density change for 25 years following clearcutting. In contrast to the requirements of Golden-winged Warblers, American Woodcock utilize a range of early successional age classes in proximity to one another to meet their changing cover needs during the breeding season (Sepik et al. 1981). For my study, aspen stands were partially clearcut to improve age class diversity. This was compared to the traditional practice of clearcutting the entire stand that results in a single age class. I compared displaying male woodcock densities to these varying degrees of stand removal and to independent variables identified as important predictors of displaying male use.

This study provides a unique opportunity to demonstrate the importance of early successional aspen forests and clearcutting harvest systems to both game and nongame species. The public generally associates aspen clearcutting and early successional habitats with game species management, and this message is perpetuated by public educational materials detailing multiple forest management techniques beneficial to specific game species, such as ruffed grouse (*Bonasa umbellus*), white-tailed deer (*Odocoileus virginianus*), moose (*Alces alces*), and beaver (*Castor canadensis*; Perala 1977, Wooden et al. 1996). Though these materials mention nongame species briefly, they fail to recommend management techniques beneficial

to specific nongame species. Game species represent a small proportion of the total wildlife community. By continually emphasizing the benefits to a few species, readers fail to learn about the high diversity of species associated with early successional communities. For example, I found 85 bird species utilizing 0-4 year-old aspen clearcuts for nesting and foraging during the breeding season (Appendix I). Of these, only 5 were game species. Through my research, I hope to encourage a shift from individual species management to community-based management.

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Chapter II

MULTIPLE SCALE RESPONSE OF DISPLAYING MALE AMERICAN WOODCOCK TO NON-TRADITIONAL ASPEN MANAGEMENT SYSTEMS IN NORTHERN WISCONSIN

Abstract

I experimentally implemented 2 alternative forest management systems to create stands with 2 aspen (*Populus* spp.) age classes in order to diversify breeding cover for American Woodcock (*Scolopax minor*). Four aspen stands were clearcut between 1996-1998 using the traditional (100% stand removal) management system. Additional stands were partially clearcut using the following alternative management systems: 1) 30% stand removal (n = 5), and 2) 60% stand removal (n = 4). I compared the abundance of displaying male woodcock during 3 breeding seasons between 1998-2000 across aspen stands and found woodcock increased between years 1998 and 2000 for sites (n = 8) surveyed all 3 years. I found no relationship between the stand removal systems and mean displaying male woodcock density in either 1999 or 2000 and concluded that creation of two aspen age classes within stands did not improve male woodcock use. Of the other independent variables measured, only the amount of clearcut edge (km/ha) explained differences in male use across sites. More displaying males used clearcuts with low edge than clearcuts with high edge. Annual increases in displaying male abundance on my sites corresponded to similar trends on U.S. Fish and

Wildlife Service Singing-ground Survey routes (n = 14) across the Northern Forest Region of Wisconsin. Statewide, woodcock on Singing-ground Survey routes exhibited different trend patterns than the subset I examined in the northern forests. I believe this discrepancy reflects a difference in woodcock population trends between the northern forest and the more urbanized, agricultural southern region of Wisconsin. Woodcock populations may be better monitored according to floristically similar regions than by state political boundaries. I recommend monitoring woodcock populations according to principal floristic regions and clearcutting larger areas of aspen forest with reduced clearcut edge to improve woodcock management on the breeding grounds.

Introduction

For over 25 years, woodcock researchers (Cushwa et al. 1977, Gregg 1982, Gutzwiller et al. 1982, Kinsley et al. 1982, Dwyer et al. 1983) have speculated on the relationship between the documented long-term decline of the American Woodcock (*Scolopax minor*) throughout its range and the loss of early successional forest cover (Kelley 2000; Figure 2.1). In Wisconsin, the 39% decline in the woodcock population since 1968 corresponds with a 40% decrease in early successional forests, primarily aspen-birch cover (*Populus* spp. and *Betula papyrifera*), since 1937 (Schmidt 1996; Figure 2.1). The increase in mid- to late-successional forest cover, particularly maple-basswood (*Acer saccharum* and *Tilia americana*) forest, is directly proportional to the decline in aspen-birch forests while other forest types have remained relatively constant over the same time period.

Even-aged management of aspen forests produces high quality woodcock breeding habitat (Hale and Gregg 1976, Bennett et al. 1982, Gregg 1984). In northern Wisconsin, high densities of males used aspen clearcuts for singing-grounds and roosting (Gregg 1982). In a study of 32 nests in northern Wisconsin, Gregg and Hale (1977) found most nests in pole-sized (5-11 inches dbh) aspen stands within 0-30 feet of an opening. They rarely found nests in northern hardwood (*Acer* spp. and *Quercus* spp.) stands and never in conifer stands. In Maine, aspen forest and alder cover provided preferred brood rearing cover while coniferous or mixed forest cover was used rarely (Reynolds et al. 1977). Though woodcock prefer aspen forest to other forest types, only the early seral stages provide adequate breeding cover.

In aspen forest, woodcock require a range of age classes (0- to 30-years old) to meet their diverse cover needs throughout the breeding season (Sepik et al. 1981). Under traditional management, an aspen stand is clearcut with 100% stand removal and regenerates as a single age class. These regenerating stands are frequently surrounded by a matrix of other forest types dominated by northern hardwoods, pine plantations (*Pinus* spp.), and swamp conifers (*Picea mariana*, *Abies balsamifera*, and *Larix laricina*) that fail to provide the diversity of aspen cover preferred by woodcock in northern Wisconsin (Gregg 1984).

Increasing aspen forest age structure can improve woodcock use when manipulation occurs at a large scale. In Michigan, Bennett et al. (1982) partially clearcut six 2,330 ha experimental areas dominated by second-growth aspen, oak, and pine using 25%, 50%, or 75% removal of forest cover as clearcuts. They observed the average number of displaying male woodcock per survey route increase proportionally to the level of forest removal. I examined displaying male response to varying degrees of forest removal at the smaller stand scale ($\leq$ 150 ha).

I defined a stand as a unit of trees that is relatively homogeneous in age, structure, composition, and physical environment (Kohm and Franklin 1997). I chose to investigate woodcock response at the stand scale for 3 reasons. First, the stand is the traditional unit of management used by industrial foresters, and thus management changes are more easily implemented. Second, a stand is a homogeneous, ecologically distinct unit potentially recognizable by woodcock. Finally, it is a scale amenable to harvest level manipulation over a large enough area to influence woodcock use.

I explored alternative management systems to create two aspen age classes in stands to provide higher quality cover for breeding woodcock than with the traditional, single age class management system. I compared displaying male density to this stand-scale manipulation in addition to other independent variables including vegetation structure of clearcuts, amount of clearcut edge, and prevalence of adjacent forest cover types.

Study Area

The study area was located in Oneida and Lincoln Counties in north-central Wisconsin on lands initially owned by Tenneco Packaging Corporation of America (PCA), Inc. and the State of Wisconsin (Figure 2.2). In November 1999, Tenneco sold 17 of 19 sites in my study to the State of Wisconsin, Tomahawk Timberlands, Wachovia Timberland Investment Management, and 2 private individuals.

All study sites were second growth aspen-birch forest dominated by quaking aspen (*Populus tremuloides*), big-tooth aspen (*Populus grandidentata*), and paper birch (*Betula papyrifera*) with scattered northern hardwood species (*Acer* spp. and *Quercus* spp.). Adjacent forest types included conifer swamps (*Picea mariana*, *Abies balsamifera*, and *Larix laricina*), pine plantations (*Pinus resinosa* and *P. banksiana*), northern hardwoods, and alder thickets (*Alnus* spp.). I identified the forest cover type at each study site following the Kotar Forest Habitat Classification System (Kotar et al 1988) based on the associated understory plant community (Appendix II).

Prominent glacial features including end and ground moraines, deposits of glacial till, eskers, kames, drumlins, drift covered bedrock ridges, and pitted outwash plains created an undulating to hilly landscape (Boelter 1988 and Mitchell 1993). Soils comprised of sandy loam and loamy sand with scattered wet depressions dominated most sites (Appendix III). Two sites had predominately nutrient-rich, silt-loam soils and were mesic to wet-mesic with considerable standing water due to a perched water table. Balsam poplar (*Populus balsamifera*) was common on one of these sites.

Methods

Aspen Stand Removal Systems

Foresters from PCA helped select 19 stands of predominantly 25-60 year-old aspen forest with similar soil types, stand structure, tree species composition, and management history. Older stands were not selected due to aspen replacement by northern hardwood species after 40 years (Giese et al. 1976). PCA foresters provided maps delineating stand boundaries created from air photos. To refine these maps, foresters superimposed the stand boundaries on U.S. Geologic Service 7.5' quadrangle maps and later ground-truthed the stand maps for accuracy. They estimated stand areas using a dot planimeter (i.e. a dot grid). Stand areas extracted from PCA's forest stand database ranged from 34.6 to 150.6 ha (80.2 ha ± 9.1 ha; mean ± SE). A dot planimeter was used to estimate the area needed to meet the harvest prescription assigned to the stands in my study.

In 1996-1998, four stands were clearcut using the traditional, 100% stand removal system and the remaining stands were partially clearcut using the following alternative management systems: 1) 30% stand removal (n = 5), and 2) 60% stand removal (n = 4; Figure 2.3). All stands were harvested using clearcutting, not to be confused with a selection harvest system that removes a percentage of the basal area. All clearcuts contained widely scattered residual trees (usually conifers or northern red oaks (*Quercus rubra*)). A fifth site selected for the 60% stand removal system could not be harvested due to early ground thaws that prevented access by heavy machinery. The remaining five sites were not manipulated (0% stand removal). In the 30% removal system, 1 stand contained 2 clearcut units and 2 stands contained 3 clearcut units. Three of the stands in the 60% removal system contained 2 clearcut units. In the remaining 3 stands in the alternative management systems and all stands in the 100% removal system, clearcuts were harvested as single units. Across treatments, 21 clearcut units were created within 13 stands. As of spring 2000, clearcut ages ranged from 1 to 4-years old.

To assess the accuracy of each stand removal treatment, I compared the intended stand removal ratio planned prior to harvest and the actual stand removal ratio calculated by comparing the clearcut area to the stand area (Appendix IV). The clearcut areas within stand boundaries obtained using the Geoexplorer II Geographic Positioning System (GPS; Trimble Navigation 1999) ranged from 11.5 to 76.1 ha (35.3 ha ± 5.7 ha). The actual stand removal ratio was calculated using the ratio of clearcut area to stand area. On average, the 30%, 60%, and 100% stand removal systems were

actually 25%, 37%, and 88% of stand removal respectively. Multiple comparisons indicated the 100% system was significantly different from the 30% and 60% systems ($F_{2, 10} = 34.94$, $P \leq 0.001$). The 30% and 60% stand removal systems were not significantly different from one another. Given the discrepancy between intended and actual ratios of stand removal, I used the actual ratios as a continuous variable in regression analyses.

Woodcock Singing-ground Surveys

As recommended by Godfrey (1975), my observers and I counted all males displaying within a stand rather than using a roadside route format like that used by the U.S. Fish and Wildlife Service (USFWS; Kelley 2000). Each year, surveys began 9 to 21 days after the arrival of displaying males when singing-ground territories seemed well established. Due to unusually mild winters and early springs in the 3 survey years, woodcock arrived on the singing-grounds 3 days to 3 weeks earlier than the average arrival date of March 25 (Gregg, personal communication). March 2000 was the warmest on record for north-central Wisconsin. In Wisconsin, earliest arrival dates for areas at the same latitude as my study area were March 2 in Barron County in 1998, March 22 in Oneida County in 1999, and March 7 in Oneida County in 2000 (Gregg personal communication). I visited each stand 3 times between 28 March - 30 April in 1998, 01 - 23 April in 1999, and 28 March - 28 April in 2000. Woodcock were absent from the 5 unharvested stands (0% stand removal) surveyed in 1998 so I did not survey these sites in subsequent years. I did not survey the stands managed with 100% stand

removal in 1998 because they were added to the study in 1999. Contractors harvested Rocky Run (30% stand removal system) in July 1998 so I only surveyed this stand in 1999 and 2000. Due to incomplete survey coverage of some stands in 1998 and the addition of 5 stands after the 1998 field season, I used 1998 survey data for the comparison of year effect but not for other analyses. For comparison of displaying male use to other independent variables, I used only 1999 and 2000 data.

I conducted singing-ground surveys in the absence of severe weather conditions including high wind, rain, snow, storms, or temperatures below -1.1 C° as recommended by Blankenship 1957, Goudy (1960), Duke (1966), Sheldon (1967), and Tautin et al. (1983). Severe weather impeded observers' ability to detect displaying males but did not deter males from displaying in rain, snow, and winds exceeding 30 mph. The chorus of anurans occasionally reduced woodcock detectability. To compensate, my observers and I spent more time surveying these areas.

We recorded all simultaneously displaying male woodcock detected within stand boundaries on stand maps. Displaying male contact points were identified as either inside or outside clearcut and stand boundaries. At sites managed with 0% stand removal, I used flagging to delineate an area approximately equal to the average clearcut size in the other 3 stand removal systems. Observers followed this marked route for the survey. In harvested stands, observers remained within the clearcut areas for most of the survey and relied on hearing displaying woodcock in unharvested areas of the stand from the clearcuts. Two observers simultaneously surveyed different halves of a stand when clearcut areas were greater than 55 ha. Knowledge of

displaying male locations from the first and second visits allowed for thorough survey coverage on the final survey visit. I selected the maximum number of displaying males across visits to calculate male density as recommended by Murphy and Thompson (1993) rather than the mean number of displaying males. Male abundance in stands and in clearcuts was the maximum number of displaying males observed from 3 visits within stand boundaries during spring courtship. Male density *in stands* was the male abundance in stands per aspen stand area (ha). Male density *in clearcuts* was the mean male density (male abundance in a clearcut unit per clearcut unit area (ha)) among all clearcut units within a stand.

Other Stand-scale Independent Variables

To determine if clearcut openings adjacent to good nesting cover were more attractive to displaying males than openings adjacent to poor nesting cover, I compared displaying male density to the prevalence of cover types adjacent to clearcut openings. I used the ArcView Geographic Information System Version 3.2 (Environmental Systems Research Institute 1999) and the Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) land cover data to quantify land cover types surrounding each clearcut. The WISCLAND land cover data was derived from Landsat Thematic Mapper satellite imagery acquired between August 1991 and May 1993 (Wisconsin Department of Natural Resources 1998).

I identified land cover types within a 100 m buffer from the clearcut edge and based the buffer width on woodcock movement patterns observed in other studies. In

northern Wisconsin, Gregg (1984) located 75% (n=72) of woodcock nests within 14 m of an opening in aspen forest and at an average distance of 120 m from a singing-ground. Most males used diurnal cover within 200 m of their singing-ground (Maxfield 1961). In aspen forest, Rabe (1977) flushed most woodcock within 25 m of clearings. I assumed a 100m-wide buffer from the edge of a clearcut included most breeding woodcock in the vicinity.

To standardize the amount of each adjacent land cover type for comparison among sites, I calculated the percentage of each land cover type in the buffered area (Figure 2.4). I examined the relationship between displaying male density in clearcuts to the prevalence of good nest cover (aspen forest and shrublands) and poor nest cover (northern hardwood forest and conifer forest) adjacent to clearcuts. The land cover data also confirmed that the ratio of residual aspen forest surrounding the clearcuts was consistent with the stand removal ratios calculated for each site. Due to the lack of statistical difference between the 30% and 60% stand removal systems and to simplify the display of land cover data, I averaged the actual ratio of stand removal for the 9 sites in these systems to produce a combined 30% stand removal system category. As expected, aspen forest was rare near the 100% stand removal sites and predominated around the combined 30% stand removal sites (Figure 2.4).

Clearcut-scale Independent Variables

Variables describing vegetation structure were good predictors of displaying male presence or absence in other studies (Kinsley et al. 1982, Gutzwiller et al. 1983).

To determine if males respond to structural features, I measured vegetation variables that may explain differences in male density across clearcuts. I surveyed vegetation between 11 June - 09 July in 1999 and 22 June - 15 July in 2000. From a random starting point, I created a grid of 12 sample points at least 100 m apart in the clearcut areas of each stand. I sampled the same 6 randomly selected grid points in 1999 and 2000 plus an additional 4 grid points in 2000. I centered a 1-m^2 quadrat at each sample point to estimate percent ground cover, percent litter cover, litter depth, and stem density of woody vegetation groups including aspen suckers, all tree seedlings (including aspen suckers), dead stems, and shrubs (1999 only). A spherical densiometer was used to estimate canopy closure. To estimate shrub-layer height-density, I measured visual obstruction of the standing vegetation with a modified Robel pole (6 X 300 cm) centered on the sample point (Robel et al. 1970). From the pole, I walked 10 m in each cardinal direction and recorded the visual obstruction from a height of 1.5 m. The Robel pole or a clinometer was used to measure shrub and tree height. To measure woody debris, I extended a tape measure 10-m in the cardinal directions from the sample point and totaled the centimeters of woody slash intercepted by the tape measure. Woody debris was defined as dead, woody material that possessed some vertical structure but did not include standing, dead woody stems (>45°), litter, or stumps.

I calculated the amount of edge for each clearcut by dividing the clearcut perimeter length (km) by the clearcut area (ha). I determined perimeter length and clearcut area from GPS data. To illustrate differences in displaying male response to

landscapes managed under high edge and low edge scenarios, I selected the following 2 independent clusters of clearcuts from my study: 1) Cedar Falls East and West, and 2) Alexander, Lily Lake, Trout Creek North, and Trout Creek South (Figure 2.2).

To this point, I used male density as a measure of male use because of the need to standardize male abundance (number of males) for comparison among clearcuts with different areas. To compare male use to edge effect, I selected male abundance (number of males) as the dependent variable. I was unable to use male density because edge is also a function of clearcut area. A comparison of male density to edge would essentially be the same as comparing male abundance to the length of the clearcut perimeter. This relationship would not address my null hypothesis that male use is unrelated to the amount of clearcut edge.

Hypotheses and Statistical Analysis

The use of the maximum count of displaying males required transformation of male abundance and density values using natural logarithms or square roots to produce a more symmetrical distribution. For analysis of variance (ANOVA) and t-test analyses, I determined if all test assumptions (continuous variables, normality, and equal variances) were met. I used the Modified Levene Equal-Variance Test to test for equal variances. Where necessary, I used natural logarithms to transform independent variables to meet these assumptions.

For comparisons of maximum displaying male abundance in stands between 1998-2000, I used a repeated measures ANOVA model. For multiple comparisons, I

used Fisher's Least Significant Difference test. The null and alternative hypotheses were as follows:

H_0: $\mu_A = \mu_B = \mu_C$; maximum male abundance was not different among years

H_A: not all μ_i are equal; maximum male abundance differed among years

To compare displaying male woodcock abundance between 1999 and 2000, I used a paired t-test with a two-sided hypothesis. Observations were paired by stand. The null and alternative hypotheses were as follows:

D = difference between observations of displaying male abundance in each stand in 1999 and 2000

H_0: $\mu_D = 0$; maximum male abundance was not different between 1999 and 2000

H_A: $\mu_D <> 0$; maximum male abundance differed between 1999 and 2000

The USFWS used trend estimation methods to compare displaying male abundance differences on Singing-ground Survey routes in the Northern Forest Region of Wisconsin between 1998-2000 (see Kelley 2000). Results were summarized by William Kendall, USFWS statistician, and reported to me. Only routes with adequate information were included in these analyses (Kendall, personal communication).

Clearcut and stand-scale variables were compared across sites to determine features correlated with displaying male abundance or density (Table 2.1). For trends across stands and clearcuts, I used simple linear regression analysis. To select independent variables for the regression analyses, I used Spearman-rank correlations

with male abundance or density greater than 0.40 and examined scatter plots for patterned relationships. The absence of nonlinear patterns supported using a linear model. In general, the null and alternative hypotheses were as follows:

H_0: $Y_i = b_0 + e_i$; there was no relationship between male abundance or density and clearcut- or stand-scale variable(s)

H_A: $Y_i = b_0 + b_1x_i + e_i$; there was a linear relationship between male abundance or density and a clearcut- or stand-scale variable

I reviewed residual plots for all regressions to evaluate equality of error variances. All errors for each regression model were checked for independence and normality. To investigate multiple variable regression models, I first used a forward selection model to reduce the set of candidate variables to 15. Then I used an All Possible Regressions procedure to investigate possible multiple variable models. If any independent variables in the best model were correlated with one another, I selected the variable with the highest correlation to the dependent variable for inclusion in the final model.

I used Akaike's Information Criterion (*AIC*) to determine if the addition of an independent variable to a linear model resulted in a better model than with only the dependent variable (male density) in the model (Table 2.2). This provided a method to evaluate the relationship of male abundance or density to independent variables and to select the best model for predicting male density across sites. The value of *AIC* for least squares models with small sample sizes ($n < 40$) is:

$$AIC_C = n \log_e (SS_e/n) + 2k + 2k\,(k+1)/(n-k-1)$$

where n is sample size, SS_e is error sum of squares, and k is the total number of estimable parameters in the model including the intercept and variance (Burnham and

Anderson 1998). To determine if a relationship exists between male abundance or density and an independent variable, I compared the AIC_C for the following 2 models:

1) $Y_i = b_0 + e_i$ (when $x_i = 1$, then $b_1 = 0$)

2) $Y_i = b_0 + b_1 x_i + e_i$

If the difference between the AIC_C for the 2 models was less than 2, then the models were equivalent. If the difference was between 3 and 7, then there is some support that the model with the smallest AIC_C was the better model. If the difference was greater than 10, then the model with the smallest AIC_C was the better model (Burnham and Anderson 1998).

I used NCSS (Hintze 2000) for analyses comparing displaying male abundance or density with clearcut- and stand-scale independent variables. I set statistical significance at $\alpha = 0.05$ probability of a Type-I error.

Results

Male Response to Clearcutting

I observed no displaying males in the five 0% removal stands visited in 1998. In contrast, I recorded displaying males in clearcut areas of all harvested stands. Because of this result, I will discuss only harvested stands beyond this point.

Year Effect

I compared the abundance of displaying males in clearcuts for the 8 harvested stands surveyed in all 3 years (Appendix V) and found a significant year effect ($F_{2,30} =$

6.34, $P = 0.01$) with a 23% per year increase between 1998 and 2000. Similarly, displaying males increased but not significantly by 14% per year on USFWS Singing-ground Survey routes in the Northern Forest Region of Wisconsin over the same period ($P > 0.10$, n =19). Between 1998-1999, woodcock abundance remained stable on the northern forest routes ($P > 0.10$) and on my study area ($P = 0.69$). When I compared data from only 1999 and 2000 for all 13 harvested stands in my study area, male abundance increased by 49% ($T_{12} = -0.6008$, $P \leq 0.001$) compared to a marginally significant 36% increase on the USFWS Northern Forest routes ($n = 14$, $P = 0.10$).

Male Response to Stand-scale Independent Variables

Male density within aspen stands averaged 0.046 males/ha (± 0.010 males/ha, n = 8), 0.075 males/ha (± 0.014 males/ha, n = 13), and 0.106 males/ha (± 0.018 males/ha, n = 13) in 1998, 1999, and 2000 respectively (Appendix IV). Actual stand removal and adjacent northern hardwood forest correlated with male density, so I used these variables in subsequent simple linear regression models (Table 2.1). Male densities *in stands* and the actual stand removal ratio were unrelated in both 1999 ($R^2 = 0.196$, P = 0.13) and 2000 ($R^2 = 0.212$, $P = 0.11$; Figure 2.5). Similarly, the actual ratio of stand removal did not explain differences in male density *in clearcuts* for 1999 ($R^2 = 0.206$, $P = 0.12$) and for 2000 ($R^2 = 0.291$, $P = 0.06$). Of the 16 cover types adjacent to clearcuts, aspen forest (38% ± 6%), northern hardwood forest (21% ± 5%), and conifer forest (15% ± 5%) were the most prevalent across sites (Appendix VI). Of these, northern hardwood forest appeared to relate negatively to male density (Table 2.1).

AIC_C confirmed poor relationships between male density and actual stand removal ratio and the prevalence of northern hardwood forest adjacent to clearcuts (Table 2.2).

Male Response to Clearcut-scale Independent Variables

Male density in clearcuts averaged 0.181 males/ha (± 0.035 males/ha, $n = 13$) and 0.250 males/ha (± 0.036 males/ha, $n = 13$) in 1999 and 2000 respectively (Appendix VI). Male density in clearcuts decreased with increasing clearcut area in both 1999 ($R^2 = 0.409$, $F_{1, 19} = 13.133$, $P = 0.002$) and 2000 ($R^2 = 0.463$, $F_{1, 19} = 16.385$, $P \leq 0.001$; Figure 2.6). Of the 14 vegetation structure variables measured (Appendix VII), only mean litter depth in 2000 appeared to be correlated with male density (Table 2.1). AIC_C results indicated no relationship (Table 2.2). Regression models containing multiple variables (both stand- and clearcut-scale) did not explain differences in male density among sites. Male abundance was highest in clearcuts with low edge in both 1999 ($R^2 = 0.25$, $F_{1, 19} = 6.234$, $P = 0.02$) and 2000 ($R^2 = 0.31$, $F_{1, 19} = 8.333$, $P = 0.01$; Figure 2.7a). Removal of 2 outliers did not change this relationship (Figure 2.7b).

Discussion

Male Response to Clearcutting

Because I found displaying male woodcock in all clearcuts and the fact that they were absent in large blocks of mature aspen forest, I believe even-aged management practices benefit breeding woodcock. Previously, researchers suggested aspen clearcuts are an important cover type for displaying males in northern Wisconsin

(Gregg and Hale 1976) and the Midwest (Dangler and Marshall 1950, Blankenship 1957).

Between 1983 and 1996, aspen forest in Wisconsin declined by 8% with the greatest loss (37%) in central Wisconsin (Schmidt 1996). Though aspen forest declined by only 1% across the northern third of the state, the recent sharp decline along the southern edge of the northern forest region may portend a northward shift in preference for uneven-aged forest management or indicate effects of global climate change. The resultant reduction in clearcutting and aspen forest will hamper efforts to stabilize the regional woodcock population.

In my study, clearcuts larger than 4.5 ha supported multiple, simultaneously displaying males. The large clearcuts in my study allowed adequate space for multiple singing-grounds making a comparison of male density with spatial and vegetation variables possible. Mendall and Aldous (1943) never observed multiple singing-grounds within a single, open (i.e. no visual barriers) clearing; this was perhaps due to the small size of openings ($\leq$ 4 ha).

Year Effect

Displaying male woodcock abundance increased substantially between 1998 and 2000 in my study area. Between 1999 and 2000, woodcock abundance increased more on the traditionally managed sites (88% mean stand removal) than on alternatively managed sites (30% mean stand removal). Similarly, Bennett et al. (1982) found a greater increase of male use on sites with 75% forest removal than on

sites with 25% or 50% removal. Displaying males may prefer large blocks of forests predominantly in early successional stages compared to small forests or those with a minor early successional component.

The similar pattern of woodcock increase on both my study area and the northern forest routes suggests the increases observed on my study area may reflect changes in the regional population. Due to the large variances associated with the small sample of USFWS routes, the similarity of displaying male trends between my study area and the northern forest routes is speculative and should not be interpreted as conclusive.

Statewide, woodcock increased significantly between 1998-1999 but did not change between 1999-2000 (Kelley 2000). The recent sharp decline in aspen forest across the southern 2/3 of the state (Schmidt 1996) may correspond with a similar decline in woodcock use. If woodcock use increases in the northern forest region while use decreases in the southern 2/3 of the state, the southern routes may have a stronger influence on the net statewide trend. Woodcock populations in northern areas with extensive forest especially with a substantial early successional aspen component may be stable or increasing despite no change or possibly a declining trend in southern areas experiencing widespread habitat degradation and loss due to agriculture and urbanization. The difference between the population trend statewide and the northern forest suggests the woodcock population trends may differ between the northern forest region and the southern part of the state. The long term, statewide trend on USFWS routes may not reflect trends in both northern and southern Wisconsin. Though these

observations and ideas are speculative and require further investigation, the current woodcock monitoring system inadequately identifies regions of increasing and declining population trends. To improve woodcock population monitoring and correlate population changes with landscape patterns, routes could be grouped by floristically similar regions (e.g. Bird Conservation Regions used by the North American Bird Conservation Initiative) rather than by state political boundaries.

Male Response to Stand-scale Independent Variables

I used singing-ground surveys as an index of woodcock response to habitat management though researchers disagree on the relationship between displaying males and actual population densities (Dwyer et al. 1983). Whitcomb and Bourgeois (1974) and Shissler and Samuel (1985) concluded counts of displaying males were good indicators of total population and generally reflected population trends. In Wisconsin, Gregg (1982) found a close relationship between displaying male abundance and the number of nesting females. In Michigan, a significant positive correlation was found between the number of broods and the number of displaying males (Rabe and Prince 1982). Similarly, the number of adult females was proportional to the number of adult males captured in Maine (Sepik and Dwyer 1982) though densities of displaying males and the total population in the study area were unrelated (Dwyer et al. 1988). Couture and Bourgeois (1977) did not find a relationship between the number of displaying males and broods in a small breeding population in Quebec. Their results were based on small sample sizes, so conclusions were not definitive.

Numerous researchers expressed concern regarding the use of male density as an indicator of habitat quality (Van Horne 1983, Hobbs and Hanley 1990, Vickery et al. 1992, Zannette 2001). Previous woodcock studies provided little information describing the relationship between displaying male densities and habitat quality. The relationship between reproductive success, predator populations, nest density, displaying male density, and habitat limiting variables at multiple scales require further investigation. In the absence of a better, logistically feasible survey method, I used singing-ground surveys to estimate displaying male density to determine relative habitat quality across treatments.

I expected the partial harvest of aspen stands to increase structural diversity and improve woodcock use relative to even-aged stands. Aspen forests managed with the traditional even-aged system seemed to lack a range of early seral stages supposedly required by woodcock during the nesting and brood rearing stages. The creation of two aspen age classes within stands failed to increase male density. The highest densities of displaying males were attained in the traditionally managed sites. Despite the lack of definitive results, the relationship between displaying male abundance and the level of stand removal was consistent with results reported by Bennett et al. (1982). This suggests displaying male densities on my sites may vary due to landscape-scale variables not measured in my study.

Dwyer et al (1988) suspected displaying males selected clearings surrounded by quality nesting habitat. Hale and Gregg (1976:112) observed, "Aspen clearcuts in northern Wisconsin appear to attract and concentrate woodcock to a much greater

degree than do other types of forest openings." Bennett et al. (1982) found displaying males preferred clearings adjacent to untreated aspen forest rather then oak-maple or pine forest. Their analysis suggested the presence of aspen forest adjacent to the clearing was more important than structural features within the clearing. Assuming male discretionary behavior exists, I predicted aspen clearcuts surrounded by mature aspen forest would be more desirable than those surrounded by mature non-aspen forest types. Effects of adjacent forest cover did not explain displaying male preference for clearcuts surrounded by non-aspen forest types. Other explanations seemed likely.

Most aspen forest adjacent to clearcuts ranged in age from 25-60 years old. According to Sepik et al. (1981) woodcock rarely used young hardwood stands older than 30 years in Maine. Perhaps mature aspen forest was no more suitable than other adjacent cover types like conifer and northern hardwood forests.

Second, the importance of forest cover adjacent to aspen clearcuts may be reduced when clearcut areas are very large. The lack of suitable nesting and foraging habitat adjacent to the traditionally harvested clearcuts may lead to both females and males spending most of their time in the clearcuts. The traditionally harvested clearcuts were large (>55 ha) and provided heterogeneous shrubby cover, topography, and soil moisture across the clearcut. I observed nesting hens, broods of all ages, solitary adults, and many groups of probe holes throughout the large clearcuts. Large-scale, young aspen clearcuts may fulfill all breeding habitat requirements including

provision of suitable cover for foraging, roosting, displaying, nesting, and brood-rearing (Gregg 1974, Hale and Gregg 1976, personal observation).

A third possible explanation for the lack of male response to stand removal ratios relates to criticism of using displaying males as an index of habitat quality. Sepik et al. (1993) suspected displaying male use did not reflect the quality of the habitat based on an examination of the male age structure in newly created clearcuts. Displaying males on the traditionally managed sites may be composed primarily of second-year males displaced by dominant males from more favorable sites. Density of female woodcock and nest productivity may better indicate habitat quality. Though the traditionally managed sites had higher densities of displaying males, they may not have a corresponding high use by females. Productivity and survival may vary among forest types as well (Longcore et al. 1996). The alternatively managed sites may provide higher quality habitat despite lower displaying male densities.

Finally, differences in male density across stands may be strongly influenced by behavioral variables. Displaying males exhibit a loose lekking system to attract females (Hirons and Owen 1982, Dwyer et al. 1988, Ellingwood et al. 1993). The impact of male conspecific attraction on displaying male densities may vary based on the size, distribution, and availability of forest openings in an area. Subdominant males occupy newly created openings faster than dominant males (Dwyer et al. 1988). Densities across sites may vary according to preferences of dominant males. The added behavioral dimension complicates differentiation of the effects of habitat variables on male density.

Male Response to Clearcut-scale Independent Variables

The number of displaying woodcock males increased as the amount of edge was reduced. Resource managers can reduce edge by either increasing clearcut area or shortening the length of the clearcut perimeter (i.e. less convoluted shape). In most cases, size of the clearcut may be easier to manipulate than the shape. Clearcut boundaries must often follow topographical features, waterways, property boundaries, or roads. Therefore, I recommend cutting large clearcuts and minimizing the length of the clearcut perimeter to the extent possible.

Mean male density was higher in small clearcuts than in large clearcuts. This suggests that managing forested landscapes for many small clearcuts will support larger woodcock populations. However, this may not always be the case. Because the amount of edge and the number of males were negatively correlated, many small clearcuts may support fewer total males than is possible in a few large clearcuts. This relationship between the amount of edge and mean male density and the number of males can be explained by comparing two independent aspen landscapes in my study using woodcock observations from 2000 (Figure 2.8). Assume the management goal is to harvest 100 ha of aspen forest in each landscape. Under a high edge management strategy (0.22 km/ha ± 0.03 km/ha), 8 clearcuts were created ranging in size from 1.4 to 27 ha (12.5 ha ± 3.3 ha). On the other landscape, 2 clearcuts approximately 50 ha (± 1 ha) in size were created under the low edge management strategy (0.15 km/ha ± 0.02 km/ha). Though the mean displaying male density was higher under the high edge management strategy (0.33 males/ha ± 0.07 males/ha) than under the low edge

management strategy (0.29 males/ha ± 0.02 males/ha), similar numbers of displaying males used clearcuts in the landscape with low edge (25 males) and in the landscape with high edge (22 males). By using the low edge management strategy, edge was reduced by 32%. Despite minor improvements in woodcock use, a third less edge on the landscape may substantially benefit edge- and area-sensitive forest wildlife species (King et al. 1996). Fewer, larger clearcuts will require fewer access roads and reduce harvest costs by increasing efficiency. Fewer roads could lead to less secondary edge creation, fragmentation, and devegetated compacted surfaces susceptible to erosion (Franklin and Forman 1993). Large aspen clearcuts harvested under best management practices can benefit woodcock and other wildlife without environmental degradation (Askins 1993, Litvaitis 1993).

Wishart and Bider (1976) and Gutzwiller et al. (1983) showed the structural features of a singing-ground were better predictors of displaying male presence than plant species composition. In my study area, vegetation structure did not explain the difference in male density across clearcuts. Increasing the number of sample plots within each clearcut may have improved my ability to correlate vegetation structure to woodcock use. The lack of male woodcock response to most clearcut-scale variables suggests variables at a larger scale may better predict displaying male density.

Male Response to Wet Sites

Of the 4 sites managed under the traditional stand removal system, two sites had mesic to wet-mesic, silt-loam soils with extensive standing water particularly in the

spring during peak male displaying activity. These sites had much lower densities of displaying males relative to the two dry sites in the same treatment. In Michigan, woodcock rarely used sites with silt loam soils relative to other soil types for singing-grounds, feeding, nesting, brood-rearing, or roosting (Blankenship 1957). Poorly drained, silt loam soils have been shown to have low earthworm biomass relative to moderate and well-drained sandy loam (Owen and Galbraith 1989). In Pennsylvania, earthworm abundance and woodcock occurrence was low on permanently wet sites relative to drier, sandy loam and loam sites (Miller 1957). In Maine and Michigan, areas with high worm densities were correlated with high woodcock brood use but only weakly related to displaying male use (Reynolds et al.1977, Rabe and Prince 1982). Sites remaining wet during the breeding site may have low earthworm biomass and therefore have lower woodcock use than on drier sites.

A second contributing factor to the relatively low displaying male density observed on these sites may relate to reduced displaying male detectability during surveys due to noise from calling anurans, a problem identified in other studies (Blankenship 1957, Duke 1966, Clark 1970). Due to the massive numbers of calling anurans attracted to both sites, the calls and flight songs of male woodcock greater than 100 m from the observer became difficult to detect. This possibly resulted in an underestimate of displaying males on these sites.

Woodcock Management

Most biologists agree woodcock populations are declining range-wide. There is much debate over the solutions required to stabilize the population. My work demonstrated the importance of large blocks of early successional aspen forest to breeding woodcock. Reducing aspen clearcut sizes will not improve woodcock use at the landscape scale. Habitat improvement for woodcock should not be used as a reason to support reducing clearcut sizes. Woodcock will respond to breeding cover creation and improvement but this may not be adequate to stabilize the population if trends continue toward smaller clearcuts.

To understand the full story of woodcock decline and recovery, we must not only better understand the limiting factors on the breeding grounds but also the role of winter and migration stop-over habitat loss, increasing migration hazards (e.g. cell towers and wind generators), contaminants (e.g. lead and pesticides), exotic species (e.g. earthworms across range and fire ants on wintering range), increasing predator populations, and global climate change.

Monitoring woodcock populations across the breeding range remains an important component of woodcock management and is critical to measuring the success of new woodcock management strategies. To improve our ability to detect woodcock response to landscape changes, I recommend monitoring woodcock populations according to floristically similar regions rather than by political boundaries. This is particularly important because detecting management impacts will be difficult, and management practices may seem ineffective initially due to relatively

low, annual woodcock recruitment (Kelley 2000). Effective management will require ongoing research and monitoring in addition to considerable patience.

Conclusions

1) Clearcutting improved woodcock use of aspen stands.

2) Between 1998-2000, increases of displaying male woodcock on my study area possibly reflected regional trends rather than the influence of changes at the clearcut- or stand-scale.

3) Partial harvest of aspen stands did not improve displaying male woodcock use.

4) Vegetation structure and the prevalence of adjacent forest cover types did not explain variation in male density across clearcuts.

5) Male abundance related negatively to the amount of clearcut edge. Results suggested more displaying males may use a few large clearcuts with low edge than many small clearcuts with high edge.

6) Early successional aspen forest on poorly drained, mesic to wet-mesic soils appeared to discourage woodcock use during spring courtship.

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Table 2.1. Spearman-rank correlation coefficients for comparisons of clearcut- and stand-scale independent variables with displaying male American Woodcock (*Scolopax minor*) abundance and density (males/ha) across aspen (*Populus* spp.) forest stands (n=13) and clearcuts (n=21) surveyed in April 1999 and March-April 2000 in Oneida and Lincoln Counties, Wisconsin.

		1999		2000	
Dependent variable vs. Independent variable	Scale[a]	r	P	r	P
Male Abundance in Clearcuts vs.					
Clearcut edge[b] (km/ha)	C	-0.580	0.01	-0.672	$\leq$0.001
Male Density in Stands vs.					
Stand area (ha)	S	-0.692	0.07	-0.637	0.10
Actual stand removal (%)	S	0.522	0.01	0.473	0.02
Male Density in Clearcuts vs.					
Clearcut area (ha)	C	-0.655	$\leq$0.001	-0.560	0.01
Actual stand removal (%)	S	-0.256	0.40	-0.357	0.23
Mean litter cover (%)	C	-0.176	0.56	-0.028	0.93
Mean ground cover (%)	C	0.383	0.20	0.267	0.38
Mean litter depth (cm)	C	0.215	0.48	-0.591	0.03
Mean visual obstruction (dm)	C	0.088	0.77	0.110	0.72
Mean canopy closure (%)	C	0.191	0.53	0.126	0.68
Mean maximum herb height (m)	C	.....	.....	0.212	0.49
Mean aspen sucker density (stems/m^2)	C	0.286	0.34	-0.237	0.44
Mean maximum aspen regeneration height (m)	C	0.240	0.43	0.050	0.87
Mean tree seedling density (stems/m^2)	C	-0.103	0.74	-0.366	0.22
Mean maximum tree regeneration height (m)	C	0.308	0.31	0.066	0.83
Mean dead woody stem density (stems/m^2)	C	0.303	0.31	-0.272	0.37
Mean shrub density (stems/m^2)	C	0.124	0.69	.....	.....
Mean woody debris (cm)	C	0.363	0.22	.....	.....
Mean maximum shrub height (m)	C	0.116	0.72	0.239	0.43
Adjacent aspen forest cover (%)	S	0.385	0.19	0.390	0.19
Adjacent northern hardwood forest cover (%)	S	-0.556	0.05	-0.515	0.07
Adjacent conifer forest cover (%)	S	-0.083	0.79	-0.238	0.43
Adjacent shrubland cover (%)	S	0.251	0.90	0.028	0.51

[a] Scale of independent variable: S=stand, C=clearcut

[b] Edge = clearcut perimeter length (km) / clearcut area (ha)

Table 2.2. I used a linear regression model to correlate independent variables with displaying male American Woodcock (*Scolopax minor*) abundance and density (males/ha) across aspen (*Populus* spp.) forest stands (n=13) and clearcuts (n=21) surveyed in April 1999 and March-April 2000 in Oneida and Lincoln Counties, Wisconsin. I used Akaike Information Criterion for small sample size (AIC_C) to determine if the addition of an independent variable to a linear model resulted in a better model than with only the dependent variable in the model. Selection of independent variables for testing using AIC_C was based on high Spearman-rank correlation coefficients ($r > 0.40$) and a patterned relationship between variables on a scatter plot.

Dependent variable vs. Independent variable	Year	R^2	F	P	SS_e	AIC_C[a]	AIC_C difference[b]	Model comparison[c]
Male Abundance in Clearcuts vs.								
Mean clearcut edge[d] (km/ha)	1999	0.247	6.234	0.02	4.806	-23.56	3.21	**
Mean clearcut edge (km/ha)	2000	0.305	8.333	0.01	4.879	-23.24	4.89	**
Mean clearcut edge (km/ha) w/o outliers	1999	0.184	3.843	0.07	4.750	-18.74	1.02	*
Mean clearcut edge (km/ha) w/o outliers	2000	0.313	7.763	0.01	4.343	-20.44	4.30	**
Male Density in Stands vs.								
Actual stand removal (%)	1999	0.196	2.685	0.13	4.504	-5.11	0.63	*
Actual stand removal (%)	2000	0.212	2.959	0.11	3.247	-9.37	0.37	*

[a] Akaike Information Criterion for small sample size (AIC_C) = n ln (SSe / n) + 2k + 2k (k+1) / (n-k-1) where n was the sample size, SS_e was the error sum of squares, and k (total number of estimable parameters fit to model)=2 for the model containing only the dependent variable, and k=3 for the model including an independent variable (Burnham and Anderson 1998).

[b] Difference between AIC_C values for the model containing only the dependent variable and the model including an independent variable

[c] * = Models are equivalent (AIC_C difference ≤2); ** = Some support for the model including the independent variable (3<AIC_C difference≤7); *** = Strong support for model including the independent variable (AIC_C difference >10)

[d] Clearcut edge = clearcut perimeter length / clearcut area

Table 2.2 (continued).

Dependent variable vs. Independent variable	Year	R^2	F	P	SS_e	AIC_C	AIC_C difference	Model comparison[c]
Male Density in Clearcuts vs.								
Clearcut area (ha)	1999	0.409	13.133	0.002	0.186	-91.90	8.29	**/***
Clearcut area (ha)	2000	0.463	16.385	< 0.001	0.139	-97.93	10.31	***
Actual stand removal (%)	1999	0.206	2.852	0.12	3.514	-8.34	0.47	*
Actual stand removal (%)	2000	0.291	4.521	0.06	2.545	-12.54	1.01	*
Mean litter depth (cm)	2000	0.250	3.676	0.08	2.691	-11.808	0.282	*
Adjacent northern hardwood forest cover (%)	1999	0.124	1.559	0.24	3.875	-7.07	1.74	*
Adjacent northern hardwood forest cover (%)	2000	0.266	3.976	0.07	2.637	-12.07	0.55	*

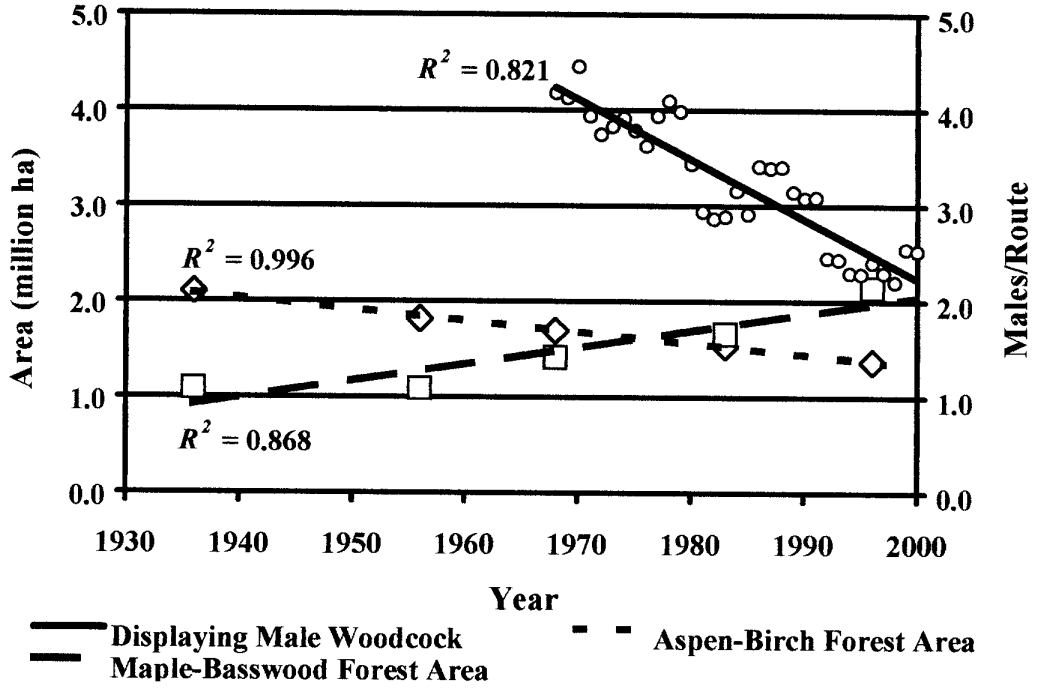
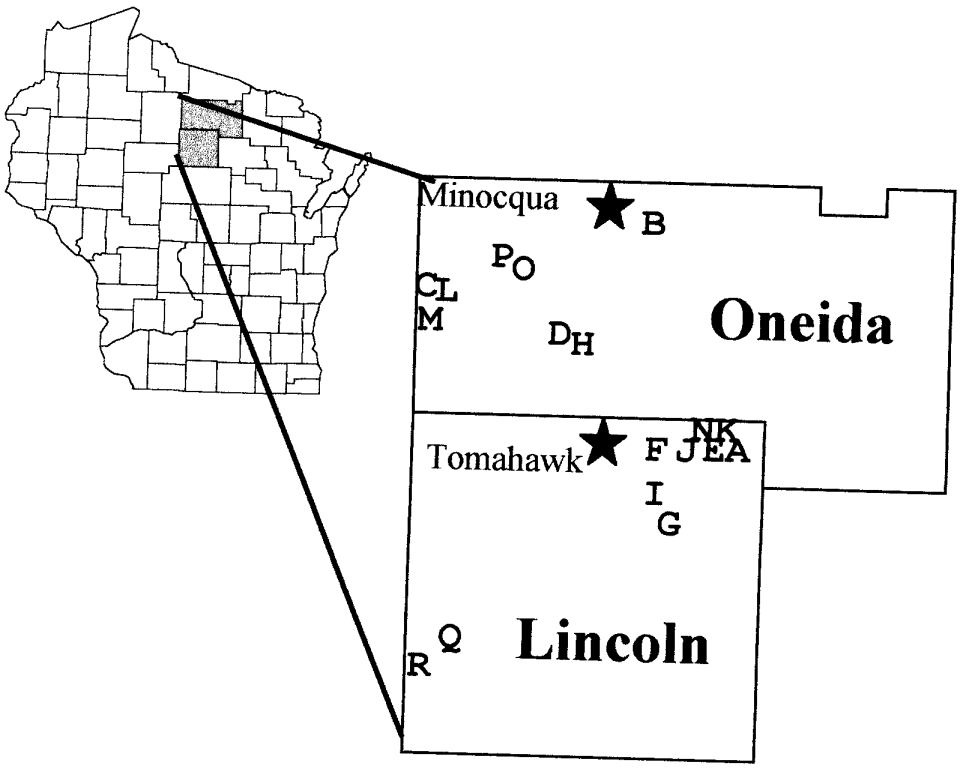


Figure 2.1. In Wisconsin, aspen-birch forest declined proportionately to the increase of maple-basswood forest from 1937 to 1996 (Schmidt 1996). The decline of displaying male American Woodcock in Wisconsin since 1968 (Kelley 2000) corresponds to the loss of aspen-birch forest in the state.



Map Letter	Site Name
	0% Stand Removal
A	Alexander Control
B	Gritzmachen
C	Price County Road Control
D	Swamp Lake
E	Trout Creek Control
	30% Stand Removal
F	Lily Lake
G	Pine Creek
H	Rocky Run
I	Skanawan Lake
J	Trout Creek South

Map Letter	Site Name
	60% Stand Removal
K	Alexander Clearcut
L	Price County Road North
M	Price County Road South
N	Trout Creek North
	100% Stand Removal
O	Cedar Falls East
P	Cedar Falls West
Q	Copper River
R	Tower Road

Figure 2.2. Oneida and Lincoln Counties, Wisconsin. Sites surveyed for displaying male American Woodcock from 1998-2000 are indicated with letters.

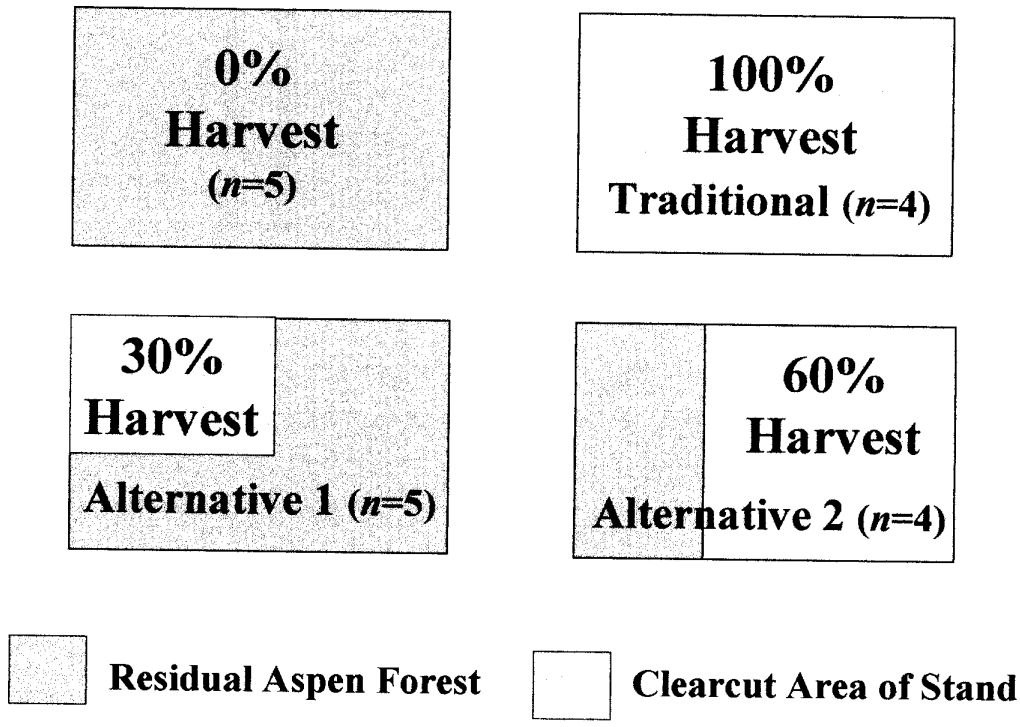


Figure 2.3. Traditional and alternative stand removal systems implemented on industrial forests in Oneida and Lincoln Counties, Wisconsin. The shape and area of aspen forest stands and clearcuts varied between sites and therefore are not accurately depicted in this diagram.

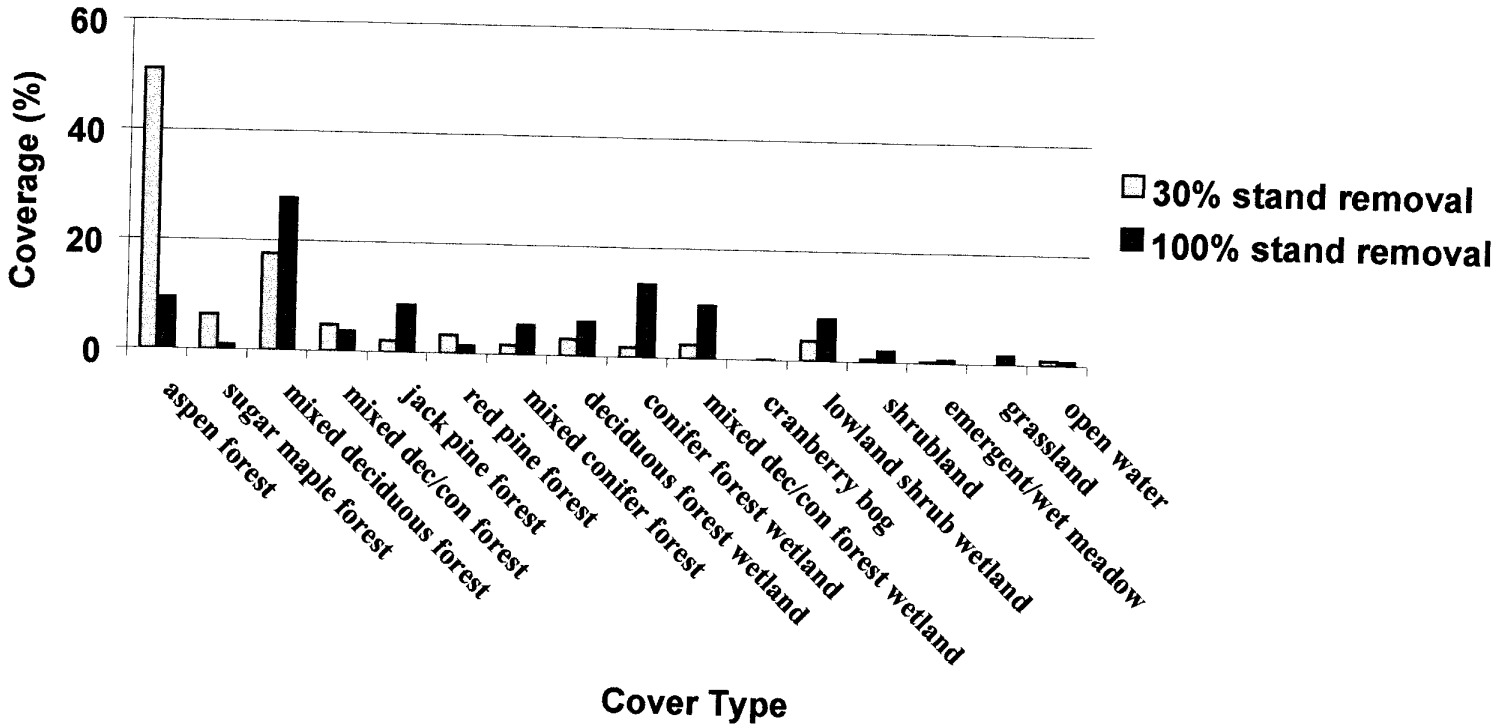


Figure 2.4. Average percentage of each land cover type calculated within a 100m buffer area around each clearcut for two aspen stand removal systems: 30% stand removal (former 30% and 60% stand removal systems combined; *n*=9) and 100% stand removal (*n*=4). ArcView 3.2 in conjunction with WISCLAND data from 1991-1993 was used to quantify land cover types in the 13 study sites in Oneida and Lincoln Counties, Wisconsin.

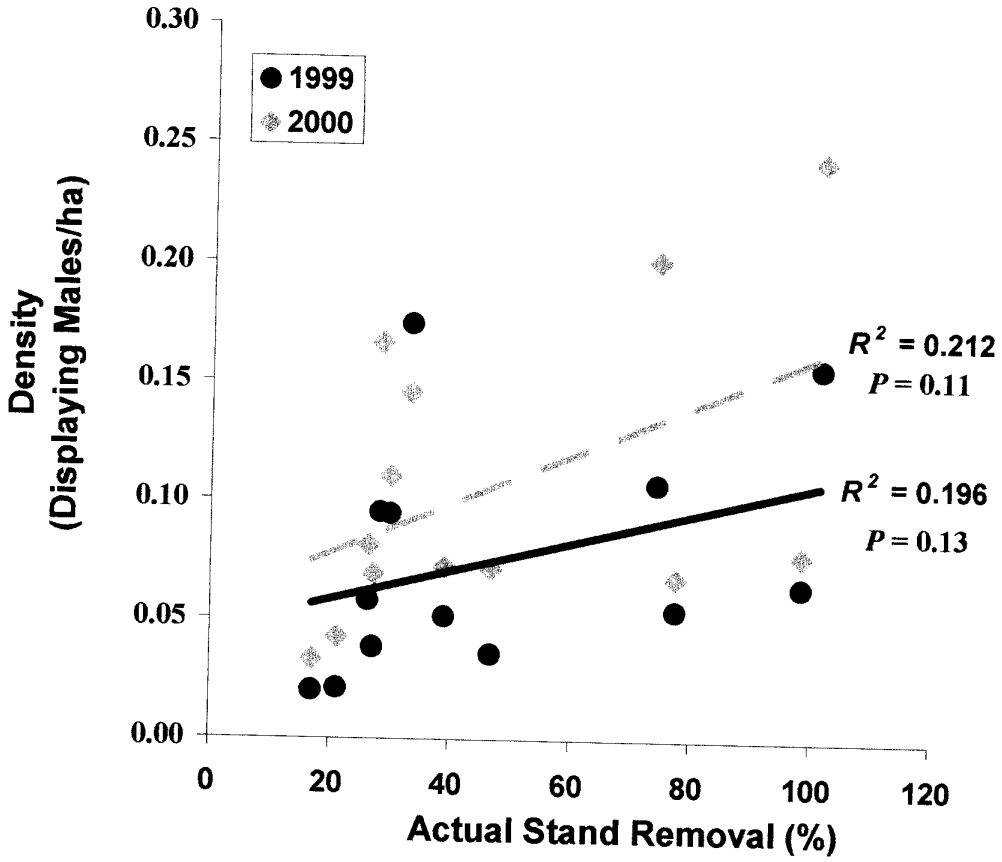


Figure 2.5. The density of displaying male American Woodcock in aspen stands increased as the ratio of actual stand removal increased on study sites surveyed during April 1999 and March-April 2000 in Oneida and Lincoln Counties, Wisconsin.

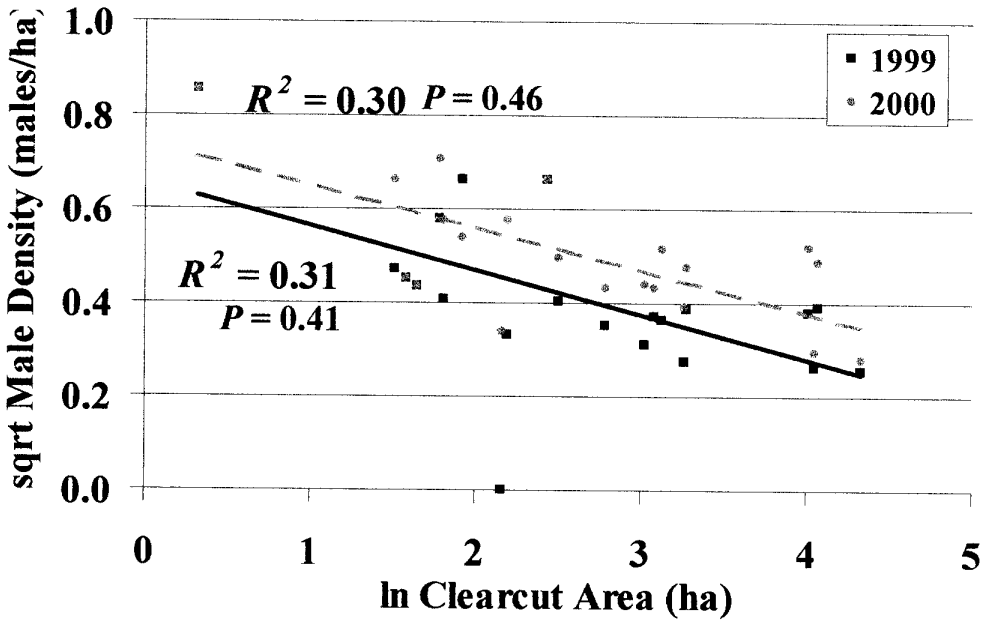


Figure 2.6. Displaying male American Woodcock density in clearcuts related negatively with clearcut area across 21 clearcuts. Clearcut area was determined with a Geoexplorer II Geographic Positioning System (Trimble Navigation 1999).

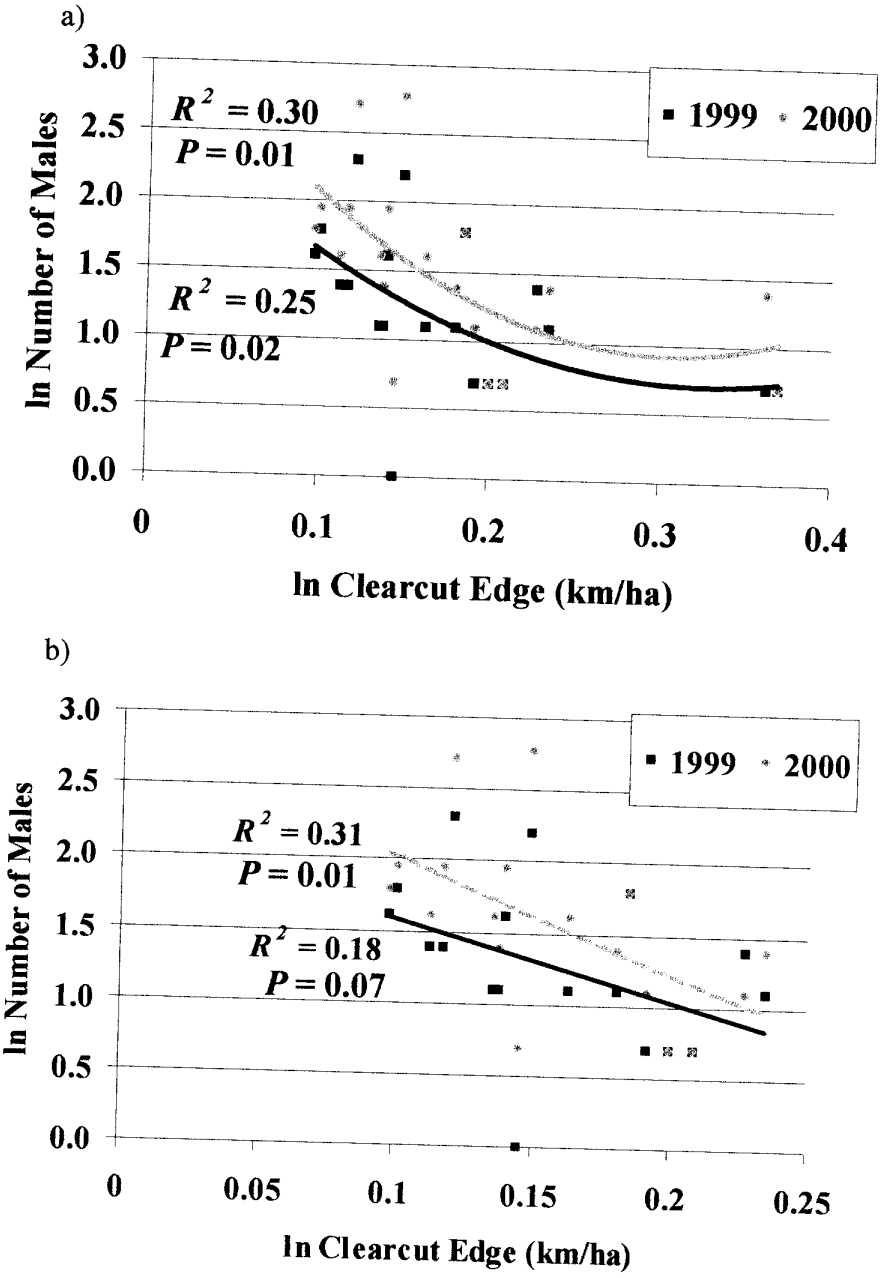
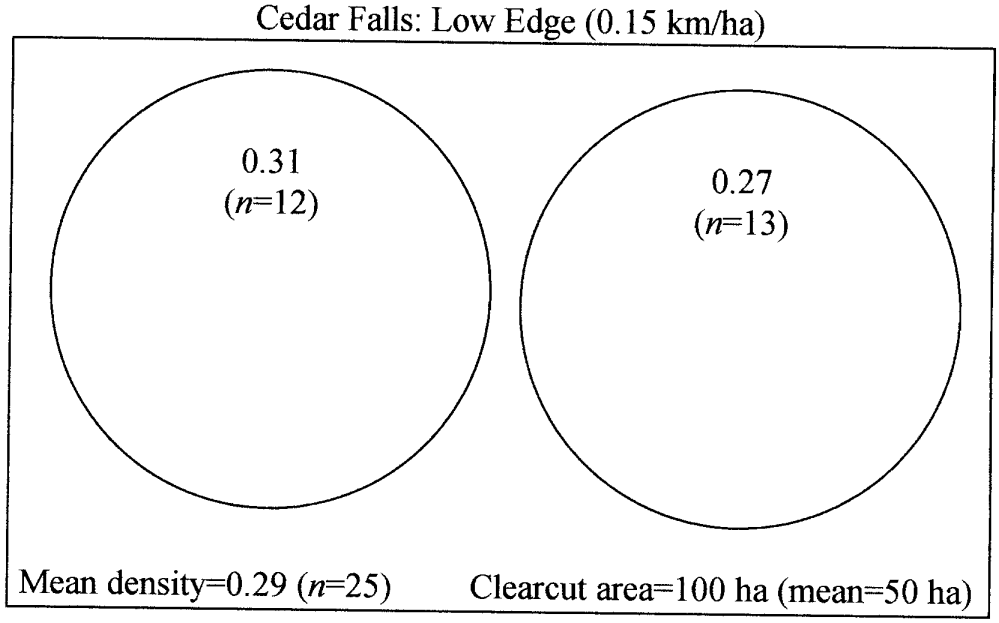


Figure 2.7. Displaying male American Woodcock abundance in clearcuts related negatively with clearcut edge a) across 21 clearcuts and b) with the removal of 2 outliers. Clearcut edge is the clearcut perimeter length (km) divided by the clearcut area (ha) as determined with a Geoexplorer II Geographic Positioning System (Trimble Navigation 1999).



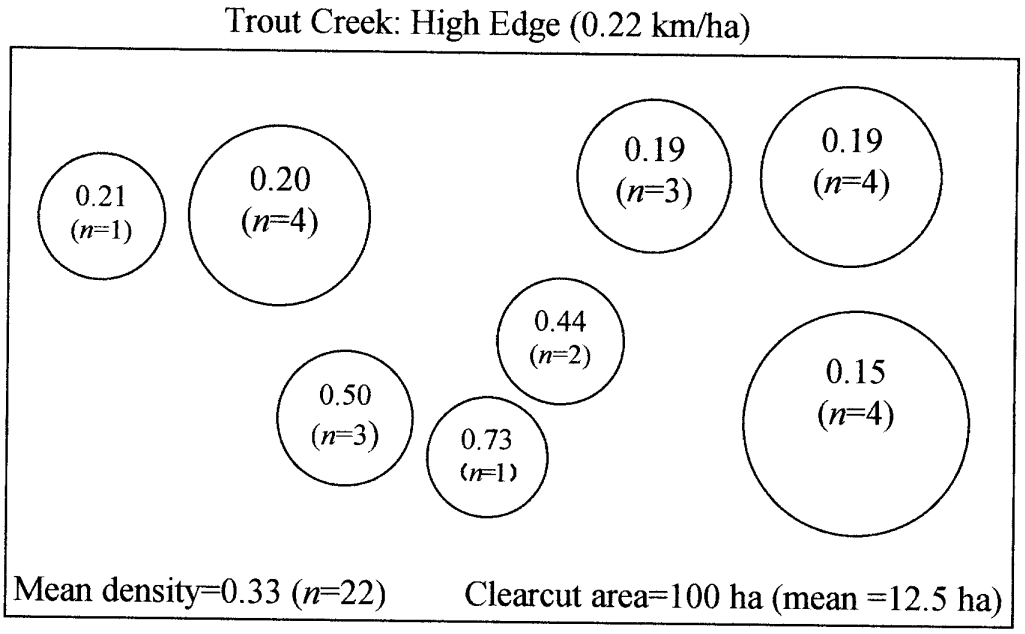


Figure 2.8. Comparison of displaying male American Woodcock mean density and abundance in clearcuts on 2 landscapes, one managed with a low edge management strategy (Cedar Falls) and one managed with a high edge management strategy (Trout Creek), Oneida and Lincoln Counties, Wisconsin, March-April 2000. Circles representing clearcut units are not shown to scale. Each circle is labeled with the observed male density (males/ha) and number of displaying males for that site.

Chapter III

GOLDEN-WINGED WARBLER DENSITY AND TERRITORY CHARACTERISTICS ACROSS AN ASPEN FOREST SUCCESSIONAL GRADIENT IN NORTHERN WISCONSIN

Abstract

Early seral deciduous forests provide important breeding habitat for Golden-winged Warblers throughout their breeding range. Though succession of these forests is suspected to contribute to the range-wide decline of Golden-wings, little is known about the effects of succession on breeding densities and territory characteristics. I compared male Golden-winged Warbler density, territory area, and territory placement across four age classes ((1) 1-4 years, (2) 6-10 years, (3) 10-19 years, and (4) 20-25 years) of aspen forests in northern Wisconsin. I surveyed 5 stands in Age Class 1 in 1999 and expanded the project in 2000 to include 4 stands in each of the 4 age classes. During spot mapping surveys in May-July 1999 and 2000, I observed a significantly higher male density for Age Class 1 (0.49 males/ha; n=9) than the male density for Age Classes 2-4 combined (0.04 males/ha; n=12; $P \leq 0.001$). I identified aspen sucker density as a good predictor of male density across age classes and territory placement in Age Class 1. In aspen stands over 6 years-old, Golden-winged Warblers located their territories in openings characterized by relatively low canopy closure (55%).

Male density and territory placement were not influenced by clearcut edge (km/ha). In 2000, mean territory area for Age Class 1 (0.82 ha; n=12) and Age Class 4 (0.54 ha; n=6) was significantly larger than the mean territory area for Age Classes 2 and 3 combined (0.18 ha; n=6; $P \leq 0.001$). Clearcutting aspen forest is the most practical strategy to increase Golden-winged Warbler breeding habitat in the Upper Great Lakes Region.

Introduction

Each spring Golden-winged Warblers (*Vermivora chrysoptera*) migrate from Central and South America to the Midwest, Northeast, and Appalachians of the United States and to southeast Canada (Figure 3.1). Golden-wings breed primarily in shrublands, but the type of communities utilized varies across the range. In the Northeast, the prevalence of shrubby fields following farmland abandonment in the twentieth century provided abundant temporary breeding habitat now being lost to forest succession. In the upper Midwest, forest cutovers, alder (*Alnus* spp.) thickets, tamarack (*Larix laricina*) bogs, and utility rights-of-way support 70% of the nation's current breeding population (Partners in Flight, unpublished data).

Between 1966 and 1990, mean numbers of Golden-winged Warblers detected on Breeding Bird Survey routes declined across the breeding range with significant declines in Wisconsin of nearly 4% per annum ($P = 0.01$; Confer 1992). Along the northern part of the breeding range, Golden-wings increased significantly in Canada ($P = 0.05$) and insignificantly in Minnesota ($P > 0.05$) perhaps due to the well documented northward expansion of the breeding range (Confer 1992). The precipitous decline of the population throughout most of the breeding range prompted concern for the species' future. Partners in Flight (unpublished data) listed Golden-wings among the 2 highest ranked species of management concern in the Upper Great Lakes Region. The U.S. Fish & Wildlife Service (1999) included Golden-wings on its list of highest conservation priority species and is assessing its status for possible listing under the Endangered Species Act. Researchers suspect the maturation of

eastern deciduous forests and urbanization of early seral woodlands as possible contributors to regional population declines. In order to meet conservation objectives, critical habitat types need to be identified for focused conservation and management efforts.

Most recent demographic studies concentrated on habitat associations in the Northeast with little emphasis on habitat types preferred by Golden-wings in the Midwest. In the western part of the breeding range, only 2 studies focused on Golden-winged Warbler populations and their habitat associations (Will 1986, Cumming 1998). Neither study investigated relative abundance, density, or productivity among different habitat types or successional stages. Impacts of habitat manipulation or forestry practices were not considered in either study. As a result of this lack of research, resource managers in the Midwest know little information about relative habitat quality across different vegetation communities and successional stages in the western breeding range. The high abundance of Golden-wings in young, managed aspen (*Populus* spp.) stands led to my exploration of forest succession impacts on their habitat use. I investigated the following 3 objectives in even-aged aspen stands in northern Wisconsin: (1) determine the aspen successional age class (-es) and vegetation structure characteristics associated with high territorial male density, (2) compare mean territory area and describe vegetation structure within territories across a successional gradient, and (3) identify vegetation structure and spatial characteristics associated with territory placement within aspen age classes.

Study Area

The study area was located in Oneida and Lincoln Counties in north-central Wisconsin on industrial forestland initially owned by Tenneco Packaging Corporation of America (PCA), Inc (Figure 3.2). In November 1999, my study sites were sold to the State of Wisconsin, Tomahawk Timberlands, and Wachovia Timberland Investment Management.

All study sites were secondary aspen-birch forest dominated by quaking aspen (*Populus tremuloides*), big-tooth aspen (*Populus grandidentata*), and paper birch (*Betula papyrifera*) with scattered northern hardwood species (*Acer* spp. and *Quercus* spp.). Adjacent forest types include conifer swamps (*Picea mariana*, *Abies balsamifera*, and *Larix laricina*), pine plantations (*Pinus resinosa* and *P. banksiana*), northern hardwoods, and alder thickets.

Prominent glacial features including end and ground moraines, deposits of glacial till, eskers, kames, drumlins, drift covered bedrock ridges, and pitted outwash plains created an undulating to hilly landscape (Boelter 1988, Mitchell 1993). Soils comprised of sandy loam and loamy sand with scattered wet depressions dominated most sites.

Methods

Definition of Terms

Forest Stand: a unit of trees with relatively homogeneous age, structure, composition, and physical environment (Kohm and Franklin 1997). Forest maps provided by foresters defined stand boundaries.

Territorial Male: a singing male defending an area from conspecific males on multiple site visits

Occupied Territory: an area defined by a set of singing perches repeatedly used by one territorial male on multiple site visits

Male Density: the maximum number of territorial males surveyed during a breeding season per aspen stand area (ha)

Golden-winged Warbler Sample Population: all territorial males inhabiting an aspen stand during a breeding season

Golden-winged Warbler Density

In 1999, I estimated the density of territorial male Golden-wings in five 1-3 year-old aspen stands harvested by clearcutting. Due to the high male densities observed, I expanded the project in 2000 to examine density differences across a successional gradient created by 25 years of clearcutting. In 2000, I surveyed 12 additional aspen stands and removed a stand surveyed in 1999 to equalize sample size across age classes. I grouped 4 stands in each of the following 4 age classes: Age Class 1) 1-4 years, Age Class 2) 6-10 years, Age Class 3) 10-19 years, and Age Class

4) 20-25 years (Figure 3.3). I did not survey older stands because I did not detect Golden-wings during point count surveys in 25-60 year-old aspen stands in the study area in 1998 (Appendix I).

To estimate territorial male density in each stand, I used the spot mapping survey protocol of the International Bird Census Committee (1970). The purpose of this survey was not to determine the exact territorial boundaries of each male but rather to distinguish between neighboring males for an accurate estimate of male density in each stand. We marked the location of each territory occupied by a singing male on a stand map. PCA foresters provided the maps delineating stand boundaries created from air photos. To refine these maps, foresters superimposed the stand boundaries on U.S. Geologic Service 7.5' quadrangle maps and later ground-truthed the stand maps for accuracy. Stand areas estimated using a Geoexplorer II Geographic Positioning System (GPS; Trimble Navigation 1999) ranged from 11.8 ha to 132.5 ha (42.0 ha ± 7.1 ha; mean ± SE). To measure the amount of edge at each stand, I divided the perimeter length of the stand (km) by the stand area (ha).

Male density surveys began 15 minutes prior to sunrise and lasted 4 hours. Observers walked through the stand systematically to minimize the chance of double counting males. In the absence of resources to capture and mark males, I differentiated individuals based on locating simultaneous singing males in adjacent territories. I assumed the male of an occupied territory regularly used a collection of singing perches not used by other males.

An observer visited the Age Class 1 stands 5-9 times between 11 May and 13 July in 1999. Territorial males became difficult to observe by late June due to a sharp drop in singing behavior. In 2000, three observers visited the 16 stands in the 4 age classes between 10 May and 12 June.

In 2000, survey effort varied with Golden-wing abundance at each stand. An observer visited stands lacking Golden-winged Warblers 2-3 times and used taped playback of Golden-wing vocalizations to confirm the absence of Golden-wings on the final visit. Stands with at least 1 male Golden-wing observation were visited 3-5 times. For stands with 8 or more males, a team of 3 observers worked together on the last 1-2 visits to ensure a complete count and to reduce the chance of double counting males.

For statistical analysis, I based male density on the visit with the highest count of territorial males. When multiple clearcuts occurred within an aspen stand, I used the mean male density among clearcut units within the stand for comparisons with other stands.

Golden-winged Warbler Territory Area

In 2000, my observers and I randomly selected up to 3 Golden-winged Warbler territories in each stand to estimate territory area. We also mapped all territories of territorial Blue-winged Warblers (*Vermivora pinus*) and their hybrids, Brewster's Warbler (*Vermivora chrysoptera* X *V. pinus*) and Lawrence's Warbler (*Vermivora chrysoptera* X *V. pinus*), in a stand. Territory mapping of the selected territories began immediately following the conclusion of the density survey at approximately 4 hours

after sunrise. Though the survey protocol remained the same as for the density survey, the mapping effort was more intense with the objective to accurately estimate territory area.

On the first visit to a stand, each observer randomly selected a previously unselected singing male observed during the density survey for a detailed spot mapping survey. On subsequent visits observers surveyed the same territory in order to obtain several independent territory area estimates without observer bias. Observers marked all singing perches used by the selected male with flagging tape using a color scheme unique to each observer. On the flagging tape, observers wrote their initials, a unique territory code, and the dates when the male used a perch. On a subsequent visit, the observer used a GPS receiver to map the perimeter of the territory from 1 survey day in order to estimate territory area. Observers repeated this procedure for each day the territory was satisfactorily mapped. I used the mean territory area among visits in the statistical analyses.

Vegetation Structure

I collected vegetation data in Golden-wing territories and at random points between 11 June - 09 July in 1999 and 22 June - 15 July in 2000. To explain differences in male densities and territory placement, I compared vegetation structure for the following 4 analyses. First, I described vegetation structure of each age class to permit comparison of my sites to other areas with different site quality and growing season length. Second, I compared male density with vegetation structure

characteristics measured at random sample points throughout stands to identify mechanisms for male density changes due to aspen succession. Third, I described the vegetation structure of territories among age classes. I did not use the random samples from throughout stands in this analysis. Finally, I compared vegetation structure within territories to random sample points to determine if Golden-wing territory placement was non-random within the stands of an age class.

To select random sample points, I created a grid of 12 sample points at least 100 m apart starting at a random point in each stand. I sampled the same 6 randomly selected grid points in 1999 and 2000 plus an additional 4 grid points in 2000. I centered a 1-m^2 quadrat on each sample point to estimate percent ground cover, percent litter cover, litter depth, and stem density of woody vegetation groups including aspen suckers, all tree seedlings (including aspen suckers), dead stems, and shrubs (1999 only). To estimate shrub-layer height-density, I measured visual obstruction of the standing vegetation with a modified Robel pole (6 X 300 cm) centered on the sample point (Robel et al. 1970). From the pole, I walked 10 m in each cardinal direction and recorded the visual obstruction from a height of 1.5 m. I used a spherical densiometer to estimate canopy closure and a Robel pole or a clinometer to measure shrub and tree height. To measure woody debris, I extended a tape measure 10-m in the cardinal directions from the sample point and totaled the centimeters of woody slash intercepted by the tape measure. Woody debris was defined as dead, woody material that possessed some vertical structure but did not include standing, dead woody stems (>45° with the ground), litter, or stumps.

Within Golden-winged Warbler territory boundaries, I created a grid of 16 points 10-m apart starting from a random point. A visual obstruction reading was taken from one cardinal direction at each sample point. For the first point, the Robel pole was read from a random cardinal direction. For the subsequent points in the grid, the pole was read from the previous point. All other vegetation variables measured at the random sample points stand-wide were also measured at 4 randomly selected grid points within each territory using the same protocol.

Hypotheses and Statistical Analysis

The use of the maximum count of territorial males required an arccosine transformation of male density values to produce a more symmetrical distribution. For analysis of variance (ANOVA) and t-test analyses, I determined if all test assumptions (continuous variables, normality, and equal variances) were met. I used the Modified Levene Equal-Variance Test to test for equal variances. Where necessary, I used natural logarithms to transform independent variables to meet these assumptions.

I used a paired t-test with a two-sided hypothesis to compare territorial male density for stands in Age Class 1 ($n = 4$) between 1999 and 2000. Observations were paired by stand. The null and alternative hypotheses were as follows:

D = difference between observations of territorial male density in each stand in 1999 and 2000

H_0: $\mu_D = 0$; male density was not different between 1999 and 2000

H_A: $\mu_D <> 0$; male density differed between 1999 and 2000

I also used a paired t-test with a two-sided hypothesis to compare vegetation structure in territories to random sample points within stands.

D = difference between a vegetation structure variable at random points and in territories.

H_0: $\mu_D = 0$; a vegetation structure variable was not different between random points and territories.

H_A: $\mu_D <> 0$; a vegetation structure variable differed between random points and territories.

For comparisons of territorial male density, territory area, and vegetation variables across age classes, I used a one-way ANOVA model. I ran separate analyses for random sample points and territory samples. For multiple comparisons, I used Fisher's Least Significant Difference test. The null and alternative hypotheses were as follows:

H_0: $\mu_A = \mu_B = \mu_C$; male density, territory area, or vegetation structure was not different among age classes

H_A: not all μ_i are equal; maximum male density, territory area, or vegetation differed among age classes

I used simple linear regression to investigate the relationship of male density across all stands with edge and vegetation structure independent variables. To select independent variables for the regression analyses, I used Spearman-rank correlations with male abundance or density greater than 0.35 and examined scatter plots for patterned relationships. The absence of nonlinear patterns supported using a linear model. In general, the null and alternative hypotheses were as follows:

H_0: $Y_i = b_0 + e_i$; there was no relationship between male density and an independent variable

H_A: $Y_i = b_0 + b_1 x_i + e_i$; there was a linear relationship between male density and an independent variable

I reviewed residual plots for all regressions to evaluate equality of error variances. All errors for each regression model were checked for independence and normality. To investigate multiple variable regression models, I first used a forward selection model to reduce the set of candidate variables to 15. Then I used an All Possible Regressions procedure to investigate possible multiple variable models. If any independent variables in the best model were correlated with one another, I selected the variable with the highest correlation to the dependent variable for inclusion in the final model.

I used Akaike's Information Criterion (*AIC*) to determine if the addition of an independent variable to a linear model resulted in a better model than with only the dependent variable (male density) in the model. This provided a method to evaluate the relationship of male density to independent variables and to select the best model for predicting male density across stands. The value of *AIC* for least squares models with small sample sizes ($n < 40$) is:

$$AIC_C = n \log_e (SS_e/n) + 2k + 2k\,(k+1)/(n-k-1)$$

where n is sample size, SS_e is error sum of squares, and k is the total number of estimable parameters in the model including the intercept and variance (Burnham and Anderson 1998). To determine if a relationship exists between male density and an independent variable, I compared the AIC_C for the following 2 models:

1) $Y_i = b_0 + e_i$ (when $x_i = 1$, then $b_1 = 0$)

2) $Y_i = b_0 + b_1 x_i + e_i$

If the difference between the AIC_C for the 2 models was less than 2, then the models were equivalent. If the difference was between 3 and 7, then there was some support that the model with the smallest AIC_C was the better model. If the difference was greater than 10, then the model with the smallest AIC_C was the better model (Burnham and Anderson 1998).

I used NCSS (Hintze 2000) for all statistical analyses. I set statistical significance at $\alpha = 0.05$ probability of a Type-I error.

Results

Vegetation Structure of Age Classes

Six of 13 vegetation structure variables differed across aspen age classes (Appendix VII). In Age Class 1, visual obstruction was significantly higher ($F_{3,17} = 7.77$, $P \leq 0.001$) and canopy closure was significantly lower ($F_{3,17} = 16.09$, $P \leq 0.001$) than in the other age classes. Maximum aspen regeneration height ($F_{3,17} = 54.61$, $P \leq 0.001$) and tree regeneration height ($F_{3,17} = 36.96$, $P \leq 0.001$) increased with increasing stand age. Aspen sucker density ($F_{3,17} = 24.69$, $P \leq 0.001$) and dead woody stem density ($F_{3,17} = 3.52$, $P = 0.04$) decreased with increasing stand age.

Golden-winged Warbler Density Across a Successional Gradient

Golden-winged Warblers immediately colonized newly created aspen clearcuts for the first breeding season following harvest. In 1999, I observed 49 territorial male Golden-winged Warblers at the 5 sites in Age Class 1. In 2000, 66 territorial males were observed across all age classes. No significant difference between male densities in 1999 and 2000 was detected for Age Class 1 so I combined density data from both years for statistical analysis ($P = 0.19$, $n = 4$). Mean territorial male density (0.48 males/ha ± 0.11 males/ha) was significantly higher in Age Class 1 than in the other age classes ($F_{3,17} = 9.21$, $P \leq 0.001$; Appendix VII). Multiple comparisons showed no difference in mean male density among Age Classes 2, 3, and 4. Mean density for Age Classes 2 - 4 combined was 0.039 (± 0.064) males/ha.

I identified differences in vegetation structure among age classes to understand mechanisms for male density changes due to aspen succession. Of the vegetation structure variables, aspen sucker density was the best predictor of male density across all stands ($R^2 = 0.52$, $F_{1,19} = 20.43$, $P \leq 0.001$; Table 3.1 and Figure 3.4). The AIC_C difference (12.59) confirmed a strong linear relationship between male density and aspen sucker density. The amount of stand edge was poorly correlated with male density ($R^2 = 0.16$) as supported by a low AIC_C difference (2.70).

Blue-winged Warbler, Lawrence's Warbler, and Brewster's Warbler were absent at all sites in 1999. In 2000, one non-territorial male Blue-winged Warbler was observed near Lily Lake Road where 2 male Brewster's Warblers were sighted (only 1 was territorial). The territory area for the territorial male Brewster's Warbler was 0.36

ha. A female Brewster's Warbler paired to a male Golden-winged Warbler was seen at Trout Creek South where one non-territorial male Brewster's Warbler was also observed briefly. No evidence of reproduction was noted for any of these individuals.

Golden-winged Warbler Territory Area

Of the 24 Golden-winged Warbler territories mapped, only 1 occupied territory was abandoned after the initial territory mapping visit. Singing males occupied all other territories through the end of June. For analysis of territory area, I combined Age Classes 2 and 3 because Age Class 2 contained only 1 territory. Mean territory area was significantly larger in Age Classes 1 and 4 than in Age Classes 2 and 3 combined ($F_{2,22} = 11.38$, $P \leq 0.001$; Table 3.2). Multiple comparisons showed no difference in mean territory area between Age Classes 1 and 4.

Territory Placement within Stand Age Classes

I expected similar vegetation structure in territories across all age classes because Confer (1992) believed Golden-wing territories had a consistent vegetation pattern regardless of community type. Six vegetation structure variables showed significant differences (Appendix VIII). I observed less ground cover in Age Class 2 than in the other age classes ($F_{3,11} = 8.44$, $P = 0.003$) though only one territory was represented in this age class. Aspen sucker density ($F_{3,11} = 7.12$, $P = 0.01$) and tree seedling density ($F_{3,11} = 6.29$, $P = 0.01$) decreased with increasing stand age. Maximum aspen regeneration height was shorter in Age Classes 1 and 2 than in Age

Classes 3 and 4 ($F_{3,11}$ = 17.31, $P \leq 0.001$). Visual obstruction was higher in Age Class 1 than Age Classes 2 and 4, and Age Class 3 was similar to the other age classes ($F_{3,11}$ = 4.13, P =0.03). Maximum herb height was taller in Age Classes 1 and 4 than in Age Class 3, and Age Class 2 was similar to the other age classes ($F_{3,6}$ = 14.46, P =0.004).

To identify vegetation structure characteristics associated with non-random territory placement within a stand, I compared random sample points stand-wide to sample points in territories. I expected no differences between random points and territories within Age Class 1 and detectable differences for the older age classes. In Age Class 1, I observed twice as many aspen suckers and 40% more tree seedlings in territories relative to random sample points (T_8=3.01, P=0.02). In Age Classes 2-4, territories had significantly less canopy closure (T_8= -3.41, P=0.02) and shorter maximum tree regeneration height (T_8= -3.77, P=0.01). Visual obstruction was higher in territories than at random sample points (T_8= 3.27, P=0.02). I measured no other differences in vegetation structure between territories and random samples among the 4 age classes (Table 3.3).

Discussion

Golden-winged Warbler Density Across a Successional Gradient

Throughout the western part of the breeding range, alder thickets, open lowland conifer stands, and young aspen forest provide a majority of the breeding habitat for the Golden-winged Warbler population. The high Golden-winged Warbler densities observed until 10 years post-harvest in my aspen stands concurred with findings from

other studies (Table 3.4). Of these studies, only Cumming (1998) focused on Golden-winged Warbler populations. Most of these researchers included Golden-wings as part of their investigation of the entire bird community's response to aspen forest succession and may not have measured Golden-winged Warbler use as accurately as my study. In northern Wisconsin, clearcut age was a strong predictor of male density with a clear preference for 1-4 year-old aspen stands. Low densities persisted in these stands until 25 years post-harvest, primarily in forest gaps, areas of poor aspen regeneration, along edges bordering shrubland cover, and along utility and road rights-of-way. Other studies found territorial males in aspen stands as old as 80 years (Table 3.4). Site quality and latitude likely affected the aspen regeneration rate among studies and thus vegetation structure better described optimal breeding cover. In my study, I associated high male densities with high aspen sucker density. Both male density and aspen sucker density were highly correlated with visual obstruction, canopy closure, maximum aspen and tree regeneration height and marginally correlated with dead woody stem density, ground cover, and maximum herb height.

The distinctly higher male densities in Age Class 1 probably were a true reflection of habitat quality despite evidence that male densities of other species did not consistently indicate habitat quality (Van Horne 1983, Hobbs and Hanley 1990). Nest productivity was recommended as a better indicator (Van Horne 1983, Vickery et al. 1992, Donovan et al. 1995, Purcell and Verner 1998); however only 2 studies investigated Golden-wing nest success in the western part of the breeding range. In northern Minnesota, 1 of 3 (33%) Golden-wing nests found in young aspen stands

successfully fledged at least one young (Hanski et al. 1996). In Michigan, Will (1986) identified 11 of 13 (85%) nests as successful in an aspen forest-abandoned field ecotone. This limited nest productivity information for Golden-wings in young aspen forests was inadequate to assess the relationship between population densities and habitat quality (Will 1986, Hanski et al. 1996).

Results from nest productivity studies of shrubland bird communities indicated that nest predation was considerably lower in recent aspen clearcuts than in older stands (Yahner and Wright 1985, Yahner and Cypher 1987, Yahner 1991, Hanski et al. 1996). In addition, ground nesting species like the Golden-winged Warbler were more likely to be successful than above ground nesting species in recent deciduous forest clearcuts (Yahner and Cypher 1987, Yahner 1991, Rudnicky and Hunter 1993, Seitz and Zegers 1993, Vander Haegen and DeGraaf 1996). The consistently higher nest success rate for ground nesting species in recent clearcuts across studies suggested the high male densities of Golden-winged Warblers observed in my study might be associated with high productivity. Future studies should seek to understand the role forest succession plays in Golden-winged Warbler productivity, to identify site features associated with high reproductive success, and to test the reliability of using male density as an indicator of habitat quality.

Golden-winged Warbler Territory Area

Territory area on my sites averaged 0.59 ha (range = 0.02 - 1.80 ha). Confer (1992) reported a territory area range of 0.4 to 6.0 ha. In New York, Ficken and Ficken (1968a) estimated territory areas between 0.4 and 0.8 ha. In Michigan, Will (1986) measured mean territory area as 1.0 ha (range = 0.41 - 3.25 ha; n=32) in an aspen forest-field ecotone, and Murray and Gill (1976) observed a range of 1.4 to 5.2 ha (n=9). Generally, mean territory areas on my study sites were smaller than in other studies. Studies of ovenbirds (*Seiurus aurocapillus*) reported an inverse relationship between territory area and prey abundance (Stenger 1958, Smith and Shugart 1987). These studies and others (see Newton 1998) suggested that relatively smaller territories were associated with higher quality habitat. Though this may be true for Golden-winged Warbler territories in my study, other factors likely influenced territory size.

In my study, territory area appeared to be limited by the location of the territory (Table 3.2). In Age Class 1, territory areas were primarily limited by boundaries of neighboring territorial Golden-wing males. In the older age classes, territories occurred in openings within the stand and were approximately the same size as the openings occupied. The comparison of vegetation structure inside territories to the rest of the stand supported these observations.

Territory Placement within Age Classes

Confer (1992:5) described Golden-winged Warbler territories range-wide as consistently having "patches of herbs, shrubs, and scattered trees, plus a forested edge."

In my study, territorial males preferred the youngest aspen stands. Within these sites, males selected areas with higher than average aspen sucker and tree seedling density contrary to speculation that Golden-wings avoided clearcuts with dense regeneration (Confer and Knapp 1981). Further, territories in my young clearcuts consisted of almost total shrub coverage and rarely contained patches of herbs without woody vegetation as observed by Confer (1992) in successional habitat on abandoned farmland in the Northeast. Studies in the western part of the breeding range also associated the presence of Golden-wings with relatively dense shrub cover in aspen stands (Huffman et al. 1997, Cumming 1998). Regional variation in the vegetation structure preferences of Golden-wings may relate to differential availability of various shrub communities across the range rather than to differences in vegetation structure preferences. In abandoned fields, woody vegetation gradually invades from adjacent areas creating a patchy mosaic of herbs and shrubs. In aspen clearcuts, most woody vegetation regenerates simultaneously creating a more homogeneous shrub community. Shrubland communities investigated in other studies were often associated with edges and therefore Golden-winged Warblers were too.

In the older stands of my study, I expected territory placement in areas with relatively short regeneration height and vegetation structure like that in Age Class 1 (Confer and Knapp 1981, Collins et al. 1982, Confer 1992, Wemmer 1993). Males selected areas with lower canopy closure, higher visual obstruction, and shorter tree regeneration height. Other researchers generally concurred on a negative association between Golden-wing site use and increasing canopy closure (Collins et al. 1982,

Confer 1992, Huffman et al. 1997, Cumming 1998). The low canopy closure in forest openings allowed the development of a dense herb and shrub layer relative to surrounding vegetation resulting in relatively high visual obstruction readings. The dense vegetation structure near ground-level may be important to conceal Golden-wing nests. Litter depth, litter cover, and woody debris did not differ between territories and random points though they may be important features relative to non-aspen cover types not investigated in my study.

Though generally associated with forest edges (Ficken and Ficken 1968b, Will 1986, Frech and Confer 1987), I observed Golden-wing territories in the middle of large clearcuts with no sign of clearcut edge use. I believe researchers associated Golden-winged Warblers with edges in other studies because most shrublands were small and had a high edge ratio (perimeter length/site area). In some cases, dense shrubby cover was not contiguous across the opening and was most prevalent around the periphery (e.g. Will 1986). For example, in abandoned fields commonly used by Golden-wings in the eastern part of the range, shrubby cover invaded from the wooded edges resulting in large areas of grasses and herbs with small patches of shrubby cover in the center of the fields. Use of edges by Golden-wings likely depends on the distribution pattern of shrubs at a site.

Despite my efforts to avoid double counting territorial male Golden-wings during density surveys, the possibility existed given the lack of color bands to differentiate males. Will (1986) observed a male defending 2 territories, one on either side of another male's territory. This "leap-frogging" behavior potentially led to an

overestimate of male density in my study, particularly in Age Class 1 stands. This behavior was probably rare and had little effect on my survey results. Female Golden-wings tended to be inconspicuous and thus we were unable to confirm the mate status for most territorial males. Perhaps many males lacked mates, increasing the likelihood of male replacement in occupied territories. Though I believe these cases were rare in my study, future studies should color band individuals to eliminate these potential sources of survey errors.

Golden-winged Warbler Management in Forested Landscapes

Recovery of the Golden-wing population will require maintenance and creation of shrub communities across the breeding range. Lowland shrublands can be maintained through protection from development and allowing the natural disturbance regime (e.g. flooding) to occur. Mechanical manipulation of lowland shrub communities will be limited due to federal and state laws protecting wetlands and shorelines, difficulty in using heavy machinery on wet soils, and the cost of habitat manipulation in these areas. Creation of upland shrub communities will be logistically easier, cheaper due to timber sale revenues, and more easily implemented on a large scale. Golden-wings use upland shrublands as readily as lowland shrub communities. Extensive aspen shrublands also can be created in less time and with less effort than is possible through lowland shrub manipulation.

Many shrub communities are transient and remain attractive to Golden-wings for a short time. After a few years at a site, Golden-wings must often find new

shrublands to inhabit. Golden-wing management requires a broad geographic perspective. For many avian species, land parcels are managed for specific species indefinitely. For Golden-winged Warblers, entire landscapes must be considered if maintaining the local population is a goal. Managers should think of landscapes as shifting mosaics of successional stages and cover types given the biodiversity and multiple-use goals for public lands. Managers should plan to maintain a certain percentage of a landscape in shrubland cover. In areas managed for commercial timber involving heavy machinery, managers should rotate shrubland cover spatially rather than maintaining it at a site indefinitely to prevent site degradation and reduced productivity from intensive, short rotation logging systems (Giese et al. 1976, Powers 1989).

In Wisconsin, aspen forest area declined by 8% between the 1983 and 1996 Forest Inventories (Schmidt 1997). Little aspen forest remains in southern Wisconsin, and the most significant loss occurred in central Wisconsin with a 36% decline. If this pattern of loss continues to shift northward, substantial habitat loss in the core of the Golden-wing breeding range may be catastrophic to the population. In Wisconsin, private individuals and public agencies own 46% and 40% of aspen forest respectively (Schmidt 1997). Golden-winged Warbler population recovery depends on the involvement of these 2 groups. With the continued negative perception of clearcutting and increasing public pressure on public agencies to reduce clearcutting practices, young aspen forests will continue to decline due to forest succession and Golden-

winged Warbler populations with them. Effective Golden-winged Warbler habitat management will require public education to dispel clearcutting myths.

As aspen forests range-wide continue to mature, increasingly less shrubland will occur on the landscape. Golden-winged Warblers will be forced into suboptimal shrub habitats and continue to decline as productivity decreases. Since a majority of the Golden-wing population breeds in the Upper Great Lakes Region, Wisconsin, Minnesota, Michigan, and Ontario possess a majority of the responsibility for maintaining breeding habitat for this species. Increasing and improving shrubland cover may be integral to stabilizing the population. Clearcutting aspen forests will be one of the more effective strategies for maintaining shrubland cover across the landscape.

Conclusions

1. The highest densities of territorial male Golden-winged Warblers occurred in 1-4 year-old aspen stands.
2. I identified aspen sucker density as a good predictor of male density.
3. Mean territory area was generally smaller than in other studies.
4. In stands over 6 years-old, territories were located in forest openings as indicated by low canopy closure relative to random points in the stand.
5. Golden-winged Warbler densities were independent of the amount of clearcut edge, and territories did not consistently include the clearcut edge.
6. Interpretation of results from this study required caution due to our inability to identify individual males with certainty and my assumption that male density was a good indicator of habitat quality.
7. Golden-winged Warbler management requires viewing the landscape as a mosaic of shifting successional stages and cover types.
8. Clearcutting aspen forest is the most practical strategy to increase Golden-winged Warbler breeding habitat in the Upper Great Lakes Region.

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Table 3.1. Spearman-rank correlation coefficients between mean vegetation structure variables[a] and territorial male Golden-winged Warbler (*Vermivora chrysoptera*) density[b] (males/ha) and mean aspen (*Populus* spp.) sucker density (stems/m^2) in aspen stands, Oneida and Lincoln Counties, Wisconsin.

Vegetation structure variables	Male density		Aspen sucker density	
	r	*P*	*r*	*P*
Litter cover (%)	-0.11	0.64	-0.24	0.29
Ground cover (%)	0.56	0.01	0.56	0.01
Litter depth (cm)	0.02	0.94	0.16	0.49
Maximum shrub height[c] (m)	0.27	0.31	0.05	0.86
Maximum herb height[c] (m)	0.36	0.17	0.49	0.05
Visual obstruction (dm)	0.64	0.002	0.74	≤ 0.001
Canopy closure (%)	-0.60	0.004	-0.84	≤ 0.001
Maximum aspen regeneration height (m)	-0.64	0.002	-0.87	≤ 0.001
Maximum tree regeneration height (m)	-0.63	0.002	-0.86	≤ 0.001
Aspen sucker density (stems/m^2)	0.68	≤ 0.001	1.00	1.00
Tree seedling density (stems/m^2)	0.23	0.31	0.43	0.05
Dead woody stem density (stems/m^2)	0.59	0.004	0.69	≤ 0.001
Shrub density[d] (stems/m^2)	0.30	0.62	0.10	0.87

[a] Vegetation structure was measured 11 June - 09 July 1999, 22 June - 15 July 2000. In 1999, I sampled vegetation at 6 random points in each stand (n=5). In 2000, I sampled vegetation at 10 random points in each stand (n=16).

[b] Golden-winged warbler surveys were conducted May-July 1999, May-June 2000, n=21.

[c] Measured in 2000 only, n=16.

[d] Measured in 1999 only, n=5.

Table 3.2. Mean territory area (ha) and description of territory locations for male Golden-winged Warblers (*Vermivora chrysoptera*) surveyed in May-July 1999 and May-June 2000 in 4 age classes of aspen (*Populus* spp.) stands located in Oneida and Lincoln Counties, Wisconsin.

Stand age class (years)	Territories[a] *n*	Territory area (ha) Mean ± SE	Territory location (*n*)
1 (1 - 4)	12	0.82 ± 0.12	▪ young, open clearcuts (12)
2 & 3 (6 - 19)	6	0.18 ± 0.04	▪ forest openings (4) ▪ overlap w/alder marsh (2)
4 (20 - 25)	6	0.54 ± 0.17	▪ utility/road right-of-ways (5) ▪ forest gap (1)

[a] I measured territory area for 1 territory in Age Class 2 and 5 territories in Age Class 3. Due to the small sample size in Age Class 2, I combined Age Classes 2 and 3 for statistical analysis of territory area.

Table 3.3. Comparison of mean vegetation structure between random sample points[a] and sample points in Golden-winged Warbler (*Vermivora chrysoptera*) territories[b] in aspen (*Populus* spp.) stands located in Oneida and Lincoln Counties, Wisconsin, June - July 1999, 2000.

	Age class (years)									
	1 (1-4)					2-4 (6-25)				
Vegetation structure variables	n^c	Territory	Random	*T* value	*P*	n^c	Territory	Random	*T* value	*P*
Litter cover (%)	9	95.9	92.5	1.42	0.19	6	96.7	97.8	-0.82	0.45
Ground cover (%)	9	85.3	81.9	1.06	0.32	6	72.5	71.3	0.15	0.89
Litter depth (cm)	9	3.0	2.6	0.58	0.58	6	2.2	2.3	-0.55	0.61
Maximum shrub height[d] (m)	4	0.9	1.1	-0.80	0.48	6	0.8	1.0	-1.13	0.31
Maximum herb height[d] (m)	4	0.9	0.9	0.45	0.69	6	0.7	0.8	-0.57	0.59
Visual obstruction (dm)	9	10.0	9.3	0.69	0.51	6	6.0	2.5	3.27	**0.02**
Canopy closure (%)	9	39.6	34.5	0.89	0.40	6	54.7	79.1	-3.41	**0.02**
Maximum aspen regeneration height (m)	9	2.6	2.2	1.11	0.17	5	10.8	12.6[e]	-0.85	0.44
Maximum tree regeneration height (m)	9	3.2	2.1	1.74	0.12	6	6.2	9.3[f]	-3.77	**0.01**
Aspen sucker density (stems/m^2)	9	5.8	2.8	3.01	**0.02**	6	0.5	0.3	0.77	0.48
Tree seedling density (stems/m^2)	9	6.1	4.4	3.02	**0.02**	6	2.3	3.1	-1.38	0.23
Dead woody stem density (stems/m^2)	9	1.7	1.4	0.79	0.45	6	0.3	0.4	-0.50	0.64
Shrub density[g] (stems/m^2)	5	19.3	11.2	1.76	0.15	.	.	.	.	.

[a] I surveyed 5 stands in 1999 and sampled vegetation at 6 random points in each stand. I surveyed 4 stands in 2000 and sampled vegetation at 10 random points in each stand.

[b] Age Class 1 was surveyed in both 1999 and 2000. Age Classes 2-4 were surveyed in 2000 only. I sampled vegetation at 2 random points in each territory in 1999 and at 4 random points in each territory in 2000. For each vegetation variable, I calculated a mean value for each stand. Golden-winged warbler territories were mapped in May-June, 1999, 2000.

[c] Number of stands occupied by territorial male golden-winged warblers in an age class.

[d] Measured in 2000 only.

[e] Aspen regeneration height varied significantly between Age Classes 2 (mean=5.5 m), 3 (mean=10.1 m), and 4 (mean=16.1 m; $F_{2,9}$=17.76, $P \leq 0.001$).

[f] Tree regeneration height varied significantly between Age Classes 2 and 3 (mean=7.6 m), and 4 (mean=12.7 m; $F_{2,9}$ = 12.59 P = 0.002).

[g] Measured in 1999 only.

Table 3.4. Aspen (*Populus* spp.) stand age preference of Golden-winged Warblers (*Vermivora chrysoptera*) surveyed in 6 studies in the western part of the breeding range. Studies are arranged according to decreasing latitude with the most northerly study area at the top and the most southerly study area at the bottom.

Stand age preference, years	Oldest stand of occurrence, years	Range of stand ages investigated, years	Stands *n*	Basis for preference (highest value)	Study (state or province)
4 - 12	80	0-100	99	Highest Site Occupancy (74 - 100%)	Cumming 1998 (MB)
4 - 8	8-12	1-mature	20	Highest Density (0.2 males/ha)	Probst et al. 1992 (MN/MI)
6	60	6-60	21	Highest Relative Abundance	Wemmer 1993 (MN[a])
5	8	2-8	12	Highest Density (0.8 males/ha)	Fouchi & Gullion 1984 (MN[a])
3	11	3-45	6	Highest Relative Abundance	Steffen 1985 (WI)
1 - 4	25	1-25	16	Highest Density (0.5 males/ha)	This study (WI)

[a] Same study area.

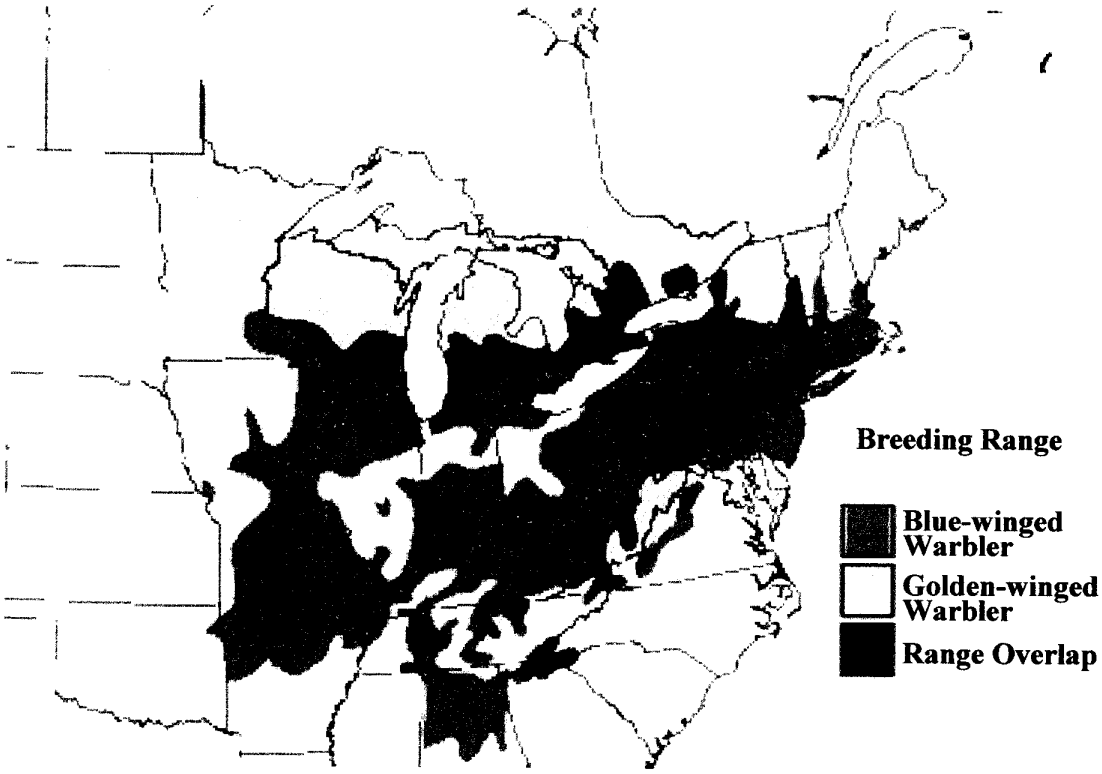

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Figure 3.1. Breeding range of the Golden-winged Warbler (*Vermivora chrysoptera*) and, its close relative, the Blue-winged Warbler (*Vermivora pinus*).

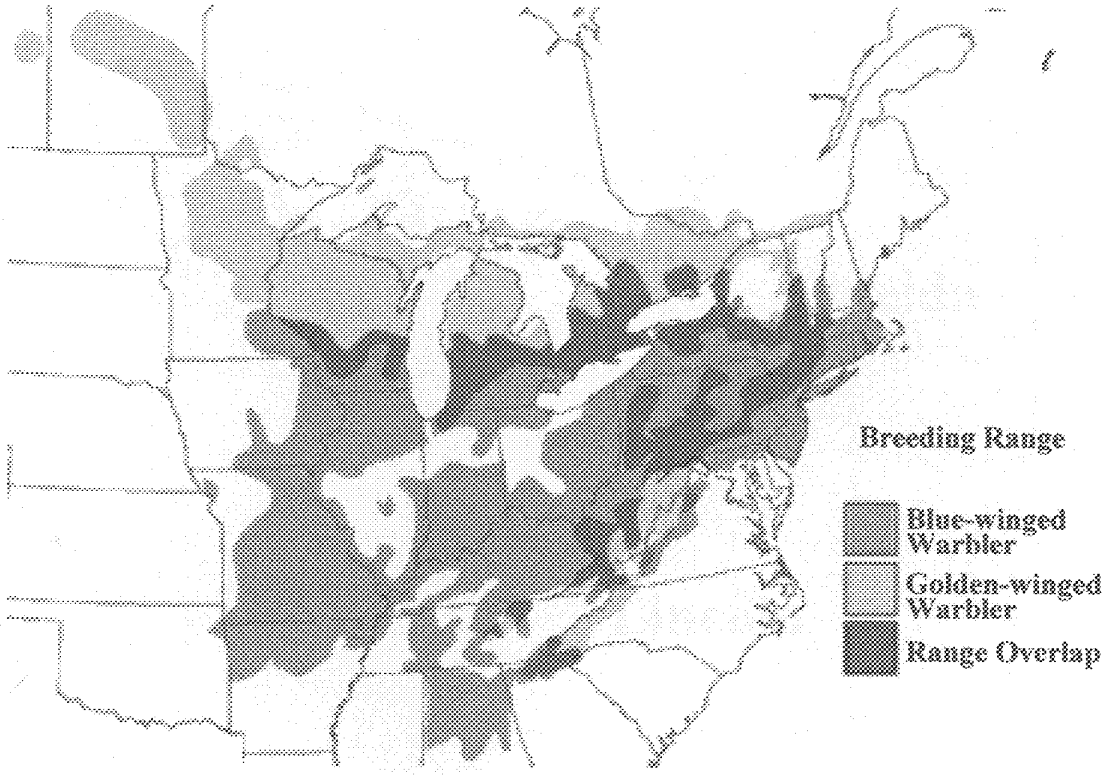

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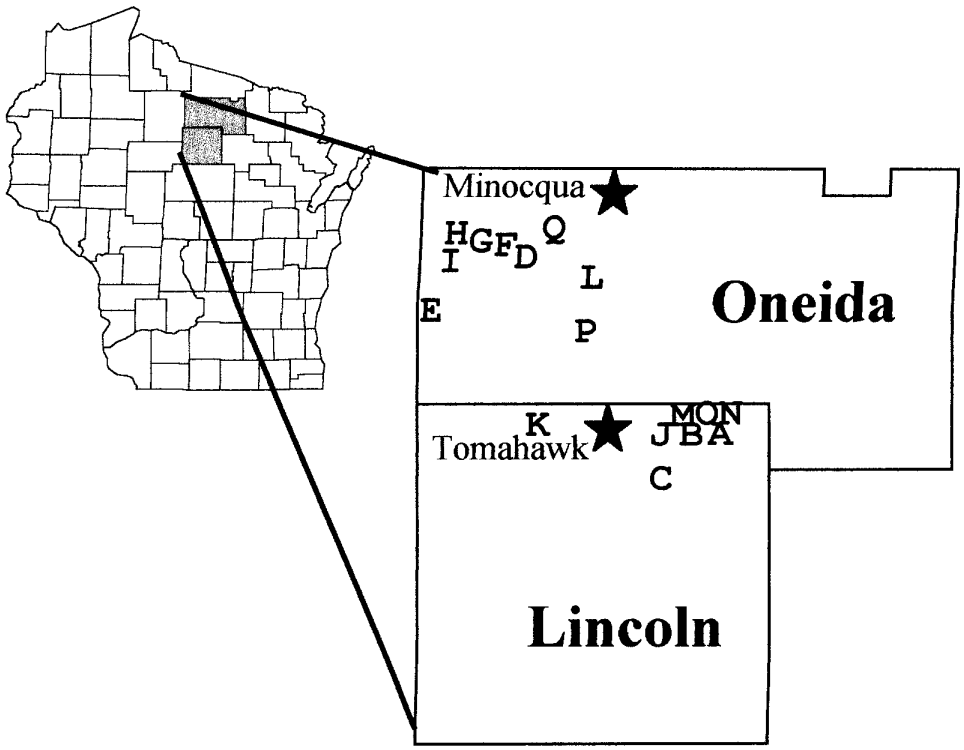
Figure 3.1. Breeding range of the Golden-winged Warbler (*Vermivora chrysoptera*) and, its close relative, the Blue-winged Warbler (*Vermivora pinus*).



Key	Site Name		Site Name
	Age Class 1 (1 - 4 years)		Age Class 3 (10-19 years)
A	Alexander Clearcut	J	Lily Lake Road
B	Trout Creek South	K	State Highway 8
C	Skanawan Lake	L	County Highway Y
D	Cedar Falls East	M	Spring Creek West
E	Price County Road South		
	Age Class 2 (6-10 years)		Age Class 4 (20-25 years)
F	Cedar Falls Fire Lane	N	Spring Creek East
G	Kennedy Fire Lane	O	Spring Creek Middle
H	Murray Fire Lane	P	Rocky Run Road
I	Stone Lake Fire Lane	Q	Creek Road

Figure 3.2. Study sites in Oneida and Lincoln Counties, Wisconsin, surveyed for territorial male Golden-winged Warblers, 1999-2000.

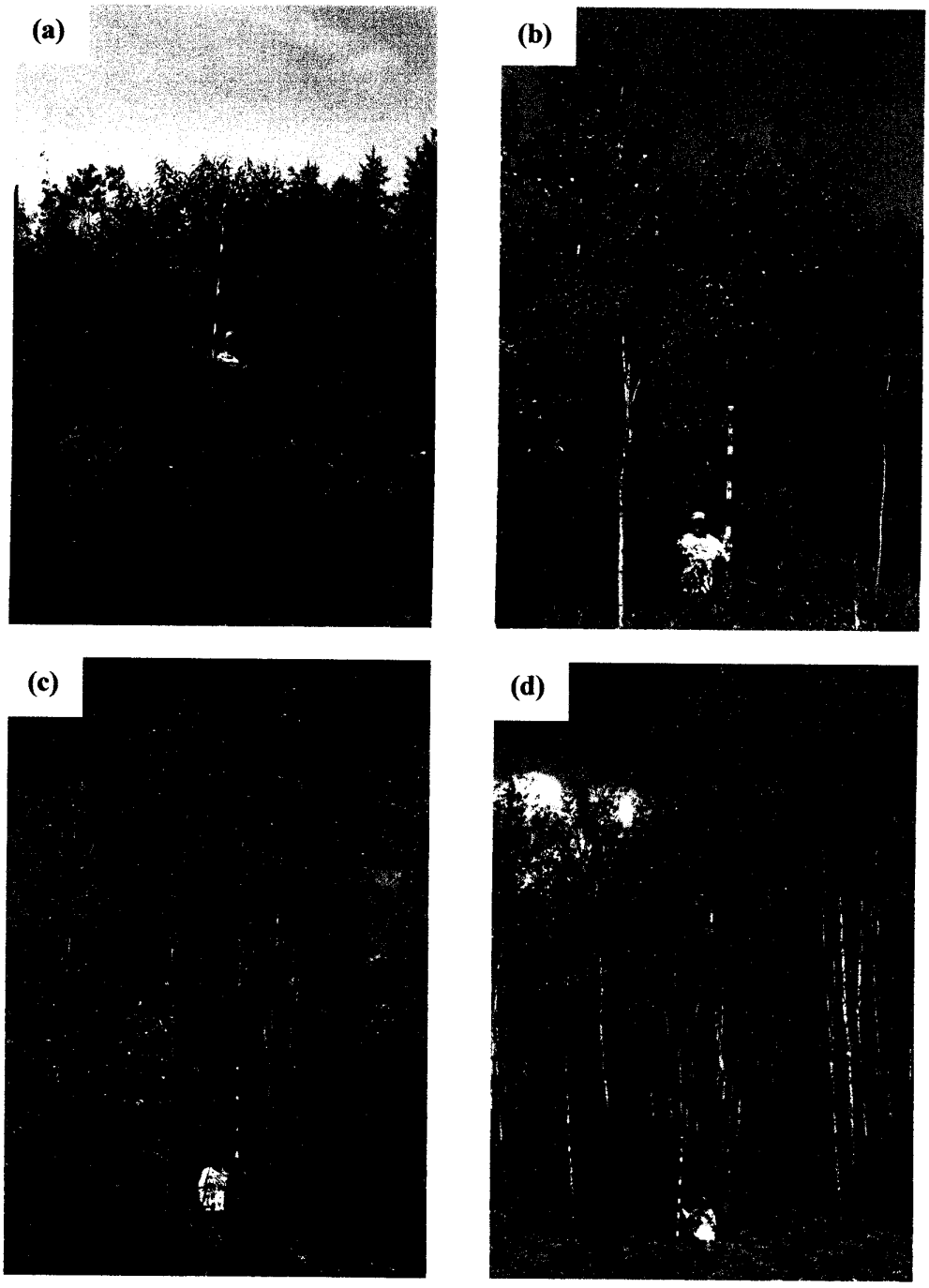


Figure 3.3. Representative aspen (*Populus* spp.) stands for the following age classes: (a) Age Class 1 (1-4 year-old stands), (b) Age Class 2 (6-10 year-old stands), (c) Age Class 3 (10-19 year-old stands), and (d) Age Class 4 (20-25 year-old stands). Amy Owen is holding a 3 m tall visual obstruction pole. Photos were taken July 2000.

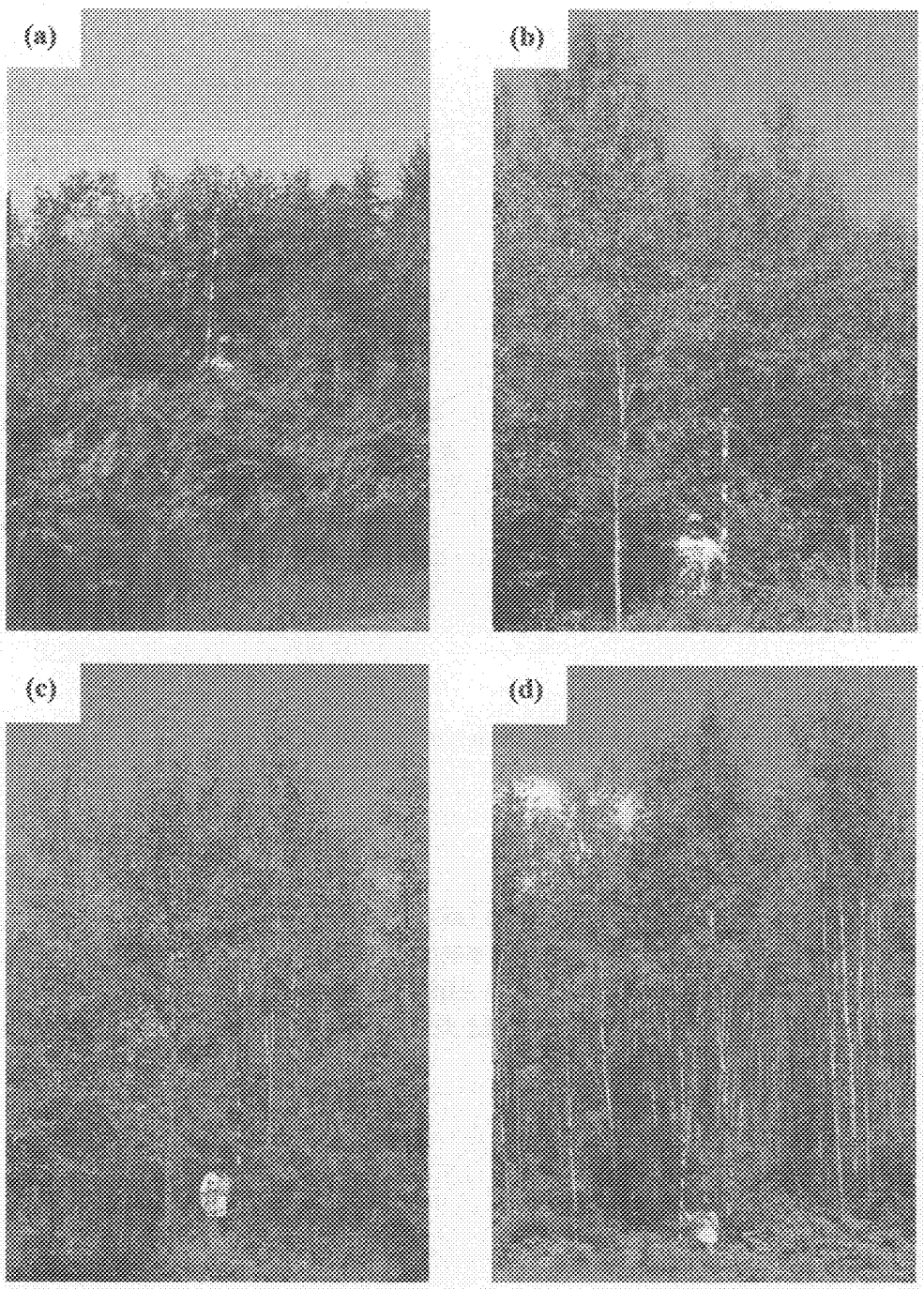


Figure 3.3. Representative aspen (*Populus* spp.) stands for the following age classes: (a) Age Class 1 (1-4 year-old stands), (b) Age Class 2 (6-10 year-old stands), (c) Age Class 3 (10-19 year-old stands), and (d) Age Class 4 (20-25 year-old stands). Amy Owen is holding a 3 m tall visual obstruction pole. Photos were taken July 2000.

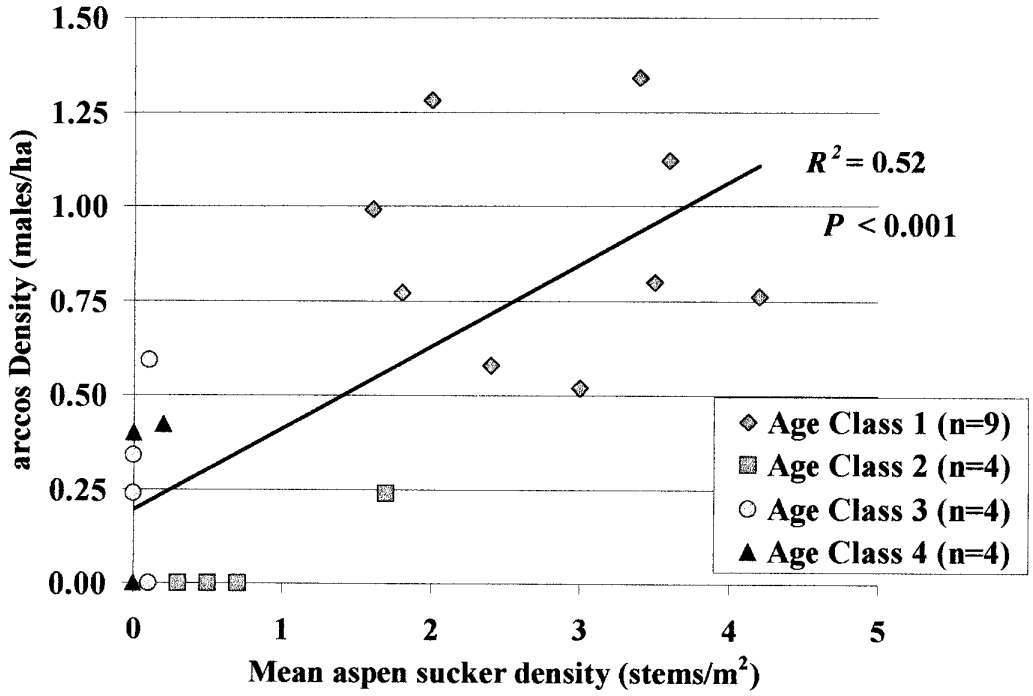


Figure 3.4. The density of territorial male Golden-winged Warblers increased significantly as mean aspen sucker density increased across aspen stands in 4 age classes, Oneida and Lincoln Counties, Wisconsin, May-July 1999 and 2000 ($F_{1,19} = 20.43$, $P \leq 0.001$).

Chapter IV

Conclusions

Forest succession in aspen (*Populus* spp.) stands affects breeding habitat quality for the 2 species I investigated in this study. American Woodcock (*Scolopax minor*) require a range of early successional forest age classes spatially close to each other. Golden-winged Warblers (*Vermivora chrysoptera*) prefer the earliest stages of forest succession, and densities decline as the aspen stands age. Management of both species requires consideration of both the spatial and temporal effects of forest succession. My research provides insight on management strategies with varying impacts on both species.

Though the partial clearcutting of aspen stands did not improve displaying male woodcock use of aspen stands, more information is required to measure the success of this management technique. First, female use and productivity may be high in stands with low displaying male densities. These 2 variables may better indicate habitat quality (Van Horne 1983, Vickery et al. 1992, Donovan et al. 1995, Purcell and Verner 1998). Second, the residual areas of the stand may be too old for woodcock use in my study. Residual aspen younger than 30 years may improve habitat quality and woodcock use.

My study provided some evidence that large clearcuts ($\geq$ 50 ha), with a minimum of edge, may support more displaying male woodcock than small clearcuts

with high amounts of edge. This may be a good tool for improving woodcock use in an area without increasing the total clearcut area. A few large clearcuts could maintain or increase woodcock use relative to many small clearcuts with the same total area. This strategy may also provide substantial benefits to wildlife species sensitive to edge and habitat fragmentation (Askins 1993, Litvaitis 1993). A large clearcut today will be a large, contiguous mature forest in 60 years.

The U. S. Fish and Wildlife Service monitors woodcock populations at the state and regional scale (Kelley 2000). My analysis of the Woodcock Singing Ground Survey routes for northern Wisconsin suggested a different population trend for the northern, forested region of the state relative to the heavily agricultural and urbanized region in the southern part of the state. Though my results were inconclusive due to small sample sizes, monitoring woodcock populations by floristically similar regions rather than by political boundaries intuitively makes sense. I recommend grouping existing survey routes according to the Bird Conservation Regions of the North American Bird Conservation Initiative. This change would allow investigation of the impacts of landscape changes on woodcock populations and provide information in units compatible with other bird conservation programs.

My study was the first to use intensive, spot-mapping surveys to estimate Golden-winged Warbler densities in aspen forests and to focus on Golden-winged Warbler response to forest succession. High aspen sucker densities and low canopy closure characterized Golden-winged Warbler territories. Golden-wings clearly preferred the earliest stages of forest succession and were negatively impacted by forest

maturation. Clearcutting is an effective tool for creating Golden-winged Warbler breeding habitat.

Shrub communities require a regular and frequent disturbance regime to prevent succession to a tree-dominated community. Both the protection of lowland shrub communities maintained by natural disturbances and the creation of upland shrub communities with logging are potentially effective strategies resource managers can use to provide Golden-wing breeding cover. Ideally, managers should target management of the shrub communities associated with high nest productivity. Most productivity information for Golden-wings comes from studies in abandoned agricultural fields (Will 1993, Larkin and Confer 1996). With the exception of these studies and scattered nest records (see Eyer 1963, Hanski et al. 1996), no substantial nest productivity data have been collected in any lowland or upland shrub communities. Nest productivity information from the predominant shrub communities in the western portion of the Golden-wing breeding range will be required to implement effective management plans in the Great Lakes Region.

To manage breeding habitat for early successional bird species and other wildlife, managers need a broad perspective. They should view the landscape as a shifting mosaic of successional stages and cover types. This perspective allows shrub communities to succeed into tree-dominated communities but also requires that new shrublands be created elsewhere in the landscape to balance the loss. For example, clearcutting a quarter of large aspen stands every 10-15 years may measurably improve

woodcock use and maintain the young, open conditions preferred by Golden-wings within the stand.

Askins (1993) described specialists of ephemeral habitat as "fugitive species." Individuals of these species are continually seeking higher quality habitat. Locating quality breeding habitat will become more difficult as the eastern deciduous forests of North America continue to mature. Even if the maturation of eastern forests is not the primary cause of the declining population trend for shrub-dependent species, the loss of breeding habitat will make population stabilization and recovery more difficult.

Fortunately, the resources and tools are available to provide quality breeding habitat for shrubland birds. Through cooperative conservation initiatives like the North American Bird Conservation Initiative, organizations traditionally focused on either game or nongame bird issues have the opportunity to combine resources for the conservation of early successional communities.

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Appendix I. Occurrence frequency[a] of bird species in mature and clearcut aspen (*Populus* spp.) forests in Oneida and Lincoln Counties, Wisconsin, 1998-2000.

Common name	Scientific name	Aspen clearcut[b] (*n*=1272)	Forest edge[c] (*n*=228)	Mature aspen[d] (*n*=180)
Alder Flycatcher	*Empidonax alnorum*	4[e]		
American Crow	*Corvus brachyrhynchos*	1	1	
American Goldfinch	*Carduelis tristis*	4	1	
American Kestrel	*Falco sparverius*	1		
American Redstart	*Setophaga ruticilla*	2	1	
American Robin	*Turdus migratorius*	3	2	1
American Woodcock	*Scolopax minor*	1		
Baltimore Oriole	*Icterus galbula*	2	1	1
Barn Swallow	*Hirundo rustica*	1		
Black-and-white Warbler	*Mniotilta varia*	2	1	1
Black-billed Cuckoo	*Coccyzus erythropthalmus*	2	1	
Black-capped Chickadee	*Poecile articapillus*	3	2	3
Barred Owl	*Strix varia*			1
Belted Kingfisher	*Ceryle alcyon*	1		
Brown-headed Cowbird	*Molothrus ater*	3	1	
Blue Jay	*Cyanocitta cristata*	2	2	1
Brewer's Blackbird	*Euphagus cyanocephalus*	1		
Brown Creeper	*Certhia americana*		1	
Brown Thrasher	*Toxostoma rufum*	1		
Black-thr. Green Warbler	*Dendroica virens*		1	
Broad-winged Hawk	*Buteo platypterus*	1	1	1
Blue-winged Warbler	*Vermivora pinus*	1		
Clay-colored Sparrow	*Spizella pallida*	2	1	

[a] The total number of occurrences for a species in 50 m. fixed-radius sample points for 3 visits in each survey season for 2 or 3 years. Eight stands were surveyed in 1998, and 13 stands were surveyed in 1999 and 2000. Each stand contained a grid of 12 sample points 125 m. apart. Each aspen clearcut contained a grid of 12 points as least 100 m apart. In 2 stands, one clearcut unit was not located the first season so we added a grid of 3 or 4 points in each new unit in spring 1999. A line of 4 sample points (125 m apart) ran parallel to the clearcut edge in mature forest cover adjacent to the clearcuts. Mature forest stands were surveyed in 1998.

[b] Aspen clearcuts (0-4 years-old)

[c] Forest edge is a zone of 100m into mature forest cover adjacent to a clearcut. Sample points in adjacent cover usually occurred in aspen forest (*n*=25) and less frequently in northern hardwood (*n*=11), conifer (*Pinus* spp., *Picea* spp.; *n*=6), or mixed hardwood-conifer (*n*=8) forest stands.

[d] Even-aged aspen stand (25-60 years-old)

[e] blank=no observations, 1=1-10 observations of a species, 2=11-50, 3=51-100, 4=101-300, 5=301-800.

Appendix I (continued).

Common name	Scientific name	Aspen clearcut[b] (*n*=1272)	Forest edge[c] (*n*=228)	Mature aspen[d] (*n*=180)
Cedar Waxwing	*Bombycilla cedrorum*	3	1	1
Chipping Sparrow	*Spizella passerina*	1		1
Cape May Warbler	*Dendroica tigrina*	1		
Common Grackle	*Quiscalus quiscula*	2	1	1
Connecticut Warbler	*Oporornis agilis*		1	
Common Raven	*Corvus corax*	1		1
Common Snipe	*Gallinago gallinago*	1		
Common Yellowthroat	*Geothlypis trichas*	5	1	1
Chestnut-sided Warbler	*Dendroica pensylvanica*	5	3	2
Downy Woodpecker	*Picoides pubescens*	2	1	1
Eastern Bluebird	*Sialia sialis*	1		
Eastern Kingbird	*Tyrannus tyrannus*	1		
Eastern Phoebe	*Sayornis phoebe*	1		
Eastern Towhee	*Pipilo erythrophthalmus*	3	1	
Eastern Wood-pewee	*Contopus virens*	1	1	1
Evening Grosbeak	*Coccothraustes vespertinus*	1		
Field Sparrow	*Spizella pusilla*	1		
Great-crested Flycatcher	*Myiarchus crinitus*	1	1	1
Gray Catbird	*Dumetella carolinensis*	3		
Golden-winged Warbler	*Vermivora chrysoptera*	4	1	
Hairy Woodpecker	*Picoides villosus*	1	1	1
Hermit Thrush	*Catharus guttatus*	1	1	2
House Wren	*Troglogytes aedon*	3	1	1
Indigo Bunting	*Passerina cyanea*	4	1	1
Killdeer	*Charadrius vociferus*	2		
Least Flycatcher	*Empidonax minimus*	1	1	2
Lincoln's Sparrow	*Melospiza lincolnii*	2	1	
Mallard	*Anas platyrhynchos*	1	1	
Mourning Dove	*Zenaida macroura*	1		
Mourning Warbler	*Oporornis agilis*	5	2	2
Myrtle Warbler	*Coronata coronata*	1	1	
Nashville Warbler	*Vermivora ruficapilla*	3	2	1
Northern Flicker	*Colaptes auratus*	2	1	1
Northern Goshawk	*Accipiter gentilis*	1		
Northern Harrier	*Circus cyaneus*	1		
Northern Parula	*Parula americana*		1	
Olive-sided Flycatcher	*Contopus borealis*	1		
Ovenbird	*Seiurus aurocapillus*	2	4	4
Pine Siskin	*Carduelis pinus*	1		
Pine Warbler	*Dendroica pinus*	1	1	

Appendix I (continued).

Common name	Scientific name	Aspen clearcut[b] (*n*=1272)	Forest edge[c] (*n*=228)	Mature aspen[d] (*n*=180)
Pileated Woodpecker	*Dryocopus pileatus*	1	1	
Purple Finch	*Carpodacus purpureus*	1		
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	2	2	1
Red-breasted Nuthatch	*Sitta canadensis*	1	1	
Red-eyed Vireo	*Vireo olivaceus*	3	3	4
Red-tailed Hawk	*Buteo jamaicensis*	2		
Ruby-thr. Hummingbird	*Archilochis colubris*	1		1
Ruffed Grouse	*Bonasa umbellus*	1	1	1
Red-winged Blackbird	*Agelaius phoeniceus*	2	1	
Sandhill Crane	*Grus canadensis*	1		
Savannah Sparrow	*Passerculus sandwichensis*	1		
Scarlet Tanager	*Piranga olivacea*	2	1	1
Solitary Sandpiper	*Tringa solitaria*	1		
Song Sparrow	*Melospiza melodia*	5	1	
Spotted Sandpiper	*Actitis macularia*	1		
Sharp-shinned Hawk	*Accipiter striatus*	1	1	
Tree Swallow	*Tachycineta bicolor*	2		
Unknown *Empidonax* sp.		1		1
Veery	*Catharus fuscescens*	2	1	1
Vesper Sparrow	*Pooecetes gramineus*	1		
Warbling Vireo	*Vireo gilvus*	1		
White-breasted Nuthatch	*Sitta carolinensis*	1	1	1
Wilson's Warbler	*Wilsonia pusilla*	1		
Winter Wren	*Troglodytes troglodytes*	1	1	1
White-throated Sparrow	*Zonotrichia albicollis*	4	1	
Yellow-breasted Chat	*Icteria virens*	1		
Yellow-bellied Sapsucker	*Sphyrapicus varius*	1		1
Yellow Warbler	*Dendroica petechia*	2	1	
Flyovers[f]				
Turkey Vulture	*Cathartes aura*	1		
Green Heron	*Butorides virescens*	1		
Great Blue Heron	*Ardea herodias*	1		
Common Loon	*Gavia immer*	1		
Common Nighthawk	*Chordeiles minor*	1		
Chimney Swift	*Chaetura pelagica*	1		
Bald Eagle	*Haliaeetus leucocephalus*	1		
Canada Goose	*Branta candadensis*	1		

[f] Species only observed flying over fixed-radius point.

Appendix II. Understory vegetation present on 18 forest stands (13 harvested and 5 uncut) used for American Woodcock (*Scolopax minor*) surveys in Oneida and Lincoln Counties, Wisconsin. Habitat types were identified using the Kotar forest classification system (Kotar et al. 1988) during the following periods: 05/29/99 - 07/21/99, 09/18/99 - 09/19/99, and 05/31/00 - 07/16/00. Plant lists were not exhaustive.

Understory vegetation		Harvested stands (Habitat type[a])												
Common name	Scientific name	Alexander (ATM)	Cedar Falls E (PMV)	Cedar Falls W (PMV/ATM)	Copper River (AViO/ATM)	Lily Lake (AvVib)	Pine Creek (ATM)	Price Co Rd N (TMC)	Price Co Rd S (ATM/ATD)	Rocky Run (PMV)	Skanawan Lk (AVVib/ATM)	Tower Road (AviO/ATM)	Trout Creek N (AQV/PMV)	Trout Creek S (AQV)
Herbs, subshrubs, ferns, ferns, allies, mosses														
adder's mouth	*Malaxis uniflora*			X[b]										
agrimony	*Agrimonia gryposepala*							X						
unknown aster	*Aster spp.*							X		X				
barren strawberry	*Waldsteinia fragarioides*	X	X		X	X	X	X		X	X		X	X
black seeded plantain	*Plantago rugelii*					X				X				
black snakeroot	*Sanicula marilandica*						X				X			
bloodroot	*Sanguinaria canadensis*						X							
blue cohosh	*Caulophyllum thalictroides*				NH[b]				X			NH		
bracken fern	*Pteridium aquilinum*	X	X	X		X	X	X	X	X	X		X	X
bugleweed	*Lycopus uniflorus*							X	X					
bull thistle	*Cirsium vulgare*							X		X				
bunchberry	*Cornus canadensis*	X	X	X	X		X	X	X	X		X		
buttercup	*Ranunculus spp.*			R[b]		R		X						
calico aster	*Aster lateriflorus*		X					X						

Appendix II (continued).

Understory vegetation (continued)		Harvested stands (continued)												
Common name	**Scientific name**	Alexander	Cedar Falls E	Cedar Falls W	Copper River	Lily Lake	Pine Creek	Price Co Rd N	Price Co Rd S	Rocky Run	Skanawan Lk	Tower Road	Trout Creek N	Trout Creek S
Canada goldenrod	*Solidago canadensis*							X						
cinnamon fern	*Osmuna cinnamomea*							X						
columbine	*Aquilegia canadensis*	X	X	X		X					X			
cow vetch	*Vicia cracca*			X							X		X	
dandelion	*Taraxacum officinale*									X				
early meadow rue	*Thalictrum dioicum*	X	X	X		X	X				X		X	X
false soloman's seal	*Smilacina racemosa*	X	X			X					X			
fireweed	*Epilobium angustifolium*							R						
flat-topped aster	*Aster umbellatus*	X	X					X						
fringed bindweed	*Polygonum cilinode*		X				X	R	X					
gaywings	*Polygala paucifolia*	X												X
giant nettle	*Urtica spp.*				X									
glaucous honeysuckle	*Lonicera dioica*		X											
goldenrod	*Solidago spp.*						X	X	X	X	X			
goldthread	*Coptis groenlandica*							X						
grasses and sedges	NA	X	X	X	X	X	X	X	X	X	X	X	X	X
ground-cedar clubmoss	*Lycopodium complanatum*		X											
ground-pine clubmoss	*Lycopodium obscurum*	X	X	X	X	X	X		X		X	X	X	X
hairy honeysuckle	*Lonicera hirsuta*		X				X				X			
hairy soloman's seal	*Polygonatum pubescens*			X								X	X	
heal-all	*Prunella vulgaris*							X						
hedge bindweed	*Convulvulus sepium*		X											
hog peanut	*Amphicarpa bracteata*						X							
horsetails	*Equisetum spp.*							X	X					
indian hemp	*Apocynum cannabinum*		X				X	X		X	X		X	

Appendix II (continued).

Understory vegetation (continued)		Harvested stands (continued)												
Common name	**Scientific name**	Alexander	Cedar Falls E	Cedar Falls W	Copper River	Lily Lake	Pine Creek	Price Co. Rd N	Price Co. Rd S	Rocky Run	Skanawan Lk.	Tower Road	Trout Creek N	Trout Creek S
indian pipe	*Monotropa uniflora*						X				X			
interrupted fern	*Osmunda claytoniana*							X						
jack-in-the-pulpit	*Arisaema atrorubens*							X	X			NH		
jewelweed	*Impatiens capensis*				NH							NH		
lady fern	*Athyrium filix-femina*		X		NH		X	X	X		X			
large-flowered bellwort	*Uvularia grandiflora*										X			
large-leaved aster	*Aster macrophyllus*	X	X	X	X	X	X	X	X	X	X	X	X	X
lion's foot	*Prenanthes alba*		X											X
low bindweed	*Convulvulus spithameus*	X	X			X								
mad-dog skullcap	*Scutellaria lateraflora*							X						
maidenhair fern	*Adiantum pedatum*				NH				X					
mitterwort	*Mitella diphyllum*				NH				X		X			
mosses	NA	X	X					X		X				
mullein	*Verbascum thapsus*					X	X	X	X	X				
northern willow herb	*Epilobium glandulosum*							X						
old-field cinquefoil	*Potentilla simplex*					X								X
orange hawkweed	*Hieracium aurantiacum*					X		X	X	X				X
partridgeberry	*Mitchella repens*				NH		X		X			X		
pearly everlasting	*Anaphalis margaritacea*					R		X	X	X				
rattlesnake fern	*Botrychium virginianum*								X					
red baneberry	*Actaea rubra*	X				X	X	X	X					
red clover	*Trifolium pratense*					X				X				X
rough avens	*Geum laciniatum*							X						
rough cinquefoil	*Potentilla norvegica*						X			X				
round-lobed hepatica	*Hepatica americana*	X	X	X	NH			X	X		X	X		

Appendix II (continued).

Understory vegetation (continued)		Harvested stands (continued)												
Common name	**Scientific name**	Alexander	Cedar Falls E	Cedar Falls W	Copper River	Lily Lake	Pine Creek	Price Co. Rd. N	Price Co. Rd. S	Rocky Run	Skanawan Lk.	Tower Road	Trout Creek N	Trout Creek S
sensitive fern	*Onoclea sensibilis*				NH		X	X						
sessile bellwort	*Uvularia sessilifolia*	X	X	X	NH		X	X	X	X	X		X	X
shield fern sp.	*Dryopteris carthusiana*							X						X
shining clubmoss	*Lycopodium lucidulum*		X											
starflower	*Trientalis borealis*		X	X	X	X	X	X	X		X	X		X
swamp thistle	*Cirsium muticum*							X						
sweet cicely	*Osmorhiza claytoni*	X			X			X				NH		
sweet-scented bedstraw	*Galium triflorum*	X	X	X	X	X	X	X	X	X	X			
tower mustard	*Arabis glabra*		X											
trillium	*Trillium grandiflorum*	X	X		X		X	X			X	X		
vetchling	*Lathyrus spp.*					X				X				X
violets (downy yellow)	*Viola pubescens*		X			X		X						
violet	*Viola spp.*		X		NH		X	X			X			
virginia creeper	*Parthenocissus quinquefolia*				NH						X			
waxflower	*Pyrola elliptica*		X				X	X	X	X				
white campion	*Lychnis alba*			R										
white Dutch clover	*Trifolium repens*			R		X								
whorled loosestrife	*Lysimachia quadrifolia*									X			X	X
wild geranium	*Geranium maculatum*	X	X								X			
wild leek	*Allium tricoccum*											NH		
wild lettuce	*Lactuca canadensis*		X					X		X				
wild lily-of-the-valley	*Maianthemum canadense*	X	X	X	X	X	X	X	X	X		X	X	X
wild rose	*Rosa carolina*			R										
wild sarsaparilla	*Aralia nudicaulis*	X	X	X	X	X		X	X		X	X	X	X
wild strawberry	*Fragaria virginiana*	X	X	X	X	X	X	X	X	X	X	X	X	X

Appendix II (continued).

Understory vegetation (continued)		Harvested stands (continued)												
Common name	**Scientific name**	Alexander	Cedar Falls E	Cedar Falls W	Copper River	Lily Lake	Pine Creek	Price Co. Rd. N	Price Co. Rd. S	Rocky Run	Skanawan Lk.	Tower Road	Trout Creek N	Trout Creek S
wintergreen	*Gaultheria procumbens*		X			X				X		NH		X
wood anemone	*Anemone quinquefolia*	X		X		X	X	X	X	X	X		X	X
wood betony	*Pedicularis canadensis*	X				X				X			X	X
wood sorrel	*Oxalis montana*					X		X						X
yarrow	*Achillea millefolium*		X	X		R	R	X						X
yellow beadlily	*Clintonia borealis*	X	X	X	X		X	X			X	X		
yellow evening primrose	*Oenothera biennis*						X							
Shrubs														
alternate-leaved dogwood	*Cornus alternifolia*						X	X	X			X		
American fly honeysuckle	*Lonicera canadensis*		X					X			X	X		
American hazelnut	*Corylus americana*									X				
arrowwood	*Viburnum recognitum*					X			X	X				
beaked hazelnut	*Corylus cornuta*	X				X	X	X		X		X		
black raspberry	*Rubus occidentalis*		X											
dwarf bushhoneysuckle	*Diervilla lonicera*	X	X					X	X	X		X	X	
Canada blueberry	*Vaccinium myrtilloides*	X	X					X		X	X	X	X	X
Canada plum	*Prunus nigra*										X			
choke cherry	*Prunus virginiana*	X	X	X		X	X		X		X			X
common blackberry	*Rubus allegheniensis*	X	X	X			X	X	X	X	X	X		
common winterberry	*Ilex verticillata*							X						
dewberry	*Rubus flagellaris*		X					X	X	X				
downy arrowwood	*Viburnum rafinesquianum*						X							X
dwarf pussy willow	*Salix tristis*		X			X	X	X		X			X	X
gooseberries	*Ribes spp.*				NH			X	X			X		

Appendix II (continued).

Understory vegetation (continued)		Harvested stands (continued)												
Common name	**Scientific name**	Alexander	Cedar Falls E	Cedar Falls W	Copper River	Lily Lake	Pine Creek	Price Co. Rd. N	Price Co. Rd. S	Rocky Run	Skanawan Lk.	Tower Road	Trout Creek N	Trout Creek S
gray dogwood	*Cornus racemosa*									X				
low sweet blueberry	*Vaccinium angustifolium*	X	X	X		X	X			X	X		X	X
maple-leaved viburnum	*Viburnum acerifolium*			X		X	X			X	X			
mountain maple	*Acer spicatum*							X			X			
pin cherry	*Prunus pensylvanica*		X				X	X		X				
red chokeberry	*Pyrus arbutifolia*							X				X		X
red-osier dogwood	*Cornus stolonifera*								X					
round-leaved dogwood	*Cornus rugosa*						X				X			
serviceberry	*Amelanchier spp.*	X	X	X		X	X			X	X		X	X
speckled alder	*Alnus rugosa*			X										
sweet-fern	*Comptonia peregrina*	R	R	X		X	X			X	R		X	X
unknown hazelnut	*Corylus spp.*	X	X	X	X				X	X	X	X	X	X
wild red raspberry	*Rubus idaeus*		X		X			X	X	X	X	X		
Tree regeneration[c]														
balsam fir (se)	*Abies balsamea*		X	X			X		X	X	X	X		X
balsam poplar (se, sap)	*Populus balsamifera*				X									
bigtooth aspen (se)	*Populus grandidentata*					X					X	X		
black cherry (se, sap)	*Prunus serrotina*	X	X	X		X		X	X	X	X			X
black spruce (se)	*Picea mariana*		X											
hawthorn (sap)	*Crataegus spp.*										X			
ironwood (sap)	*Ostrya virginiana*						X		X					
northern red oak (sap)	*Quercus rubra*	X		X	X	X	X			X	X	X	X	X
paper birch (se)	*Betulla papyrifera*				X					X	X	X		

Appendix II (continued).

Understory vegetation (continued)		Harvested stands (continued)												
Common name	**Scientific name**	Alexander	Cedar Falls E	Cedar Falls W	Copper River	Lily Lake	Pine Creek	Price Co. Rd. N	Price Co. Rd. S	Rocky Run	Skanawan Lk.	Tower Road	Trout Creek N	Trout Creek S
quaking aspen (se, sap)	*Populus tremuloides*	X	X	X	X	X	X	X	X	X	X	X	X	X
red maple (se, sap)	*Acer rubrum*	X	X	X	X	X	X	X	X	X	X	X	X	X
sugar maple (se)	*Acer saccharum*				X			X			X	X		
unknown ash (se)	*Fraxinus spp.*				X			X	X	X		X		
white ash (se)	*Fraxinus americana*				X			X						
white pine (se)	*Pinus strobus*	X	X	X		X					X			X
white spruce (se)	*Picea glauca*						X	X		X				X
Canopy/subcanopy trees														
ash	*Fraxinus spp.*							X	X					
basswood	*Tilia americana*							X						
black cherry	*Prunus serotina*							X						
choke cherry	*Prunus virginiana*							X						
hackberry	*Celtis occidentalis*							X						
hackberry	*Celtis occidentalis*							X						
ironwood	*Ostrya virginiana*								X					
jack pine	*Pinus banksiana*									X				
northern red oak	*Quercus rubra*								X					
paper birch	*Betulla papyrifera*							X						
pin cherry	*Prunus pennsylvanica*							X						
quaking aspen	*Populus tremuloides*	X	X	X		X	X	X	X	X	X		X	X
red maple	*Acer rubrum*							X	X					
red pine	*Pinus resinosa*										X			
sugar maple	*Acer saccharum*				NH			X				NH		
white pine	*Pinus strobus*									X	X			

Appendix II (continued).

Understory vegetation		Uncut stands (Habitat type[a])				
Common name	Scientific name	Alexander Control (ATM)	Gritzmachen (AVVib)	Price Co Rd Control (TMC)	Swamp Lake (PMV)	Trout Creek Control (AVVib)
Herbs, subshrubs, ferns, fern allies, mosses						
barren strawberry	*Waldsteinia fragarioides*		X[a]			X
black snakeroot	*Sanicula marilandica*					X
blue cohosh	*Caulophyllum thalictroides*					X
bracken fern	*Pteridium aquilinum*		X	X		X
bugleweed	*Lycopus uniflorus*			X		
bunchberry	*Cornus canadensis*			X		
false soloman's seal	*Smilacina racemosa*		X			X
goldenrod	*Solidago spp.*			X		X
grasses and sedges	NA		X	X		X
ground-pine clubmoss	*Lycopodium obscurum*		X			
hog peanut	*Amphicarpa bracteata*					X
hooked crowfoot	*Ranunculus recurvatus*			X		
horsetails	*Equisetum spp.*			X		
indian hemp	*Apocynum cannabinum*			X		
indian pipe	*Monotropa uniflora*		X			
interrupted fern	*Osmunda claytoniana*			X		
lady fern	*Athyrium filix-femina*			X		X
large-leaved aster	*Aster macrophyllus*		X	X		X
old-field cinquefoil	*Potentilla simplex*		X			
rosey twisted stalk	*Streptopus roseus*					X
rough avens	*Geum laciniatum*			X		
round-lobed hepatica	*Hepatica americana*		X			X
royal fern	*Osmunda regalis*			X		

Appendix II (continued).

Understory vegetation (continued)		Uncut stands (continued)				
		Alexander		Price Co Rd		Trout Creek
Common name	**Scientific name**	Control	Gritzmachen	Control	Swamp Lake	Control
sensitive fern	*Onoclea sensibilis*					X
sessile bellwort	*Uvularia sessilifolia*		X	X		X
starflower	*Trientalis borealis*		X	X		
sweet cicely	*Osmorhiza claytoni*					X
sweet-scented bedstraw	*Galium triflorum*		X	X		X
trillium	*Trillium grandiflorum*					X
violets (downy yellow)	*Viola pubescens*		X			X
waxflower	*Pyrola elliptica*			X		
whorled loosestrife	*Lysimachia quadrifolia*					X
wild lettuce	*Lactuca canadensis*			X		
wild lily-of-the-valley	*Maianthemum canadense*		X	X		X
wild sarsaparilla	*Aralia nudicaulis*		X	X		X
wild strawberry	*Fragaria virginiana*			X		X
wintergreen	*Gaultheria procumbens*		X			
wood anemone	*Anemone quinquefolia*		X	X		
wood sorrel	*Oxalis montana*			R		
yarrow	*Achillea millefolium*		X			
yellow beadlily	*Clintonia borealis*		X			
Shrubs						
alternate-leaved dogwood	*Cornus alternifolia*			X		
American fly honeysuckle	*Lonicera canadensis*			X		
American hazelnut	*Corylus americana*					X
beaked hazelnut	*Corylus cornuta*		X	X		
dwarf bushhoneysuckle	*Diervilla lonicera*		X	X		X
Canada blueberry	*Vaccinium myrtilloides*		X			
common blackberry	*Rubus allegheniensis*		X	X		
dewberry	*Rubus flagellaris*		X	X		

Appendix II (continued).

Understory vegetation (continued)		Uncut stands (continued)				
		Alexander		Price Co Rd		Trout Creek
Common name	**Scientific name**	Control	Gritzmachen	Control	Swamp Lake	Control
dwarf pussy willow	*Salix tristis*			X		
gooseberries	*Ribes spp.*			X		
low sweet blueberry	*Vaccinium angustifolium*					X
maple-leaved viburnum	*Viburnum acerifolium*		X			X
round-leaved dogwood	*Cornus rugosa*			X		
serviceberry	*Amelanchier spp.*		X			
sweet-fern	*Comptonia peregrina*					X
wild red raspberry	*Rubus idaeus*			X		
Tree regeneration[b]						
balsam fir (se)	*Abies balsamea*		X			
bigtooth aspen (se)	*Populus grandidentata*		X			
black ash (se)	*Fraxinus nigra*			X		
black cherry (se, sap)	*Prunus serrotina*		X	X		
ironwood (sap)	*Ostrya virginiana*					X
northern red oak (sap)	*Quercus rubra*		X			X
paper birch (se)	*Betulla papyrifera*					X
quaking aspen (se, sap)	*Populus tremuloides*			X		
red maple (se, sap)	*Acer rubrum*		X	X		
slippery elm (sap)	*Ulmus rubra*			X		
sugar maple (se)	*Acer saccharum*		X	X		
white ash (se)	*Fraxinus americana*			X		
Canopy/subcanopy trees						
ash	*Fraxinus spp.*			X		X
bigtooth aspen	*Populus grandidentata*		X		X	X
bur oak	*Quercus macrocarpa*					X
ironwood	*Ostrya virginiana*					X

Appendix II (continued).

Understory vegetation (continued)		Uncut stands (continued)				
		Alexander		Price Co Rd		Trout Creek
Common name	**Scientific name**	Control	Gritzmachen	Control	Swamp Lake	Control
jack pine	*Pinus banksiana*					X
northern red oak	*Quercus rubra*		X	X	X	X
paper birch	*Betulla papyrifera*		X		X	X
quaking aspen	*Populus tremuloides*	X	X	X	X	X
red maple	*Acer rubrum*		X	X	X	X
shagbark hickory	*Carya ovata*					X
sugar maple	*Acer saccharum*		X			X
white spruce	*Picea glauca*					X

[a] Habitat types: AQV=Acer-Quercus/Vaccinium, ATD = Acer-Tsuga/Dryopteris, ATM=Acer-Tsuga/Maianthemum, AViO=Acer/Viola-Osmorhiza, AVVib=Acer/Vaccinium-Viburnum, PMV=Pinus/Maianthemum-Vaccinium, TMC=Tsuga/Maianthemum-Coptis

[b] Plant presence: X=species present, R=species only observed along roads, NH=species only found in mature northern hardwood forest adjacent to clearcut

[c] Tree size-class: se=seedling (≤ 50 cm tall), sap=sapling (> 50 cm tall and ≤ 2.5 cm DBH)

Appendix III. Soil conditions for 18 forest stands used for American Woodcock (*Scolopax minor*) surveys in Oneida and Lincoln Counties, Wisconsin, 1998-2000 (Boelter 1988, Mitchell 1993).

	Soil conditions		
Site	**Soil type**	**Soil moisture**	**Soil nutrient quality**
Harvested			
Alexander	sandy loam	dry mesic	poor/medium
Cedar Falls East	loamy sand	dry mesic	medium
Cedar Falls West	loamy sand	dry mesic	poor/medium
Copper River	silt loam/sandy loam	mesic	medium/rich
Lily Lake	sandy loam	dry mesic	medium
Pine Creek	sandy loam	dry mesic	medium
Price Co. Rd. North	loamy sand/loam	mesic	medium
Price Co. Rd. South	loamy sand/sandy loam	dry mesic/mesic	medium
Rocky Run	sandy loam	dry mesic	poor/medium
Skanawan Lake	sandy loam	dry mesic	medium
Tower Road	silt loam	mesic	medium/rich
Trout Creek North	loamy sand	dry/dry mesic	poor
Trout Creek South	loamy sand	dry	poor
Uncut			
Alexander Control	sandy loam	dry mesic	medium
Gritzmachen	sandy loam	dry mesic	medium
Price Co. Rd. Control	loamy sand	mesic	poor/medium
Swamp Lake	sandy loam	dry mesic	medium
Trout Creek Control	sandy loam	dry mesic	medium

Appendix IV. Displaying male American Woodcock (*Scolopax minor*) abundance and density (males/ha) in aspen (*Populus* spp.) stands surveyed in March-April 1998, April 1999, and March-April 2000 in Oneida and Lincoln Counties, Wisconsin.

Site name	Stand area (ha)	Intended stand removal[a] (%)	Actual stand removal[b] (%)	Maximum males in stand[c]			Male density in stand[d]		
				1998	1999	2000	1998	1999	2000
Alexander Control	97	0	0	0	NA	NA	0	NA	NA
Gritzmachen	156	0	0	0	NA	NA	0	NA	NA
Price Co. Rd. Control	111	0	0	0	NA	NA	0	NA	NA
Swamp Lake	96	0	0	0	NA	NA	0	NA	NA
Trout Creek Control	41	0	0	0	NA	NA	0	NA	NA
Lily Lake	150	30	17	1[e]	3	5	0.007[e]	0.020	0.033
Pine Creek	34	30	33	3	6	5	0.087	0.174	0.145
Rocky Run	86	30	26	NA[f]	5	7	NA	0.058	0.081
Skanawan Lake	94	30	21	2	2	4	0.021	0.021	0.042
Trout Creek South	42	30	28	2[e]	4	7	0.047[e]	0.095	0.166
Alexander Clearcut	56	60	47	4	2	4	0.072	0.036	0.072
Price Co. Rd. North	64	60	30	4[e]	6	7	0.063[e]	0.094	0.110
Price Co. Rd. South	130	60	27	5[e]	5	9	0.038[e]	0.038	0.069
Trout Creek North	97	60	39	3[e]	5	7	0.031[e]	0.051	0.072
Cedar Falls East	58	100	101	NA	9	14	NA	0.157	0.244
Cedar Falls West	75	100	74	NA	8	15	NA	0.107	0.201
Copper River	74	100	78	NA	4	5	NA	0.054	0.068
Tower Road	77	100	98	NA	5	6	NA	0.065	0.078

[a] Estimated stand removal (prior to site manipulation) is the percentage of the stand area intended for harvest by clearcutting.

[b] Actual stand removal (following site manipulation) is the percentage of the stand area harvested by clearcutting. The clearcut area was measured with a Trimble Explorer II Geographic Positioning System, and the original stand area was estimated using a dot planimeter.

[c] The maximum number of displaying males observed stand-wide among the 3 visits during spring courtship each year.

[d] Male density in stand (males/ha) = maximum males in stand / stand area (ha)

[e] A clearcut unit within the stand was not surveyed resulting in partial stand coverage relative to surveys conducted in 1999 and 2000.

[f] NA = not applicable i.e. stand was not surveyed in 1998

Appendix V. Displaying male American woodcock (*Scolopax minor*) abundance and density (males/ha) in 21 clearcuts occurring in 13 aspen (*Populus* spp.) stands surveyed in March-April 1998, April 1999, and March-April 2000 in Oneida and Lincoln Counties, Wisconsin.

Site (unit[a])	Clearcut area (ha)	Clearcut edge[b] (km/ha)	Maximum males in clearcuts[c]			Male density in clearcuts[d]		
			1998	1999	2000	1998	1999	2000
Alexander Clearcut	26	0.177	3	2	4	0.115	0.076	0.153
Cedar Falls East	58	0.129	NA[e]	9	14	NA	0.154	0.240
Cedar Falls West	55	0.161	NA	8	15	NA	0.145	0.271
Copper River	57	0.103	NA	4	5	NA	0.070	0.088
Lily Lake (E)	21	0.146	1	2	4	0.049	0.097	0.195
Lily Lake (W)	5	0.232	NA	1	1	NA	0.206	0.206
Pine Creek	11	0.203	3	5	5	0.263	0.439	0.439
Price Co. Rd. North (E)	12	0.148	4	3	3	0.328	0.246	0.246
Price Co. Rd. North (W)	7	0.256	NA	2	2	NA	0.293	0.293
Price Co. Rd. South (E)	26	0.151	5	4	6	0.190	0.152	0.228
Price Co. Rd. South (W)	9	0.436	NA	1	3	NA	0.111	0.334
Rocky Run	23	0.124	NA	3	6	NA	0.132	0.265
Skanawan Lake (E)	6	0.211	1	1	2	0.165	0.165	0.330
Skanawan Lake (M)	9	0.156	0	0	1	0	0	0.116
Skanawan Lake (W)	5	0.222	0	1	1	0	0.191	0.191
Tower Road	76	0.106	NA	5	6	NA	0.066	0.079
Trout Creek North (E)	22	0.119	NA	3	4	NA	0.138	0.185
Trout Creek North (W)	16	0.198	3	2	3	0.185	0.123	0.185
Trout Creek South (E)	5	0.212	1	1	2	0.221	0.221	0.442
Trout Creek South (M)	1	0.447	NA	1	1	NA	0.730	0.730
Trout Creek South (W)	6	0.265	1	2	3	0.168	0.336	0.504

[a] E = east, M = middle, W=west
[b] Clearcut edge = clearcut perimeter length (km) / clearcut area (ha)
[c] The maximum number of displaying males observed across all clearcut units within a stand among the 3 visits during spring courtship.
[d] Displaying male density = maximum males in clearcuts / clearcut area
[e] NA = not applicable i.e. this clearcut was not surveyed in 1998

Appendix VI. Ratio of aspen forest (*Populus* spp.), northern hardwood forest (*Acer* spp. and *Quercus* spp.), conifer forest (*Pinus* spp., *Picea mariana*, *Abies balasmifera*, and *Larix laricina*), and shrubland (*Alnus* spp. and cutover *Populus* spp.) within a 100m buffer surrounding clearcut areas of 13 aspen stands in Oneida and Lincoln Counties, Wisconsin. Coverage data was obtained using ArcView Geographic Information System Version 3.2 (Environmental Systems Research Institute 1999) and the Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) land cover data.

	Land cover type (%)			
Site	Aspen forest	Northern hardwood forest	Conifer forest	Shrubland
Alexander	47	9	24	5
Cedar Falls East	8	4	66	9
Cedar Falls West	8	2	35	28
Copper River	14	36	5	2
Lily Lake	65	18	13	1
Pine Creek	47	17	0	0
Price Co. Rd. North	45	9	0	10
Price Co. Rd. South	54	17	0	7
Rocky Run	60	14	6	8
Skanawan Lake	39	43	1	1
Tower Road	8	70	10	0
Trout Creek North	41	22	23	6
Trout Creek South	61	10	15	4
Mean (SE)	38 (5.94)	21 (5.23)	15 (5.21)	1 (0.56)

Appendix VII. Vegetation structure variables (mean ± SE) for clearcuts in 13 aspen stands located in Oneida and Lincoln Counties, Wisconsin. Vegetation variables were sampled between 11 June - 09 July, 1999 (n=6) and 22 June – 15 July, 2000 (n=10).

Site name	Harvest date[a]	Litter cover (%)		Litter depth (cm)		Ground cover (%)		Maximum herb height (m)
		1999	2000	1999	2000	1999	2000	2000
Alexander	W 1996-1997	89.8 ± 7.1	91.5 ± 5.2	2.3 ± 0.4	2.3 ± 0.4	87.5 ± 5.6	91.5 ± 3.9	0.9 ± 0.1
Cedar Falls East	S 1997	95.8 ± 1.6	95.0 ± 2.4	2.9 ± 0.3	2.6 ± 0.8	70.8 ± 5.6	74.0 ± 3.9	0.8 ± 0.1
Cedar Falls West	S 1997	85.8 ± 14.2	98.3 ± 1.5	17.5 ± 14.6	12.6 ± 9.7	65.0 ± 13.9	82.5 ± 5.2	0.8 ± 0.1
Copper River	W 1998-1999	92.3 ± 4.6	87.4 ± 9.8	3.7 ± 0.8	12.2 ± 8.7	18.5 ± 5.0	66.1 ± 11.0	0.5 ± 0.1
Lily Lake	W 1997-1998	78.8 ± 15.4	66.3 ± 8.0	3.1 ± 0.8	2.1 ± 0.4	72.5 ± 15.0	69.1 ± 8.2	0.6 ± 0.1
Price Co Rd North	W 1997-1998	92.0 ± 4.6	100.0 ± 0.0	12.8 ± 12.0	1.8 ± 0.3	86.3 ± 3.1	91.0 ± 3.5	0.8 ± 0.1
Pine Creek	W 1997-1998	87.7 ± 7.6	87.0 ± 4.8	6.8 ± 2.4	1.3 ± 0.2	84.3 ± 5.3	97.0 ± 1.1	0.9 ± 0.1
Price Co Rd South	W 1997-1998	79.5 ± 9.0	86.3 ± 10.2	2.4 ± 1.2	1.3 ± 0.4	82.5 ± 10.6	76.0 ± 10.1	0.8 ± 0.1
Rocky Run	S 1998	61.7 ± 11.0	78.0 ± 6.6	1.1 ± 0.3	1.4 ± 0.4	82.5 ± 1.7	81.5 ± 5.7	0.7 ± 0.1
Skanawan Lake	W 1997-1998	95.8 ± 1.0	95.5 ± 1.6	3.6 ± 1.0	2.6 ± 0.6	78.3 ± 4.6	91.5 ± 4.5	0.9 ± 0.1
Trout Creek North	W 1997-1998	87.5 ± 6.6	89.0 ± 7.4	11.3 ± 7.4	3.8 ± 2.3	70.5 ± 13.9	83.0 ± 8.3	0.8 ± 0.1
Trout Creek South	W 1996-1997	98.5 ± 0.7	100.0 ± 0.0	3.7 ± 0.2	2.0 ± 0.3	80.8 ± 4.0	96.0 ± 1.3	1.1 ± 0.2
Tower Road	W 1996-1997	95.7 ± 3.2	100.0 ± 0.0	5.2 ± 0.8	3.2 ± 0.2	65.8 ± 12.2	92.2 ± 2.9	0.9 ± 0.1

[a] W = winter, S = summer

Appendix VII. (continued).

Site name	Canopy closure (%)		Visual obstruction (dm)		Shrub density (stems/m^2)	Maximum shrub height (m)	Dead woody vegetation density (stems/m^2)	
	1999	2000	1999	2000	1999	2000	1999	2000
Alexander	35.8 ± 9.4	47.2 ± 9.7	17.1 ± 2.1	5.8 ± 0.6	18.7 ± 7.0	1.3 ± 0.2	2.7 ± 0.8	1.2 ± 0.7
Cedar Falls East	25.6 ± 10.4	52.2 ± 12.3	7.6 ± 2.8	7.3 ± 2.0	2.2 ± 2.2	0.7 ± 0.2	3.0 ± 1.3	0.7 ± 0.5
Cedar Falls West	38.1 ± 13.5	40.3 ± 11.7	10.3 ± 1.5	2.7 ± 0.4	10.8 ± 4.5	0.6 ± 0.1	2.5 ± 1.5	1.1 ± 0.5
Copper River	0.0 ± 0.0	13.9 ± 6.7	0.7 ± 0.1	2.8 ± 0.4	0.0 ± 0.0	0.3 ± 0.1	0.0 ± 0.0	0.7 ± 0.6
Lily Lake	18.7 ± 8.7	33.1 ± 7.0	7.5 ± 1.6	5.0 ± 1.0	5.8 ± 4.5	0.7 ± 0.1	1.6 ± 0.8	0.0 ± 0.0
Price Co Rd North	9.3 ± 1.9	15.5 ± 7.3	6.3 ± 1.0	5.8 ± 0.9	10.0 ± 6.3	0.5 ± 0.0	1.3 ± 1.3	0.0 ± 0.0
Pine Creek	9.4 ± 3.2	41.6 ± 6.4	8.4 ± 0.9	7.3 ± 1.0	4.5 ± 2.6	0.8 ± 0.1	0.5 ± 0.2	0.5 ± 0.3
Price Co Rd South	7.7 ± 3.2	15.8 ± 6.6	10.5 ± 1.8	4.7 ± 1.0	21.2 ± 11.0	0.6 ± 0.1	1.2 ± 0.8	0.6 ± 0.3
Rocky Run	0.0 ± 0.0	0.3 ± 0.2	3.6 ± 0.2	4.1 ± 0.5	2.0 ± 1.3	0.6 ± 0.1	1.3 ± 1.2	0.0 ± 0.0
Skanawan Lake	14.9 ± 9.1	31.2 ± 11.6	6.6 ± 1.4	6.5 ± 1.0	2.7 ± 1.5	1.2 ± 0.2	0.2 ± 0.2	0.1 ± 0.1
Trout Creek North	1.2 ± 0.8	6.6 ± 2.9	4.2 ± 0.9	4.3 ± 0.8	17.5 ± 7.2	0.5 ± 0.1	0.3 ± 0.2	0.1 ± 0.1
Trout Creek South	47.3 ± 9.7	64.0 ± 10.6	16.0 ± 3.0	7.9 ± 1.2	11.0 ± 2.2	1.9 ± 0.4	2.3 ± 1.6	0.9 ± 0.4
Tower Road	26.8 ± 14.7	57.8 ± 12.6	12.7 ± 2.9	8.1 ± 1.4	2.8 ± 1.6	0.6 ± 0.1	0.3 ± 0.2	2.6 ± 0.8

Appendix VII. (continued).

Site name	Woody debris (cm)	Aspen sucker density (stems/m^2)		Maximum aspen height (m)		Tree seedling density (stems/m^2)		Maximum tree height (m)	
	1999	1999	2000	1999	2000	1999	2000	1999	2000
Alexander	145.0 ± 25.1[b]	1.6 ± 0.6	3.6 ± 0.9	2.1 ± 0.4	2.4 ± 0.4	2.9 ± 1.1	6.3 ± 1.6	1.8 ± 0.4	2.5 ± 0.5
Cedar Falls East	84.8 ± 25.2	2.4 ± 1.1	3.0 ± 0.8	2.1 ± 0.3	3.4 ± 0.8	3.5 ± 1.4	3.0 ± 0.7	1.8 ± 0.4	3.2 ± 0.7
Cedar Falls West	172.2 ± 44.9	2.9 ± 1.6	3.3 ± 1.3	2.5 ± 0.5	3.1 ± 0.6	3.6 ± 1.9	3.8 ± 1.3	2.5 ± 0.5	3.1 ± 0.6
Copper River	157.6 ± 12.4	4.8 ± 2.2	8.4 ± 2.3	0.4 ± 0.1	1.9 ± 0.2	7.2 ± 2.3	15.9 ± 3.9	0.4 ± 0.1	1.9 ± 0.2
Lily Lake	153.2 ± 31.1[b]	4.9 ± 1.9	4.6 ± 1.1	1.4 ± 0.2	1.8 ± 0.1	10.2 ± 2.9	5.3 ± 1.3	1.5 ± 0.3	1.8 ± 0.1
Price Co Rd North	116.5 ± 15.4[b]	5.5 ± 1.1	6.2 ± 1.0	1.4 ± 0.2	1.8 ± 0.1	6.4 ± 1.4	6.7 ± 1.1	1.4 ± 0.2	1.8 ± 0.1
Pine Creek	304.8 ± 30.1[b,c]	2.8 ± 1.1	6.2 ± 1.3	1.4 ± 0.2	2.7 ± 0.2	4.2 ± 1.7	7.1 ± 1.6	1.4 ± 0.2	2.8 ± 0.4
Price Co Rd South	155.8 ± 24.2[b]	4.2 ± 1.8	3.5 ± 1.1	1.8 ± 0.2	1.8 ± 0.3	5.5 ± 2.2	6.6 ± 1.3	1.5 ± 0.3	1.8 ± 0.4
Rocky Run	55.3 ± 12.6	2.2 ± 0.9	6.9 ± 1.4	0.7 ± 0.1	1.1 ± 0.1	3.5 ± 1.3	9.3 ± 1.5	0.7 ± 0.1	1.1 ± 0.1
Skanawan Lake	101.4 ± 10.4[b]	1.8 ± 0.7	2.7 ± 0.7	1.1 ± 0.2	2.9 ± 1.3	2.4 ± 0.8	4.8 ± 1.0	1.0 ± 0.2	2.9 ± 1.3
Trout Creek North	137.6 ± 20.1[b]	1.7 ± 1.0	3.7 ± 0.8	0.9 ± 0.2	1.3 ± 0.1	6.3 ± 2.9	7.3 ± 2.1	0.8 ± 0.2	1.3 ± 0.1
Trout Creek South	226.1 ± 70.6[b,b]	2.0 ± 0.8	3.4 ± 1.0	2.1 ± 0.1	3.1 ± 0.3	2.8 ± 1.0	6.3 ± 1.7	2.1 ± 0.1	2.9 ± 0.3
Tower Road	92.2 ± 6.3	1.9 ± 1.1	4.8 ± 1.5	1.7 ± 0.4	3.1 ± 0.5	4.3 ± 1.8	12.3 ± 3.0	1.6 ± 0.4	2.9 ± 0.5

[b] Samples collected in June 25 – July 24, 1998.
[c] The slash at this site was not chipped.

Appendix VIII. Vegetation structure at random sample points[a] in 4 age-classes of aspen (*Populus* spp.) stands located in Oneida and Lincoln Counties, Wisconsin, June - July 1999, 2000.

Vegetation structure variables	Stand age, years (n^b)												$F_{3,17}$	P^c
	1-4 (9)			6-10 (4)			10-19 (4)			20-25 (4)				
	mean	SE		mean	SE		mean	SE		mean	SE			
Litter cover (%)	92.5	2.1	**A**	96.5	1.1	**A**	98.8	0.8	**A**	92.8	3.4	**A**	1.59	0.09
Ground cover (%)	81.9	2.8	**A**	73.0	1.5	**AB**	67.2	4.7	**B**	73.7	6.0	**AB**	3.00	0.06
Litter depth (cm)	2.6	0.3	**A**	2.8	0.4	**A**	2.6	0.2	**A**	1.8	0.2	**A**	1.61	0.22
Maximum shrub height[d] (m)	1.1	0.3	**A**	0.8	0.1	**A**	1.0	0.3	**A**	0.9	0.1	**A**	0.41	0.75
Maximum herb height[d] (m)	0.9	0.1	**A**	0.8	0.0	**AB**	0.7	0.1	**B**	0.8	0.1	**AB**	2.44	0.12
Visual obstruction (dm)	9.3	1.5	**A**	3.3	0.4	**B**	2.2	0.3	**B**	2.7	0.3	**B**	7.77	**≤ 0.001**
Canopy closure (%)	34.5	6.5	**A**	68.1	2.9	**B**	79.1	3.9	**B**	85.2	4.3	**B**	16.09	**≤ 0.001**
Maximum aspen regeneration height (m)	2.2	0.2	**A**	5.5	0.6	**B**	10.1	1.6	**C**	16.1	1.3	**D**	54.61	**≤ 0.001**
Maximum tree regeneration height (m)	2.1	0.2	**A**	4.4	0.3	**B**	7.8	1.6	**C**	12.1	1.0	**D**	36.96	**≤ 0.001**
Aspen sucker density (stems/m^2)	2.8	0.3	**A**	0.8	0.3	**B**	0.1	0.0	**C**	0.1	0.1	**C**	24.69	**≤ 0.001**
Tree seedling density (stems/m^2)	4.4	0.6	**A**	3.4	0.6	**A**	3.9	1.2	**A**	3.0	1.0	**A**	0.63	0.53
Dead woody stem density (stems/m^2)	1.4	0.3	**A**	0.5	0.2	**AB**	0.5	0.4	**AB**	0.1	0.1	**B**	3.52	**0.04**
Shrub density[e] (stems/m^2)	11.2	3.9	.	.	.	.	.	.	.	.	.	.	.	.

[a] I surveyed 5 stands in 1999 and sampled vegetation at 6 random points in each stand. I surveyed 4 stands in 2000 and sampled vegetation at 10 random points in each stand.
[b] Number of stands in an age-class.
[c] Values denoted by a different letter for a given vegetation structure variable differed ($\alpha = 0.05$).
[d] Measured in 2000 only, df = 3, 12.
[e] Measured in 1999 only.

Appendix IX. Density of territorial male Golden-winged Warblers (*Vermivora chrysoptera*) in 4 age-classes of aspen (*Populus* spp.) stands located in Oneida and Lincoln Counties, Wisconsin, May-July 1999, May-June 2000, and associated mean vegetation structure variables within territories[a], 11 June - 09 July 1999, 22 June - 15 July 2000.

	Stand age, years (n^b)													
	1-4 (9[c])			6-10 (1)			10-19 (3)			20-25 (2)			$F_{3,11}$	P^d
Vegetation structure variables	**mean**	**SE**		**mean**	**SE**		**mean**	**SE**		**mean**	**SE**			
Male density[e] (males/ha)	0.49	0.11	**A**	0.01	0.01	**B**	0.07	0.04	**B**	0.04	0.03	**B**	9.21	**≤0.001**
Litter cover (%)	95.9	1.2	**A**	99.8	.	**A**	97.5	2.5	**A**	93.9	1.8	**A**	0.77	0.54
Ground cover (%)	85.3	217	**A**	42.5	.	**B**	77.0	5.8	**A**	80.8	10.4	**A**	8.44	**0.003**
Litter depth (cm)	3.0	0.8	**A**	2.6	.	**A**	2.3	0.5	**A**	1.8	0.4	**A**	0.24	0.86
Maximum shrub height[f] (m)	0.9	0.1	**AB**	0.3	.	**A**	1.0	0.2	**B**	0.7	0.1	**AB**	2.46	0.16
Maximum herb height[f] (m)	0.9	0.0	**A**	0.8	.	**AB**	0.7	0.0	**B**	0.8	0.0	**A**	14.46	**0.004**
Visual obstruction (dm)	10.0	1.0	**A**	3.7	.	**B**	7.7	2.2	**AB**	4.6	0.3	**B**	4.13	**0.03**
Canopy closure (%)	39.6	4.0	**A**	67.0	.	**A**	52.6	8.6	**A**	51.6	26.5	**A**	1.21	0.35
Maximum aspen regeneration	2.6	0.3	**A**	3.5	.	**A**	13.5	5.1	**B**	11.8	1.2	**B**	17.31	**≤0.001**
Maximum tree regeneration	3.2	0.7	**A**	4.4	.	**AB**	4.4	2.0	**AB**	9.9	1.1	**B**	2.04	0.17
Aspen sucker density (stems/m^2)	5.8	0.9	**A**	1.5	.	**AB**	0.0	NA	**B**	0.7	0.6	**B**	7.12	**0.01**
Tree seedling density (stems/m^2)	6.1	0.7	**A**	2.8	.	**AB**	2.2	0.4	**B**	2.1	0.4	**B**	6.29	**0.01**
Dead woody stem density	1.7	0.6	**A**	0.8	.	**A**	0.2	0.1	**A**	0.2	0.2	**A**	1.10	0.39

[a] I sampled vegetation at 2 random points in each territory in 1999 and at 4 random points in each territory in 2000.
[b] Number of stands occupied by territorial male golden-winged warblers in an age-class. I mapped 12 territories in Age-class 1, 1 territory in Age-class 2, 5 territories in Age-class 3, and 6 territories in Age-class 4.
[c] I surveyed 5 stands in 1999 and 4 stands in 2000.
[d] Values denoted by a different letter for a given variable differed ($\alpha = 0.05$).
[e] Golden-winged warbler surveys were conducted at 9 stands in Age-class 1 and at 4 stands each in Age-classes 2-4. I combined data from 1999 and 2000 given male density was the same in both years (P=0.25).
[f] Measured in 2000 only, df = 3, 6.

APPROVED R. Scott Lutz

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