

**FALL MIGRATION CHRONOLOGY AND HABITAT USE OF THE AMERICAN  
WOODCOCK IN THE WESTERN GREAT LAKES REGION**

By

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## *Chapter I*

### **INTRODUCTION TO FALL MIGRATION CHRONOLOGY AND HABITAT USE OF THE AMERICAN WOODCOCK IN THE WESTERN GREAT LAKES REGION**

#### *Introduction*

Since 1968, the U.S. Fish and Wildlife Service (FWS) has documented a decline of American woodcock (*Scolopax minor*) populations. In an attempt to reverse these persistent declines, the FWS adjusted woodcock hunting season dates or reduced bag limits in both the Eastern (1985 and 1998) and Central (1998) management regions (Woehr 1999). Continued declines, despite harvest management, have impelled research efforts to address woodcock population dynamics.

McAuley et al. (1999) began to address potential impacts of harvest on woodcock population dynamics in the Eastern management region. In recognition of the need for similar data in the Central management region, my research group initiated a western Great Lakes telemetry project in Michigan, Minnesota, and Wisconsin. We began in 2002, with each state taking the lead in data collection and analyses for particular aspects of the research. Aside from addressing harvest and other impacts on survival of woodcock, we collected data on local movements, habitat use, and migration chronology. Following a pilot study year in Minnesota in 2001, we conducted our research during the fall periods from 2002 to 2004

My thesis describes data we collected on habitat use and migration chronology of woodcock in the western Great Lakes Region. I hope this work will assist in defining management practices that might help alleviate woodcock declines.

### ***The American Woodcock***

The American woodcock (*Scolopax minor*) is a migratory game bird found throughout the eastern United States and southeastern Canada. Woodcock belong to the shorebird family (*Scolopacidae*) but are unique among members of the family in their preference for forested habitats. Woodcock feed mainly on earthworms (*Lumbricidae*), and their long pliable bill, short legs, and eyes set far back on their head for visibility while feeding are adaptations for their unique diet and ground dwelling existence.

There has been a growing concern over long-term population declines of woodcock throughout their range, which the USFWS separates into two management units -- the Central and Eastern Flyways. Spring Singing-ground Surveys are the principal means of monitoring year-to-year changes in the number of courting males and serve as an index to woodcock populations. The number of males heard on the Singing-ground Surveys declined an average of 2.1% and 1.8% per year in the Eastern and Central Management regions, respectively from 1968 to 2004 (Kelley 2004).

### ***Habitat Use***

Woodcock tend to use different nocturnal and diurnal habitats on a daily basis (Parris 1986). Nocturnal habitats are generally simple in vegetative structure and include old fields, pastures, and recently disturbed areas. These habitats are used principally for courtship and roosting activities (Straw et al. 1994, Wishart and Bider 1976). Diurnal habitats are usually early successional forests and shrub stands with high vertical stem densities. Examples of diurnal habitats include young aspen (*Populus* spp.) and alder (*Alnus* spp.) stands, dogwood

(*Cornus* spp.), and hazelnut (*Corylus* spp.) thickets (Bennett et al. 1982, Sepik and Dwyer 1982).

### Habitat

The area of aspen in Michigan, Minnesota, and Wisconsin has decreased by 21% since the mid-1960's (1960s and 1970s: Stone 1966, Chase et al. 1970, and Spencer and Thorne 1972; 1990s: Miles et al. 1995 and Leatherberry and Spencer 1996; 1980s: Spencer et al. 1988). Many have cited this reduction in aspen forest acreage as the driving force for declining woodcock populations. However, attempts to correlate trends in changing forestlands and woodcock populations have shown few significant relationships (Woehr 1999, Dessecker and Pursglove 2000), with the exception of a negative correlation with urban/industrial land use (Dwyer et al. 1983). Nevertheless, this lack of significant associations has not curbed the perception that habitat change is the major cause of woodcock population declines across the primary breeding range (Owen et al. 1977, Straw et al 1994, Woehr 1999, Dessecker and Pursglove 2000, Kelley 2004).

The question of what constitutes quality woodcock habitat is central to the question of potential habitat use. This, however, has proven difficult to answer despite years of collective research on woodcock habitat use. Wishart and Bider (1976) ranked woodcock habitat as good or poor based on signs of use by woodcock and reported greater use of habitat in cover types with greater open soil surface. They found no significant differences in use of diurnal habitat based on soil characteristics (pH, texture, and drainage), earthworm abundance, overstory coverage, or age of stands.

Another study (Liscinsky 1972) ranked cover type first, soil drainage second, and food supply third in order of importance to woodcock. Sepik and Derleth (1993) determined that size class and overstory type might be good indicators of the quality of woodcock habitat. They identified alder and balsam fir (*Abies balsamea*) as low-value covers and sapling aspen as a high-value cover in their assessment. However, only 8% of woodcock locations were within “high-quality,” sapling-sized aspen (Sepik and Derleth 1993). These somewhat contradictory findings suggest a need to reexamine what constitutes “quality” woodcock habitat.

Past research has revealed that woodcock may exhibit a distinct seasonal change in habitat preference. Wishart and Bider (1976) documented seasonal shifts, including a shift in autumn away from mixed and deciduous woods and an increase in use of alder despite no significant changes in habitat conditions or earthworm abundance. Mendall and Aldous (1943) reported similar findings.

Past work on woodcock has documented changes in habitat use with environmental changes, particularly with drought. Gregg (1984) reported greater use of alder during a drought year (1976) in Wisconsin. Also during a drought year, Sepik et al. (1983) found a significant decrease in earthworm biomass under alders but not under conifers. They also found that during droughts woodcock used conifer and mixed conifer-hardwood stands almost exclusively, in contrast with normal conditions when conifers are typically not an important cover type for woodcock. Abnormal environmental conditions — and perhaps even normal seasonal changes in environmental conditions — may complicate our understanding of quality woodcock habitat.

### Importance of Earthworm Abundance in Habitat Selection by Woodcock

Another factor investigated as a correlate of quality woodcock habitat is the abundance of their main prey item — earthworms. Evidence for the selection of diurnal habitat by woodcock in response to earthworm densities is contradictory (Parris 1986). Some research has shown direct and significant relationships between earthworm abundance and the intensity by which woodcock use different cover types (Hudgins et al. 1985, Parris 1986, Reynolds et al. 1977). However, other studies have found no differences in numbers or biomass of earthworms between heavily used woodcock covers and those used less frequently (Liscinsky 1972, Wishart and Bider 1976, Gregg 1984).

Removing woodcock from the equation and focusing on earthworm abundance in relation to environmental variables still yields conflicting information. Parris (1986) found that worm abundance was associated with type of overstory cover, and he found limited or no association between soil characteristics such as moisture, temperature, and pH. In contrast, Owen and Galbraith (1989) reported a strong relationship between earthworm biomass and the soil environment, with pH being the strongest predictor measured.

We know that many factors affect earthworm abundance (e.g., vegetation, soil moisture, and soil temperature; Reynolds and Jordan 1975) and there are likely thresholds and optimum levels for each. Therefore, we should not be surprised that woodcock, in relation to worms alone, would demonstrate dynamic habitat affinities over time. As managers, we should not attempt to oversimplify their habitat needs. Imprecise or incomplete delineation of potential woodcock habitat may mask relationships between habitat and woodcock population trends (Dessecker and Pursglove 2000).

### Objectives of Habitat Investigation

The objectives of my habitat investigation were to ascertain woodcock diurnal habitat affinities with relation to cover types, edges, earthworm abundance, and soil types. I also sought to determine the appropriate scales at which to measure these relationships. I chose to focus my investigation on both the micro-habitat and home range scales. At the micro-habitat scale, I compared woodcock use points to randomly located points within the same stand and in close proximity (within approximately 25 m). At the home range scale, I made comparisons across cover types (between 35 and 200 m from use points) and at a scale that captures the majority of after hatch year (AHY) female movements (Doherty et al. In press). By determining what habitat components woodcock favor, and at what scales, we may subsequently understand which habitat components are most limiting to woodcock.

### ***Migration Chronology***

Woodcock, like all migratory, temperate-zone birds, follow annual cycles of reproduction and migration. The timing of which is controlled by proximate and ultimate factors. Ultimate factors are evolutionary and proximate factors are cues. External factors serve to synchronize the annual cycle with the seasons (notably day length), modify the timing of annual cycles (e.g. temperature and rainfall), and in regard to migration, to inhibit or stimulate the overt act of migration (e.g. wind direction) breaking it up into intermittent series of actual flights (Marshall 1960, Nisbet and Drury 1968). The difference between classes of external factors is the proximity of their effects. Factors such as photoperiod, which have effects that act over long periods and are predictable from year to year, may affect the physiological state of readiness for migration. On the other hand, factors like

adverse weather may have more immediate effects on whether woodcock migrate. In subsequent reporting, I will focus on proximate factors that affect migration behavior with both long and short-term effects of on woodcock departure.

### Demographics of Woodcock Migration

Woodcock migrate in fall from a broad northern breeding range into southern Atlantic coastal and Gulf states (Keppie and Whiting 1994). Birds from the northeastern states and provinces (eastern flyway) migrate into the southern Atlantic states, while birds west of the Appalachian Mountains migrate into the Gulf States — little crossover occurs between the flyways (Coon et al. 1977). Departure from breeding areas begins in late September and continues into mid-December. Peak periods of migration vary among years and locations but are likely related to local environmental conditions.

Woodcock migrate after sunset (Coon et al. 1976) at low altitudes. They tend to embark on migration either individually or in small, loose flocks (Sheldon 1967, Keppie and Whiting 1994). Woodcock departure from the breeding grounds in fall is more irregular and spread out than departure from their southern wintering grounds in spring (Keppie and Whiting 1994) and may take many weeks to complete, earning woodcock status as a “hop migrator”.

In shorebirds, females usually migrate before males and adults leave before young (Gauthreaux 1982). Several authors have examined demographic differences in timing of migration for woodcock, although the results are not entirely congruous. Gregg (1984) found that fall departures appeared related to age class, with immature woodcock leaving ahead of adults. Sepik and Derleth (1993) found no difference in timing of fall departure by age or

sex class. Krementz et al. (1994) also found no difference in timing of migration by sex or age for spring migration.

### Moon Phase

Less well documented is the relative importance of factors that may determine timing of departure, though there has been wide speculation. Moon phase is one possible factor. Coon et al. (1976) found that fall woodcock departures took place within an 11-day period preceding a full moon. Krementz et al. (1994) reported similar results for migrating woodcock departing the southern wintering grounds in spring. However, neither of these studies did more than to note that woodcock departed around a full moon.

### Weather Factors

Weather systems in fall that are especially important to woodcock migration include the passage of cold fronts. Godfrey (1974) found that woodcock in Minnesota appeared to respond to passages of weather fronts and wind shifts during fall migration, and Krohn (1973) reported massive flights of woodcock at Cape May Peninsula in New Jersey following early snow and northwest winds.

In the northern hemisphere, winds blow counterclockwise around areas of low pressure (a low to the east and/or a high to the west), thus northerly winds, along with temperature, humidity, and barometric pressure, tend to vary in predictable ways as a function of pressure systems (Bagg et al. 1950). The synoptic weather conditions of fronts are the conditions when peak numbers of birds tend to migrate (Richardson 1990a).

In Pennsylvania, Coon et al. (1976) found a majority of their radiomarked woodcock departed when winds were out of the northwest, with rising barometric pressure, and with pressure centers approaching highs from the north and west or retreating lows to the north and east or both. These conditions are synoptic of weather front passages and appear to illicit migration. At Cape May, Krohn et al. (1977) observed large influxes of woodcock during nights with strong northwest winds after cold fronts.

However, the relative importance of weather variables associated with fronts are not agreed upon. Robbins (1949) found temperature, tailwinds, and pressure to be the more important variables in bird migration. Richardson (1966) reported rising humidity and lack of rain, along with tailwinds and temperature, to be the most important variables. Work by Nisbet and Drury (1968) indicated that correlations with tailwind were spurious. They also introduced the important distinction that Richardson's data (1966) were based on arrivals of grounded migrants or arrested waves of migration — hence results among studies may not be comparable. This is also true for data on migration density and investigations of departure volumes. A closer look at the importance of different atmospheric and weather variables on the onset of migration is necessary.

### Influence of Prey Availability

Food availability may be another important factor determining the timing of migration for woodcock. Recognizing that temperate region birds store fat immediately prior to migration, Owen and Krohn (1973) reported data on fat deposition and weight gain that indicated woodcock in Maine were not physiologically prepared to migrate until mid-October. Wishart (1977) found that the major migration from study areas in Quebec

occurred between 9 and 31 October and speculated the timing was due to snow and freezing temperatures, conditions that reduced food availability during this period.

Earthworms respond to suboptimal surface conditions by migrating deeper into the soil or entering a state of aestivation, or inactivity (Edwards and Lofty 1977, Reynolds and Jordan 1975), thereby becoming unavailable to woodcock (Rabe et al 1983). In general, earthworm biomass correlates negatively with temperature and positively with moisture, though a medium range of both parameters is optimal (Reynolds et al. 1977). Krementz et al. (1994) hypothesized that spring migration from Atlantic coastal wintering grounds would vary less in colder years due to more uncertainty in food availability in the north, but they found no significant relationships between departure dates and temperature.

Using air temperature as an index of worm availability is problematic because air temperature may not be the best predictor of soil temperature. Soil temperatures not only exhibit a lag response to changes in air temperature, but can also vary widely with moisture level, topography, vegetative cover, and other microclimate factors (Rabe et al. 1983). These factors may mask relationships involving soil conditions and ultimately earthworm availability for woodcock.

Earthworms respond to extremes of environmental conditions (soil temperature and moisture) and become less available to woodcock (Rabe et al. 1983, Owen and Galbraith 1989). This could affect woodcock migration chronology in several ways. Following Owen and Krohn's (1973) model, woodcock may wait until earthworms are most plentiful in mid-fall to take advantage of maximum potential energy supplies before departing. Another possibility, which seems to be most widely accepted, is that decreasing food supply forces their departure in late fall.

### Objectives-Migration Chronology

My overlying objective is to gain an understanding of woodcock migration chronology by examining relationships between external factors and departures of woodcock in fall. I considered demographic differences in departure of woodcock and looked at the effects of external factors.

### *Study Areas*

My research was part of a larger study of woodcock ecology in the western Great Lakes region and included paired study sites in Minnesota, Michigan, and Wisconsin (Figure 1.2). In each state, we selected one heavily hunted study site and a non-hunted or low-pressure site. We selected study sites in large blocks of industrial private and public owned forests with high woodcock densities. Study sites among the three states were of comparable forests types and latitudes.

### Michigan

Study sites in Michigan were within the Copper Country State Forest in northern Dickinson County in the Upper Peninsula of Michigan. We concentrated fieldwork primarily in the eastern half of the 25,728-ha Dickinson Woodcock Research Unit. Deciduous species common within the Michigan study sites included aspen, red maple (*Acer rubrum*), and paper birch (*Betula papyrifera*). Dominant species in coniferous forests included balsam fir (*Abies balsamea*) and black spruce (*Picea mariana*). We also encountered alder in wet lowlands.

## Minnesota

Our Minnesota study sites were located within the southern portion of the 15,672-ha Mille Lacs Wildlife Management Area and the adjacent 1,166-ha Four Brooks Wildlife Management Area. These areas are in east-central Minnesota in Mille Lacs County and have similar vegetative communities and management. Management focused primarily on providing hunting opportunities to the public through habitat manipulation for game species. Vegetative communities included aspen on disturbed sites, mixed hardwoods with a fair representation of oak (*Quercus* spp.) on drier sites, maple (*Acer* spp.) in more mesic sites, and alder and willow (*Salix* spp.) in lowland habitats.

## Wisconsin

Wisconsin study sites were within the Lincoln County Forest and Tomahawk Timberlands industrial forest. Both study areas are in Lincoln County in north-central Wisconsin and are managed primarily for timber and recreational opportunities. Terrain in both areas is rolling with boggy wet basins. Forest cover is mostly northern mesic type. Sugar maple (*Acer saccharum*) dominated the better-drained soils while red maple (*Acer rubrum*) dominated the more mesic sites. The wet basins were dominated by spruce-fir (*Picea-Abies*) on wet, mineral soils and spruce-tamarack (*Picea-Larix*) bogs on wet, organic soils.

## *Climate*

Differing climatic conditions can affect organisms in a variety of ways, both directly and indirectly, and any ecological study must consider general climate. This is especially

true when considering habitat use and migration chronology of woodcock. Climate extremes are familiar to woodcock and often result in mortality (Mendall and Aldous 1943, Sheldon 1967). Sepik et al. (1983) and Gregg (1984) reported low body mass, with reduced availability of earthworms, and changes in habitat use of woodcock during drought conditions. We observed disparate weather among years worth noting, although no anomalous extremes occurred during our study (Appendix I).

We conducted our research over 3 fall field seasons from 2002 to 2004. Annual precipitation was highest in 2002 for all 3 states and was above normal by 5.46 inches in Michigan, 9.71 inches in Minnesota, and 7.01 inches in Wisconsin. In contrast, 2003 was a drought year across all 3 states and precipitation was below normal by 1.35, 5.30, and 5.27 inches in Michigan, Minnesota, and Wisconsin, respectively. Precipitation in 2004 was normal (close to long-term averages).

A temperature anomaly occurred during the primary portion of woodcock migration in October 2002. The mean October and November temperatures were lower than in the following 2 years, and on 21-22 October 2002, all three-study areas received 7-8 inches of snow (appendix I).

Our 2004 field season was marked by higher than normal mean temperatures from September to November, although August 2004 was unusually cold with lows near freezing. Fall 2004 was generally mild with relatively few days having minimum temperatures  $\leq 32^{\circ}$  F and with very little snowfall (Appendix I). Temperatures in 2003 fell somewhere between those in 2002 and 2004 and were closer to long term averages.

### *Overview*

My thesis describes research conducted during the fall periods (approximately August 15 – November 10) from 2002 to 2004 in study areas in Michigan, Minnesota, and Wisconsin. Study areas were of similar latitude and vegetational composition for comparisons across states. I discuss migration chronology in chapter 2 of my thesis, followed by a discussion of woodcock habitat use in chapter 3. My final chapter will provide further discussion on both migration chronology and habitat use with an emphasis on the management implications of my work.

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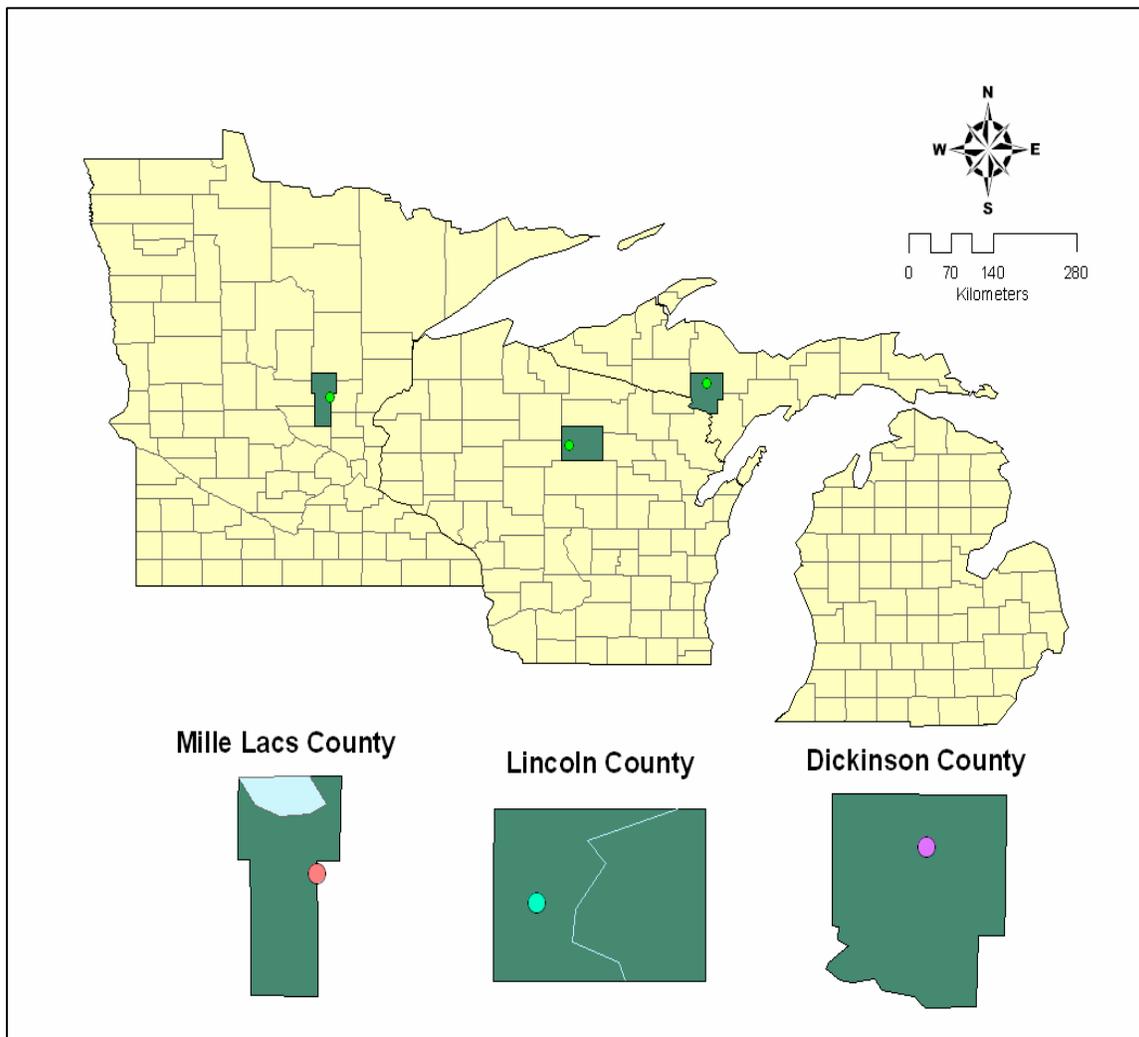
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**Figure 1.1. American woodcock study site locations in Michigan, Minnesota, and Wisconsin – the western Great Lakes Region.**



## *Chapter II*

### **FALL MIGRATION CHRONOLOGY OF THE AMERICAN WOODCOCK IN THE WESTERN GREAT LAKES REGION**

#### *Introduction*

American woodcock (*Scolopax minor*) are a migratory game bird found throughout the eastern United States and southern Canada. They migrate from a broad area comprising their breeding range to wintering grounds on the Southern Atlantic Coast and Gulf States (Figure 2.1). Woodcock are managed on the basis of two relatively distinct populations (Eastern and Central) separated roughly by the Appalachian Mountains (Coon et al. 1977). My research focused on woodcock migrating in fall from the primary breeding range of the Central Flyway in the Western Great Lakes Region.

Many researchers have speculated, based largely on anecdotal evidence, about the relative importance of factors that influence the timing of woodcock migration in fall. Excluding investigations into sex and age differences, little or no testing has been done with woodcock migration data to determine factors that influence departures in spring or fall. Fall flights of woodcock are more irregular and reportedly more dependent on weather conditions than in spring (Mendall and Aldous 1943, Keppie and Whiting 1994). Sheldon (1967) reported observations and records for thirteen years from central Massachusetts that indicated spring migration is more predictable, regardless of weather conditions. Sheldon (1967) also noted the apparently paradoxical behavior of woodcock arriving in spring when the breeding grounds are often covered in snow, while snow prompts them to depart in fall. Krementz et

al. (1994) found no significant relationships between the timing of spring migration from Atlantic coastal sites and temperatures but noted that woodcock departed around a full moon.

To gain understanding of woodcock migration chronology, I investigated the relative importance of external factors to fall departure of woodcock. My first objective was to consider differences in departure by sex, age, location, and year. Secondly, I investigated the effects of time-dependent environmental variables (external factors) on timing of departure.

Time-dependant factors may function in a variety of ways to influence the migratory restlessness or *Zugunruhe* (Rappole and Warner 1976) of woodcock. Nisbet and Drury (1968) described how external factors, such as day length, may serve to synchronize annual cycles with seasons so that *Zugunruhe* develops around the same time each year. They added that other factors, such as rainfall and temperature, may modify the timing of annual cycles so *Zugunruhe* occurs early in some years and later in others. Local factors such as food availability, wind direction, and local weather may actually inhibit or stimulate the act of migration, breaking it into intermittent flights (Nisbet and Drury 1968). My aim was to determine the relative importance of 15 different environmental factors in their affects on the timing of woodcock migration in fall. I did this using a time-to-event analysis (survival analysis) with time dependent environmental covariates.

### *Study Areas*

My research was part of a larger study of woodcock ecology in the western Great Lakes Region and included study sites in Minnesota, Michigan, and Wisconsin (Figure 2.2).

We selected study sites in large blocks of industrial private and public owned forests with high woodcock densities. Study sites among the three states were of comparable forests types and similar latitudes.

### *Climate*

We conducted our field research from August through November from 2002 through 2004. For comparisons of climate among years I used National Oceanic and Atmospheric Administration (NOAA) data from the nearest NOAA weather station to respective study sites (<http://cdo.ncdc.noaa.gov/ancsum/ACS>). Stations were located  $\leq 30$  miles from each study site.

Among the three years, annual precipitation was highest in 2002 at all sites and was above long-term averages by 5.46 inches in Michigan, 9.71 inches in Minnesota, and 7.01 inches in Wisconsin. In contrast, 2003 was a drought year and precipitation was below normal at all sites (MI: -1.35; MN: -5.30; WI: -5.27). Precipitation in 2004 fell within long-term averages.

During my fall data-collection period, 2002 represented somewhat of a temperature anomaly, especially in October when major woodcock migration occurs. Mean October and November temperatures were lower in 2002 than the following years, and on October 21-22 all three states received 7-8 inches of snow (Appendix I). Our 2004 field season was marked by higher than normal mean temperatures from September to November; however, mid-August was unusually cold with lows near freezing. Fall 2004 was generally mild with relatively few days with minimum temperatures  $\leq 32^{\circ}$  F and very little snow in late fall

(Appendix I). Temperature conditions in 2003 fell somewhere between those in 2002 and 2004 and were closer to long-term averages.

## *Methods*

### Capture

We captured resident woodcock in Minnesota, Michigan, and Wisconsin beginning in mid-August until the end of September from 2002 to 2004. We terminated our capture efforts on September 30 each year to reduce the possibility of capturing non-resident migrating woodcock (Mendall and Aldous 1943, Gregg 1984). Capture techniques included spotlighting (Rieffenberger and Kletzly 1967) and intercepting woodcock flights to roost fields at dusk with the use of mist nets (Sheldon 1960, McAuley et al. 1993). We used the outer three primary feathers, secondary feathers, and bill length to age and sex woodcock (Mendall and Aldous 1943, Greely 1953, Martin 1964). We classified ages as HY (fledged young of the year) or AHY (all older birds). We weighed woodcock and attached a 4.4 gram radio transmitter to birds >140 g using single loop wire harness and livestock-tag cement (McAuley et al. 1993). Following transmitter attachment, we released woodcock at locations where captured.

### Radio Telemetry

We searched  $\geq 5$  times/week for radiomarked woodcock using handheld yagi and/or rubberized H-antennas and portable receivers. We continued our relocation of radiomarked woodcock until mortality, migration, or completion of field work each fall. We searched for

missing signals on the ground (All Terrain Vehicle, vehicle, and on foot) as well as from the air following the methods of Gilmar et al. (1981). When we could not detect a woodcock on three consecutive aerial telemetry flights within a 30-km radius, we classified the individual as “having emigrated from the study area” and did not search for the individual on subsequent flights. We did, however, continually search for all missing signals on the ground for the duration of our field work.

Aside from daily telemetry, we also randomly selected a subset of AHY female woodcock in each year (2002:  $n = 32$ ; 2003:  $n = 48$ ; 2004:  $n = 46$ ) to relocate  $\geq 5$  times/week and collect earthworm abundance samples. We collected earthworms from locations approximately 10 m from actual woodcock locations in an effort to minimize disturbance to our sub-sample woodcock.

### Predictor Variables

I obtained daily non-weather data such as day length (DL; the period between sunrise and sunset in minutes), proportion of moon surface illuminated at midnight each night (MOON), and whether the moon was waxing or waning (WW) from the U.S. Naval Observatory’s Astronomical Applications Department (Table 2.1; <http://aa.usno.navy.mil/data/docs>). We also sampled earthworms at our sub-sample AHY female woodcock locations inside a 35-cm<sup>2</sup> area using an oriental hot mustard solution extraction technique (Lawrence and Bowers 2002). To compare worm samples across a large geographic area (Hale et al. 2004) we calculated ash-free dry mass for each earthworm sample to the nearest 0.0001 g. I used a daily average of worm biomass (WMS) as an index to food availability and a predictor variable for timing of migration.

I obtained weather data from NOAA (<http://cdo.ncdc.noaa.gov>) databases (Table 2.1) including average daily temperature (TA); number of heating degree days (HDD), a relative value which is the departure of the average of the maximum and minimum temperature from 65° F; average barometric pressure/day (BP); relative humidity at sunset (RH); average horizontal visibility from sunset to midnight in miles (VIS); resultant wind speed in miles/hour (RWND); and resultant wind direction (RDIR). I divided resultant wind into three categorical wind directions (east: 30–140°, south: 150– 260°, and northwest: 270–20°) based on prevailing wind directions at each study site (Figure 2.3). We recorded daily precipitation at our respective study sites (PREC) in inches. I also included several weather differentials as predictor variables, namely the direction of change (“+” trend is increasing pressure, “-“ is decreasing pressure) in average barometric pressure from the previous day (BPC), the change in average relative humidity from the previous day (RHC), and the barometric pressure trend (BPT; the maximum – minimum barometric pressure value) within a day.

### *Statistical Analysis*

I divided my analysis of woodcock departures into two main objectives. My first objective was to analyze the data for differences in the timing of migration by location (MI, MN, and WI), year (2002-2004), sex (male or female), or age (HY and AHY). I used results from my demographic analysis to organize further analysis for objectives related to the study of environmental variable effects on timing of departure.

### Departure Data

I included woodcock that emigrated from the study sites in migration analyses and did not include birds that died during the course of our study. I also excluded woodcock that were missing and unable to be relocated prior to September 15 (<4 weeks from the beginning of our capture efforts and field season,  $n = 16$ ). I suspected equipment failure in a number of these cases and/or pre-migratory dispersal movements, but I had little evidence to suggest early migratory departures. Since I was interested in the effects of covariates on woodcock departures, and not in the length of time a woodcock was present on the study areas, I used 15 September (Julian date 258) as starting points for all woodcock entering into the study in each year rather than to stagger their entry.

For analysis of time-dependent environmental variables, I separated the birds that departed our study areas into 2 event categories: departure and censored observations. When I did not know the exact date of departure for a radiomarked woodcock I calculated a median date between the date last observed and the date first confirmed gone (departure interval). I included individuals with a departure interval  $\leq 3$  days, using the median for departure date, when analyzing environmental data. An example of the maximum interval (3 days) I included in the departure data is a woodcock that was present on the study areas on Friday, not tracked over the weekend, and gone Monday. Median dates fell between days for woodcock with a 3-day departure interval so I rounded up if the Julian date was odd, the digit before 0.5, and rounded down if the date was even. I censored all individuals with a departure interval  $>3$  on the date last observed.

For demographic data analysis without time-dependent environmental variables, I used the median dates of departure for all individuals without an exact departure date

regardless of departure intervals. I did not round median dates of departure in my analysis of demographic data. I used a perpetual Julian date calendar system, which numbers each day in the year from 1 to 365, to record departure and censor dates of woodcock. Under a normal Julian calendar system our 2004 field season was a Julian leap year which means there were 29 rather than 28 days in February 2004. Our research took place after February and for our purposes we adjusted the Julian date to a perpetual system by subtracting 1 from the 2004 Julian date so, for example, in each year September 15 was always Julian day 258.

### Demographic Data

I used a four way analysis of variance (ANOVA) to test for main effects and interaction effects of location (state), year, sex, and age on the timing of woodcock departures using SAS (SAS Institute Inc. 1999). My response variable was the departure date (Julian), or median date of departure, for each individual.

### Survival Analysis of Time-dependent Environmental Variables

I used a survival-based analysis with time-dependent covariates to investigate the effects of environmental variables (covariates) on woodcock departures. Survival analysis is used predominately in biomedical sciences often with the event of interest in observing time to death either of patients or of laboratory animals. In social sciences, survival analysis has been used to estimate the “survival” of events such as jobs, marriage, and birth of children, and in engineering sciences the event of interest is often time to failure of engineered parts. In this case the event I am interested in is departure and the analysis I used looked at time to departure.

The use of survival analysis to investigate migration has several advantages. First, I was able to investigate the effects of seasonal variables that change over time on woodcock departure. Time-dependent covariates allow the hazard function (the instantaneous rate of departure for individuals that have not yet departed) at a particular time to depend on most recent measurement of explanatory variables. Another advantage is the ability to include into the study, with censoring, individuals that never reach the event of interest. Censoring allows individuals that are observed for variable lengths of time but do not experience the event (or endpoint) of interest to remain in the study. Censoring allows the calculation of probability functions without attributing event times, in our case departure dates to individuals without a known exact date of departure (censored observations). I provide an overview of survival analysis, but others present more detailed accounts of survival methods (Lee 1992, Hosmer and Lemeshow 1999).

In survival analysis, a binary variable,  $\delta$ , is used to denote whether an individual's departure time was observed ( $\delta = 1$ ) or not (censored observations;  $\delta = 0$ ). In addition to censoring, the feature that best distinguishes event-time analysis from other methods is its use of the hazard ( $h(t)$ ), survivorship ( $S(t)$ ), and probability density ( $f(t)$ ) functions to describe survival distributions. These three functions have mathematically equivalent relationships and given any one of them the others can be derived:

$h(t) = f(t)/S(t)$ , "Instantaneous" conditional rate of failure (proportional to probability and conditional on surviving up to time  $t$ );

$S(t) = P(T > t)$ , probability that an individual survives longer than  $t$ ;

$f(t) = d/dt F(t)$ , probability of failure in a small unit of time.

There are 2 main modeling approaches for estimating and comparing survival distributions: parametric and non-parametric. Parametric approaches assume the data possess a known mathematical form with defined parameters and include such distributions as exponential and Weibull. Non-parametric approaches either make no underlying assumptions of distributions, or some mathematical forms are left unspecified (semi-parametric). Commonly used non-parametric models include the Cox proportional hazards model and Kaplan-Meier product limit estimator (Hosmer and Lemeshow 1999).

I used a parametric survival approach with an exponential distribution to explore the association of time-dependent covariates and timing of departure. Parametric models with exponential distribution follow the form:

$$f(t) = \lambda \exp(-\lambda t), \quad S(t) = \exp(-\lambda t), \quad h(t) = \lambda.$$

Here, the exponential regression model assumes that the survival time distribution is exponential and contingent on the values of a set of independent variables ( $z_i$ ). The rate parameter of the exponential distribution can then be expressed as:

$$S(z) = \exp(a + b_1 * z_1 + b_2 * z_2 + \dots + b_m * z_m)$$

$S(z)$  denotes the survival times,  $a$  is a constant, and the  $b_i$ 's are the regression parameters. The Chi-square goodness-of-fit value is computed as a function of the log-likelihood for the model with all parameter estimates ( $L_1$ ), and the log-likelihood of the

model in which all covariates are forced to zero ( $L_0$ ). If this Chi-square value is significant, we reject the null hypothesis and assume that the independent variables are significantly related to survival times.

The model I used is an exponential regression model with time-dependent covariates in MATLAB (MathWorks 2001) with the form:

$$P_z(\text{Dep}_t | z) = e^{-(\alpha + b'z(t))},$$

where the probability ( $P$ ) of Departure (Dep) at time ( $t$ ) given covariates ( $Z$ ) equals the negative exponential ( $e$ ) of intercept ( $\alpha$ ) + estimated value of standard error ( $b'$ ) \* covariates ( $z$ ) at time ( $t$ ). To assess the fit of the models, I graphed the Nelson-Aalen estimators (Nelson 1969, 1972, Aalen 1978).

### Earthworm Analysis

Because there were many missing values, I excluded WMS (average worm biomass per day) from my analysis of time-dependent covariates. I instead used univariate analyses (MINITAB 1999) to examine the relationship between worm abundance and departure date using linear regression. I regressed the mean departure date against the mean worm abundance and the variance of worm abundance by state and year. I also regressed the variance of departure dates against the mean worm abundance for each state and year. I was interested in knowing if departures would be less dispersed (lower variance) with lower worm abundance under the assumption that worms were a limiting factor to woodcock remaining on the northern breeding grounds in fall. I performed the different regressions on

departure data for (1) only the AHY female woodcock that I used for worm-sample locations ( $n = 98$ ), and (2) for all woodcock ( $n = 759$ ). In both cases worm data were from 3,050 worm samples over the three states and years.

Lastly, I looked at the effects of worm abundance on departure date for individual woodcock using linear regression. My objective was to investigate if AHY females with higher worm abundance at foraging locations left earlier or later than those in sites with lower worm abundance. I analyzed females with  $\geq 11$  worm-sample locations ( $n = 86$ ); however most woodcock ( $n = 77$ ) had  $\geq 20$  samples.

## *Results*

### General Departure

From 2002 to 2004, 804 radiomarked woodcock emigrated from our study sites in MI, MN, and WI. I used departure information for 787 of those woodcock (Table 2.2) after eliminating 17 cases of equipment failures and/or pre-migratory dispersals. We also had a number of woodcock ( $n = 28$ ) still present on our study sites at the end of our field seasons for which we were unable to record departure dates. I included these 28 woodcock in survival analysis as censored observations on the date last observed; however I did not include them in demographic analysis. Of our total departures ( $n = 787$ ), 83 (10.5%) had a 3-day interval period and another 94 (12%) had 2-day intervals. We recorded exact departure dates for the remaining 610 (78%) woodcock.

The majority of our radiomarked woodcock departed our study sites in either October (52% of woodcock,  $n = 395$ ) or November (42%,  $n = 319$ ). The remaining birds departed in

September (4.9%,  $n = 37$ ) or surprisingly late in the month of December (1.1%,  $n = 8$ ; Figure 2.4). The mean date of migration for all years and states was 28 October (Julian date 301). The earliest departure date, 15 September (258), and the latest departure date, 27 December (361), were both recorded in Michigan 2004. All but one (MN 2002: 3 Nov) mean departure date for the three states and years fell in late October.

### Departure by Demographics

I found no difference in timing of departure by state, year, sex, or age ( $P > 0.10$ ; Table 2.3). I did however find an interaction effect between state and year ( $F = 10.63$ ,  $P < 0.001$ ) and a weak state and sex interaction effect ( $F = 2.57$ ,  $P = 0.077$ ). Woodcock departed at similar times in Michigan and Wisconsin in 2002 and 2003 and in Michigan and Minnesota in 2004 (Figure 2.5) with differences in departure between state-years in MN during 2002 and 2003 and WI in 2004.

It is more difficult to see any real differences in timing of departure by the interaction of state and sex (Figure 2.6). In all three years, females in Michigan departed earlier than males by approximately 4 days. However, we did not record a difference between sexes in Minnesota, and females in Wisconsin departed 2 days *later* than male woodcock. My analysis suggests that for investigation of environmental variable effects, it is appropriate to separate the data either by state and year or to pool data across years or states due to the lack of main effects by year and state alone. I found no need, however, to add sex or age of woodcock as covariates.

### Correlation of Environmental Factors

I found no strong correlations among weather variables with the exception of heating degree days (HDD) and average daily temperature (TA), which were negatively correlated in respective years-states (Pearson product-moment correlation from -0.7983 in MN 2004 to -0.9998 in MN 2002). The variable DL was also negatively correlated, though more variably among state-years, with HDD (-0.6946 in MN 2003 to -0.8807 in MN 2004) and to a lesser extent with TA (0.4787 in WI 2003 to 0.8570 in WI 2002). Due to the high correlations and little contribution in preliminary analysis, I excluded HDD from analysis of covariates.

### Survival Analysis of Environmental Factors

I could not analyze MN 2002 data independently from the other state-years due to the high number of censored observations relative to the number of predictors (48% as many predictors as cases). Analysis of Nelson-Alaen residuals indicated that a parametric model with an exponential distribution provided a good fit (Figure 2.7) and adequately described the data.

My analysis of time-dependent covariates indicated that several environmental factors may influence timing of departure (Table 2.4, Appendix II). The most significant variable across all arrangements (by state and year, pooled by year and state) was day length (Table 2.4). The estimated coefficient for DL is always negative and indicates that the probability of departure increases with decreasing DL (Appendix II). When I plotted cumulative departure against DL, I observed that in all state-years woodcock began to migrate around the same time, but departure rate after initial departures varied as the result of more proximate factors (Figure 2.8).

Moon phase was also a significant variable, especially with data pooled over years and/or states. The positive estimated coefficients for MOON suggest that woodcock are more likely to depart with a higher percent illumination of the moon's surface. I did not detect differences between departures on a waxing versus waning moon; however, it appears in either case that woodcock prefer to depart with a gibbous moon (illumination > 50%; Figure 2.9). Nearly half of all departures occurred with  $\geq 80\%$  illumination for both a waning (49%) and waxing (62%) moon.

Other significant factors in my models were barometric pressure (BP), horizontal visibility (VIS), and a northwest resultant wind direction (RDIRnw). Estimated coefficients for barometric pressure were largely positive and suggested greater likelihood of departure with higher barometric pressure. Barometric pressure trend (BPT), an index to pressure instability within a day, was also a significant variable in several models. The coefficients of BPT are less easily interpreted, but a higher number of positive estimated coefficients suggest that greater instability (higher values for max-min pressure within a day) usually resulted in greater probability of departure. Higher visibility and a northwest wind both resulted in a greater likelihood for departure in a number of my models ( $n = 6/15$ ) as well.

Other significant variables appeared in my models, but with greater variability and often with coefficients not easily interpreted. These results suggest that several variables have overriding importance among states and years — namely the importance of widespread factors like day length and moon phase — but that more proximate factors also serve to modify the timing of migration within years, albeit in less predictable ways.

### Effects of Earthworm Abundance on Timing of Departure

I found no relationship between earthworm abundance and the timing of woodcock departure by state and year (Table 2.5) or by individual ( $F = 2.10$ ,  $P = 0.152$ ). In respective analyses of mean worm abundance by state and year, the direction of slope was inconsistent between analyses of departures of AHY females alone and for all woodcock departures. This supports my earlier result of lack of effects of earthworm abundance on departure.

### *Discussion*

Most studies of bird migration have relied on counts of birds in the process of migration. Past researchers have used counts of grounded birds, counts of nocturnal migration against the moon or visible diurnal migration, or radar counts (Pyle et al. 1993). These techniques measure response to external factors of migrants and may miss important factors that initiate migration of resident birds. I was able to take a comprehensive look at factors affecting the timing of departure for resident woodcock using radio-telemetry and survival analysis a unique technique for analysis of migration chronology data.

My analysis supports research that reported woodcock migration was not sex or age specific in fall (Sepik et al. 1993). I conclude that higher proportions of adult female woodcock harvested in fall (Kelley 2005) were not likely a result of disparate timing of migration, which could theoretically place females at greater risk due to prolonged exposure to hunting on the breeding grounds or along their migratory route.

The difference among departure dates by state and year (Table 2.2) is not surprising considering the differing local climate conditions. In general, across all states and years,

2004 conditions (precipitation and temperature) were mild and relatively normal, and mean departure dates fell somewhere between those in 2002 and 2003. Michigan and Wisconsin demonstrated similar departure rates under similar conditions. Both states had earliest departure dates coinciding with colder conditions in 2002 and late departure dates with drought in 2003. Minnesota, however, had opposite relationships to drought in 2003 (with earlier departure) and cold in 2002 (with later departure). These differences were most visible in analysis of departure with state and year interactions considered (Table 2.2).

My analysis also suggests that despite varying local climate conditions woodcock initiate migration around the same time each year using photoperiod as a cue (Figure 2.8). Photoperiod appears to provide an initial proximate cue which serves to synchronize fall migration within the fall period. This was true regardless of local, seasonally varying factors. For example, woodcock initiated migration around the same time each year though corresponding average temperatures ranged from 45 °F (WI 2003) to 70 °F (MI 2004).

My results imply that the moon phase is important in modifying the timing of woodcock departures. Moon phase may act as a navigational aid for woodcock migration in different ways. Woodcock migrate at low elevations and likely use moonlight to avoid collision with obstacles while in route. Woodcock may also use the moon as tool for orientation and direction of their migratory route as has been found recently in skylark migration (James et al. 2000). A waxing moon is higher in the sky earlier in the evening and gets progressively later as the moon ages through its cycle. A waning moon is rising and setting much later than a waxing moon, and a waning non-gibbous (<50% full) moon would likely rise too late to be advantageous to woodcock flights. The majority of land-birds are nocturnal migrants, usually taking off within 1/2 to 1 hour after sunset with a gradual

reduction in the numbers aloft after midnight (Richardson 1998). Similar findings for the timing migration have been observed for woodcock (Coon et al. 1976), which indicates that departure likely coincides with a moonlit sky for navigational aid.

Several weather variables were also important in many of my models and indicate important modifying effects of weather. Barometric pressure, for example, is associated with synoptic weather fronts and changing climatic conditions. My results are consistent with other bird migration studies that found pronounced migration after the passage of a cold front, marked by low but increasing barometric pressure, clearing skies, and tailwinds (Bagg 1950, Pyle et al 1993, Richardson 1998). This effect was indicated by barometric pressure appearing repeatedly as a significant factor in my models. Furthermore, barometric pressure trend, a measure of pressure change within a day, and visibility were also significant variables in many models.

Northwest winds also often correspond to retreating low pressure systems (Richardson 1998) and showed significance in several models. However, I found that the prevailing winds during the fall period were northwest winds and in fact woodcock may have simply taken advantage of what winds were most available; consequently the results of wind analysis should be interpreted with some caution.

Perhaps my most surprising result was the lack of any clear relationship between woodcock departure and earthworm abundance. This finding contradicts two predominate theories: (1) that woodcock are forced to depart due to decreasing earthworm availability, and (2) that woodcock depart when sufficient fat reserves are obtained — presumably concurrent with greatest earthworm availability. One presumption of both theories is that woodcock are acting in the present based on a resource that has a direct response on energy

balance and fitness, an ultimate cue. However my analyses suggest that woodcock may initiate migration based primarily on seasonal cues like day length and with intermittent flights broken up by more local weather patterns favorable to actual flight (i.e., moon phase, NW wind direction, high visibility, etc.) – a much more conservative approach.

Another possibility is that woodcock are better at finding earthworms than we were using our sampling technique, and that earthworm availability poses no real obstacle to woodcock. We do know that the most heavily used cover types (seedling/sapling aspen, Chapter 3) in this study were also often the covers with the lowest earthworm abundance, another indication that woodcock were making choices independent of earthworm availability. Earthworm availability is not likely a limiting factor on the southern wintering grounds prior to spring migration, and I believe it plays minor importance in determining the timing of fall migration as well. In fact earthworms in the northern breeding grounds are a relatively new exotic species introduced by European settlement (Gates 1982). Earthworms would have been virtually absent from these areas following the last period of glaciations some 10,000-11,000 years ago. It would be difficult to imagine such new exotic species could drive an evolutionary behavior of woodcock (migration) in less than 150 years.

My interpretation of woodcock migration chronology is that photoperiod is an initial proximate factor of overriding importance based on evolutionary strategy. This helps explain why woodcock migration in spring seems less tied to weather than migration in fall (Mendall and Aldous 1943, Sheldon 1967, Keppie and Whiting 1994). Woodcock on the wintering grounds have few proximate cues to suggest what conditions will be like in the north; hence they are likely to migrate into snow covered northern breeding grounds based on photoperiod alone. On the other hand woodcock on the breeding grounds are apt to find

conditions more, not less, favorable as they migrate southward; hence proximate weather conditions in the north break migration into intermittent series of flights more closely tied to local weather conditions. Photoperiod likely serves to synchronize the *Zugunruhe* of woodcock in fall such that woodcock at northern latitudes initiate migration prior to woodcock at lower latitudes despite proximate weather in different locales within the breeding range. This also helps explain why fall migration is reportedly more irregular and longer than in spring (Keppie and Whiting 1994). Woodcock on wintering ranges occupy more similar latitudes and photoperiods than they do when they occupy the broad area of their breeding range.

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**Table 2.1. Time dependent environmental covariates used in survival (time-to-event) analysis of woodcock departure data.**

Covariate	Description
BP:	Average daily barometric pressure in inches of mercury
BPC:	Barometric pressure change (current day average – previous day average; 0 = falling pressure, 1 = rising pressure)
BPT:	Barometric pressure trend (maximum – minimum value in a day)
TA:	Average daily temperature (°F)
HDD:	Heating degree days (departure from 65 °F of [Maximum temperature + Minimum temperature/2])
RH:	Relative humidity at sunset (%)
RHT:	Relative humidity trend (current day average – previous day average)
PREC:	Precipitation (inches/day)
RWND:	Resultant wind speed on a given day (miles/hr)
RDIR:	Resultant wind direction (NW, S, or E)
MOON:	Percent surface illumination of the moon at midnight
WW:	Waxing or waning moon phase (1 = waxing, 0 = waning)
WMS:	Average ash-free dry weight of worm collected (to nearest 0.0001 g)
VIS:	Average horizontal visibility from sunset to midnight (statute miles)
DL:	Day length (min)

**Table 2.2. Number of radiomarked American woodcock that migrated from the Great Lakes breeding grounds by year, state, sex, and age (HY = fledged young of the year, AHY = all older birds).**

		Michigan			Minnesota			Wisconsin			Total
		2002	2003	2004	2002	2003	2004	2002	2003	2004	
AHY	F	29	15	28	28	30	24	14	18	21	207
AHY	M	24	8	16	15	22	35	19	16	4	159
HY	F	15	15	15	30	22	10	21	15	33	176
HY	M	24	22	27	20	20	27	35	23	46	244
Unknown	F						1				1
Total		92	60	86	93	94	97	89	72	104	787

**Table 2.3. ANOVA table of type III sums of squares testing for demographic relationship among state (Michigan, Minnesota, or Wisconsin), year, sex, age, and timing of fall migration for American woodcock ( $n = 759$ ) in the western Great Lakes Region, 2002-2004.**

Source	df	MSE	F Value	Pr > F
State	2	105.134669	0.56	0.5712
Year	2	426.214681	2.27	0.1038
State*Year	4	1994.855171	10.63	<.0001
Sex	1	125.027776	0.67	0.4145
Age	1	146.937383	0.78	0.3764
State*Sex	2	481.677281	2.57	0.0774
Year*Sex	2	83.573334	0.45	0.6407
State*Age	2	81.793617	0.44	0.6468
Year*Age	2	169.913389	0.91	0.4047
Error	758			

**Table 2.4. Time-dependent environmental factors with significant effects on the timing of departure from survival (time-to-event) analysis of 16 variables for data by state, year and pooled by state, year and state\*year.**

State	Year	Significant Variables
MI	2002	DL, BP, VIS*
MI	2003	DL
MI	2004	DL, VIS*, RDIR <sub>nw</sub>
MN	2002	**
MN	2003	DL, BPC
MN	2004	x
WI	2002	x
WI	2003	DL
WI	2004	DL, MOON, RDIR <sub>nw</sub> , PREC, RDIR <sub>s</sub> *
ALL	2002	DL, MOON*, BP, BPT, BPC*, VIS, RH, WW*
ALL	2003	DL, MOON, BP
ALL	2004	DL, MOON, BP, BPT, VIS, RDIR <sub>nw</sub> , PREC
MI	ALL	DL, MOON*, BP*, RDIR <sub>nw</sub> , TA
MN	ALL	DL, MOON, BPT, VIS*, RDIR <sub>nw</sub> *, PREC
WI	ALL	DL, MOON, WW, RHC
ALL	ALL	DL, MOON, BP, BPT, VIS, RDIR <sub>nw</sub> , PREC*, RWND, TA

\*\* MN 2002 could not be analyzed independently from other states-years due to high number of censored observations. Acronyms are described in table 2.1.

\* Indicates weak significance ( $0.05 < P \leq 0.10$ ); all other variables are significant at  $\alpha \leq 0.05$ .

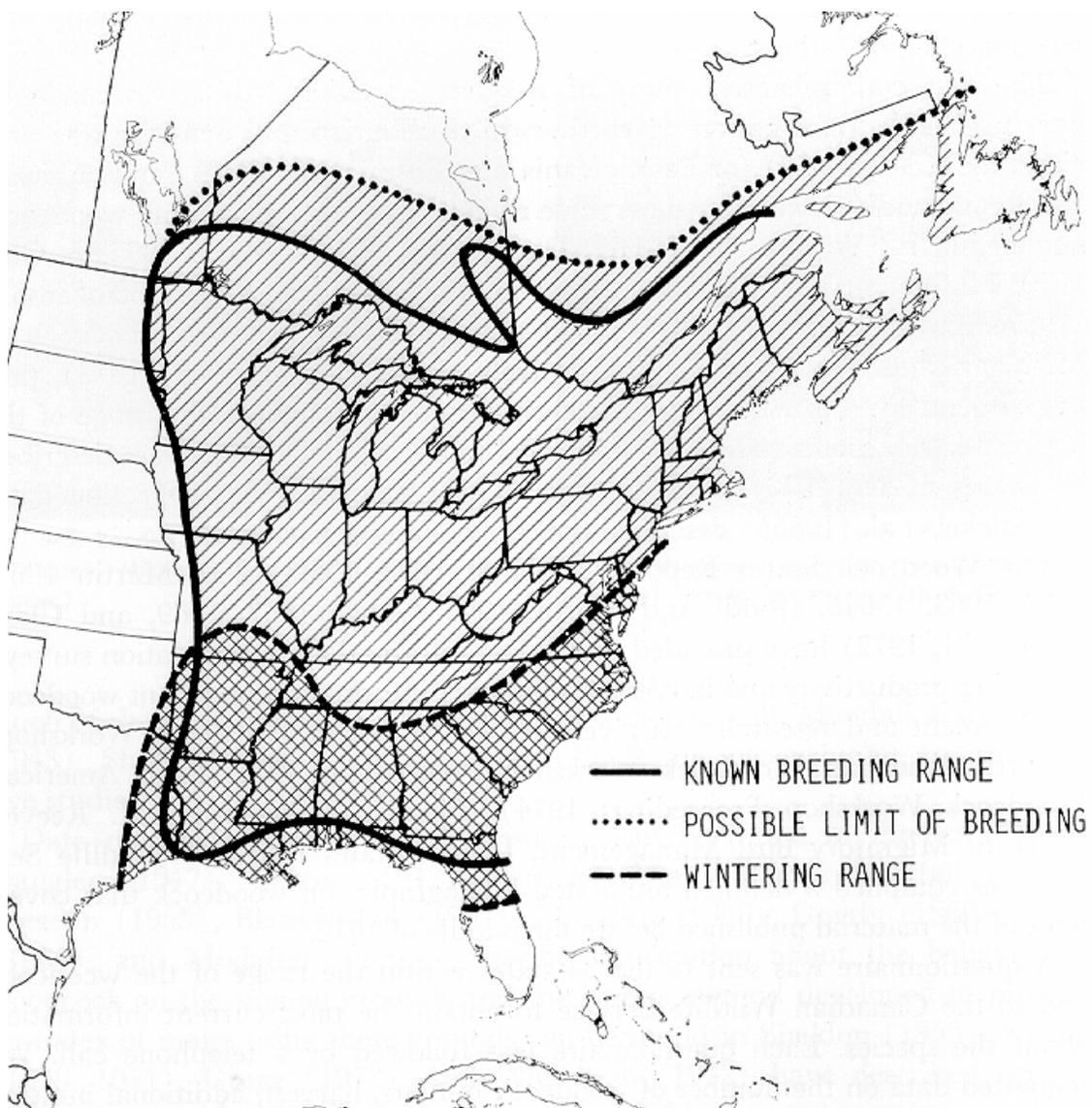
**Table 2.5. Relationships between departure date and worm abundance, departure date and the variance of worm abundance, and the variance of departure dates and worm abundance for woodcock in fall in the western Great Lakes Region.**

Response variable	Predictive equation	<i>t</i>	<i>P</i>
AHY F ( <i>n</i> = 98)			
Dep. Date <sup>a</sup>	= 306 – 30.1 ( $\bar{x}$ mean worm biomass)	-0.87	0.41
Dep. Date	= 303 – 9.3 ( $\bar{x}$ variance worm biomass)	-0.21	0.84
Var. Dep. Date <sup>b</sup>	= 58.7 + 1032 ( $\bar{x}$ mean worm biomass)	1.93	0.10
ALL ( <i>n</i> = 759)			
Dep. Date	= 300 + 4.5 ( $\bar{x}$ mean worm biomass)	4.47	0.87
Dep. Date	= 303 – 9.3 ( $\bar{x}$ variance worm biomass)	-0.21	0.89
Var. Dep. Date	= 200 – 177 ( $\bar{x}$ mean worm biomass)	-0.28	0.79

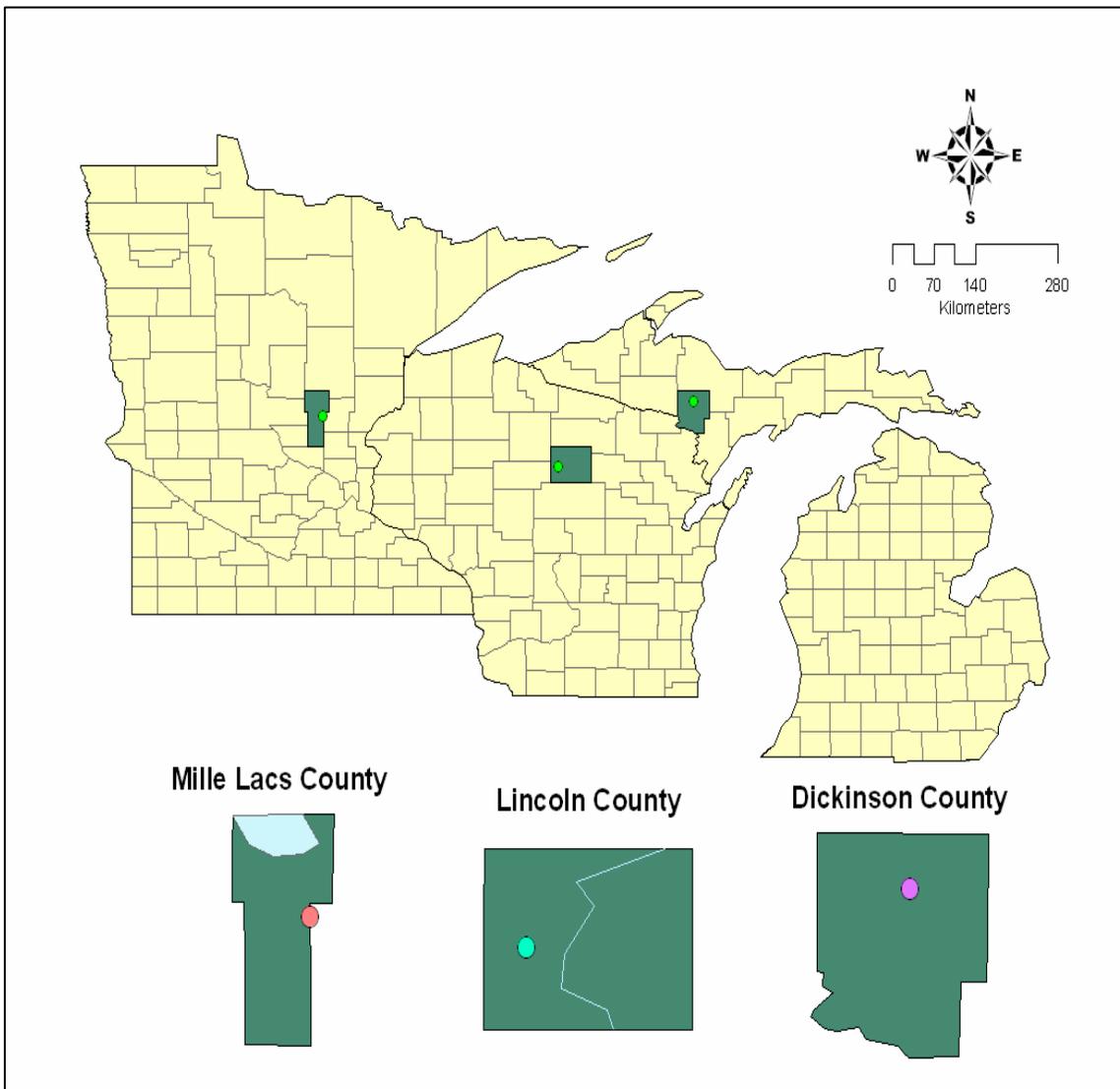
<sup>a</sup> Dep. Date = mean date of departure

<sup>b</sup> Var. Dep. Date = the variance of the mean departure date

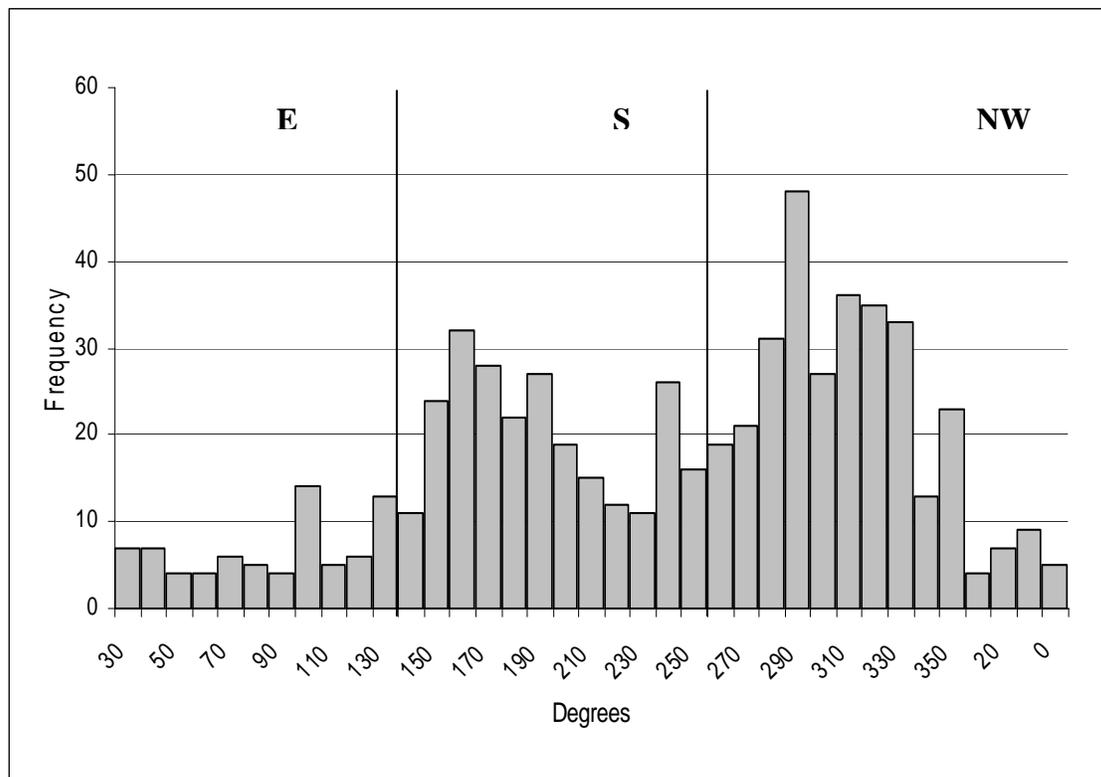
Figure 2.1. Woodcock breeding and wintering ranges (from Sanderson 1977).



**Figure 2.2. American woodcock study site locations in Michigan, Minnesota, and Wisconsin – the western Great Lakes Region.**

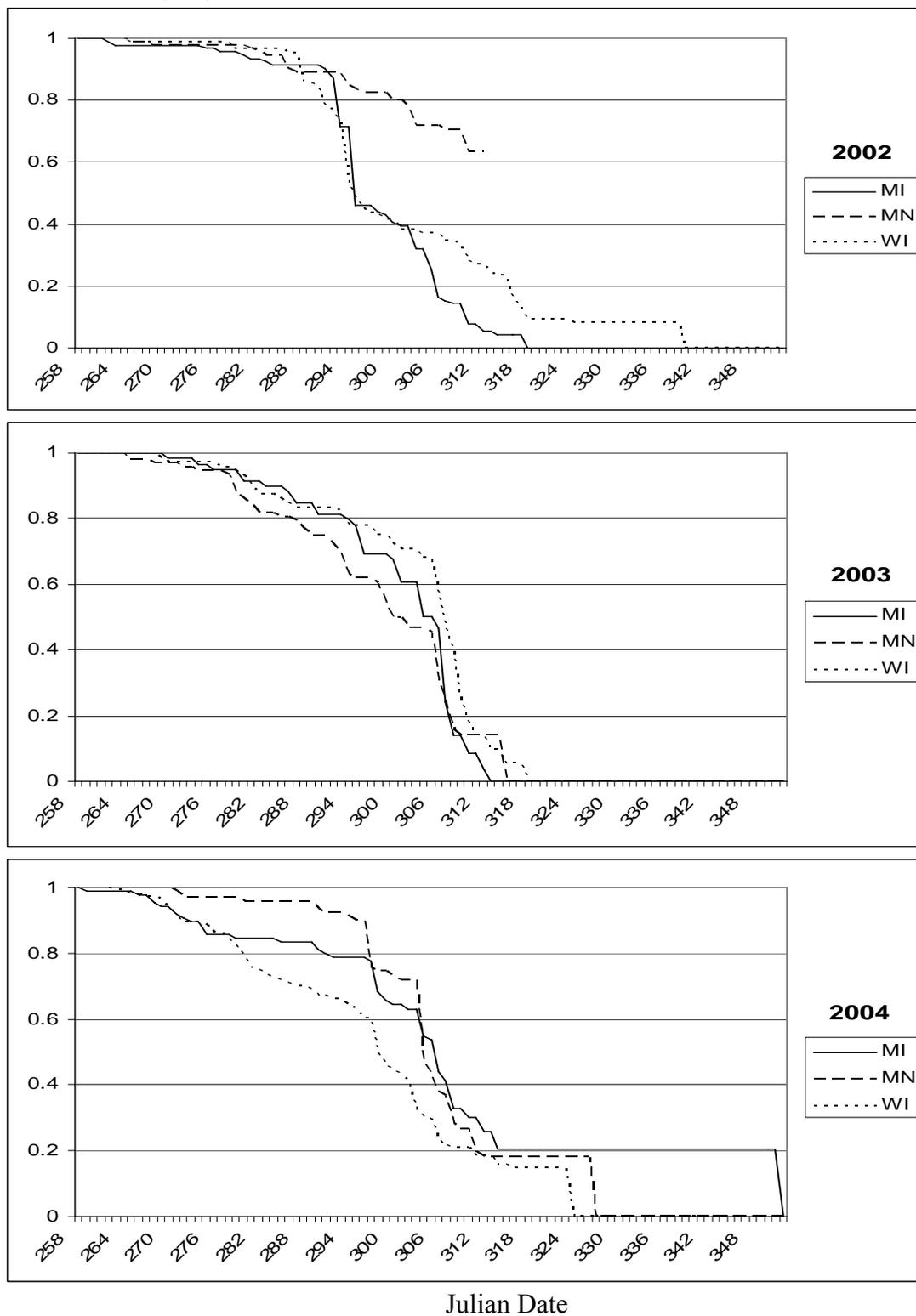


**Figure 2.3. Frequency of resultant wind directions during the fall period while woodcock were present on study areas (668 days) from 2002 – 2004 in Michigan, Minnesota, and Wisconsin.**

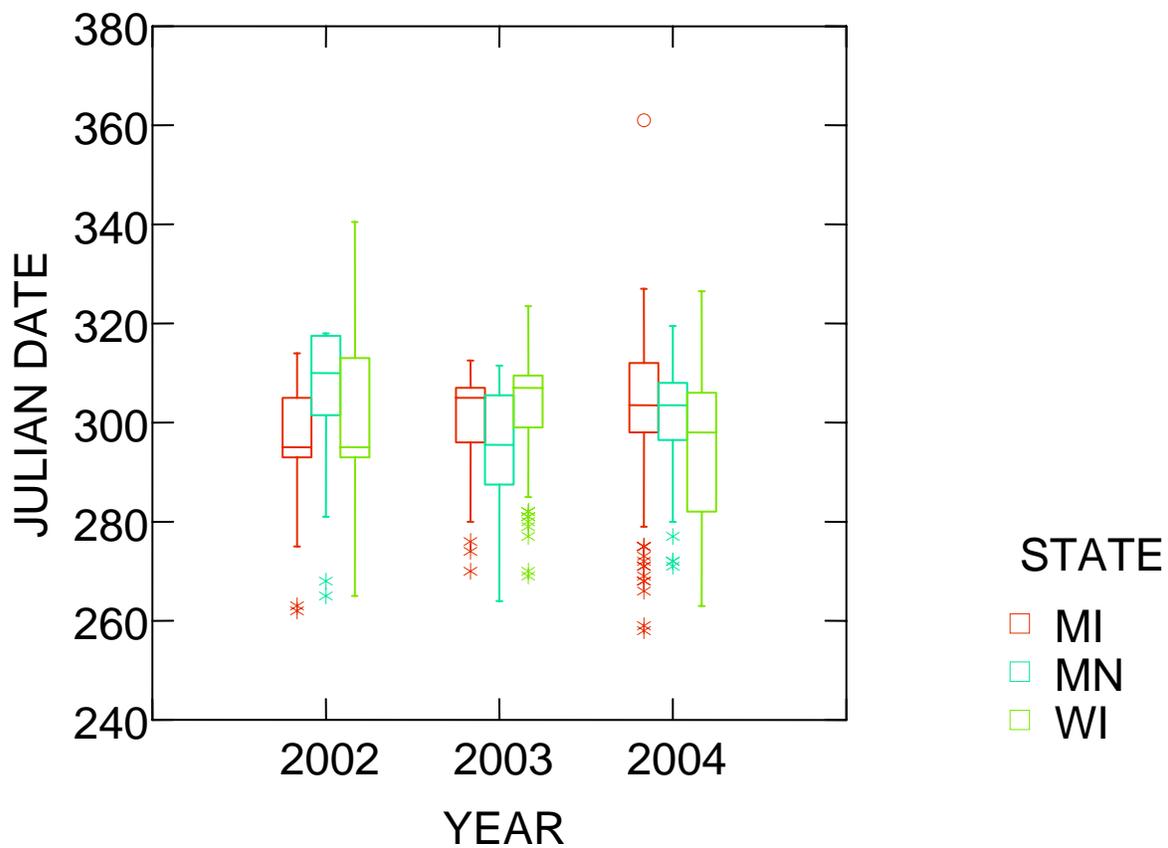


**E:** 30-140°  
**S:** 150-260°  
**NW:** 270-20°

**Figure 2.4. Kaplan-Meier (1958) survival (departure) probability curves of woodcock departure from northern breeding grounds in fall from September 15 (258) to December 17 (351).**



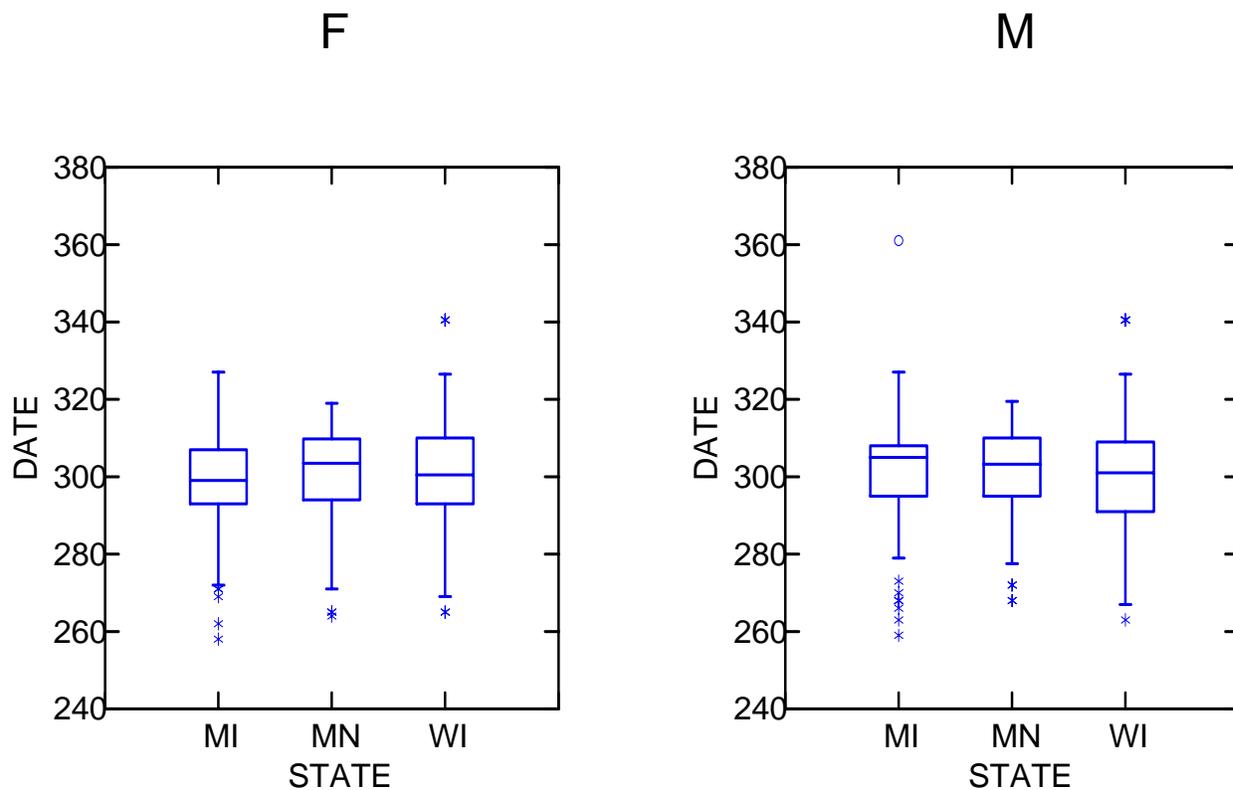
**Figure 2.5. Box and whiskers plot of the timing of departure (Julian date) for woodcock (n = 759) from Michigan, Minnesota, and Wisconsin in fall 2002-2004.**



\* Value outside inner fences (upper and lower box hinge  $\pm 1.5 \times$  (spread of box plot))

o Value outside outer fences (upper and lower box hinge  $\pm 3.0 \times$  (spread of box plot))

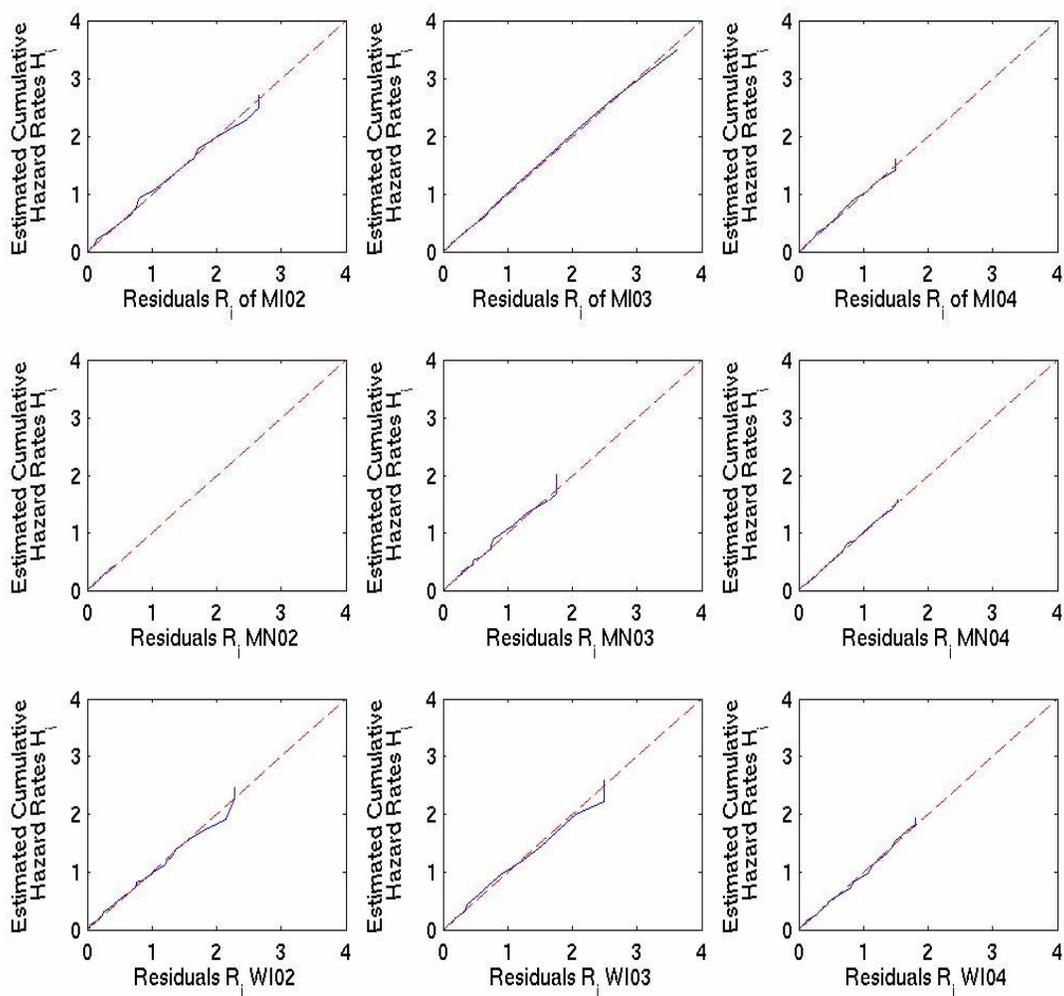
**Figure 2.6. Box and whiskers plot of the timing of departure (Julian date) for woodcock (n = 759) by state and sex from Michigan, Minnesota, and Wisconsin in fall 2002-2004.**



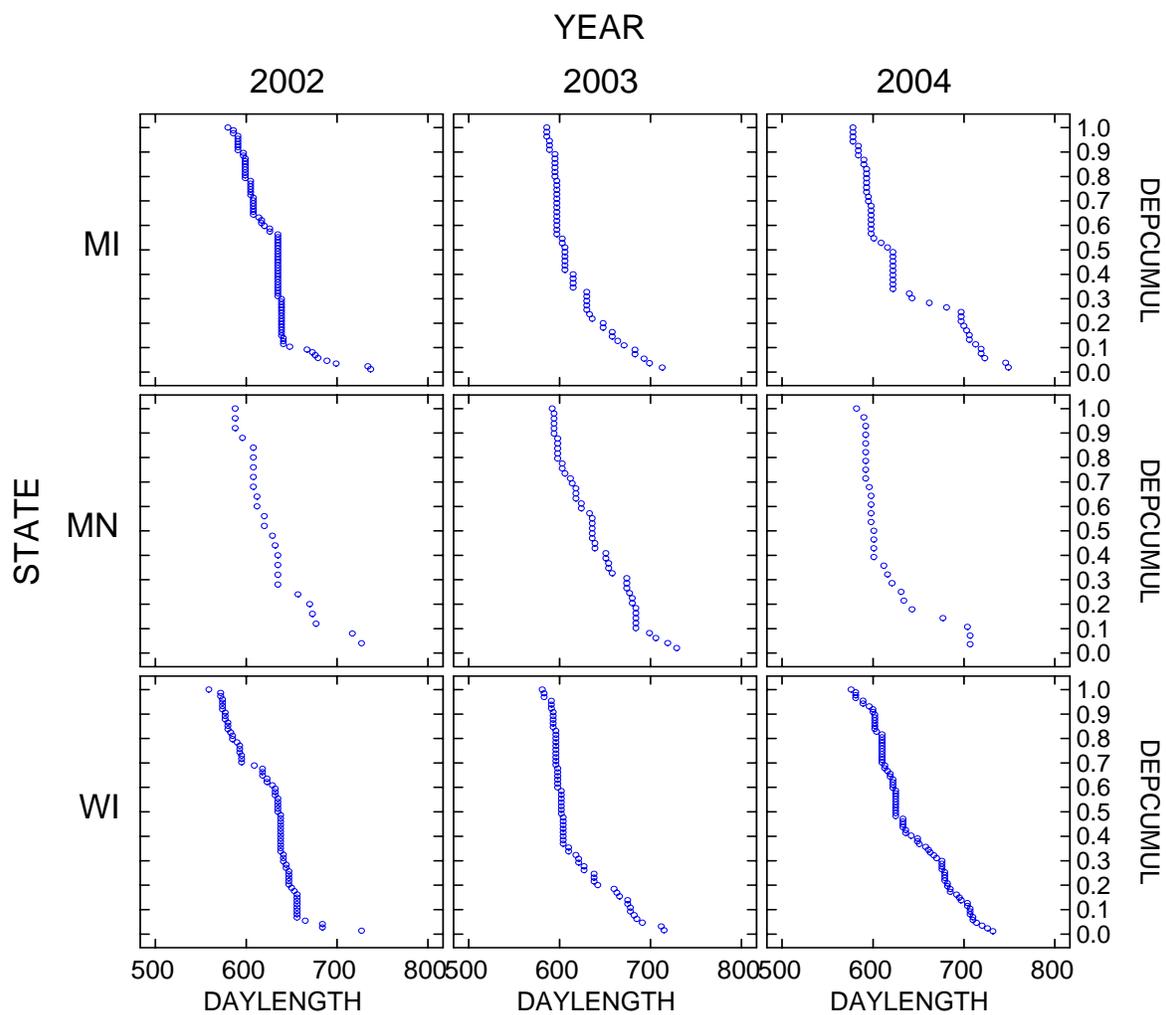
\* Value outside inner fences (upper and lower box hinge  $\pm 1.5 \times$  (spread of box plot))

o Value outside outer fences (upper and lower box hinge  $\pm 3.0 \times$  (spread of box plot))

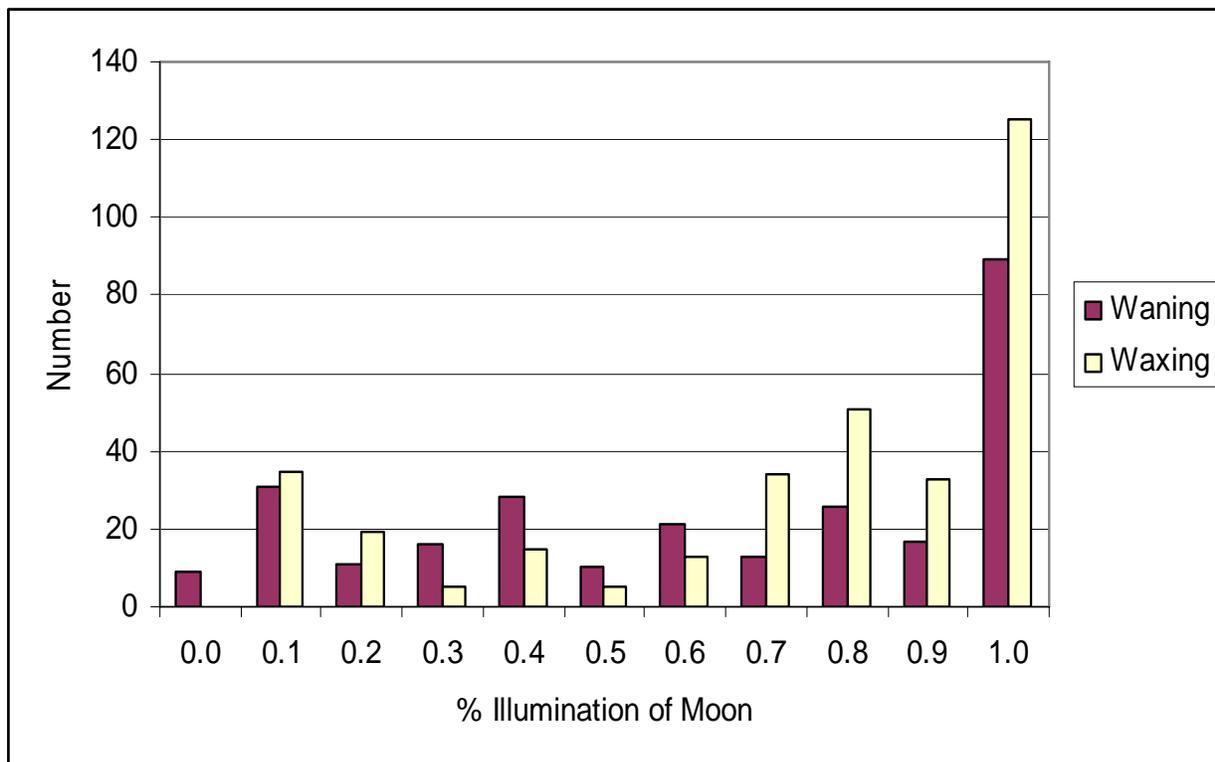
**Figure 2.7.** Graphical assessment for goodness-of-fit of the exponential survival (time-to-event) model using Nelson-Aalen estimator residuals for data from Michigan, Minnesota, and Wisconsin 2002-2004. A unity of slope indicates a reasonable fit.



**Figure 2.8. Cumulative woodcock departure (fraction gone/total) between 0 and 1 in order woodcock departed by day length in minutes.**



**Figure 2.9. Woodcock departures by % illumination of the surface of the moon for both a waxing (n = 335) and waning (n = 271) moon. Data are from all non-censored observations by illumination bin (no moon = 0, full = 1, waning bin  $1 \leq 0.99$  illumination).**



### *Chapter III*

## **FALL DIURNAL HABITAT USE BY ADULT FEMALE AMERICAN WOODCOCK IN THE WESTERN GREAT LAKES REGION**

### *Introduction*

The American woodcock (*Scolopax minor*) is a migratory game bird whose primary breeding range occurs in southeastern Canada and the northeastern and Lake States of the U.S. (Parris 1986). Woodcock populations in the United States are divided into two management units, the Central and Eastern Flyways, separated by the Appalachian Mountains. Woodcock belong to the shorebird family (*Scolopacidae*) but are unique among members of the family in their preference for forested habitats.

Due to concerns over long-term population declines often attributed to changes in habitat, particularly the loss of early successional forests, several research efforts have focused on woodcock habitat preferences. However, accurate estimates of woodcock habitat availability are difficult to obtain, (Woehr 1999). Forest inventory data have often been used to estimate availability of woodcock habitat, but correlations between gross trends in forest cover types and woodcock population numbers have shown few significant relationships. Woehr (1999) speculated that perhaps not all seedling/sapling hardwood forest is suitable woodcock habitat and in turn may be a factor in the lack of observed correlations between forest inventory data and woodcock population trends. Supporting this contention, Gregg (1984) reported that a number of aspen stands within his study areas were not used by woodcock. His research suggested that in addition to selecting only certain stands, woodcock used only small areas within chosen stands.

There is little consensus among past research on the habitat characteristics woodcock favor, but two characteristics often discussed are habitat structure and earthworm availability. Studies conducted previously indicated that structure is most important (Liscinsky 1972), while others found that woodcock habitat use was related primarily to earthworm abundance (Reynolds et al. 1977, Parris 1986). Contrary to Reynolds et al. (1977) and Parris (1986), Wishart and Bider (1976) noted no relationship between earthworm biomass and woodcock habitat use.

The difficulty of understanding woodcock habitat use may be exacerbated by changing environmental conditions (e.g., soil moisture) and habitat preference variation over seasons. Woodcock have shown distinct changes in habitat preference by season (Mendall and Aldous 1943, Wishart and Bider 1976) and with different environmental conditions within and among years (Sepik et al. 1983, Gregg 1984). Wishart and Bider (1976), for example, found that woodcock use shifted to alder habitat during autumn despite high soil moisture throughout their southwestern Quebec study areas. These authors suggested that perhaps alder woods act as traditional migration staging areas.

Woodcock have also shown an affinity for forest edges in their selection of habitat; they nest near edges and courtship behavior occurs in openings near edges (McAuley et al. 1996, Wishart and Bider 1976). Additionally, Parris (1986) noted that woodcock select edges for diurnal cover during summer and fall. Edge proximity, as well as the simple nature of diurnal habitat structure – early seral and even aged stands, may play an important role in diurnal habitat selection.

I used past research on woodcock habitat affinities to develop objectives for my investigation of woodcock habitat use in fall. My first objective was to describe habitat use

over space (MI, MN, and WI) and time (2002-2004) while determining whether alder acts as a staging cover in fall as has been suggested, though not tested, in past research efforts.

Secondly, I sought to explore conflicting results concerning the importance of habitat structure versus earthworm availability in determining woodcock use of cover types. I did this under the assumption that structural selection is likely an effect of predator avoidance while earthworm abundance determines whether the basic food requirements of woodcock are met. To test hypotheses concerning these objectives we measured distances to nearest edge and the number of stems per hectare for structural characteristics related to predator avoidance and sampled earthworms as an index to food availability.

We collected habitat-use data at two spatial scales (micro-habitat and home range). Habitat use was sampled during field work in 2002 at the micro-habitat scale; this, corresponds to Johnson's (1980) *fourth-order of selection* — the actual procurement of food items within a *third-order selection*. The second level I investigated was the home range scale, with data collected in 2003 and 2004; this corresponds to Johnson's *third-order selection* — the usage made of various habitat components within the home range (Johnson 1980). I selected these scales to try and better understand observations like Gregg's (1984) that describe woodcock use of particular stands (*third-order*) and locations within stands (*fourth-order*) to the exclusion of other adjacent stands and locations within stands.

### *Study Areas*

My research in Wisconsin was part of a larger study of woodcock ecology in the western Great Lakes region that also included study sites in Michigan and Minnesota (Figure

3.1). In each state, researchers selected woodcock study sites in large blocks of industrial private and public owned forests with high woodcock densities. Each of the three states had paired study sites for purposes related to other aspects of the larger study of woodcock ecology (Andersen et al. 2001). All study areas contained similar principal cover types used by woodcock including alder, aspen, mesic mixed hardwoods (MMH), northern mixed hardwoods (NMH), upland shrub (Up shrub), conifer, and meadows. These cover types are similar and based on the community types outlined in the Wisconsin Natural Heritage Inventory (NHI). The corresponding inventory communities are alder, northern hardwood swamp - MMH, and northern mesic forest – NMH. Conifer cover type included several NHI communities which are mesic cedar forest, black spruce swamp, and tamarack swamp. Meadow cover included the NHI northern sedge meadow community, but meadow cover also includes old fields, and wildlife openings. There is no Great Lakes NHI community type for aspen. Aspen stands are generally seral forests to other hardwood forest communities; however aspen is an important woodcock cover and I included it as a cover type. I also split shrub data into upland shrub (hazelnut; *Corylus cornuta*, witch hazel; *Hamamelis virginiana*, gray dogwood; *Cornus racemosa*), and willow (*Salix* spp).

### Michigan

Study sites in Michigan were located within the Copper Country State Forest in northern Dickinson County in the Upper Peninsula. Field work was primarily concentrated in the eastern half of the 25,728-ha Dickinson Woodcock Research Unit. Deciduous species common within Michigan study sites included aspen (*Populus* spp.), red maple (*Acer rubrum*), and paper birch (*Betula papyrifera*). Dominant species in coniferous forests

included balsam fir (*Abies balsamea*) and black spruce (*Picea mariana*). Alder (*Alnus* spp.) was also found in wet lowlands.

### Minnesota

In Minnesota, study sites were located within the southern portion of the 15,672-ha Mille Lacs Wildlife Management Area and the adjacent 1,166-ha Four Brooks Wildlife Management Area. These areas were in east-central Minnesota in Mille Lacs County and had similar vegetative communities and management. Management was focused on providing hunting opportunities to the public through habitat manipulation for game species. Vegetative communities included aspen on disturbed sites, mixed hardwoods with a fair representation of oak (*Quercus* spp.) on drier sites, and maple (*Acer* spp.) in more mesic sites. Alder and willow were also present in lowland habitats.

### Wisconsin

Wisconsin study sites were in the Lincoln County Forest and Tomahawk Timberlands industrial forest. Both study areas were in Lincoln County in north-central Wisconsin and were managed primarily for timber and recreational opportunities. Terrain in both areas is rolling with boggy wet basins. Forest cover is mostly northern mesic. Sugar maple (*Acer saccharum*) dominated the better-drained soils while red maple (*Acer rubrum*) dominated the more mesic sites. The wet basins contained spruce-fir (*Picea-Abies*) on wet mineral soils and spruce-tamarack (*Picea-Larix*) bogs on wet organic soils.

## *Methods*

### Capture

We captured resident woodcock in Minnesota, Michigan, and Wisconsin between mid-August and the end of September from 2002 through 2004. We terminated our capture efforts on 30 September each year to reduce the possibility of capturing non-resident, migrating woodcock (Mendall and Aldous 1943, Gregg 1984). Capture techniques included spotlighting (Rieffenberger and Kletzly 1967) and intercepting woodcock flights to roost fields at dusk with the use of mist nets (Sheldon 1960, McAuley et al. 1993). We used the outer three primary feathers, secondary feathers, and bill length to age and sex woodcock (Mendall and Aldous 1943, Greeley 1953, Martin 1964). We classified ages as HY (fledged young of the year) or AHY (all older birds). We weighed woodcock and attached a radio transmitter to birds >140 g using single loop wire harness and livestock-tag cement following the techniques of McAuley et al. (1993). Following transmitter attachment, we released woodcock at capture sites.

### Radiotelemetry

In early September of each year we randomly selected a subset of radiomarked, adult female woodcock for our habitat study. We collected habitat information at sites approximately 10 m from actual woodcock locations in an effort not to flush our sub-sample woodcock. We wanted to minimize disturbance that might influence woodcock behaviors. We located our sub-sample of woodcock  $\geq 5$  times per week using hand held yagi and/or rubberized H-antennas and portable receivers. We took coordinates for each daily location

within approximately 2-14 m of the true woodcock location using a hand-held Global Positioning System (GPS). We estimated the distance to fixed transmitters to determine our accuracy. We continued locating radiomarked woodcock until mortality or loss of radio contact. We searched for missing signals on the ground (ATV, vehicle, and on foot) and from the air following the methods of Gilmar et al (1981). When we failed to detect radiomarked woodcock on three consecutive aerial telemetry flights, we classified these individuals as emigrated and removed them from future aerial searches. We continually scanned for “missing” individuals from the ground for the duration of our field work.

### Habitat Sampling

To avoid flushing our sub-sample woodcock, we began by circling individuals using radiotelemetry to determine their exact location. We conducted sampling within 10 m, oriented at random, from the woodcock. We classified habitats where birds were located according to over-story cover type and size class of stems. We determined cover type by observing the dominant canopy species — with dominance defined by greatest percent cover. Cover types we included were aspen (AS), northern mixed hardwoods (NMH), conifer (Conifer), and mesic mixed hardwoods (MMH) by size class, alder, upland shrub (Up shrub), willow, and meadow. We used three size classes: (1) seedling/sapling (S), <10 cm diameter at breast height (DBH); (2) pole (P), between 10 and 30 cm DBH; and (3) mature (M), >30 cm DBH.

At each woodcock location we quantified the distance to the nearest edge if an edge was within sight (approximately 30 m), and we recorded edge type (e.g., adjacent cover types, water bodies, roads, trails etc.). We also estimated the number of woody stems per

0.004 ha (40 m<sup>2</sup>) along bent transects. We determined the transect length by the length of the observers' outstretched arms span (Penfound and Rice 1957). To reduce error associated with pacing in dense habitats, each researcher used a rope specific to their arm span to assure we sampled a 0.004 ha area. Observers walked perpendicularly from the line between the daily use location sampling point and the true location of the woodcock for approximately 10 m (half the distance based on a 20-m transect). The observer then turned 90° in the direction of the woodcock and sampled the remaining 0.002 ha. We used this L-shaped transect to minimize observer influence on woodcock behavior, while still allowing the collection of habitat variables characterized by woodcock use locations. We used Braun-Blanquet (1932) cover classes to estimate the density of *Rubus* sp.

We estimated earthworm biomass within a 35-cm<sup>2</sup> (0.1225 m<sup>2</sup>) plot at each daily use location with a spicy-mustard solution extraction method following the protocol of Lawrence and Bowers (2002). We collected earthworms that surfaced during a 5-minute period and subsequently determined the ash-free dry mass for each sample (to the nearest 0.0001 g) in order to compare samples over a large geographic area (Hale et al. 2004). We used the biomass of earthworm samples as an index to food availability.

In 2002, we compared micro-habitat characteristics between woodcock use locations and random locations within a stand. We sampled random locations approximately 20 m apart, at a random bearing from, and within the same habitat type as the daily use location. Habitat sampling at random locations was identical to that at woodcock use locations. We paired use and random locations for every sub-sample AHY female woodcock located twice per week.

In 2003 and 2004, we established random locations using a random bearing from use locations and a random distance between 35 and 200 m, our home range scale. We did not collect worm samples or estimate the number of stems/ha for random locations in 2003 or 2004 because this information was already available from use location data at the home-range scale. This scale was a comparison of diurnal habitat features across cover types which captures the majority (>80% are within 200m) of AHY female woodcock movements (Doherty et al. In Review).

### Statistical Analysis

I used MINITAB (Minitab 1999) to analyze habitat data comparisons between woodcock use and random locations. I conducted investigations that included cover-type affiliation across sampling scales; woodcock use of habitat in relation to earthworm abundance, stem densities, and edge proximity at the micro-habitat scale; and comparisons of earthworm abundance by cover type and woodcock use of edge proximity at the home-range scale. I defined cover types as “preferred” when the observed use frequency was greater than the expected use frequency and when the corresponding random-location frequency was less than expected. For all comparisons I considered significant differences as  $P \leq 0.05$  and defined weak evidence as  $0.05 < P < 0.1$ .

### *Cover Type Affiliation*

One of my objectives in delineating woodcock habitats was simply to describe qualitatively the cover types that woodcock used and the amount of use different cover types received. I also used home-range scale habitat data that we collected in 2002 and 2003 to

compare used and random locations taken across covers to explore habitat preferences. I analyzed cover-type data from use and random locations with Chi-square tests. My null hypothesis was that there was no difference between the proportion of use and random point frequency by cover.

I was also interested in testing the hypothesis that alder is used as a staging cover prior to migration. To test this I used paired *t*-tests and divided the fall period into 2 blocks of time: the first block was cover use in late August through September (summer); the second was October through early November (fall). If alder was used as a staging cover I would expect greater woodcock use of alder in fall (October-November) than summer (August – September). I used two blocks of time to retain adequate sample sizes and used only individuals with  $\geq 15$  locations in each period. I tested for differences between the mean frequency of alder use over the entire late summer/fall period and mean use within each period. My null hypothesis was that alder use is constant for each individual through time.

#### *Micro-habitat Use*

In 2002 we paired woodcock use locations with random locations twice per week for comparisons at a micro-habitat scale. I compared stem density, edge proximity, and earthworm abundance between all use and random points.

I analyzed stem density comparisons by cover type and size class using individual woodcock as the experimental unit as well as using data pooled across all sub-sample woodcock. I used paired-sample student *t*-tests of means with the null hypothesis that there was no difference between the mean number of stems at use locations and random locations. To assess edge proximity, I calculated the proportion both of use and random locations that

were either  $\leq 15$  m or  $> 15$  m from an edge and conducted chi-square tests for comparison between location types. I did this to determine if woodcock had a propensity for close proximity to edges in fall as has been found in other seasons. I used location data from 2002, 2003, and 2004, although in 2002 our random locations were located in the same cover type as paired use locations. I also used two-sample *t*-tests to test for differences in earthworm biomass between use and random data. My null hypothesis was that there was no difference in mean ash-free dry earthworm weights between use and random points sampled in the same cover type.

#### *Home Range Scale Habitat Use*

We sampled earthworms at use locations but did not sample worms or stem densities at random locations. At the home-range scale I investigated whether AHY female woodcock selected locations and cover types on the basis of food abundance and edge proximity; however, I did not make random-point comparisons at this scale for stems density and earthworms. Comparisons of stem densities and earthworm abundance among cover types were already possible using use information we collected.

I used the same analysis for home-range scale edge proximity data as I did for micro-habitat-scale data collected in 2002. In 2003 and 2004, however, we sampled across cover types at a home-range scale. Analyses consisted of chi-square tests to compare the proportion of locations  $\leq 15$  m from an edge between use and random locations.

I used earthworms sampled at use locations from 2002 through 2004 to determine if earthworm abundance varied across cover types. I combined upland shrub and willow cover data due to limited sample sizes for analysis of earthworm data. In order to meet the

assumption of normally distributed data I had to split worm data into presence and absence (i.e., samples where we found earthworms and samples where we did not). I analyzed the presence/absence data first, using chi-square tests. My null hypothesis was that the proportion of locations where we found earthworms (presence) and where we did not find earthworms (absence) would not differ by cover type.

I used an ANOVA analysis in SYSTAT (Systat 2000) to tests for main effects of state, year, and cover type for all presence data. My response variable was the log weight of earthworm samples where worms were found (presence data,  $n = 2, 496$ ). I transformed data to log scale to meet assumptions of normality. I also plotted the log weights against the date of sampling to determine if I needed to account for a temporal effect. I used Tukey multiple comparisons (Systat 2000) to determine which covers were different from one another in earthworm biomass.

## ***Results***

### AHY Female Sub-set Sampling

We randomly selected 139 AHY female woodcock (2002:  $n = 37$ , 2003:  $n = 54$ , and 2004:  $n = 48$ ) across the three states to serve as our sub-samples for habitat sampling. Of these woodcock, we sampled a minimum of 20 habitat-use locations for 90 individuals (2002:  $n = 19$ , 2003:  $n = 38$ , and 2004:  $n = 33$ ), and we sampled habitat variables at approximately 3,440 use locations. We also randomly sampled habitat variables at approximately 2,850 paired random locations for comparison to use locations. In 2002 we sampled habitat variables at 266 random locations within the same stand as our AHY female

use locations for comparisons of micro-habitat features. In 2003 and 2004 we sampled 2,583 random locations for habitat variable comparisons at the home-range scale across cover types.

### Cover Type Affiliation

Our sub-set of AHY Female woodcock used a variety of cover types (Table 3.1). The most commonly used cover across states was AS/S and alder was used frequently as well, but the relative importance of cover types differed among years and states (Table 3.1). Our woodcock used some covers heavily in one state, such as conifer (*Picea*, *Larix*, and *Abies*) in MI, with little or no use in other states. We also observed cover-type preference by individuals, as some individual woodcock utilized one particular cover type while others utilized several (Appendix III). I was not able to use GIS analysis to determine cover type area for estimates of availability due to the lack of consistent GIS information among states and outdated coverage.

I found some distinct preferences in cover-type use by woodcock at the home range scale (across cover types). Radiomarked woodcock used AS/S more than expected in all states and years except for in Minnesota during 2004 (Tables 3.2 A and B). Alder was also a preferred cover type in Wisconsin during 2003 ( $P < 0.01$ ,  $X^2 = 11.08$ ) and 2004 ( $P < 0.01$ ,  $X^2 = 17.68$ ) and Minnesota in 2003 ( $P < 0.01$ ,  $X^2 = 18.97$ ) and 2004 (at  $\alpha = 0.10$ ,  $P = 0.08$ ,  $X^2 = 3.10$ ). Random points fell in meadows and NMHM in greater proportion than use points except for NMHM in Minnesota 2004, where no difference ( $P = 0.76$ ,  $X^2 = 0.10$ ) was observed.

Results for conifer and ASM use were less well defined. In Michigan 2003 use points were located in conifer a greater proportion of the time than random points ( $P = 0.04$ ,  $X^2 = 4.35$ ). However in Wisconsin 2003 random points were in conifer cover in greater proportion ( $P = 0.03$ ,  $X^2 = 5.00$ ). Wisconsin woodcock were located in ASM in greater proportion ( $P = <0.01$ ,  $X^2 = 10.60$ ) than random points in 2003, but in Michigan 2004 ( $P = 0.03$ ,  $X^2 = 4.90$ ) and Minnesota 2003 ( $P <0.01$ ,  $X^2 = 9.54$ ) random points were within ASM a greater proportion of the time. I pooled conifer cover size classes due to limited sample sizes, but conifer covers were mostly mature sized with some pole size covers included.

#### *Alder Use by Period*

I found no difference between the mean frequency of alder use over the entire fall and periods of use in August/September ( $P = 0.99$ ,  $T = -0.01$ ) or October/November ( $P = 0.78$ ,  $T = -0.28$ ) using individuals with  $\geq 15$  locations in each time period ( $n = 28$ ). Similarly, I found no difference using individuals with  $\geq 10$  observations in each time period ( $n = 60$ ).

#### Micro-habitat Use

We collected habitat information for comparisons between random and use locations at a micro-habitat scale. We sampled at random locations for roughly one-third of our use points in Wisconsin ( $n = 77$ ) and Minnesota ( $n = 105$ ), and in Michigan nearly half of our use points were paired with random points ( $n = 54$ ).

### *Stems per Hectare*

Stem density comparisons showed some consistent differences across the states. For example, I found a negative association between woodcock use and mature stems in upland shrub covers in Minnesota ( $P = 0.04$ ,  $t = -2.37$ ) and AS/S covers in Wisconsin ( $P = 0.09$ ,  $t = -1.70$ ) for data pooled across individuals by cover type (Table 3.3, Appendix IV). In Minnesota, shrub stem density was higher at use points than at random points within alder ( $P = 0.04$ ,  $t = 2.20$ ) and AS/S ( $P = 0.06$ ,  $t = 1.93$ ) cover types. However, in AS/S covers, densities of seedling/sapling-sized stems were higher at random points than at use points ( $P = 0.02$ ,  $t = -2.55$ ). We did not frequently encounter willow covers in study sites in Michigan or Wisconsin, but within willow covers in Minnesota the density of *Rubus* sp. was higher at use locations ( $P < 0.01$ ,  $t = 3.78$ ). Stem density comparisons by individuals were similar to data pooled across individuals; however, unlike the pooled data in Minnesota, use sites of an individual woodcock in Michigan had higher seedling/sapling densities in AS/S cover ( $P = 0.06$ ,  $t = -2.39$ , Appendix V and VI A, B, C).

### *Edge Proximity*

Radiomarked AHY female woodcock in Wisconsin were located  $\leq 15$  m from an edge more than expected in AS/S ( $P < 0.01$ ,  $\chi^2 = 15.55$ ) and NMHM ( $P = 0.04$ ,  $\chi^2 = 4.29$ ) cover types. In Minnesota 2002, we located woodcock  $\leq 15$  m from an edge more than expected in AS/S ( $P = 0.02$ ,  $\chi^2 = 5.80$ ) and upland shrub ( $P = 0.10$ ,  $\chi^2 = 2.73$ ) covers. In Michigan, the proportion of distances  $\leq 15$  and  $> 15$  m to an edge were not different between use and random locations for any cover type (Table 3.4).

### *Earthworm Abundance*

I found no differences between earthworm biomass at use locations and random locations by cover or pooled across covers (Table 3.5). I was unable to analyze earthworm data by cover type at the micro-habitat level for Minnesota because very few random points were sampled for earthworms. Micro-scale earthworm comparisons were troubled by small sample sizes for many covers and high variability, which likely reduced my ability to detect differences.

### Earthworm Abundance Across Cover Types

Ratios of presence/absence of earthworms at sampling locations by cover type were similar to the total ratio of presence/absence points for all covers (Appendix IV). The only strong evidence ( $P < 0.05$ ) for differences in presence/absence ratios was in upland shrub and ASP covers. Observed earthworm presence counts were greater than expected for upland shrub ( $P < 0.01$ ,  $X^2 = 15.64$ ) and ASP ( $P = 0.03$ ,  $X^2 = 4.98$ ) covers; likewise absence counts were fewer. There was weak evidence for greater presence/absence ratios for ASM ( $P = 0.08$ ,  $X^2 = 3.05$ ) and other ( $P = 0.05$ ,  $X^2 = 3.78$ ) cover types. The only cover with lower observed presence (and more observed absence) counts than expected was AS/S, although evidence was weak ( $P = 0.10$ ,  $X^2 = 2.78$ ).

I found no temporal effect on earthworm biomass (Figure 3.2), but I found differences in earthworm biomass among years ( $P < 0.01$ ,  $F = 32.89$ ), states ( $P < 0.01$ ,  $F = 60.35$ ), and cover types ( $P < 0.01$ ,  $F = 14.77$ ). Earthworm biomass was lowest in 2003 and was highest in 2004, though 2003 was similar to 2004 (Figure 3.4). Michigan had the lowest earthworm biomass in all years, and Wisconsin had highest biomass in both 2002 and 2003.

Conifer, AS/S, and MMH were lower in earthworm abundance than all other covers, but did not differ from one another (Figure 2.3).

### Edge Proximity Within Home-range Scale

In 2003 a greater proportion of use points were  $\leq 15$  m from an edge for mature and pole-size aspen in Michigan ( $P < 0.01$ ,  $\chi^2 = 8.70$ ;  $P = 0.05$ ,  $\chi^2 = 3.93$ , respectively) and Wisconsin ( $P = 0.01$ ,  $\chi^2 = 6.39$ ;  $P < 0.01$ ,  $\chi^2 = 7.24$ , respectively; Table 3.4). I found no difference between use and random points in proximity to edge in AS/S in 2003 in Wisconsin, Michigan, or Minnesota. In Wisconsin, a greater proportion of use points were in close proximity to edges ( $\leq 15$  m) in NMHM ( $P < 0.01$ ,  $\chi^2 = 12.60$ ) and MMHM ( $P < 0.01$ ,  $\chi^2 = 7.22$ ).

In 2004, Wisconsin had higher proportions of use points  $\leq 15$  m from an edge in NMHM ( $P < 0.01$ ,  $\chi^2 = 6.95$ ). In Michigan, use points were  $\leq 15$  m from an edge in greater proportion for woodcock located in AS/S ( $P = 0.03$ ,  $\chi^2 = 4.77$ ). In Minnesota, in both ASM and NMHM, use points were  $\leq 15$  m from an edge more frequently than random points ( $P < 0.07$ ,  $\chi^2 = 3.28$ , and  $P < 0.06$ ,  $\chi^2 = 3.57$  respectively).

Types of edges that we most frequently encountered near our AHY female locations included meadows, trails, and logging roads, as well as ecotones — edges where two or more forest cover types meet (e.g., we were frequently near NMHM covers while sampling woodcock use locations in AS/S covers). We also found woodcock near streams, beaver ponds, and other water bodies. Across all states and years, meadows were the only edge type observed more frequently at woodcock use points than at paired random points (Table 3.6).

## *Discussion*

While many factors likely contribute to woodcock habitat selection, I focused my investigation on stand characteristics, edge proximity, and stem density and earthworm biomass for food procurement needs. My results suggest that forest structure is more important to woodcock than food availability. In particular, I found evidence for woodcock selecting close edge proximity and greater shrub development in a variety of different cover types and size classes.

AHY female woodcock demonstrated a preference for proximity ( $\leq 15$  m) to edges in a variety of cover types at both micro-habitat and home-range scale comparisons between use and random points. This was especially pronounced in mature sized cover types (NMHM, MMHM, and ASM), but also in an early seral habitat, AS/S. Gregg (1984) noted that a shrub component appeared to be a prerequisite for woodcock use of many maturing aspen stands in his work in Wisconsin. It is feasible that better sunlight conditions near forest edges allow greater shrub development, which benefits woodcock use of mature habitats. A similar shrub relationship may also be true in young cover types; for example, in Minnesota 2002 I observed higher shrub stem densities at use locations in alder and AS/S but fewer seedling sapling sized stems. Woodcock in Minnesota during this same time were frequently near edges (Table 3.4).

In Minnesota, shrub stem densities were greater at use locations in alder and AS/S and *Rubus* densities were higher in willow covers at use locations. Seedling/sapling stem counts in young aspen covers were higher at random locations in Minnesota. This is interesting and may be a result of woodcock selecting young aspen with more heterogeneity

in the form of a shrub layer interspersed with seedling/sapling aspen. Analysis of stem densities by individual woodcock indicate similar results: in all cases with differences, seedling/sapling aspen stems within AS/S covers were fewer at use locations while shrub stem counts were always greater (Appendix III A, B, C). This may be an artifact of site quality, with greater species diversity and competition with shrub species in higher quality sites. It could also be an edge effect, with greater competition between even aged aspen and shrub species along edges due to increased sunlight. Another interesting finding was a negative association with mature trees in AS/S (WI) and upland shrub (MN) covers. Large residual stems left in clear cuts may provide predator perches and could negatively influence woodcock usage of such sites.

Surprisingly, I found no difference in earthworm abundance between used and random locations within a stand, which suggests that woodcock are likely not selecting habitat at the micro-scale based on food procurement. Woodcock selection of cover types with low earthworm biomass also indicates that woodcock do not select habitats at the home-range scale on the basis of earthworm availability. The only cover type with a lower presence to absence ratio compared with the overall ratio across covers was for AS/S, which was also one of the most heavily used cover types across state-years. It also had the lowest abundance of earthworms of any cover across state-years (Figure 3.3).

The proportion of alder use was highest in all states in 2003, a drought year. This use of alder supports past research (Gregg 1984, Sepik et al. 1983) that habitat use changes with different environmental conditions. All covers were lower in earthworm biomass in 2003, but alder cover had the greatest mean earthworm biomass during this period (Figure 3.4). I

found no difference in the frequency of alder use between early and late time periods, which does not support for the hypothesis that alder cover is used as staging cover.

I found woodcock used a variety of covers and their habitat preferences were not always similar from year to year or among states. This finding led me to conclude that habitat preferences of woodcock likely shift with changing environmental conditions. The result of these shifts involves a diversity of cover types used over time. I believe that my work suggests the necessity of cover-type diversity when managing for woodcock.

My investigation illustrates the importance of structural characteristics in woodcock use of habitats. Structural characteristics of edge proximity and stem density may benefit woodcock in the form of protection from predators, namely proximity to edge for escape routes (Parris 1986), high stem density for concealment, and lack of mature trees in early seral habitats which conceivably could act as perching trees and place them at greater risk to avian predators. My finding that stem density and proximity to edge were related to cover-type use suggests that creation of these microhabitat features could be goals for cover-type management. These components were often provided by stems in the shrub layer.

Woodcock did not select dense aspen stems in AS/S stands, but rather selected for young aspen stands with a greater shrub species stem count. Both the utility of shrub species intermixed in aspen cuts and negative associations of mature residual stems could have important implications for silvicultural practices intended to benefit woodcock and other early seral forest gamebirds.

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**Table 3.1. Cover types (% of total) used in 2002, 2003, and 2004 by AHY female woodcock in Dickinson County, Michigan, Mille Lacs County, Minnesota, and Lincoln County, Wisconsin.**

Habitat category	Michigan			Minnesota			Wisconsin		
	2002 (n = 117)	2003 (n = 412)	2004 (n = 461)	2002 (n = 310)	2003 (n = 484)	2004 (n = 276)	2002 (n = 218)	2003 (n = 531)	2004 (n = 483)
Alder	8.5	12.4	8.2	20	21.7	8.0	11	20.2	17.6
Aspen seedling/sapling	39.3	44.7	68.5	26.8	25.2	15.2	72.5	39.7	42.0
Aspen mature	--	5.6	2.2	7.7	4.8	9.4	2.3	14.7	7.2
Aspen pole	5.1	6.8	3.0	22.9	11.6	14.9	2.3	6.6	7.7
Meadow	--	0.7	2.2	0.3	1.2	0.7	--	--	0.6
Mesic mixed hardwood mature	11.1	0.5	--	--	1.0	4.7	--	1.5	--
Northern mixed hardwood mature	3.4	1.4	4.6	2.9	10.3	8.7	6.4	11.7	6.8
Northern mixed hardwood pole	--	--	--	--	3.3	3.6	--	0.8	1.4
Northern mixed hardwood sapling	12	--	--	0.3	1.9	0.4	2.3	0.9	7.0
Conifer	19.7	27.7	11.3	--	--	--	--	3.4	5.2
Upland shrub	0.9	0.2	--	5.8	3.5	13.1	3.2	0.2	4.3
Willow	--	--	--	13.2	15.5	21.1	--	--	--
Total	100	100	100	100	100	100	100	100	100

**Table 3.2a. Cover type Chi-square test comparisons between our AHY female sub-set woodcock use location frequency and randomly located point frequency in 2003.**

	Michigan			Minnesota			Wisconsin		
	Ran	Use	P-value	Ran	Use	P-value	Ran	Use	P-value
Alder	48	51	0.758	53	105	0.000	55	107	0.001
AS/S <sup>1</sup>	137	184	0.001	66	122	0.000	136	211	0.002
ASM <sup>2</sup>	22	23	0.885	47	23	0.002	36	78	0.001
ASP <sup>3</sup>	18	28	0.131	72	56	0.094	24	35	0.410
Meadow	68	3	0.000	32	6	0.000	56	--	0.000
M.M.H.M. <sup>4</sup>	2	2	0.998	7	5	0.532	3	8	0.214
N.M.H.M. <sup>5</sup>	24	6	0.001	102	50	0.000	100	62	0.000
N.M.H.P. <sup>6</sup>	--	--	--	14	16	0.763	4	4	0.813
N.M.H.S. <sup>7</sup>	1	--	--	7	9	0.650	--	5	--
Conifer	88	114	0.037	1	--	--	29	18	0.025
Up. Shrub <sup>8</sup>	1	1	--	9	17	0.127	3	1	0.241
Willow	2	--	--	62	75	0.298	2	--	--
Other	--	--	--	--	--	--	--	--	--
Total	411	412	--	472	484	--	448	529	--

**Table 3.2b. Cover type Chi-square test comparisons between our AHY female sub-set woodcock use location frequency and randomly located point frequency in 2004.**

	Michigan			Minnesota			Wisconsin		
	Ran	Use	P-value	Ran	Use	P-value	Ran	Use	P-value
Alder	31	38	0.418	12	22	0.078	40	85	0.000
AS/S <sup>1</sup>	199	316	0.000	43	42	0.892	135	203	0.000
ASM <sup>2</sup>	22	10	0.028	21	26	0.454	35	35	0.935
ASP <sup>3</sup>	15	14	0.818	41	41	0.986	35	37	0.871
Meadow	60	10	0.000	73	2	0.000	62	3	0.000
M.M.H.M. <sup>4</sup>	1	--	--	6	13	0.104	4	--	--
N.M.H.M. <sup>5</sup>	57	21	0.000	26	24	0.757	67	33	0.000
N.M.H.P. <sup>6</sup>	--	--	--	5	10	0.193	16	7	0.052
N.M.H.S. <sup>7</sup>	--	--	--	--	1	--	21	34	0.083
Conifer	64	52	0.200	--	--	--	34	25	0.199
Up. Shrub <sup>8</sup>	--	--	--	18	35	0.015	6	21	0.004
Willow	1	--	--	30	60	0.001	--	--	--
Other	4	--	--	--	--	--	19	--	--
Total	454	461	--	275	276	--	474	483	--

<sup>1</sup>Aspen seedling/sapling<sup>2</sup>Aspen mature<sup>3</sup>Aspen pole<sup>4</sup>Mesic mixed hardwoods mature<sup>5</sup>northern mixed hardwoods mature<sup>6</sup>Northern mixed hardwoods pole<sup>7</sup>Northern mixed hardwoods seedling/sapling<sup>8</sup>Upland shrub

**Table 3.3. Stem densities (stems/Ha) with evidence for differences between sites used by woodcock and random sites within the same stand for radio-marked woodcock in Michigan, Minnesota, and Wisconsin, from September to November 2002.**

State (n)	Cover Type	Stem Size	Use (stems/ha)		Random (stems/ha)		t	P-value
			Mean	SD	Mean	SD		
MI (24)	AS/S <sup>1</sup>	Pole	156	302	94	253	2.30	0.031
MI (10)	Conifer	Seed/Sap	1496	1331	608	594	2.03	0.073
MN (32)	AS/S	Shrub	5963	4903	4159	2833	1.93	0.063
MN (32)	AS/S	Seed/Sap	6803	4379	9793	8378	-2.55	0.016
MN (19)	Alder	Shrub	9796	6386	6892	2870	2.20	0.041
MN (12)	Up Shrub <sup>2</sup>	Mature	42	97	240	294	-2.37	0.037
MN (22)	Willow	Rubus <sup>3</sup>	1.77	1.14	1.15	0.99	3.78	0.001
WI (55)	AS/S	Mature	5	34	200	852	-1.70	0.094

<sup>1</sup>Aspen seedling/sapling cover type

<sup>2</sup>Upland shrub cover type

<sup>3</sup>*Rubus* values are measures of density on a Braun-Blanquet cover scale

**Table 3.4. Chi-square comparisons (*P*-values) for distances  $\leq$  and  $>15$  m to an edge for use and random points for AHY female woodcock in 2002, 2003, and 2004 in Michigan, Minnesota, and Wisconsin.**

Habitat category	Michigan			Minnesota			Wisconsin		
	2002	2003	2004	2002	2003	2004	2002	2003	2004
Alder	0.134	0.979	0.738	0.421	0.717	0.638	0.160	<0.001	0.503
Aspen mature	--	0.003	0.186	0.172	0.811	0.596	<0.050	0.012	1.000
Aspen pole	>0.500	0.047	0.340	0.202	0.583	0.607	--	0.007	0.859
Aspen seedling/sapling	0.690	0.624	0.029	0.016	0.211	0.070	<0.001	0.851	0.773
Northern mixed hardwood mature	--	--	0.143	--	0.689	0.059	0.038	<0.001	0.008
Northern mixed hardwood pole	--	--	--	--	0.526	0.171	--	--	0.679
Northern mixed hardwood sapling	--	--	--	--	--	--	< 0.050	--	0.391
Northern mixed hardwood	0.401	0.656	--	0.513	--	--	0.369	--	--
Upland shrub and willow	--	--	--	0.098	0.940	0.763	0.381	--	0.650
Conifer	0.181	0.161	0.897	--	--	--	--	0.180	0.694
Mesic mixed hardwood mature	--	--	--	--	--	--	--	0.007	--
Mesic mixed hardwood	0.825	--	--	--	0.038	0.637	--	--	--
All Covers	0.781	0.046	0.015	0.418	0.822	0.009	<0.001	<0.001	0.578

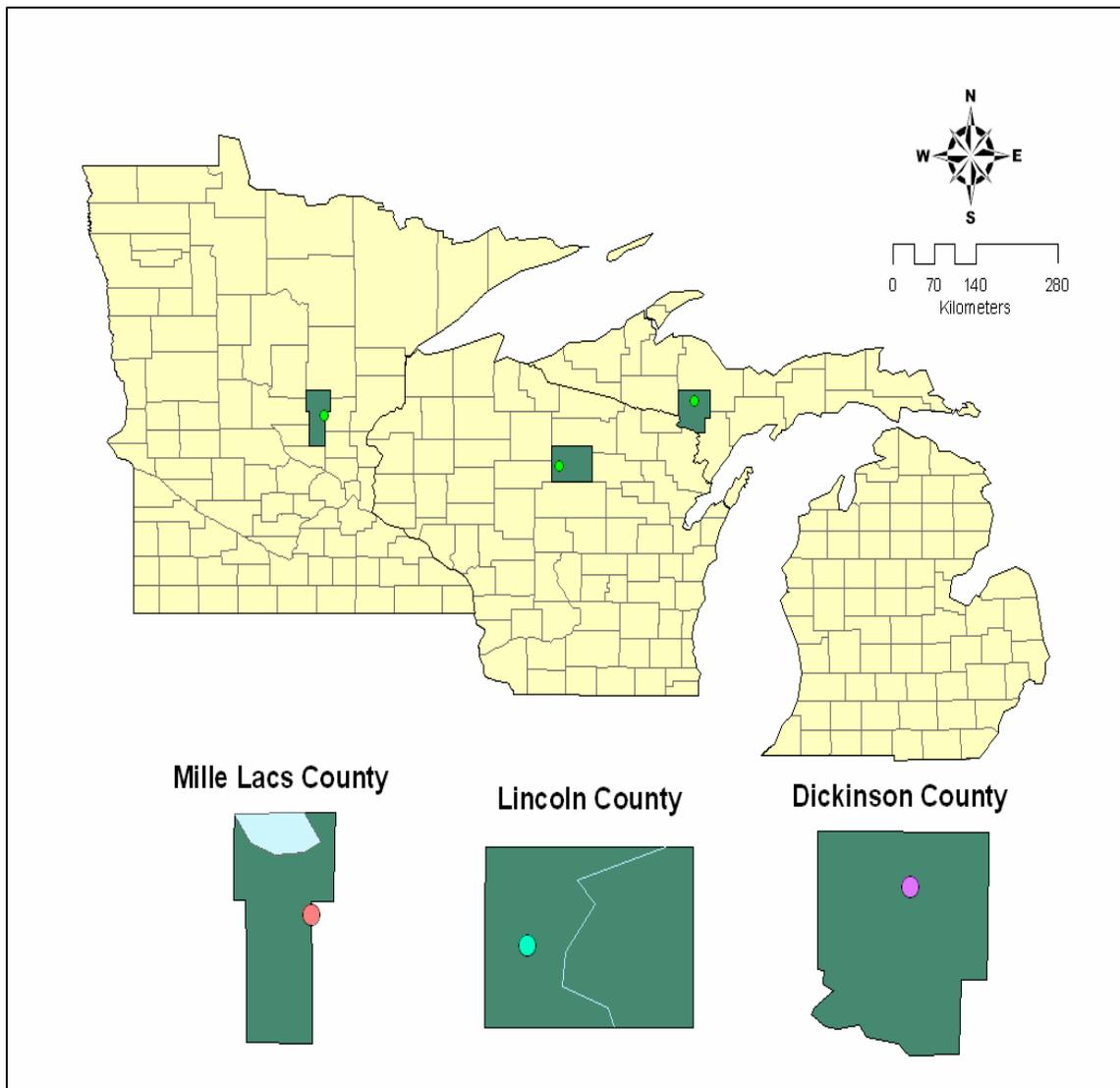
**Table 3.5. Comparisons of ash-free dry weight of earthworms sampled at locations used by AHY female woodcock and randomly paired locations within the same cover type in fall 2002 in Michigan, Minnesota, and Wisconsin.**

<b>Michigan</b>	<b>Use</b>	<b>Random</b>	<b>df</b>	<b>t Stat</b>	<b>P-value</b>
Alder	0.0705	0.0458	8	0.577	0.579
Aspen S/S	0.1225	0.0571	45	1.439	0.157
NMHM	--	--	--	--	--
NMHS	0.0534	0.024	4	1.900	0.130
Conifer	0.0165	0.1153	9	-1.122	0.291
MMHM	0.1196	0.0202	8	1.743	0.120
All Covers	0.0774	0.0599	73	0.608	0.545
<b>Minnesota</b>					
Alder	--	--	--	--	--
Aspen S/S	--	--	--	--	--
NMHM	--	--	--	--	--
NMHS	--	--	--	--	--
Conifer	--	--	--	--	--
MMHM	--	--	--	--	--
All Covers	0.0878	0.0817	15	0.120	0.906
<b>Wisconsin</b>					
Alder	0.5117	0.2151	25	1.524	0.140
Aspen S/S	0.0863	0.0561	174	1.175	0.242
NMHM	0.4716	0.7083	4	-0.451	0.675
NMHS	0.0936	0.0115	--	1.400	--
Conifer	--	--	--	--	--
MMHM	--	--	--	--	--
All Covers	0.1789	0.1164	160	1.372	0.172

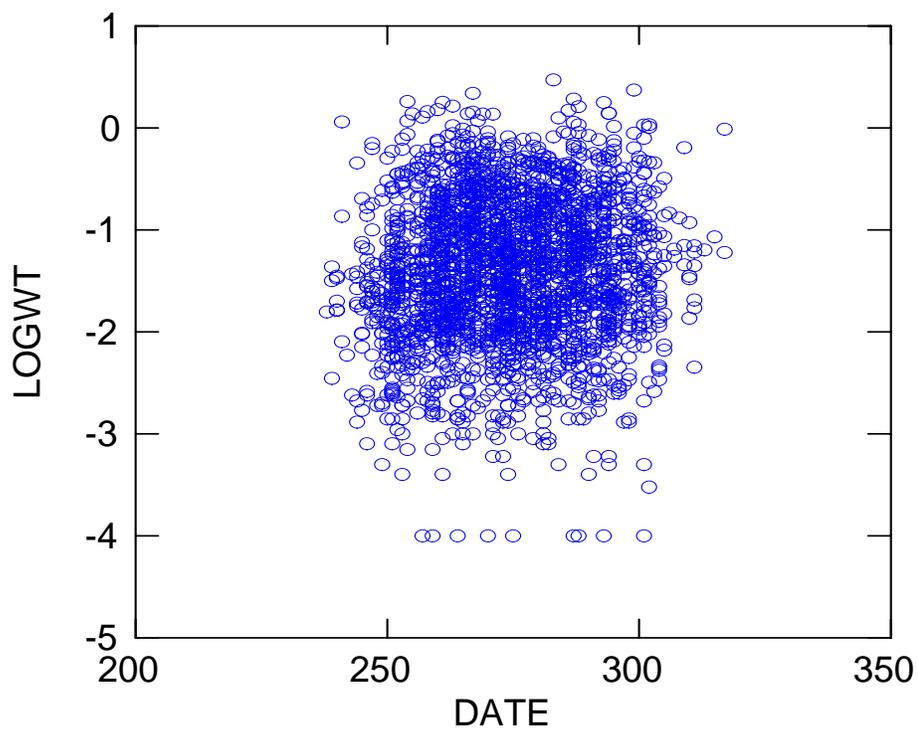
**Table 3.6. Edge types encountered (% of total) near AHY female woodcock use locations and random locations in Michigan, Minnesota, and Wisconsin from 2002-2004.**

<b>2002</b>	Use Locations (% of Total)					Random Locations (% of Total)				
	n	Meadow	Trail/Road	Ecotone	Water	n	Meadow	Trail/Road	Ecotone	Water
MI	117	19.7	19.7	55.6	0	54	11.1	24.1	55.6	0
MN	385	0.3	14.1	58.7	0	133	0	11.3	57.9	0
WI	154	65.6	7.8	13.6	9.7	36	58.3	2.8	27.8	11.1
<b>2003</b>										
MI	412	24.5	13.3	57.3	0.5	412	12.4	17.4	67.5	0
MN	473	31.3	19.2	45	3	465	25.6	22.4	50.1	0.9
WI	494	28.1	16.2	39.3	9.3	392	16.1	12.5	54.6	4.3
<b>2004</b>										
MI	461	17.4	40.1	40.8	0	461	15.4	32.8	50.1	0.2
MN	276	47.1	11.6	38.4	0.4	276	21.4	15.2	56.5	2.2
WI	290	37.6	13.1	35.5	7.6	282	24.5	16	47.9	7.4

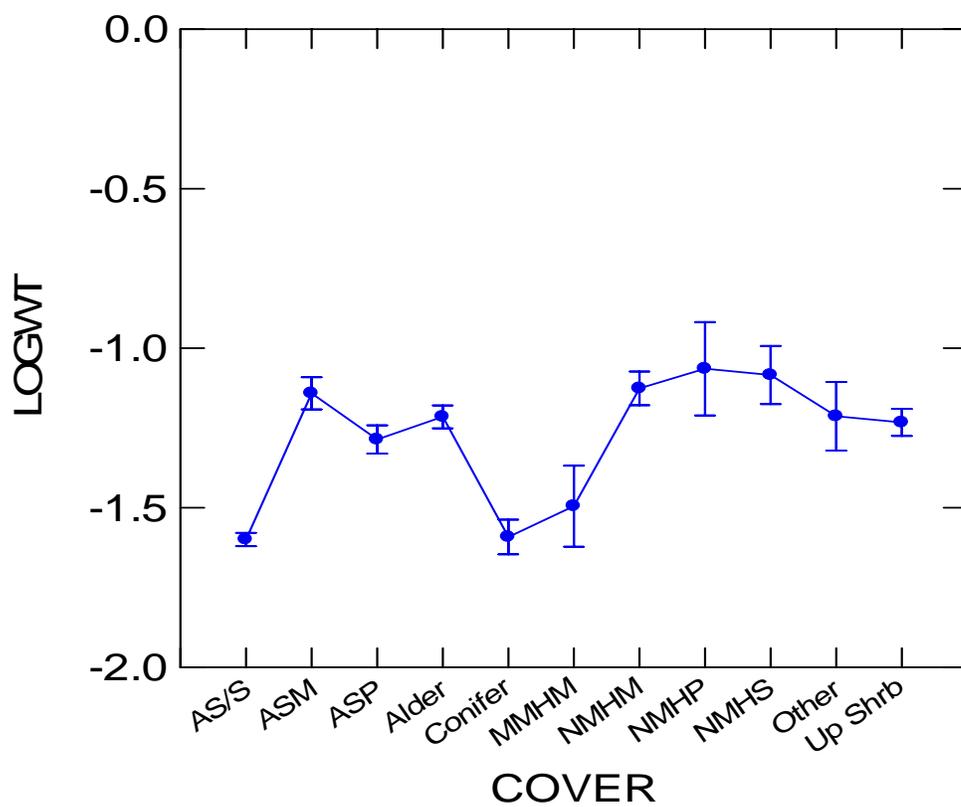
**Figure 3.1. American woodcock study areas in Michigan, Minnesota, and Wisconsin—the western Great Lakes Region**



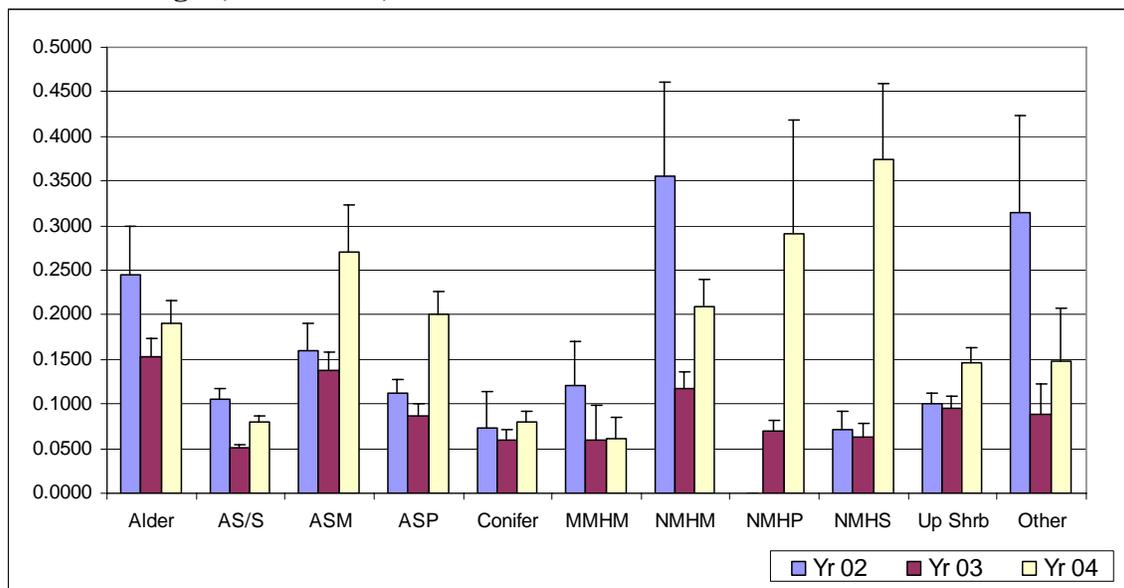
**Figure 3.2. Scatter plot of log transformed earthworm weights for all locations where earthworms were sampled and found from 2002 - 2004 and date indicating no time (date) effect given the random configuration of the data.**



**Figure 3.3. Least square mean comparisons of the log earthworm biomass by cover type for earthworms sampled in Michigan, Minnesota, and Wisconsin from 2002-2004.**



**Figure 3.4. Mean ash-free dry earthworm weights (in grams) by cover type and year across Michigan, Minnesota, and Wisconsin.**



## *Chapter IV*

### *Conclusions*

Woodcock migration has often been noted by outdoor enthusiasts and hunters who take note when “flight birds are in”. High numbers of woodcock seen afield in late fall may be a result of resident woodcock grouping before migration or they could indeed be northern birds that are either resting in route or grounded due to adverse weather. None of these circumstances, however, provides much information on factors responsible for influencing woodcock migration. Similar problems have troubled research attempts aimed at determining factors that influence migration by observing woodcock in the process of migration. Such attempts assume factors responsible for initiating migration are the same factors that influence behavior in route. Counts of birds in migration are an imprecise reflection of the numbers taking off, and are not ideal for analysis of weather effects on the propensity to migrate (Richardson 1990). My research was the first attempt to elucidate the relationship between environmental and weather factors in determining the timing (*initiation*) of woodcock migration for resident woodcock in fall.

Results of my investigation indicated that there are many factors that likely contribute to the onset of woodcock migration including factors often described by observations of woodcock in the process of migration, namely synoptic weather variables of low pressure systems like barometric pressure changes and northwest wind directions (Krohn 1973, Godfrey 1974). My research indicates that these weather variables may be of secondary importance to photoperiod, which served as the initial cue and in all years demonstrated the greatest influence on woodcock migration (Chapter 2). Photoperiod likely serves to

synchronize the *Zugstimmung*, the initiation of migration of woodcock such that woodcock at northern latitudes initiate migration prior to woodcock at lower latitudes despite proximate weather in different locales. This also helps explain why fall migration is reportedly more irregular and longer than in spring (Keppie and Whiting 1994). Woodcock on wintering ranges occupy more similar latitudes and photoperiods than they do spread over the broad area of their breeding range and acting on photoperiod alone woodcock migration would be more concentrated from wintering grounds in spring.

Once migration begins, local weather influenced the rate of migration; however, I found no association of earthworm availability influencing the timing of migration. Moon phase was important in modifying the timing of migration as has been suggested in past research (Krementz 1994). My research indicates that woodcock tend to depart near a full moon which likely serves as a navigational aid. I found no indication that woodcock departure is different between sexes or ages. This indicates that different harvest ratios of woodcock are not likely directly related to differences in the timing of departure. This is especially noteworthy when considering the higher harvest ratio of adult female woodcock in fall hunting seasons (Kelly 2005).

I found after hatch year (AHY) female woodcock in our study used a diverse mix of cover types. This finding makes defining quality woodcock habitat problematic (Chapter 3). My finding of woodcock using many cover types suggests woodcock habitat management is more complex than the traditional mantra of simply providing early seral cover types. I found alder cover used extensively in all states during 2002, a drought year, for example. This should remind managers not to oversimplify woodcock habitat needs into acres of seedling/sapling forest habitat. Most forest inventory figures, for example, do not include

area estimates for alder or lowland brush, both habitat types of equal importance to aspen as an indicator of woodcock habitat (Gregg 1984).

My investigation of woodcock habitat indicates that AHY female woodcock are not selecting habitat on the basis of food procurement. I found no differences in earthworm abundance between sites used by AHY female woodcock and similar sites within the same stand (micro-habitat scale). Similarly, woodcock frequently used cover types with lower worm abundance than neighboring covers available to them (home range scale; between 35 – 200 m from use locations).

I did find evidence that AHY female woodcock select habitat at different scales on the basis of structural characteristics using stem density and edge proximity at the micro-habitat scale and edge proximity alone at the home range scale. At a micro scale AHY female woodcock demonstrated a negative association to mature tree stems in seedling sapling aspen and upland shrub covers. Our AHY female woodcock also showed evidence of selecting young aspen covers with a shrub component. At both scales woodcock demonstrated an affinity for proximity (within 15 m) to edges, especially meadow edges.

My investigation of AHY female habitat use emphasizes the need for management of a diversity of habitats especially a range of early seral habitat types in close proximity and with interspersed openings. My study also suggests that leaving residual large trees in clear cuts should be avoided when possible. Site quality may also be an important consideration when placing clear cuts and I would recommend cutting over a range of soils types to ensure adequate shrub development for woodcock diurnal habitat needs.

Additional research is needed to determine whether existing forest inventory data adequately captures the diversity of habitats woodcock use especially shrub and alder covers

and whether GIS technology scales can improve upon those data. The many failed attempts at correlating woodcock population data to forest inventory data suggests to me a need to focus on better refined scales of observing habitat and/or population indices. I also recommend that controlled experiments on woodcock related to photoperiod be conducted, in particular it is of interest to know if photoperiod controls aspects of woodcock physiology and development. Photoperiod could have important implications on the speed of development; especially with late re-nest attempts, and the timing of molts.

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**Appendix I. Fall period climate summary for nearest National Oceanic and Atmospheric Administration data source to study areas in Michigan (Iron Mountain), Minnesota (Milaca) and Wisconsin (Merrill).**

<b>2002</b>	<b>Michigan</b>				<b>Minnesota</b>				<b>Wisconsin</b>			
<b>Temp</b>	Aug	Sept	Oct	Nov	Aug	Sept	Oct	Nov	Aug	Sept	Oct	Nov
Mean	67.2	60.98	41	29.5	66.6	60.1	38.4	29.1	66.8	60.1	40.6	29.8
Dep Norm	1.3	4.1	-4.2	-1.7	-0.1	3.1	-6.2	0	1.5	4.2	-4.1	-0.6
Low	46	34	20	11	46	32	13	11	45	33	20	12
# < 32	0	0	18	29	0	1	19	30	0	0	20	29
<b>Precip</b>												
Total	3.91	3.55	6.25	0.31	4.39	5.49	3.19	0.08	5.23	5.31	4.21	0.27
Dep Norm	0.13	-0.1	3.6	-1.72	0.35	2.58	0.9	-1.6	0.88	1.02	1.62	-2.08
Max Snow												
Depth	0	0	8	1	0	0	8	1	0	0	7	1
Max Snow			22-	23-			21-	21-			22-	30-
Date	x	x	Oct	Nov	x	x	Oct	Nov	x	x	Oct	Nov
Total Snow	0	0	8.5	0.7	0	0	8.0	1.0	0	0	7.0	0.5
<b>2003</b>	<b>Michigan</b>				<b>Minnesota</b>				<b>Wisconsin</b>			
<b>Temp</b>	Aug	Sept	Oct	Nov	Aug	Sept	Oct	Nov	Aug	Sept	Oct	Nov
Mean	68.8	59	44.8	32.1	69.9	58.5	46.9	26.9	69.4	58.5	44.9	30.3
Dep Norm	2.9	2.2	-0.4	0.9	3.2	1.5	2.3	-2.2	4.1	2.6	0.2	-0.1
Low	43	30	25	8	42	30	20	1	42	28	22	4
# < 32	0	2	15	25	0	2	14	27	0	2	17	26
<b>Precip</b>												
Total	5.32	4.46	1.17	1.91	0.77	3.25	1.46	0.68	2.44	2.88	0.98	2.03
Dep Norm	1.54	0.81	-1.48	-0.12	3.27	0.34	-0.83	-1	1.91	1.41	-1.61	-0.32
Max Snow												
Depth	0	0	0	1	0	0	1	6	0	0	0	1
Max Snow			1-	5-			30-	24-				25-
Date	x	x	Oct	Nov	x	x	Oct	Nov	x	x	x	Nov
Total Snow	0	0	0.5	2.3	0	0	1.0	10.5	0	0	0	1.5
<b>2004</b>	<b>Michigan</b>				<b>Minnesota</b>				<b>Wisconsin</b>			
<b>Temp</b>	Aug	Sept	Oct	Nov	Aug	Sept	Oct	Nov	Aug	Sept	Oct	Nov
Mean	61.7	62.2	47	34.6	61.5	62.7	47	34.2	60.6	61.4	45.8	34
Dep Norm	-4.2	5.4	1.8	3.4	-5.2	5.7	2.4	5.1	-4.7	5.5	1.1	3.6
Low	37	30	24	13	36	34	26	12	35	30	24	12
# < 32	0	1	10	25	0	0	8	22	0	2	14	23
<b>Precip</b>												
Total	3.48	1.74	4.9	1.78	1.96	6.5	3.39	0.64	2.16	2.58	5.38	1.56
Dep Norm	-0.3	-1.91	2.25	-0.25	2.08	3.59	1.1	-1.04	2.19	1.71	2.79	-0.79
Max Snow												
Depth	0	0	0	2	0	0	0	1	0	0	0	1
Max Snow				29-				27-				28-
Date	x	x	x	Nov	x	x	x	Nov	x	x	x	Nov
Total Snow	0	0	0	3.0	0	0	0	1.3	0	0	0	1.0

**Appendix II. Results of exponential survival model analysis of time dependent covariate effects on departure.**

	<u>Michigan</u>		<u>Minnesota</u>		<u>Wisconsin</u>		<u>All States</u>	
2002	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value
intercept	-66.695	<b>0.036</b>	x	x	-91.689	0.924	-4.709	0.294
BP	2.735	<b>0.022</b>	x	x	3.161	0.920	0.285	<b>0.027</b>
BPC	-0.359	0.392	x	x	0.130	0.947	0.413	<b>0.061</b>
BPT	2.592	0.551	x	x	1.187	0.619	2.736	<b>0.002</b>
RH	-0.006	0.768	x	x	0.019	0.909	0.017	<b>0.014</b>
MOON	0.352	0.293	x	x	0.058	0.990	0.466	<b>0.057</b>
WW	0.666	0.208	x	x	1.108	0.898	0.282	<b>0.080</b>
VIS	0.287	<b>0.098</b>	x	x	0.122	0.574	0.178	<b>0.002</b>
DL	-0.026	<b>0.001</b>	x	x	-0.020	0.704	-0.018	<b>&lt;0.001</b>
2003	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value
intercept	-70.921	0.752	-31.875	0.494	13.583	0.757	2.288	0.559
BP	2.953	0.700	1.496	0.335	-0.098	0.947	0.300	<b>0.007</b>
BPC	-0.443	0.245	-0.953	<b>0.026</b>	0.223	0.725	-0.139	0.435
RH	0.022	0.196	0.017	0.515	0.010	0.379	0.010	0.105
MOON	1.107	0.545	0.636	0.436	0.941	0.207	0.910	<b>0.003</b>
WW	-0.945	0.182	0.619	0.319	-0.092	0.870	0.137	0.541
DL	-0.028	<b>0.000</b>	-0.023	<b>0.001</b>	-0.025	<b>0.006</b>	-0.024	<b>&lt;0.001</b>
2004	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value
intercept	-3.926	0.875	129.006	0.650	4.845	0.944	-3.137	0.373
BP	0.275	0.758	-4.413	0.664	0.114	0.960	0.246	<b>0.044</b>
BPT	-0.773	0.606	3.644	0.268	-1.065	0.310	2.127	<b>&lt;0.001</b>
RH	0.023	0.184	-0.024	0.726	0.011	0.686	-0.008	0.183
PREC	0.646	0.591	-3.682	0.214	-1.054	<b>0.043</b>	-0.841	<b>0.012</b>
RDIR <sub>nw</sub>	1.915	<b>0.000</b>	-0.216	0.743	1.389	<b>0.051</b>	0.671	<b>0.002</b>
RDIR <sub>s</sub>	0.950	0.196	-1.489	0.345	1.411	<b>0.070</b>	0.332	0.146
MOON	-0.251	0.772	2.749	0.362	1.277	<b>0.012</b>	1.139	<b>0.000</b>
WW	-0.250	0.521	-2.192	0.459	-0.186	0.491	-0.294	<b>0.078</b>
VIS	0.219	<b>0.080</b>	-0.213	0.543	0.021	0.507	0.082	<b>&lt;0.001</b>
DL	-0.019	<b>0.007</b>	-0.001	0.956	-0.024	<b>&lt;0.001</b>	-0.016	<b>&lt;0.001</b>
ALL	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value	$\hat{\beta}$	P-value
intercept	-14.583	0.227	-12.888	0.482	1.983	0.842	0.130	0.949
BP	0.765	<b>0.059</b>	0.682	0.297	0.182	0.584	0.194	<b>0.002</b>
BPT	0.991	0.189	3.466	<b>&lt;0.001</b>	0.213	0.696	1.632	<b>&lt;0.001</b>
TA	-0.037	<b>0.002</b>	0.023	0.117	-0.003	0.746	-0.013	<b>0.023</b>
RH	0.010	0.106	0.006	0.468	0.004	0.517	0.005	0.173
RHC	-0.007	0.181	-0.003	0.632	0.010	<b>0.043</b>	0.004	0.159
PREC	0.235	0.653	-1.407	<b>0.011</b>	0.168	0.428	-0.287	<b>0.084</b>
RDIR <sub>nw</sub>	0.600	<b>0.004</b>	0.415	<b>0.063</b>	0.331	0.146	0.432	<b>0.000</b>
RWND	0.006	0.823	-0.020	0.537	-0.022	0.350	-0.027	<b>0.047</b>
MOON	0.375	<b>0.097</b>	0.834	<b>0.008</b>	0.732	<b>0.001</b>	0.765	<b>&lt;0.001</b>
WW	-0.071	0.617	0.259	0.176	0.357	<b>0.036</b>	0.125	0.150
VIS	0.007	0.886	0.147	<b>0.076</b>	0.008	0.725	0.057	<b>0.000</b>
DL	-0.018	<b>&lt;0.001</b>	-0.024	<b>0.000</b>	-0.020	<b>&lt;0.001</b>	-0.019	<b>&lt;0.001</b>

**Appendix III. Cover type use (% of total n by individual) for AHY female woodcock with greater than 10 sampled locations in Michigan, Minnesota, and Wisconsin from 2002-2004.**

MI 2002	(n)	Alder	AS/S	ASM	ASP	Meadow	MMHM	NMHM	NMHP	NMHS	Conifer	Up Shrb	Willow
150.123	20	25	65	--	5	--	5	--	--	--	--	--	--
151.451	15	13	73	--	--	--	--	13	--	--	--	--	--
151.613	22	--	--	--	--	--	--	--	--	--	95	5	--
151.662	30	--	73	--	17	--	--	7	--	--	3	--	--
151.693	10	--	--	--	--	--	--	--	--	100	--	--	--
151.852	13	23	--	--	--	--	69	--	--	--	8	--	--
Total (%)		9	39	0	5	0	11	3	0	12	20	1	0

MN 2002	(n)	Alder	AS/S	ASM	ASP	Meadow	MMHM	NMHM	NMHP	NMHS	Conifer	Up Shrb	Willow
150.022	32	--	--	9	28	3	--	--	--	--	--	--	59
150.044	36	8	--	17	75	--	--	--	--	--	--	--	--
150.053	35	37	3	6	6	--	--	3	--	--	--	23	23
150.102	33	3	55	15	18	--	--	3	--	--	--	6	--
150.203	34	71	3	--	6	--	--	3	--	--	--	3	15
150.242	25	12	76	--	--	--	--	12	--	--	--	--	--
150.301	30	--	63	3	--	--	--	3	--	--	--	17	10
150.323	25	--	4	4	72	--	--	4	--	--	--	4	12
150.473	32	--	75	19	--	--	--	0	--	3	--	3	--
150.632	16	50	--	--	44	--	--	0	--	--	--	--	6
150.703	11	82	--	--	--	--	--	0	--	--	--	--	18
Total (%)		20	27	8	23	0	0	3	0	0	0	6	13

WI 2002	(n)	Alder	AS/S	ASM	ASP	Meadow	MMHM	NMHM	NMHP	NMHS	Conifer	Up Shrb	Willow
150.922	25	--	96	--	--	--	--	--	--	4	--	--	--
150.942	15	27	60	--	--	--	--	--	--	--	--	13	--
151.151	28	7	54	7	7	--	--	11	--	--	--	14	--
151.591	27	--	100	--	--	--	--	--	--	--	--	--	--
151.662	30	--	97	--	--	--	--	3	--	--	--	--	--
151.722	17	94	--	--	--	--	--	6	--	--	--	--	--
151.763	13	--	77	--	8	--	--	--	--	15	--	--	--
151.862	28	4	50	7	7	--	--	25	--	4	--	4	--
151.962	18	--	100	--	--	--	--	--	--	--	--	--	--
Total (%)		11	72	2	2	0	0	6	0	2	0	3	0

**Appendix III (continued)**

MI 2003	(n)	Alder	AS/S	ASM	ASP	Meadow	MMHM	NMHM	NMHP	NMHS	Conifer	Up Shrb	Willow
150.122	14	29	7	--	14	7	7	7	--	--	29	--	--
150.183	10	10	90	--	--	--	--	--	--	--	--	--	--
150.951	35	37	29	20	--	--	--	3	--	--	11	--	--
151.361	39	13	13	--	--	--	--	--	--	--	74	--	--
151.412	18	28	28	11	--	--	--	11	--	--	22	--	--
151.473	32	3	94	--	--	--	--	3	--	--	--	--	--
151.543	45	--	51	--	2	--	--	--	--	--	47	--	--
151.622	38	--	66	--	3	3	--	--	--	--	29	--	--
151.702	45	7	80	--	--	--	--	--	--	--	13	--	--
151.772	44	2	5	27	52	--	2	2	--	--	7	2	--
151.811	45	16	20	4	--	--	--	--	--	--	60	--	--
151.923	45	24	64	--	--	2	--	--	--	--	9	--	--
Total (%)		12	45	6	7	1	0	1	0	0	28	0	0

MN 2003	(n)	Alder	AS/S	ASM	ASP	Meadow	MMHM	NMHM	NMHP	NMHS	Conifer	Up Shrb	Willow
150.002	21	5	--	52	10	--	--	--	5	--	--	24	5
150.083	38	--	29	--	39	--	--	21	8	--	--	--	3
150.093	41	22	--	5	12	--	--	--	--	--	--	5	56
150.133	26	77	--	--	--	--	--	19	--	--	--	4	--
150.382	40	5	15	5	15	3	5	--	--	--	--	3	50
150.393	26	23	12	4	4	4	--	38	8	--	--	4	4
150.403	20	35	--	--	35	--	--	--	--	--	--	5	25
150.583	22	23	--	9	--	--	--	--	--	--	--	14	55
150.922	26	8	27	4	12	--	4	15	8	23	--	--	--
150.942	19	--	84	--	11	--	--	5	--	--	--	--	--
151.192	35	11	83	--	--	3	--	3	--	--	--	--	--
151.223	25	--	40	--	4	4	--	44	8	--	--	--	--
151.242	10	70	--	--	--	--	--	--	--	--	--	--	30
151.323	26	15	73	--	8	--	--	--	--	--	--	--	4
151.403	34	62	6	3	3	--	--	21	6	--	--	--	--
151.683	29	10	3	10	38	--	--	--	3	--	--	10	24
151.992	37	19	49	--	--	3	5	8	8	8	--	--	--
Total (%)		22	25	5	12	1	1	10	3	2	0	4	15

## Appendix III (continued)

WI 2003	(n)	Alder	AS/S	ASM	ASP	Meadow	MMHM	NMHM	NMHP	NMHS	Conifer	Up Shrb	Willow
150.571	11	--	--	100	--	--	--	--	--	--	--	--	--
150.643	15	13	7	40	27	--	--	13	--	--	--	--	--
150.692	18	--	72	--	28	--	--	--	--	--	--	--	--
150.713	34	--	97	--	--	--	--	3	--	--	--	--	--
150.811	40	--	95	--	--	--	--	3	--	--	3	--	--
150.823	22	--	9	--	86	--	--	--	--	5	--	--	--
150.913	36	36	3	50	3	--	6	--	3	--	--	--	--
150.924	38	--	97	--	--	--	--	--	--	--	3	--	--
150.973	35	54	9	9	--	--	--	17	--	--	11	--	--
151.044	30	93	7	--	--	--	--	--	--	--	--	--	--
151.291	36	3	28	6	--	--	3	39	--	8	14	--	--
151.302	31	55	39	--	--	--	--	6	--	--	--	--	--
151.465	40	25	5	45	5	--	5	--	5	3	8	--	--
151.533	35	23	43	3	--	--	6	23	3	--	--	--	--
151.582	46	11	--	33	--	--	--	48	--	--	7	2	--
151.882	48	2	79	--	8	--	--	10	--	--	--	--	--
Total (%)		20	40	15	7	0	2	12	1	1	3	0	0
WI 2004	(n)	Alder	AS/S	ASM	ASP	Meadow	MMHM	NMHM	NMHP	NMHS	Conifer	Up Shrb	Willow
150.293	19	--	53	--	42	5	--	--	--	--	--	--	--
150.442	23	30	39	30	--	--	--	--	--	--	--	--	--
150.542	23	22	4	--	4	--	--	39	--	--	4	26	--
150.722	34	--	6	21	--	--	--	6	3	62	--	3	--
150.851	10	--	100	--	--	--	--	--	--	--	--	--	--
150.911	20	10	15	30	5	--	--	10	--	--	5	25	--
150.972	30	20	77	--	3	--	--	--	--	--	--	--	--
151.000	33	52	3	6	3	--	--	9	--	12	--	15	--
151.261	34	38	47	--	--	--	--	3	3	6	3	--	--
151.284	33	--	67	--	--	--	--	9	12	12	--	--	--
151.301	36	11	17	11	19	--	--	33	3	--	3	3	--
151.442	27	56	41	--	--	--	--	4	--	--	--	--	--
151.503	30	--	10	23	57	--	--	--	--	--	--	10	--
151.583	11	--	82	--	--	--	--	--	--	18	--	--	--
151.763	40	--	95	--	--	3	--	--	--	3	--	--	--
151.892	35	11	80	6	--	3	--	--	--	--	--	--	--
151.955	34	35	--	--	3	--	--	--	--	--	62	--	--
Total (%)		18	42	7	8	1	0	7	1	7	5	4	0

## Appendix III (continued)

MI 2004	(n)	Alder	AS/S	ASM	ASP	Meadow	MMHM	NMHM	NMHP	NMHS	Conifer	Up Shrb	Willow
150.071	19	--	58	5	5	--	--	--	--	--	32	--	--
150.083	30	13	47	--	23	--	--	13	--	--	3	--	--
150.282	22	--	95	--	--	--	--	5	--	--	--	--	--
150.301	41	--	100	--	--	--	--	--	--	--	--	--	--
150.332	18	17	67	17	--	--	--	--	--	--	--	--	--
150.402	33	--	67	--	--	--	--	30	--	--	3	--	--
150.482	22	5	91	5	--	--	--	--	--	--	--	--	--
150.551	41	2	93	5	--	--	--	--	--	--	--	--	--
150.912	31	13	77	--	--	--	--	--	--	--	3	6	--
151.022	15	--	7	--	--	47	--	--	--	--	47	--	--
151.382	37	3	14	5	8	--	--	--	--	--	70	--	--
151.693	36	11	58	--	--	8	--	11	--	--	11	--	--
151.711	26	42	35	--	4	--	--	8	--	--	12	--	--
151.873	37	--	89	3	3	--	--	--	--	--	5	--	--
151.902	41	15	85	--	--	--	--	--	--	--	--	--	--
151.953	10	10	90	--	--	--	--	--	--	--	--	--	--
Total (%)		8	69	2	3	2	0	5	0	0	11	0	0

MN 2004	(n)	Alder	AS/S	ASM	ASP	Meadow	MMHM	NMHM	NMHP	NMHS	Conifer	Up Shrb	Willow
150.772	31	--	19	--	6	--	--	--	--	--	--	3	68
150.863	12	8	--	83	8	--	--	--	--	--	--	--	--
150.901	18	22	--	6	17	--	--	28	--	--	--	--	28
150.982	31	10	--	32	19	--	--	16	23	--	--	--	--
151.042	29	--	31	--	17	--	17	--	--	--	--	3	7
151.180	31	--	13	3	6	--	13	23	--	--	--	10	3
151.302	16	--	6	6	13	--	13	--	--	--	--	6	6
151.713	32	--	3	--	13	--	3	--	--	--	--	9	3
151.833	30	20	7	10	33	7	--	--	--	3	--	10	10
151.933	31	13	55	--	13	--	--	19	--	--	--	--	--
Total (%)		8	15	9	15	1	5	9	4	0	0	13	22

**Appendix IV A. The mean number of stems/ha by size class for cover types in Michigan 2002**

Aspen Seed/Sap (n=24) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	4989.25	4745.41	5115.48	5060.55	-1.429	0.166
Seed/sapling	4651.39	3457.77	5309.90	5000.71	-0.776	0.445
Pole	156.25	302.28	93.75	253.37	2.304	0.031
Mature	0.00	0.00	0.00	0.00	0.000	0.000
Rubus variable	1.67	0.92	1.79	0.88	-0.827	0.417

Alder (n=4) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	1081.84	658.44	1830.36	795.60	-1.252	0.299
Seed/sapling	2966.67	891.21	2953.13	1022.37	0.098	0.928
Pole	125.00	144.34	62.50	125.00	0.522	0.638
Mature	0.00	0.00	62.50	125.00	-1.000	0.391
Rubus variable	1.25	0.96	1.75	0.50	-1.732	0.182

Northern Mixed Hardwoods (n=5) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	4334.11	2503.52	3321.02	1742.17	1.096	0.335
Seed/sapling	2091.55	744.98	2216.67	845.30	-0.227	0.833
Pole	50.00	111.80	0.00	0.00	1.000	0.374
Mature	0.00	0.00	0.00	0.00	na	na
Rubus variable	2.60	0.89	3.00	0.00	-1.000	0.374

Conifer Stand (n=10) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	2913.06	2562.52	3466.25	3147.15	-0.396	0.702
Seed/sapling	1495.83	1331.12	608.33	593.56	2.030	0.073
Pole	325.00	271.31	350.00	282.05	-0.218	0.832
Mature	222.92	174.59	475.00	447.99	-1.700	0.123
Rubus variable	0.20	0.42	0.10	0.32	1.000	0.343

Mesic Mixed Hardwoods (n=6) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	2060.42	1704.84	2202.78	3193.49	-0.090	0.931
Seed/sapling	1611.11	888.06	2475.69	4173.50	-0.454	0.669
Pole	250.00	136.93	152.78	238.14	1.019	0.355
Mature	250.00	223.61	83.33	129.10	1.348	0.235
Rubus variable	0.50	0.55	0.83	0.41	-1.581	0.175

**Appendix IV B. The mean number of stems/ha comparisons by size class for cover types in Minnesota 2002**

Aspen Seedling / Sapling ( n=32) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	5962.50	4903.28	4158.98	2833.06	1.929	0.0630
Seed/sapling	6802.98	4378.69	9792.95	8377.93	-2.547	0.0160
Pole	148.44	268.35	113.28	204.19	0.800	0.4295
Mature	109.38	323.40	50.78	134.18	0.919	0.3651
Rubus variable	1.25	0.67	1.19	0.86	0.360	0.7212

Aspen Pole (n=26) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	4583.33	3201.90	5930.61	4250.27	-1.329	0.1957
Seed/sapling	1529.49	1379.62	1739.42	1908.65	-0.493	0.6264
Pole	889.42	707.40	836.54	957.06	0.272	0.7882
Mature	115.38	176.50	96.15	142.77	0.420	0.6784
Rubus variable	1.73	0.83	1.58	0.86	1.162	0.2560

Aspen Mature ( n= 8) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	5697.40	2853.90	6391.15	2662.28	-0.843	0.4270
Seed/sapling	2926.04	3118.54	2338.54	2046.63	0.912	0.3920
Pole	359.38	408.82	625.00	1274.75	-0.819	0.4397
Mature	531.25	451.93	281.25	247.76	1.214	0.2641
Rubus variable	0.75	1.04	1.25	1.04	-1.183	0.2753

Alder (n=19) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	9795.61	6386.24	6891.67	2870.04	2.202	0.0410
Seed/sapling	237.94	424.77	355.26	495.23	-1.382	0.1839
Pole	157.89	521.82	111.84	238.97	0.405	0.6899
Mature	13.16	57.35	72.37	152.05	-1.531	0.1431
Rubus variable	1.84	1.17	1.89	0.99	-0.175	0.8631

Northern Mature Hardwoods (n=4) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	6729.17	4312.25	3750.00	2334.08	1.035	0.3770
Seed/sapling	2223.96	2053.77	1819.94	973.72	0.362	0.7415
Pole	437.50	426.96	187.50	239.36	1.732	0.1817
Mature	125.00	144.34	125.00	144.34	0.000	1.0000
Rubus variable	0.50	0.58	0.25	0.50	0.196	0.3910

## Appendix IV B. (continued)

Upland Shrub (n=12) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	10734.38	4161.44	12121.88	5832.47	-0.821	0.4293
Seed/sapling	1154.17	1400.48	588.54	569.38	1.321	0.2132
Pole	333.33	587.11	83.33	162.83	1.459	0.1725
<b>Mature</b>	<b>41.67</b>	<b>97.31</b>	<b>239.58</b>	<b>294.16</b>	<b>-2.370</b>	<b>0.0372</b>
Rubus variable	1.58	0.90	1.17	0.72	1.449	0.1753

Willow (n=22) Stems/Ha by size	Use		Random		t	p
	Mean	St. Dev	Mean	St. Dev		
Shrub	10301.33	10374.05	5743.77	7149.94	-0.042	0.9672
Seed/sapling	340.91	431.82	441.83	732.66	-0.629	0.5364
Pole	113.64	125.00	167.75	264.46	-0.182	0.8577
Mature	45.45	34.09	125.27	87.81	0.326	0.7473
<b>Rubus variable</b>	<b>1.77</b>	<b>1.14</b>	<b>1.15</b>	<b>0.99</b>	<b>3.780</b>	<b>0.0011</b>

**Appendix IV C. The mean number of stems/ha by size class for cover types in Wisconsin 2002**

<b>Aspen s/s (n=55)</b>	<b>Use</b>			<b>Random</b>				
<b>Stems/Ha by size</b>	<b>Mean</b>	<b>St. Dev</b>	<b>SE</b>	<b>Mean</b>	<b>St. Dev</b>	<b>SE</b>	<b>t</b>	<b>p</b>
Shrub	3508	4728	638	3675	4025	543	-0.22	0.823
Seed/sapling	5805	3613	487	6182	3307	446	-0.88	0.385
Pole	36.4	155.3	20.9	40.9	157.8	21.3	-0.33	0.742
<b>Mature</b>	<b>5</b>	<b>34</b>	<b>5</b>	<b>200</b>	<b>852</b>	<b>115</b>	<b>-1.7</b>	<b>0.094</b>
Rubus variable	1.345	0.865	0.117	1.236	0.637	0.086	0.95	0.347

<b>Alder (n=7)</b>	<b>Use</b>			<b>Random</b>				
<b>Stems/Ha by size</b>	<b>Mean</b>	<b>St. Dev</b>	<b>SE</b>	<b>Mean</b>	<b>St. Dev</b>	<b>SE</b>	<b>t</b>	<b>p</b>
Shrub	15500	9183	3471	12518	9075	3430	0.65	0.538
Seed/sapling	357	470	178	36	94	36	1.67	0.146
Pole	71.4	189	71.4	0	0	0	1	0.356
Mature	71.4	122	46.1	0	0	0	1.55	0.172
Rubus variable	1.429	1.134	0.429	1.429	0.976	0.369	0	1

<b>NMHM (n=5)</b>	<b>Use</b>			<b>Random</b>				
<b>Stems/Ha by size</b>	<b>Mean</b>	<b>St. Dev</b>	<b>SE</b>	<b>Mean</b>	<b>St. Dev</b>	<b>SE</b>	<b>t</b>	<b>p</b>
Shrub	9671	3904	1746	9440	11391	5094	0.050	0.960
Seed/sapling	1183	511	228	1617	704	315	-0.960	0.389
Pole	125	177	79	450	473	211	-1.770	0.152
Mature	150	136.9	61.2	150	136.9	61.2	0.000	1.000
Rubus variable	1.4	1.14	0.51	1.4	1.342	0.6	0.000	1.000

**Appendix V. Stem densities (stems/Ha) at sites used by woodcock and random sites within the same stand for radio-marked woodcock in Wisconsin, Michigan, and Minnesota, from September to November 2002.**

State	Woodcock I.D. ( <i>n</i> )	Cover Type	Stem size	Use		Random		<i>P</i> -value
				Mean	SD	Mean	SD	
Wisconsin	150.942 (5)	AS/S <sup>a</sup>	Seed/Sap	9949.0	8389.0	5927.0	4620.00	0.101
Wisconsin	151.862 (6)	AS/S	Shrub	12439.0	6188.0	5326.0	3787.00	0.093
Minnesota	150.053 (3)	Alder <sup>b</sup>	Shrub	7791.7	1582.8	5770.8	641.45	0.066
Minnesota	150.203 (9)	Alder	Shrub	12851.9	6679.9	8229.2	3189.71	0.099
Minnesota	150.323 (7)	ASP <sup>c</sup>	Pole	517.9	398.1	250.0	260.21	0.047
Minnesota	150.301 (6)	AS/S	Seed/Sap	8822.9	6223.0	22041.7	7625.07	0.000
Minnesota	150.022 (4)	Willow <sup>d</sup>	Rubus <sup>e</sup>	2.0	0.8	1.0	0.82	0.092
Minnesota	150.792 (11)	Willow	Rubus	1.6	1.1	0.9	0.82	0.024
Michigan	151.451 (6)	AS/S	Seed/Sap	5531.3	2008.5	9666.7	3914.45	0.063
Michigan	151.662 (12)	AS/S	Pole	145.8	198.2	41.7	9731.00	0.054

<sup>a</sup> Aspen seedling/sapling cover type

<sup>b</sup> Alder cover type

<sup>c</sup> Pole-sized aspen cover

<sup>d</sup> Willow cover type

<sup>e</sup> *Rubus* values are measures of density on a Braun-Blanquet cover scale

**Appendix VI A. Mean stems/ha comparisons by size and cover type for individual woodcock in Michigan 2002.**

Bird ID (n)	Stems/ha	Mean	Std. Dev.	T-stat	P-value
150.123 (6)	Shrub Use	604.17	388.86	-1.784	0.135
	Shrub Random	2218.75	2381.49		
	Seed/Sap Use	7625.00	3615.07	-0.226	0.830
	Seed/Sap Random	8072.92	5411.56		
	Pole Use	333.33	516.40	1.000	0.363
	Pole Random	291.67	458.71		
	Rubus value use	2.33	0.82	-1.000	0.363
	Rubus value random	2.50	0.55		

Bird ID (n)	Mean # stems	Mean	Std. Dev.	T-stat	P-value
151.451(6)	Shrub Use	1450.69	1119.47	0.363	0.732
	Shrub Random	1248.61	831.08		
	Seed/Sap Use	5531.25	2008.48	-2.387	0.063
	Seed/Sap Random	9666.67	3914.45		
	Rubus value use	2.17	0.75	0.000	1.000
	Rubus value random	2.17	0.98		

Bird ID (n)	Mean # stems	Mean	Std. Dev.	T-stat	P-value
151.662 (12)	Shrub Use	8951.07	3464.86	-0.862	0.407
	Shrub Random	9697.28	3975.65		
	Seed/Sap Use	2724.65	2816.05	1.221	0.248
	Seed/Sap Random	1750.00	1915.35		
	Pole Use	145.83	198.24	2.159	0.054
	Pole Random	41.67	97.31		
	Rubus value use	1.08	0.67	-1.483	0.166
	Rubus value random	1.25	0.62		

**Appendix VI B. Mean stems/ha comparisons by size and cover type for individual woodcock in Minnesota 2002.**

Bird ID (n)	Stems/ha	Mean	Std. Dev.	T-stat	P-value
150.053 (3) Alder Cover	Shrub Use	7791.67	1582.78	3.698	0.0660
	Shrub Random	5770.83	641.45		
	Seed/Sap Use	416.67	144.34	-0.862	0.4797
	Seed/Sap Random	722.22	473.85		
	Pole Use	83.33	144.34	-1.941	0.1917
	Pole Random	375.00	330.72		
	Mature Use	0	0.00	-1.000	0.4226
	Mature random	125	216.51		
	Rubus value use	1.00	1.33	-0.378	0.7418
	Rubus value random	1.00	0.58		
Bird ID (n)	Stems/ha	Mean	Std. Dev.	T-stat	P-value
150.203 (9) Alder Cover	Shrub Use	12851.85	6679.90	1.866	0.0990
	Shrub Random	8229.1667	3189.71		
	Seed/Sap Use	27.7777	83.33	-0.610	0.5590
	Seed/Sap Random	83.33	250.00		
	Pole Use	0.00	0.00	na	na
	Pole Random	0.00	0.00		
	Mature Use	0.00	0.00	na	na
	Mature random	0.00	0.00		
	Rubus value use	1.67	1.32	-1.315	0.2249
	Rubus value random	2.11	0.93		
Bird ID (n)	Stems/ha	Mean	Std. Dev.	T-stat	P-value
150.473 (3) Aspen Mature Cover	Shrub Use	5027.78	2118.59	-1.801	0.2134
	Shrub Random	5633.33	1581.75		
	Seed/Sap Use	3608.33	3214.84	1.799	0.2139
	Seed/Sap Random	2208.33	1897.09		
	Pole Use	375.00	216.51	1.732	0.2254
	Pole Random	250.00	250.00		
	Mature Use	583.33	520.42	1.109	0.3828
	Mature random	250.00	0.00		
	Rubus value use	0.00	0.00	0.211	0.4226
	Rubus value random	1.00	1.73		

## Appendix VI B. (continued)

Bird ID (n)	Stems/ha	Mean	Std. Dev.	T-stat	P-value
150.022 (5) Aspen Pole Cover	Shrub Use	4550.00	2864.62	-1.369	0.2430
	Shrub Random	8358.33	5781.44		
	Seed/Sap Use	491.67	323.29	0.087	0.9346
	Seed/Sap Random	450.00	873.21		
	Pole Use	800.00	758.29	0.726	0.5082
	Pole Random	400.00	575.54		
	Mature Use	100.00	223.61	0.408	0.7040
	Mature random	50.00	111.80		
	Rubus value use	0.80	0.45	0.000	1.0000
	Rubus value random	0.80	0.84		
Bird ID (n)	Stems/ha	Mean	Std. Dev.	T-stat	P-value
150.044 (9) Aspen Pole Cover	Shrub Use	3489.35	1360.64	-0.914	0.3873
	Shrub Random	4501.85	3410.12		
	Seed/Sap Use	1898.15	1125.41	-0.682	0.5148
	Seed/Sap Random	2458.33	2118.79		
	Pole Use	1111.11	638.74	-1.219	0.2576
	Pole Random	1583.33	1075.29		
	Mature Use	194.44	208.33	0.286	0.7824
	Mature random	166.67	176.78		
	Rubus value use	1.89	0.78	0.173	0.3466
	Rubus value random	1.67	0.87		
Bird ID (n)	Stems/ha	Mean	Std. Dev.	T-stat	P-value
150.323 (7) Aspen Pole Cover	Shrub Use	7084.52	4787.28	-0.392	0.7083
	Shrub Random	8255.36	3649.94		
	Seed/Sap Use	1803.57	1904.36	1.451	0.1970
	Seed/Sap Random	774.05	395.60		
	Pole Use	517.86	398.10	2.500	0.0465
	Pole Random	250.00	260.21		
	Mature Use	35.71	94.49	-0.548	0.6036
	Mature random	71.43	121.99		
	Rubus value use	2.14	0.69	0.000	1.0000
	Rubus value random	2.14	0.69		

## Appendix VI B. (continued)

Bird ID (n)	Stems/ha	Mean	Std. Dev.	T-stat	P-value
150.102 (5) Aspen Seedling/Sapling Cover	Shrub Use	4762.50	2545.74	0.612	0.5739
	Shrub Random	4193.33	1328.73		
	Seed/Sap Use	3968.21	1646.33	-1.176	0.3049
	Seed/Sap Random	5783.33	2454.87		
	Pole Use	250.00	353.55	0.187	0.3739
	Pole Random	300.00	325.96		
	Mature Use	150.00	136.93	1.633	0.1778
	Mature random	50.00	111.80		
	Rubus value use	1.20	0.45	0.374	0.7489
	Rubus value random	1.40	1.14		
Bird ID (n)	Stems/ha	Mean	Std. Dev.	T-stat	P-value
150.242 (7) Aspen Seedling/Sapling Cover	Shrub Use	5404.76	1698.56	-0.814	0.4466
	Shrub Random	6278.57	3667.06		
	Seed/Sap Use	4736.31	2078.39	1.153	0.2926
	Seed/Sap Random	3998.21	2083.06		
	Pole Use	35.71	94.49	0.000	1.0000
	Pole Random	35.71	94.49		
	Mature Use	35.71	94.49	-0.853	0.4262
	Mature random	125.00	239.36		
	Rubus value use	1.00	0.82	-0.354	0.7358
	Rubus value random	1.14	1.07		
Bird ID (n)	Stems/ha	Mean	Std. Dev.	T-stat	P-value
150.301 (6) Aspen Seedling/Sapling Cover	Shrub Use	4666.67	9605.55	1.156	0.2999
	Shrub Random	354.17	502.60		
	Seed/Sap Use	8822.92	6222.97	-5.960	0.0002
	Seed/Sap Random	22041.67	7625.07		
	Pole Use	166.667	408.25	1.000	0.3632
	Pole Random	0	0.00		
	Mature Use	83.33	204.12	1.000	0.3632
	Mature random	0.00	0.00		
	Rubus value use	1.00	0.00	na	na
	Rubus value random	1.00	0.00		

**Appendix VI B. (continued)**

<b>Bird ID (n)</b>	<b>Stems/ha</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>T-stat</b>	<b>P-value</b>
150.473 (8) Aspen Seedling/Sapling Cover	Shrub Use	7938.54	4355.08	1.358	0.2168
	Shrub Random	5171.88	2091.13		
	Seed/Sap Use	7049.48	3057.36	0.187	0.8571
	Seed/Sap Random	6835.94	4129.72		
	Pole Use	93.75	129.39	-0.552	0.5983
	Pole Random	125.00	188.98		
	Mature Use	31.25	88.39	0.000	1.0000
	Mature random	31.25	88.39		
	Rubus value use	1.88	0.83	1.667	0.1395
	Rubus value random	1.25	0.89		
<b>Bird ID (n)</b>	<b>Stems/ha</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>T-stat</b>	<b>P-value</b>
151.143 (5) Aspen Seedling/Sapling Cover	Shrub Use	5491.67	4114.31	1.221	0.2893
	Shrub Random	4121.67	939.71		
	Seed/Sap Use	10023.33	6066.47	-1.170	0.3070
	Seed/Sap Random	13781.55	7099.44		
	Pole Use	200.00	353.55	0.791	0.4734
	Pole Random	75.00	187.50		
	Mature Use	0.00	0.00	-1.000	0.3739
	Mature random	50.00	125.00		
	Rubus value use	1.00	0.00	-0.408	0.7040
	Rubus value random	1.20	1.26		
<b>Bird ID (n)</b>	<b>Stems/ha</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>T-stat</b>	<b>P-value</b>
150.053 (4) Upland Shrub Cover	Shrub Use	10682.29	5997.09	-0.014	0.9898
	Shrub Random	10703.13	5398.64		
	Seed/Sap Use	625.00	444.88	-1.000	0.3910
	Seed/Sap Random	843.75	779.79		
	Pole Use	500.00	1000.00	0.196	0.3910
	Pole Random	0.00	0.00		
	Mature Use	0.00	0.00	0.196	0.3910
	Mature random	93.75	187.50		
	Rubus value use	1.50	1.29	1.000	0.3910
	Rubus value random	1.25	0.96		

**Appendix VI B. (continued)**

<b>Bird ID (n)</b>	<b>Stems/ha</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>T-stat</b>	<b>P-value</b>
150.301 (4) Upland Shrub Cover	Shrub Use	11255.21	4916.85	-0.521	0.6384
	Shrub Random	13375.00	6758.57		
	Seed/Sap Use	1337.50	1425.00	1.109	0.3485
	Seed/Sap Random	593.50	534.00		
	Pole Use	250.00	353.55	0.000	1.0000
	Pole Random	250.00	204.12		
	Mature Use	125.00	144.34	-1.732	0.1817
	Mature random	500.00	353.55		
	Rubus value use	1.25	0.50	0.000	1.0000
	Rubus value random	1.25	0.50		
<b>Bird ID (n)</b>	<b>Stems/ha</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>T-stat</b>	<b>P-value</b>
151.143 (3) Upland Shrub Cover	Shrub Use	10812.50	1501.30	0.379	0.7409
	Shrub Random	9883.33	5741.15		
	Seed/Sap Use	458.33	260.21	0.372	0.7458
	Seed/Sap Random	354.17	416.15		
	Pole Use	166.67	288.68	1.000	0.4226
	Pole Random	0.00	0.00		
	Mature Use	0.00	0.00	-2.000	0.1835
	Mature random	166.67	144.34		
	Rubus value use	2.33	0.58	1.512	0.2697
	Rubus value random	1.00	1.00		
<b>Bird ID (n)</b>	<b>Stems/ha</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>T-stat</b>	<b>P-value</b>
150.022 (4) Willow Cover	Shrub Use	14947.92	5223.19	0.096	0.9293
	Shrub Random	14343.75	11646.43		
	Seed/Sap Use	312.50	473.24	0.676	0.5472
	Seed/Sap Random	125.00	144.34		
	Pole Use	62.50	125.00	-0.676	0.5472
	Pole Random	250.00	500.00		
	Mature Use	0.00	0.00	-1.000	0.3910
	Mature random	62.50	125.00		
	Rubus value use	2.00	0.82	2.445	0.0917
	Rubus value random	1.00	0.82		

**Appendix VI B. (continued)**

<b>Bird ID (n)</b>	<b>Stems/ha</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>T-stat</b>	<b>P-value</b>	
150.053 (3) Willow Cover	Shrub Use	7091.67	3133.52	0.021	0.9848	
	Shrub Random	7027.78	2268.95			
	Seed/Sap Use	250.00	433.01	-1.606	0.2495	
	Seed/Sap Random	833.33	1040.83			
	Pole Use	166.67	288.68	1.000	0.4226	
	Pole Random		144.34			
	Mature Use	166.67	288.68	0.211	0.4226	
	Mature random	0.00	0.00			
	Rubus value use	1.67	1.53	1.000	0.4226	
	Rubus value random	1.33	1.53			
	<b>Bird ID (n)</b>	<b>Stems/ha</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>T-stat</b>	<b>P-value</b>
	150.792 (11) Willow Cover	Shrub Use	9125.00	5421.94	-0.110	0.9149
Shrub Random		9428.03	5093.93			
Seed/Sap Use		363.64	312.92	0.000	1.0000	
Seed/Sap Random		363.64	699.70			
Pole Use		159.09	174.80	0.614	0.5527	
Pole Random		113.64	241.52			
Mature Use		45.45	105.41	0.559	0.5884	
Mature random		22.73	79.06			
Rubus value use		1.64	1.14	2.667	0.0236	
Rubus value random		0.91	0.82			

**Appendix VI C. Mean stems/ha comparisons by size and cover type for individual woodcock in Wisconsin 2002.**

Bird ID (n)	Stems/Ha	Mean	Std. Dev.	T-stat	P-value
	Shrub Use	1333	1281		
	Shrub Random	3125	3251	-1.58	0.152
	Seed/Sap Use	5150	2284		
	Seed/Sap Random	6218	2199	-1.46	0.183
150.922 (9) AS/S Cover	Pole Use	0	0		
	Pole Random	27.8	83.3	-1	0.347
	Mature Use	0	0	*	*
	Mature random	0	0		
	Rubus value use	1.111	0.782		
	Rubus value random	1.444	0.527	-1.15	0.282

Bird ID (n)	Stems/Ha	Mean	Std. Dev.	T-stat	P-value
	Shrub Use	1475	1659		
	Shrub Random	3450	3845	-1.06	0.348
	Seed/Sap Use	9949	8389		
	Seed/Sap Random	5927	4620	2.12	0.101
150.942 (5) AS/S Cover	Pole Use	0	0	*	*
	Pole Random	0	0		
	Mature Use	0	0	*	*
	Mature random	0	0		
	Rubus value use	1.2	0.447		
	Rubus value random	0.8	0.447	1	0.374

Bird ID (n)	Stems/Ha	Mean	Std. Dev.	T-stat	P-value
	Shrub Use	6725	4182		
	Shrub Random	6000	4250	0.33	0.756
	Seed/Sap Use	4158	2297		
	Seed/Sap Random	4900	2555	-0.9	0.42
151.151 (5) AS/S Cover	Pole Use	300	447		
	Pole Random	250	433	1	0.374
	Mature Use	0	0	*	*
	Mature random	0	0		
	Rubus value use	1.8	2.168		
	Rubus value random	1.6	0.894	0.27	0.799

**Appendix VI C. (continued)**

<b>Bird ID (n)</b>	<b>Stems/Ha</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>T-stat</b>	<b>P-value</b>
	Shrub Use	1869	2921		
	Shrub Random	1944	2153	-0.07	0.948
	Seed/Sap Use	4269	1931		
	Seed/Sap Random	6259	3518	-1.69	0.13
151.591 (9)	Pole Use	27.8	83.3		
AS/S Cover	Pole Random	0	0	1	0.347
	Mature Use	0	0		
	Mature random	917	1992	-1.38	0.205
	Rubus value use	1.667	0.5		
	Rubus value random	1.556	0.527	0.43	0.681

<b>Bird ID (n)</b>	<b>Stems/Ha</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>T-stat</b>	<b>P-value</b>
	Shrub Use	1587	2603		
	Shrub Random	3688	5456	-1.15	0.274
	Seed/Sap Use	7318	2383		
	Seed/Sap Random	8378	3549	-1.14	0.279
151.662 (12)	Pole Use	0	0		
AS/S Cover	Pole Random	41.7	144.3	-1	0.339
	Mature Use	0	0		
	Mature random			-1	0.339
	Rubus value use	1.167	0.389		
	Rubus value random	1.167	0.577	0	1

<b>Bird ID (n)</b>	<b>Stems/Ha</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>T-stat</b>	<b>P-value</b>
	Shrub Use	2667	4193		
	Shrub Random	4417	7001	-1.08	0.395
	Seed/Sap Use	3801	1084		
	Seed/Sap Random	3764	446	0.08	0.943
151.763 (3)	Pole Use	0	0		
AS/S Cover	Pole Random	0	0	*	*
	Mature Use	0	0		
	Mature random	0	0	*	*
	Rubus value use	2.333	0.577		
	Rubus value random	1.333	0.577	1.73	0.225

## Appendix VI C. (continued)

Bird ID (n)	Stems/Ha	Mean	Std. Dev.	T-stat	P-value
	Shrub Use	12439	6188		
	Shrub Random	5326	3787	2.08	0.093
	Seed/Sap Use	3000	1974		
	Seed/Sap Random	2646	1599	0.33	0.753
151.862 (6) AS/S Cover	Pole Use	41.7	102.1		
	Pole Random	41.7	102.1	0	1
	Mature Use	42	102		
	Mature random	333	408	-1.78	0.135
	Rubus value use	1	0.632		
	Rubus value random	0.833	0.753	1	0.363

Bird ID (n)	Stems/Ha	Mean	Std. Dev.	T-stat	P-value
	Shrub Use	3569	3988		
	Shrub Random	3302	3128	0.16	0.878
	Seed/Sap Use	7788	1530		
	Seed/Sap Random	7646	1883	0.12	0.907
151.962 (6) AS/S Cover	Pole Use	0	0	*	*
	Pole Random	0	0		
	Mature Use	0	0	*	*
	Mature random	0	0		
	Rubus value use	1.167	0.753		
	Rubus value random	1	0.632	0.54	0.611

Bird ID (n)	Mean # stems	Mean	Std. Dev.	T-stat	p-value
	Shrub Use	20594	8949		
	Shrub Random	15500	8449	0.66	0.556
	Seed/Sap Use	344	400		
	Seed/Sap Random	62	125	1.17	0.328
151.722(4) Alder	Pole Use	0	0	*	*
	Pole Random	0	0		
	Mature Use	62.5	125		
	Mature random	0	0	1	0.391
	Rubus value use	1.5	1.291		
	Rubus value random	1	0.816	1	0.391

**Appendix VI C. (continued)**

<b>Bird ID</b>	<b>Mean # stems</b>	<b>Mean</b>	<b>Std. dev.</b>	<b>T-stat</b>	<b>P-val</b>
	Shrub Use	11931	3289		
	Shrub Random	12350	14853	-0.06	0.961
	Seed/Sap Use	1403	584		
	Seed/Sap Random	1750	866	-0.45	0.698
151.862(3) NMHM	Pole Use	208	191		
	Pole Random	667	505	-1.57	0.257
	Mature Use	166.7	144.3		
	Mature random	166.7	144.3	0	1
	Rubus value use	1	1		
	Rubus value random	0.667	1.155	1	0.423