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I am submitting herewith a thesis written by Daniel Matthew Hinnebusch entitled "Nesting Success and Population Densities of Grassland Birds in the Breeding and Wintering Seasons in Tennessee and Kentucky." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

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NESTING SUCCESS AND POPULATION DENSITIES OF GRASSLAND BIRDS IN THE BREEDING AND WINTERING SEASONS IN TENNESSEE AND KENTUCKY

A Thesis

Presented for the

Master of Science degree

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Daniel Matthew Hinnebusch

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DEDICATION

This thesis is dedicated to my beautiful fiancé, Melissa Valentine, who has stood by me and been my best friend through every step of the process. She supported me during the rough patches and shared my joy when the sun was shining. I look forward to holding her in my arms for the rest of our life.

I must also acknowledge my parents, Matt and Cindy Hinnebusch. They shaped me into the man I am today with their love and wisdom. Without their guidance and the good example they set I would not be where I am today.

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ABSTRACT

Grassland and shrub/scrub breeding birds have experienced severe population declines since the beginning of the Breeding Bird Survey in 1966 (Sauer et al. 2007). Habitat loss and degradation are likely the primary causes of decline (Herkert 1994, Warner 1994, Johnson and Igl 2001). Partners in Flight (PIF) continental population objectives call for managers to increase populations by up to 100% for several of the species found in the Big Barrens, north-central Tennessee and south-central Kentucky, such as Dickcissel (*Spiza americana*), Henslow's Sparrow (*Ammodramus henslowii*), and Prairie Warbler (*Dendroica discolor*; Rich et al. 2004).

The quantity and quality of breeding season habitat are important in determining the future population trends of grassland birds throughout North America. Herkert (1995) identified the loss and degradation of breeding season habitat as the most likely cause of most population declines. It is important to determine the relative importance of habitat features for grassland birds on multiple scales in terms of population density as well as productivity. I compared population densities of breeding grassland birds in the Big Barrens with field characteristics (e.g. field size, vegetation measurements) to determine which habitat features promoted field use by each species (Chapter 2). I also monitored 39 Henslow's Sparrow nests and 122 Field Sparrow nests in the Big Barrens during the 2006 and 2007 breeding seasons (Chapter 3). Estimates of Mayfield (1961, 1975) nest success were within the documented ranges for both Henslow's Sparrow (23.8%, 95% CI: 10.7 – 40.5%) and Field Sparrow (15.4%; 95% CI: 9.5 – 23.1%). I also found evidence that Field Sparrows are at least double-brooded in the Big Barrens.

In addition to my work in the Big Barrens during the breeding season, we also sampled the winter bird community in the Big Barrens and in eastern Tennessee from 2003-07 using a variety of methods, including mist netting, widely dispersed point counts, rope dragging transects, and line transects (Chapter 4). My results indicated that a variety of habitats, including disturbed fields and agricultural fields in addition to grasslands dominated by native vegetation, is necessary to support the entire winter grassland bird community in the mid-South.

EXECUTIVE SUMMARY

Grassland bird species populations have been declining throughout eastern North America for several decades. Of 14 species in this group occurring in the eastern United States, 11 have significant negative population trends since the beginning of the Breeding Bird Survey in 1966 (Sauer et al. 2005). Using BBS data, Herkert (1995) estimated an average annual population change of -1.4 ± 0.7% for 13 grassland bird species in the Midwest. Population declines have largely been attributed to habitat loss and degradation, perhaps exacerbated by area sensitivity for many species (Herkert 1994, Warner 1994, Walk and Warner 1999, Hunter et al. 2001, Johnson and Igl 2001, Bakker et al. 2002, Herkert et al. 2003, Patten et al. 2006). Loss of native grassland habitats to intensive agriculture or other agricultural uses that reduce habitat quality has been linked with declines for this group of birds as a whole (Murphy 2003). However, for many grassland species, it is still unknown which habitat characteristics are important in determining habitat quality (Peterjohn 2003).

The Big Barrens is a 1.2-million-ha region of mostly open habitat in Tennessee and Kentucky. The region was mostly native grassland with few trees prior to the arrival of European settlers (McInteer 1946), but most of the area is now in intensive agriculture and small forest patches (Chester et al. 1997). Remnant and restored patches of native grassland vegetation remain in the Big Barrens. The greatest concentration of grasslands with native vegetation is on Fort Campbell Military Reserve (FCMR), which supports almost all of the open habitat bird species native to the region (Moss 2001, Dykes 2005). Open habitat dominated by native vegetation is also found on property managed by the Tennessee Wildlife Resources Agency (TWRA) and on privately-owned land enrolled in

the Conservation Reserve Program (CRP) of the Natural Resources Conservation Service.

In Chapter 2, I present and discuss the results of bird surveys that I conducted on open habitats in the Big Barrens on fields under 3 ownership types: CRP, FCMR, and TWRA. Of the 6 species of grassland obligate bird species that I observed (Dickcissel [*Spiza americana*], Eastern Meadowlark [*Sturnella magna*], Grasshopper Sparrow [*Ammodramus savannarum*], Henslow's Sparrow [*A. henslowii*], Horned Lark [*Eremophila alpestris*], and Sedge Wren [*Cistothorus platensis*]), only 1 (Dickcissel) was observed on TWRA fields. Six and 5 of those species were observed on FCMR and CRP fields, respectively. TWRA fields supported 13 species of shrub/scrub birds of the 15 that were observed in this study; I observed 11 species of shrub/scrub birds on both CRP fields and FCMR fields. Diversity of the grassland bird community, estimated using Shannon's diversity index (Shannon 1948), was greater on FCMR fields (1.76 ± 0.05) than on TWRA fields (1.43 ± 0.07; $P = 0.0007$); TWRA fields (1.66 ± 0.09) did not differ from either of the other ownership classes in bird diversity. My results in Chapter 2 indicated that different management practices by different field owners lead to different vegetation conditions. The diverse group of open-habitat birds in the Big Barrens requires an equally diverse set of habitat conditions. For open grassland birds, the management practices of FCMR provide better habitat for true grassland birds than either of the other 2 ownership types; FCMR fields also supported most of the other early successional species observed in the study. CRP fields supported most of the same birds as FCMR fields, but the true grassland birds were not well represented and diversity was not as great. Vegetation factors are likely not wholly responsible for the observed results, but application of FCMR management practices (i.e., regular burning) to fields under other ownership types should benefit early successional birds throughout the Big Barrens.

In Chapter 3, I present and discuss the results of an analysis of 39 Henslow's Sparrow nests and 122 Field Sparrow (*Spizella pusilla*) nests. Estimates of nest daily survival rate (DSR) were similar to 5-year estimates on FCMR from 1999-2003 (Moss 2001, Giocomo 2005) for both Henslow's Sparrow (0.942 ± 0.013; 1999-2003 estimate: 0.938 ± 0.009; Table 3-4) and Field Sparrow (0.928 ± 0.008; 1999-2003 0.926 ± 0.006, 276 nests; Table 3-5). The closeness of these estimates suggests that habitat quality for grassland birds on FCMR has been fairly consistent through the last decade. Although I observed differences in the bird community (see Chapter 2), I did not find evidence that nesting success differed among the 3 ownership types for Field Sparrows, and I did not have a sufficiently large sample size to compare among ownership types for Henslow's Sparrow. I also observed a double-peaked pattern of Field Sparrow nest activity through the breeding season, indicating that Field Sparrows are at least double-brooded in the Big Barrens. The pattern of Henslow's Sparrow nest activity did not suggest double brooding, but the length of time that Henslow's Sparrow nests were monitored was long enough to allow for the completion of 2 broods.

In Chapter 4, I discuss results of an investigation of the winter bird community of the mid-South (defined here as Tennessee, Kentucky, and northern Georgia, Alabama, and Mississippi). I learned about the ecology of winter birds in the mid-South while assessing the effectiveness of sampling that community with a variety of methods, including point counts, rope dragging surveys, mist nets, and variable width line transects. I sampled these birds in both the Big Barrens and in eastern Tennessee. I observed greater population densities of grassland birds on fields dominated by native vegetation (18.92 birds/ha; 95% $CI_{Bonferroni}$ = 12.70 – 28.19 birds/ha) than on harvested agricultural fields (2.51 birds/ha; 95% $CI_{Bonferroni}$ = 0.97 – 6.52 birds/ha); population density of birds on burned fields was 7.86 birds/ha (95% $CI_{Bonferroni}$ = 4.26 – 14.53 birds/ha). However, patterns of abundance for individual species varied across field types. Some habitat types with lower overall diversity (e.g., harvested row crop fields) provided habitat for some species that generally were not found in other field types. Conservation of a variety of habitat types throughout a landscape is important to maintain greater levels bird diversity on a regional scale. I also observed differences in the composition of the bird community in field interiors and on field edges; therefore, land managers should take into account the importance of habitat heterogeneity, especially with respect to providing shrub/scrub habitat along the field borders of other open-habitats. The bird community also was temporally dynamic during winter, indicating that some open-habitat birds utilize a nomadic strategy, seeking out different areas during different parts of winter. It is thus important to maintain a variety of habitats through the entire season.

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CHAPTER 1

INTRODUCTION

Grassland bird species populations have been declining throughout eastern North America for several decades. Of the 14 species in this group occurring in the eastern United States, 11 have significant negative population trends since the beginning of the Breeding Bird Survey (BBS) in 1966 (Sauer et al. 2005). Using BBS data, Herkert (1995) estimated an average annual population change of -1.4 ± 0.7% for 13 grassland bird species in the Midwest. Population declines have largely been attributed to habitat loss and degradation, perhaps exacerbated by area sensitivity for many of the species (Herkert 1994, Warner 1994, Walk and Warner 1999, Hunter et al. 2001, Johnson and Igl 2001, Bakker et al. 2002, Herkert et al. 2003, Patten et al. 2006). Although there is some evidence that grassland birds are sensitive to small patch size (Gates and Gysel 1978, Renfrew et al. 2005), recent research has cast some doubt on this conclusion (Winter et al. 2006). Loss of native grassland habitats to intensive agriculture or other agricultural uses that reduce habitat quality has been linked with declines for this group of birds as a whole (Murphy 2003). However, for many grassland species, it is still unknown which habitat characteristics are important in determining habitat quality (Peterjohn 2003).

Illinois provides a good example of the extent of the loss of grasslands in the eastern United States, where by 1960 the native prairie existed primarily along railroads and old cemeteries. The 103,600 km^2 of grassland that existed in the state before European settlement has been reduced to a mere 10.4 km^2 (Mlot 1990). Early successional habitats reached a peak in the eastern United States in the late 19th century but have declined to a small portion of the landscape since that time (Lorimer 2001).

Exotic grass species such as tall fescue (*Festuca arundinacea*) and orchardgrass (*Dactylis glomerata*) now occupy a large proportion (>9%) of the ground cover in eastern United States grasslands (Tracy and Sanderson 2000).

Although destruction and degradation of habitat is generally accepted as the principle cause of the declines in many grassland bird species populations, it is unclear whether the birds are more limited during the breeding or wintering seasons. Nesting success is typically low overall for grassland birds in eastern North America (Kershner and Bollinger 1996, Winter and Faaborg 1999, Herkert et al. 2003, Giocomo et al. 2008). For example, Giocomo et al. (2008) estimated Mayfield (1961) nest success for 5 species in north-central Tennessee. The greatest rate of any of the five species (Grasshopper Sparrow [*Ammodramus savannarum*]) was 33.8% (95% CI: 24.5-46.4%). Most grassland bird species compensate for low nest success by being capable of double or even triple brooding (Giocomo et al. 2008).

The Big Barrens is a 1.2-million-ha region of mostly open habitat in Tennessee and Kentucky. The region was mostly native grassland with few trees prior to the arrival of European settlers (McInteer 1946), but most of the area is now in intensive agriculture and small forest patches (Chester et al. 1997). However, remnant and restored patches of grasslands dominated by native vegetation remain in the Big Barrens. The greatest concentration of grasslands dominated by native vegetation is on Fort Campbell Military Reserve (FCMR), which supports almost all of the open habitat bird species native to the region (Moss 2001, Dykes 2005). Grasslands dominated by native vegetation are also found on property managed by the Tennessee Wildlife Resources Agency (TWRA) and on private land enrolled in the Natural Resource Conservation Service's Conservation Reserve Program (CRP).

Large patches of grassland and other open habitats are maintained on many military installations in the eastern United States because they are needed for training activities such as landing helicopters and parachute training (Cully and Michaels 2000, Giocomo 2005). Large portions of these grasslands are maintained by periodic burning (Chester et al. 1997, Cully and Michaels 2000). These military grasslands often represent relict prairies with similar vegetation to historical conditions (Chester et al. 1997, Moss 2001, Giocomo 2005). Airports also maintain large areas of grasslands around runways that resemble native grasslands to varying degrees, although airports were not sampled in this study (Kershner and Bollinger 1996). FCMR is a military base in the southern part of the Big Barrens on the border of Tennessee and Kentucky that maintains about 10,000 ha of native warm-season grass (NWSG) fields (Giocomo 2005).

Eastern grasslands are disturbance-dependent ecosystems. Historically, fire was an important component in the maintenance of many of the grasslands east of the Mississippi River, as evidenced by historical accounts (Gleason 1912, Cowles 1928) and by dating of charcoal $\delta^{13}C$ and examination of pollen-assemblages in lake sediments in the region (Nelson et al. 2006). Fires were caused by lightning and were set by Native Americans intentionally and accidentally (Russell 1983, Askins 2000). In addition to fire, drought and grazing were also important in maintenance of grasslands before European colonization (DeSelm 1994). Grassland bird species are often referred to as successional or early successional species because they use habitats dependent on fire or other types of disturbance (Hunter et al. 2001).

There is an especially great need for studies focused on birds that use open habitats during the non-breeding season (Vickery and Herkert 2001, Peterjohn 2003). Most grassland bird research to date has dealt with the breeding season. The winter grassland bird community differs from the breeding bird community in most areas (Best et al. 1998). As is the case for many wildlife species, especially in the winter, food and cover are both important habitat features for wintering sparrows. For example, wintering White-throated Sparrows (*Zonotrichia albicollis*) foraged preferentially on food closer to thick cover in an experimental study (Schneider 1984). Watts (1990) described a similar tradeoff between cover and food for Song Sparrow (*Melospiza melodia*) and Savannah Sparrows (*Passerculus sandwichensis*). A better understanding of the dynamics of the winter grassland bird community is necessary to develop effective management strategies, especially in the mid-South region (Tennessee, Kentucky, and parts of northern Mississippi, Alabama, and Georgia), where little work has been done to understand winter grassland bird ecology.

I studied open habitat birds in both breeding and wintering seasons. In Chapter 2, I discuss the results of bird surveys that I conducted in the Big Barrens on fields under 3 ownership classes: military fields managed by FCMR, fields managed by the Tennessee Wildlife Resources Agency, and privately-owned fields enrolled in the Natural Resources Conservation Service's Conservation Reserve Program. Chapter 3 summarizes an analysis of the nesting biology of the Henslow's Sparrow (*Ammodramus henslowii*), a grassland specialist, and the Field Sparrow (*Spizella pusilla*), a species that uses a broader range of open habitats, on the same fields for which surveys are discussed in Chapter 2. In Chapter 4, I describe research conducted on grassland and shrub/scrub birds in the Big

Barrens and in eastern Tennessee during winter. In addition to discussing what was learned about wintering birds in the mid-South, I also outline gaps in our knowledge, as well as the relative effectiveness of the various methods used to sample the community.

Chapter 2

CHAPTER 2

POPULATION DENSITIES OF BREEDING GRASSLAND BIRDS ON FIELDS IN THREE OWNERSHIP CLASSES IN THE BIG BARRENS, TENNESSEE AND KENTUCKY

Introduction

Habitat destruction and degradation are likely linked to population declines of many species of grassland birds (Johnson and Schwartz 1993, Askins et al. 2007). Native grassland loss has been extensive throughout the United States (Samson and Knopf 1994, Johnson and Igl 2001, Brennan and Kuvlesky 2005). Grassland loss has been driven by conversion of grasslands to agriculture and succession of many open habitats in the eastern United States to forested habitat (Norment 2002, Askins et al. 2007). Changes in the historical disturbance regime, such as increased fire suppression, have added to losses (Herkert et al. 1996, Reinking 2005) because most grasslands in the eastern United States are only maintained through regular disturbance. Native Americans played an important role in maintaining native grasslands before European colonization, likely through a combination of intentional fires, accidental fires, and an apparent lack of ability to suppress naturally-caused wildfires (Day 1953, Russell 1983).

In addition to the direct effects of habitat loss, further intensification of agriculture and decreasing heterogeneity of agricultural landscapes have likely exacerbated negative population trends (Warner 1994). Grassland fragmentation has also been found to have a negative effect on population density (Johnson and Igl 2001), species richness (Helzer and Jelinski 1999), and nest survival (Herkert et al. 2003) of grassland birds. However, for many grassland species, it is still unknown which habitat characteristics are important in determining habitat quality (Peterjohn 2003).

This study took place in the Big Barrens region of Tennessee and Kentucky (a description of the study area follows in the Methods section of this chapter) on fields under 3 different ownership classes: military-managed fields on Fort Campbell Military Reserve (FCMR), privately-owned fields enrolled in the Conservation Reserve Program (CRP), and fields managed by the Tennessee Wildlife Resources Agency (TWRA). These ownership classes are associated with different management strategies and landscape attributes. Research has shown that FCMR supports almost all of the grassland bird species that historically occurred in the region (Moss 2001, Dykes 2005). A notable exception is the Greater Prairie-Chicken (*Tympanuchus cupido*), which has been extirpated from the Big Barrens since the 1800s. FCMR has the best known example of habitats for grassland birds in the region; a comparison of those fields with CRP and TWRA fields can provide an assessment of how effective the management practices are at creating satisfactory conditions for grassland birds on state and privately-owned fields.

***Study Design and Objectives* –** I hypothesized that the differences in management techniques between ownership types will lead to differences in the vegetation structure and composition and thus the bird communities using the fields will also differ. Differences in bird use by ownership type could be evident within species, among diversity indices calculated for each field type, or a combination of both. Furthermore, I expect to find that the density of each species of bird is correlated with vegetation characteristics to which it has biological ties.

My objectives were to (1) estimate population densities of grassland birds in grasslands dominated by native vegetation under the 3 ownership types (FCMR, CRP, and TWRA), (2) compare bird diversity among ownership types using Shannon's diversity index, (3) identify important variables that explain a large amount of the variation in vegetation characteristics among ownership types, and (4) construct models that relate variation in bird density by species to vegetation variables.

Methods

Study area – During the breeding season, I surveyed fields in the Big Barrens under the 3 different ownership types (Figure 2-1; tables and figures are presented in appendices to each chapter). The Big Barrens, part of the Pennyroyal Plain, is a 1.2-million-ha region of mostly open habitat in Kentucky and Tennessee. This area was once covered almost entirely by native grasslands but was shifted to a forest-dominated landscape following European settlement (McInteer 1946). It is now dominated by a mosaic of forests and agriculture with patches of remnant or restored grassland (Chester et al. 1997). Private fields were selected as study sites opportunistically based on landowner permission. TWRA-managed grasslands were sampled at Cedar Hill Swamp and Haynes Bottom Wildlife Management Areas, the only state-owned grasslands within the Big Barrens.

The Conservation Reserve Program (CRP) is administered by the Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA) that began as part of the Food Security Act of 1985. The program provides technical assistance and financial incentives to farmers to conserve soil, limit crop surpluses, and provide habitat for birds and other wildlife taxa (Johnson and Schwartz 1993, Osborn 1993). In some regions this program has been successful in creating habitat suitable for grassland birds (Johnson and Igl 1995, Patterson and Best 1996, McCoy et al. 2001), but some researchers have questioned whether CRP has had an overall positive effect on grassland birds and suggest improvements that might make the program better for bird conservation (McCoy et al. 1999, Brennan and Kuvlesky 2005, Dykes 2005). Greater abundance of several species of grassland birds has been observed on CRP fields compared to crop fields (McCoy et al. 2001). However, density may not be the best indicator of habitat quality (Van Horne 1983). Fields enrolled in this program are managed under a diverse set of practices and the resulting vegetation structures support different bird communities (Delisle and Savidge 1997).

Two sites (each containing 2 fields with 2 bird surveys) were sampled in the Kranz property in Todd County, Kentucky. Each of these sites were enrolled in the program in September 2003 and seeded with big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and indiangrass (*Sorghastrum nutans*) in April 2004. The areas of the sites enrolled were 44.9 and 20.8 ha. The other CRP site was on the Arthur property in Christian County, Kentucky; it was enrolled and planted at the same time as the Kranz sites, and its 20.7 ha were also seeded with big bluestem, little bluestem, and indiangrass.

Fields on FCMR are primarily managed for military training (Moss 2001). Tactical operations training occurs on all fields and larger fields are also used for helicopter and parachute training exercises. In all, FCMR manages 10,000 ha of open habitat (Giocomo 2005), which is one of the most extensive grassland complexes east of the Mississippi River (Moss 2001). Prescribed fire is the principal management technique for open habitats in FCMR, along with some mechanical manipulations such as mowing and bush-hogging. Herbicide treatments are occasionally used to remove nonnative, invasive plants such as *Sericea lespedeza* (D. Moss, pers. comm.). Fields are burned every other year (with about half of all fields burned each year), mostly to control woody vegetation, which can prevent helicopter landing and makes training more difficult. Conditions on most FCMR fields resemble conditions on historic grasslands in the region, in terms of species composition and vegetative structure (Chester et al. 1997). Grassland birds were researched on FCMR from 1999-2003 by Moss (2001) and Giocomo (2005).

TWRA Wildlife Management Areas (WMA) are managed under a very diverse set of objectives; the 2 WMAs used in this study were the only WMAs within the study area that had open habitats. Both Cedar Hill Swamp and Haynes Bottom WMAs were managed primarily for hunting. The vegetation at Cedar Hill Swamp was not manipulated during the duration of this study, and woody encroachment was pronounced. Open areas at Haynes Bottom are managed with periodic mowing (approximately biennial) to control the spread of woody vegetation. The lower section of Haynes Bottom, along a bend in the Cumberland River, is managed for waterfowl hunting and the grasslands dominated by native vegetation are interspersed with strips of corn (*Zea mays*), small wetlands, and duck blinds. Haynes Bottom contained the only fields that were intentionally disturbed during the breeding season; Haynes Bottom is frequently used as a training area for hunting dogs, and strips were mowed through many of the fields in early June 2007 to allow easy access to dog trainers. Mowed strips did not exceed 10% of total field area on any field.

Surveys were conducted each year on all of the fields that were used for nest searching (Chapter 2) as well as 2 private fields (Arthur and Helsley) on which I did not search for nests. In 2007 I did not search for nests on 2 of the FCMR fields (Training Areas 17 and 27) that we used in 2006 because those fields had been burned in early spring, 2007, and nest density of target species was expected to be low; however, I sampled 2007 population densities on both of those fields.

***Bird Surveys* –** I sampled birds using an area mapping technique in which I walked a transect that bisected the centers of up to nine 1-ha squares (Figure 2-2). Some fields were too small or irregularly shaped for nine 1-ha squares, and plots were designed to cover as much of the field as possible (for examples see Figure 2-2). All birds observed by sight or song within that area were recorded. Birds that were observed flying over the plot were recorded, but I only included flyover birds in the analysis if they appeared to be using the habitat (e.g. an American Kestrel [*Falco sparverius*] hunting for prey over the plot but not actually landing). I recorded the location of each bird observed on a map of the survey plot and accounted for bird movements to minimize the chance of counting an individual more than once. Based on these data, I calculated a density for each species on each field.

Bird species differ in detectability by species, gender, and age class because of physical and behavioral factors (Bibby et al. 2000, Diefenbach et al. 2003). The main physical factors that influence detection rates are size and coloration of individuals varying among species. Behavioral factors include typical perching height, reactions of the bird to the observer, volume and frequency of vocalization, rate of movement, and changing behavior throughout the breeding season. Calder (1990) specifically addressed sound volume as a complicating factor in density estimation. However, with the area search method that was used in this study, differences in detection probability were likely minimal because I walked within 70 m (distance from the center of a square ha to a corner of that square) of every point in the plot.

I conducted all surveys myself to eliminate observer bias. All surveys started after 1 June so that nearly all of the migrants were gone and regular breeding species were present. Furthermore, I sampled each survey plot twice each year, once in June and once in July. No survey was started after 10:00 to avoid effects resulting from lower bird activity later in the day or other time of day effects. I did not survey any fields while it was raining or in wind that was strong enough to noticeably affect bird behavior or impair my hearing.

***Shannon's Diversity Index* –** I characterized the diversity of the bird community on each field using Shannon's diversity index (H'; Shannon 1948),

$$H' = -\sum_{i=1}^{S} \frac{n_i}{N} \ln\left(\frac{n_i}{N}\right)$$

where S = the number of species observed, N = the total number of individuals observed, and n_i = the number of individuals observed for the i-th species. Both species richness and evenness (or relative abundance within the sample) are accounted for in this diversity index (Tramer 1969). I used Shannon's diversity index as a response variable in my statistical analysis.

Vegetation sampling – Vegetation was sampled once each year in June or July at 5 systematically chosen points within each sampled area. If a field was large enough to contain the 9-ha plot, vegetation was sampled at the middle point and the four points closest to the corners of the plot (Figure 2-2, *a*; points 1, 3, 5, 7, and 9). On smaller or irregularly-shaped plots (Figure 2-2, *b* and *c*, respectively), I sampled vegetation at a set of 5 points that were spread out as much as possible but still on the points used for bird surveys. I sampled vegetation on 17 fields in 2006 and on 21 fields in 2007, for a total of 85 and 105 vegetation sampling plots, respectively. I averaged estimates for each variable for the 5 points on each field.

I recorded whether or not each field had been burned within the last year and whether or not it had been mowed. Other data were based on measurements on 1-m^2 plots. Within the 1-m^2 plot, I measured the tallest vegetation (cm) for each of 3 vegetation types: grass, woody, and forb. I measured depth (cm) of litter at each corner of the square plot and at the center of the plot. The percent ground cover was also recorded in each of 8 cover types: litter, bare ground, live woody vegetation, dead woody vegetation, cool-season grass, warm-season grass, forbs, and other. To estimate the horizontal density of the vegetation, I used a board marked with 20 100-cm^2 squares arranged in 2 columns and 10 rows. One observer held the board while another viewed the board from 10 m in each cardinal direction and recorded the number of squares visible. Finally, I recorded the distance to the edge of the habitat and the distance to the nearest tree for each vegetation sampling point.

Statistical Analysis – I compared bird densities and Shannon's diversity index among ownership types and between years using repeated measures ANOVA in SAS 9.1.3 (SAS

Institute, Inc. 2003). Measures were repeated by each field within each year. Years and ownership types were compared for each species that was observed on at least 20% of the fields. I controlled the overall error rate of $\alpha = 0.05$ for all the above ANOVA tests using a Bonferroni correction; with 11 tests, $\alpha_{Bonferroni} = 0.0047$. I controlled the overall error rate on pairwise comparisons among field types, within each species, using Tukey's Honestly Significant Difference test.

Vegetation data were compared between years and among sites using ANOVA. Eleven variables were used in this analysis: forb height, woody vegetation height, grass height, litter depth, the number of visible coverboard squares (index of vegetation density with decreasing density from 0 to 20), and the proportion of ground covered in litter, bare ground, cool-season grass, native warm-season grass, dead woody vegetation, live woody vegetation, and forbs. I controlled the overall error rate of $\alpha = 0.05$ for all the above ANOVA tests using a Bonferroni correction; with 11 tests, $\alpha_{Bonferroni} = 0.0047$. I controlled the overall error rate on pairwise comparisons among field types, within each vegetation variable analyzed, using Tukey's Honestly Significant Difference test.

I also used principal variables analysis, a technique that can identify the independent variables that are most important in accounting for variation in the data, in NCSS 2007 (Hintze 2007). Principal components analysis is the first step of principal variables analysis. I included all vegetation variables and retained the minimum number of principal components necessary to represent at least 80% of the variation in the data. The retained principle components scores were then used as dependent variables for multivariate variable selection (from the original 12 independent variables) using McHenry's algorithm (McHenry 1978).

I used all 12 vegetation variables (live and dead woody vegetation were not summed as they were for comparisons among ownership types; Table 2-6) for regression of population densities of each of the 12 most common bird species against vegetation covariates. I classified four of the species as true grassland birds, Dickcissel (*Spiza americana*), Grasshopper Sparrow (*Ammodramus savannarum*), Henslow's Sparrow (*A. henslowii*), and Red-winged Blackbird (*Agelaius phoeniceus*). The other 8 birds were classified as shrub/scrub species, including American Goldfinch (*Carduelis tristis*), Blue Grosbeak (*Passerina caerulea*), Common Yellowthroat (*Geothlypis trichas*), Field Sparrow (*Spizella pusilla*), Indigo Bunting (*Passerina cyanea*), Northern Bobwhite (*Colinus virginianus*), Prairie Warbler (*Dendroica discolor*), and Yellow-breasted Chat (*Icteria virens*).

For each species, I tested a null model (intercept only), a global model with the entire pool of variables for that species, a single variable model for each of the variables, and 2 combinations of the variables that were chosen based on biological relevance. Four of the species used in the regression analysis (Dickcissel, Field Sparrow, Grasshopper Sparrow, and Henslow's Sparrow) were analyzed on FCMR by Giocomo (2005) in a comparison between nest sites for that species and randomly-selected vegetation plots. For each of those 4 species, I selected the starting pool of variables to include all of those that differed from the random vegetation plots. I chose 2 *a priori* models for each of these species individually. Because a large proportion (range: 0.50-0.67) of the variables were significant in Giocomo's (2005) analysis for those 4 species, I chose to use all 12 variables as the starting pool for the other 8 species. I ran an identical set of models for the 7 shrub/scrub species in that group. I chose a unique set of models for Red-winged

Blackbird because it was the only species classified as a grassland species that was not analyzed by Giocomo (2005).

Results

***Bird Densities* –** Across both years, I observed 1,744 individual birds of 46 species. Across all species for all surveys, I observed an average of 7.72 (± 0.92) species per survey. Based on the classifications used by Sauer et al. (2005), 6 of the species observed were grassland breeding birds and 15 were successional or scrub breeding birds (Table 2-3). The other species were urban, wetland, or woodland breeding birds or were not associated with a specific habitat. All 6 grassland species were observed on FCMR fields, as opposed to 4 and 1 species for CRP and TWRA fields, respectively (Table 2-3, Figure 2-3). TWRA fields were richest in successional or scrub breeding birds with 13 species; 11 successional or scrub breeding species were observed on each of the other 2 field types.

The mean density of all species across all surveys was 4.15 (± 0.31) birds per ha. Twelve species were observed on at least 20% of the surveys: American Goldfinch, Blue Grosbeak, Common Yellowthroat, Dickcissel, Field Sparrow, Grasshopper Sparrow, Henslow's Sparrow, Indigo Bunting, Northern Bobwhite, Prairie Warbler, Red-winged Blackbird, and Yellow-breasted Chat. Observed densities of these species ranged from 0.04 (± 0.01) Blue Grosbeaks per ha to 0.69 (± 0.06) Field Sparrows per ha (Table 2-2).

After Bonferroni correction, bird densities differed among the 3 ownership types for 3 species: Common Yellowthroat ($F_{2,33} = 6.99$, $P = 0.0029$), Field Sparrow ($F_{2,33} = 5.50$, $P = 0.0087$), and Red-winged Blackbird ($F_{2,33} = 12.96$, $P < 0.0001$). Common

Yellowthroat density was lower on CRP fields than on FCMR (P_{Tukey} = 0.0086) and TWRA fields (P_{Tukey} = 0.0075), but there was no difference between FCMR and TWRA (Table 2-4). TWRA fields had greater Field Sparrow densities than CRP (P_{Tukey} = 0.0086) or FCMR fields (P_{Tukey} = 0.0210). Red-winged Blackbird densities were greater on CRP fields than on FCMR fields ($P_{Tukey} < 0.0001$).

In addition to the relationships described above, several of the 12 species analyzed were not observed on 1 of the ownership types (Table 2-4). Prairie Warblers were not observed on CRP fields during the area search surveys although they were observed incidentally during nest searching. Blue Grosbeak, Grasshopper Sparrow, and Henslow's Sparrow were all absent from TWRA fields, and only Blue Grosbeak was observed incidentally on that ownership type. All 12 of the species that were observed on at least 20% of the plots were observed on FCMR fields.

All 12 of the species analyzed were observed in both 2006 and 2007. Using the same Bonferroni correction as above, Common Yellowthroat ($F_{1,33}$ = 12.08, P = 0.0014), Henslow's Sparrow ($F_{1,33}$ = 10.18, P = 0.0031), and Indigo Bunting ($F_{1,33}$ = 8.30, P = 0.0069) densities were greater in 2006 than in 2007. If the same comparisons are made after restricting from the sample all fields that were burned in the same year as the area search, only the Common Yellowthroat had greater density in 2006 than in 2007 ($F_{1,25}$ = 9.43, P = 0.0051). All burned fields sampled were FCMR fields and all were in 2007. Those fields were sampled in the 2006 breeding season, burned during the 2006-07 winter, and sampled as burned fields in the 2007 breeding season.

Shannon's Diversity Index – The mean estimate of Shannon's diversity index across all area search plots was 1.61 (± 0.08), with a range from 0.96 to 2.25. This index was greater in 2006 (H' = 1.75 ± 0.07) than in 2007 (H' = 1.49 ± 0.05; P = 0.0037). FCMR (H' = 1.76 ± 0.05) fields were more diverse than CRP fields (H' = 1.43 ± 0.07; P = 0.0007), but diversity did not differ between either of those two ownership types and TWRA fields (H' = 1.66 ± 0.09; $P_{FCMR,TWRA}$ = 0.6543, $P_{CRP,TWRA}$ = 0.1100).

Vegetation **–** There were no differences between 2006 and 2007 for any of the vegetation variables. Average forb height differed among ownership types ($F_{2,32}$ = 7.26, P = 0.0025; Figure 2-4). FCMR fields (70.27 cm) had shorter average forb height than TWRA fields (100.01 cm; P_{Tukey} = 0.0020). The proportion of ground covered in litter ($F_{2,32}$ = 6.90, p = 0.0032; Figure 2-5) also differed among ownership types. Litter coverage was less on FCMR fields (4.93 ± 1.42%) than on CRP fields (10.53 ± 1.72%; P_{Tukey} = 0.0173) and TWRA fields (13.87 ± 2.18%; P_{Tukey} = 0.0017); litter coverage did not differ between CRP fields and TWRA fields (P_{Tukey} = 0.2391).

In principal components analysis, the first 6 eigenvalues accounted for 81.3% of the variation in the data, so I chose to retain 6 principal components. I had fairly clear interpretation without any rotation (Table 2-5). Factor 1 was heavily loaded with the proportion of ground cover in bare ground and negatively loaded with grass height. The proportion of ground covered with forbs was the only heavily loaded variable in Factor 2. Height of woody vegetation and woody proportion of ground cover were heavily loaded in factor 3. Average litter depth and the proportion of ground covered in litter were heavily loaded in Factor 4. Proportion of ground cover in cool-season grasses and dead woody vegetation are loaded in Factors 5 and 6, respectively. Principal variables analysis indicated that a single vegetation variable, proportion of ground cover in dead woody vegetation, was the best to describe the variation in the vegetation data (Wilks' λ =

0.0016; $F_{6,183} = 19{,}443.6$, $P < 0.001$). Addition of the 2nd variable, warm-season grass cover, decreased Wilks' λ by only 0.0015.

Regression of Vegetation vs. Bird Densities – I retained all models for which $\Delta AIC \leq 2.0$. Model notation is described in Table 2-6. The number of models retained for each species ranged from 2 to 7, with the exception of Prairie Warbler, for which 13 models were retained. Average litter depth and the proportion of ground covered by litter were the most common among the retained models for the true grassland species, Dickcissel (Table 2-7), Grasshopper Sparrow (Table 2-8), Henslow's Sparrow (Table 2-9), and Red-winged Blackbird (Table 2-10). The β estimates were negative for each of the former 3 species (although only average litter depth was significant with $\alpha = 0.10$, for both Dickcissel and Grasshopper Sparrow; Table 2-19).

I retained at least 2 models for each of the 12 shrub/scrub species, including American Goldfinch (Table 2-11), Blue Grosbeak (Table 2-12), Common Yellowthroat (Table 2-13), Field Sparrow (Table 2-14), Indigo Bunting (Table 2-15), Northern Bobwhite (Table 2-16), Prairie Warbler (Table 2-17), and Yellow-breasted Chat (Table 2-18). Height of woody vegetation was important in many of the retained models for this group of birds. Common Yellowthroat, Field Sparrow, Indigo Bunting, and Northern Bobwhite all had at least 1 model that contained height of woody vegetation with a significant β estimate (Table 2-20). That β estimate was positive for the former 3 species and negative for the Northern Bobwhite. Indigo Bunting density had a positive relationship with herbaceous height in both of the models retained for that species. Yellow-breasted Chat density was positively correlated with the proportion of ground cover in live woody vegetation.

Discussion

Differences in vegetation among ownership types likely reflect differences in the management practices applied on those fields. The fire regime maintained on FCMR may be responsible for the high proportion of ground cover in native warm-season grasses, which covered significantly more ground on these fields than on TWRA fields. Composition of tallgrass prairies can be strongly affected by the frequency of fire; productivity of big bluestem (*Andropogon gerardii*) and indiangrass (*Sorghastrum nutans*) declines several breeding seasons after a burn (Gibson and Hulbert 1987, Howe 1994). Although only one of the CRP fields was burned with anywhere near the regularity of the FCMR fields, CRP fields also supported a greater proportion of ground cover in native warm-season grasses than TWRA fields.

Based on principal variables analysis, ground cover in native warm-season grass was identified as the 2nd most important variable for describing variation in vegetation characteristics. This relationship was expected and is supported by the significant differences in native warm-season grass density between ownership types. The other variable identified in principal variables analysis was density of dead woody vegetation. The density of dead woody vegetation on all sites was low and the highest estimate on any ownership type was 1.8% on CRP fields. However, presence or absence of dead woody vegetation may be important in predicting the values of other vegetation variables. For example, recently-burned fields should tend to have lower densities of almost every vegetation type but have a higher than average density of dead woody vegetation. FCMR fields were burned regularly, but only 12 of 38 (31.6%) surveys conducted on FCMR fields were on fields that had been burned since the previous growing season. The regularity of burning on FCMR fields may explain the lower forb height on those fields than on TWRA fields.

Different bird communities were observed on fields under different ownerships. Using the classification system from Sauer et al. (2005), CRP and FCMR fields supported 4 and 6 species of the grassland breeding birds observed in this study, respectively, but of these species TWRA fields supported only the Dickcissel (Figure 2-3). These findings suggest that TWRA fields were unsuitable for some of the true grassland obligate birds like Henslow's Sparrow and Horned Lark. However, only 3 of the 6 grassland breeding species, Dickcissel, Grasshopper Sparrow, and Henslow's Sparrow, were observed on more than 20% of the area search plots. Eastern Meadowlark was observed on only 13 plots (18.31%) and Horned Lark and Sedge Wren were each observed on only 1 plot each (1.41%). It is possible that a greater number of grassland breeding birds were observed on FCMR fields simply by chance because more FCMR fields were surveyed (11) than CRP (6) or TWRA fields (5). I suspect that this was not the sole reason for the distributional differences because FCMR had more grassland species even after sampling intensity was accounted for.

There were few significant differences among field types for individual species of the 12 analyzed (Table 2-4). FCMR fields supported a greater density of Common Yellowthroats, a species with a significant negative population trend, than CRP fields; conversely, CRP supported greater densities of Red-winged Blackbirds than FCMR fields. The Red-winged Blackbird is also declining (Sauer et al. 2005), but it is still abundant on a continental scale. Neither of these species is considered a conservation concern. Although neither woody vegetation height nor proportion of ground covered in woody vegetation were found to be different between FCMR and CRP fields, observed values for FCMR were greater than observed values for CRP in both cases. Common Yellowthroats favor habitats with thick vegetation (Guzy and Ritchison 1999) and dense, short woody vegetation (Stewart 1953); the woody vegetation may not be dense enough on CRP fields to support as many Common Yellowthroats as FCMR fields. It is also possible that there were patches of vegetation on both fields in which suitable Common Yellowthroat breeding habitat was supported, but the patches were not as prevalent on CRP fields. Red-winged Blackbirds tend to favor sedge meadows and even crop fields as upland breeding habitat (Yasukawa and Searcy 1995), and fields like those found on FCMR, with a greater proportion of ground covered in native warm-season grass, might be a more marginal habitat for that species.

Two of the true grassland bird species, Henslow's and Grasshopper Sparrow, were not observed at all on TWRA fields. Lack of management targeted towards grassland passerines may be creating habitat unsuitable for these species. Although fewer true grassland species were observed on TWRA fields than CRP or FCMR fields, TWRA fields supported a greater number of Field Sparrows than the other two ownership types. Field Sparrows are an abundant bird in the Big Barrens, but significant population declines have been detected by the BBS (Sauer et al. 2005). TWRA is providing important habitat for some grassland species, but changes in habitat management approach may be needed to support more true grassland species.

Regression of population densities with vegetation covariates revealed a negative correlation with proportion of ground covered in cool-season grass and Field Sparrow abundance (Table 2-20). Field Sparrows are classified as shrub/scrub birds, and the typical cool-season grass field may not have the proper structure for those birds. Cool-season grasses accounted for a relatively low proportion of ground cover (2.9 ± 0.8%; Figure 2-5); however, greater cool-season grass density may indicate vegetation composition and vertical structure of an early successional stage. Woody vegetation, which was positively correlated with Yellow-breasted Chat population density (Table 2-20), another shrub/scrub species, may be more prevalent in a later successional stage than are cool-season grasses.

All 4 species that had proportion of ground covered in warm-season grass in one of the top models, Henslow's Sparrow (Table 2-19), Indigo Bunting, Northern Bobwhite, and Prairie Warbler (2-20), had a positive correlation with warm-season grass coverage (the β estimate was only significant for the Northern Bobwhite model). This is particularly interesting when compared with the relationships between cool-season grass coverage and Common Yellowthroat, Field Sparrow, and Prairie Warbler population densities. It is important that managers take these relationships into account when planting grass on a field if there is a desire to provide habitat for breeding grassland birds. Not only was cool-season grass coverage negatively correlated with population density for 3 shrub/scrub species, but 2 species with relatively high levels of management concern showed a positive correlation with warm-season grass coverage. If grassland bird conservation in the Big Barrens is a management objective, then the choice between cool and warm-season grass appears to strongly favor selection of warm-season grass.

Regression results for Blue Grosbeak yielded an unexpected finding. The proportion of ground covered by forbs and vertical vegetation density were negatively correlated (i.e. the inverse index of vertical vegetation thickness was positively correlated) with population density. These results are inconsistent with expected habitat characteristics associated with a bird classified as a shrub/scrub bird. Shugart and James (1973) observed Blue Grosbeaks in open habitat with a developed but short woody vegetation layer, but Blue Grosbeak density may actually be greatest in the breeding season immediately following a disturbance, when vegetation structure is least developed (Engstrom et al. 1984). Blue Grosbeak also showed positive correlations with both forb and bare ground coverage, which seems almost contradictory. Blue Grosbeak habitat may differ from the average conditions found in the fields in which they occurred. I usually observed Blue Grosbeaks singing from and nesting in a patch of vegetation (of ~0.5 ha) that was taller than the surrounding vegetation. An analysis that compared specific points used by Blue Grosbeaks to average field conditions might better reveal the habitat preferences for that species. A greater sample size of vegetation plots on each field would also help by increasing the power of all comparisons.

Population densities of 2 species were correlated with the proportion of ground covered with woody vegetation. The Yellow-breasted Chat had a positive correlation and the Northern Bobwhite had a negative correlation. Yellow-breasted Chat is well documented as a shrub/scrub species that favors dense woody vegetation (Parnell 1969, Eckerle and Thompson 2001), consistent with a positive correlation with taller woody vegetation. Northern Bobwhite is also typically classified as a shrub/scrub bird (e.g. Sauer et al. 2007), but Northern Bobwhites prefer native warm-season grasses as nesting substrate and select against shrub/scrub habitat during the breeding season (D. Buehler, pers. comm.). The negative correlation with woody vegetation height that I observed may reflect a broader range of suitable habitat types available to the Northern Bobwhite, which was also observed by Spears et al. (1993), where Northern Bobwhites used habitats from the time of disturbance until ≥ 5 yr after disturbance. Woody vegetation may be more important to Northern Bobwhites during the winter, especially in regions where snow is common (Brennan 1999).

My results indicated that different management practices by different field owners lead to different vegetation conditions. The diverse group of open habitat birds in the Big Barrens requires an equally diverse set of habitat conditions. For open grassland birds, the management practices of FCMR appeared to be providing better habitat for true grassland birds than either of the other 2 ownership types; FCMR fields also supported most of the other early successional species observed in the study. CRP fields supported most of the same birds as FCMR fields, but the true grassland birds were not as well represented. The 2 TWRA WMAs surveyed in this study provided habitat for many shrub/scrub species but only for the Dickcissel among true grassland birds. Vegetation factors are likely not wholly responsible for the observed results, but application of FCMR management practices (i.e., regular burning) to fields under other ownership types should benefit early successional birds throughout the region.

Appendix

Table 2-1. Study sites used for bird surveys and nest searching on privately owned fields enrolled in the Conservation Reserve Program (CRP), fields on Fort Campbell Military Reserve (FCMR), and fields managed by the Tennessee Wildlife Resources Agency (TWRA) in the Big Barrens, Tennessee and Kentucky, 2006-07. The field areas listed below include the total area of the sampled open patch; however, in the case of CRP fields the entire open area was not surveyed because portions of that open patch were outside the boundaries of the property enrolled in CRP.

Ownership Class	**Study Site**	**Area (ha)**
CRP	Arthur	58.02
	Kranz (A)	221.54
	Kranz (B)	81.93
FCMR	Los Banõs Drop Zone	153.60
	Suckchon Drop Zone	549.75
	Training Area 17	396.22
	Training Area 27	79.71
	Training Area 32(A)	12.97
	Training Area 32(B)	33.20
	Training Area 48	117.29
TWRA	Cedar Hill Swamp	39.16
	Haynes Bottom (A)	73.76
	Haynes Bottom (B)	81.41
	Haynes Bottom (C)	129.83

Table 2-2. Summary of results of surveys of breeding birds in the Big Barrens, Tennessee and Kentucky, 2006-07.

Common Name	**Scientific Name**	**Number of Individuals Observed**	**Mean Density (Birds / ha)**	**SE (Density)**	**Proportion of Surveys**
American Goldfinch	*Carduelis tristis*	36	0.082	0.020	0.225
American Robin	*Turdus migratorius*	4	0.011	0.008	0.042
Bachman's Sparrow	*Aimophila aestivalis*	3	0.008	0.005	0.042
Barn Swallow	*Hirundo rustica*	30	0.066	0.020	0.197
Bell's Vireo	*Vireo bellii*	4	0.006	0.004	0.042
Blue-gray Gnatcatcher	*Polioptila caerulea*	2	0.005	0.003	0.028
Brown-headed Cowbird	*Molothrus ater*	6	0.016	0.008	0.070
Blue Grosbeak	*Passerina caerulea*	21	0.044	0.010	0.225
Brown Thrasher	*Toxostoma rufum*	2	0.006	0.004	0.028
Carolina Wren	*Thryothorus ludovicianus*	2	0.012	0.010	0.028
Cedar Waxwing	*Bombycilla cedrorum*	16	0.035	0.025	0.042
Chimney Swift	*Chaetura pelagica*	15	0.037	0.024	0.056
Cliff Swallow	*Petrochelidon pyrrhonota*	28	0.059	0.029	0.085
Common Grackle	*Quiscalus quiscula*	30	0.082	0.035	0.141
Common Yellowthroat	*Geothlypis trichas*	150	0.342	0.044	0.676
Dickcissel	*Spiza americana*	184	0.363	0.062	0.479
Eastern Bluebird	*Sialia sialis*	4	0.012	0.009	0.028
Eastern Kingbird	*Tyrannus tyrannus*	9	0.021	0.009	0.085
Eastern Meadowlark	*Sturnella magna*	31	0.065	0.024	0.183
Eastern Towhee	*Pipilo erythropthalmus*	20	0.051	0.018	0.183
Eastern Wood-Pewee	*Contopus virens*	1	0.003	0.003	0.014
Tufted Titmouse	*Baeolophus bicolor*	3	0.011	0.011	0.014
European Starling	*Sturnus vulgaris*	61	0.208	0.181	0.028
Field Sparrow	*Spizella pusilla*	281	0.694	0.061	0.944
Green Heron	*Butorides virescens*	1	0.003	0.003	0.014
Grasshopper Sparrow	*Ammodramus savannarum*	69	0.111	0.032	0.211
Hairy Woodpecker	*Picoides villosus*	1	0.003	0.003	0.014
Henslow's Sparrow	*Ammodramus henslowii*	144	0.316	0.049	0.479
Horned Lark	*Eremophila alpestris*	5	0.008	0.008	0.014
Indigo Bunting	*Passerina cyanea*	220	0.540	0.045	0.901
Killdeer	*Charadrius vociferus*	2	0.003	0.003	0.014
Mallard	*Anas platyrhynchos*	1	0.002	0.002	0.014
Mourning Dove	*Zenaida macroura*	11	0.026	0.013	0.056
Northern Bobwhite	*Colinus virginianus*	42	0.097	0.022	0.324
Northern Cardinal	*Cardinalis cardinalis*	10	0.032	0.013	0.099
Northern Mockingbird	*Mimus polyglottos*	1	0.003	0.003	0.014
Orchard Oriole	*Icterus spurius*	9	0.017	0.008	0.085
Prairie Warbler	*Dendroica discolor*	60	0.148	0.037	0.352
Purple Martin	*Progne subis*	6	0.017	0.008	0.070
Ruby-throated Hummingbird	*Archilochus colubris*	4	0.011	0.005	0.056
Red-winged Blackbird	*Agelaius phoeniceus*	123	0.339	0.059	0.451
Sedge Wren	*Cistothorus platensis*	1	0.002	0.002	0.014
White-breasted Nuthatch	*Sitta carolinensis*	4	0.014	0.010	0.028
White-eyed Vireo	*Vireo griseus*	13	0.041	0.014	0.141
Willow Flycatcher	*Empidonax trailii*	4	0.012	0.008	0.042
Yellow-breasted Chat	*Icteria virens*	70	0.172	0.032	0.437
Total		**1744**	**4.153**	**0.305**	**1.000**

Table 2-3. Occurrence patterns of grassland and successional or scrub dependent birds by ownership type in the Big Barrens, Tennessee and Kentucky, 2006-07.

			Observed on…		
	Common Name	**Scientific Name**	**CRP**	**FCMR**	**TWRA**
Grassland	Dickcissel	*Spiza americana*	Yes	Yes	Yes
	Eastern Meadowlark	*Sturnella magna*	Yes	Yes	No
	Grasshopper Sparrow	*Ammodramus savannarum*	Yes	Yes	No
	Henslow's Sparrow	*Ammodramus henslowii*	Yes	Yes	No
	Horned Lark	*Eremophila alpestris*	No	Yes	No
	Sedge Wren	*Cistothorus platensis*	No	Yes	No
	Total		**4**	**6**	**1**
Successional or Scrub	American Goldfinch	*Carduelis tristis*	Yes	Yes	Yes
	Bell's Vireo	*Vireo bellii*	No	Yes	No
	Blue Grosbeak	*Passerina caerulea*	Yes	Yes	No
	Brown Thrasher	*Toxostoma rufum*	Yes	No	Yes
	Carolina Wren	*Thryothorus ludovicianus*	Yes	No	Yes
	Common Yellowthroat	*Geothlypis trichas*	Yes	Yes	Yes
	Eastern Towhee	*Pipilo erythrophthalmus*	No	Yes	Yes
	Field Sparrow	*Spizella pusilla*	Yes	Yes	Yes
	Indigo Bunting	*Passerina cyanea*	Yes	Yes	Yes
	Northern Bobwhite	*Colinus virginianus*	Yes	Yes	Yes
	Northern Cardinal	*Cardinalis cardinalis*	Yes	No	Yes
	Prairie Warbler	*Dendroica discolor*	No	Yes	Yes
	White-eyed Vireo	*Vireo griseus*	Yes	Yes	Yes
	Willow Flycatcher	*Empidonax traillii*	No	No	Yes
	Yellow-breasted Chat	*Icteria virens*	Yes	Yes	Yes
	Total		**11**	**11**	**13**

Table 2-4. Mean population density of grassland birds by species and ownership type in the Big Barrens, Tennessee and Kentucky, 2006-07. The letters next to estimates for Common Yellowthroat, Field Sparrow, and Red-winged Blackbird correspond to significantly different groups (estimates are different if they do not share a letter). Overall error rate was controlled at $\alpha = 0.05$ using Tukey's Honestly Significant Difference.

Species	CRP		FCMR		TWRA	
	Individuals per ha	SE	Individuals per ha	SE	Individuals per ha	SE
American Goldfinch	0.082	0.034	0.063	0.027	0.196	0.047
Blue Grosbeak	0.025^{AB}	0.019	0.069^{A}	0.015	0.000^{B}	0.000
Common Yellowthroat	0.136^{B}	0.080	0.459^{A}	0.063	0.561^{A}	0.104
Dickcissel	0.264	0.147	0.606	0.118	0.217	0.187
Field Sparrow	0.556^{B}	0.122	0.668^{B}	0.097	1.192^{A}	0.158
Grasshopper Sparrow	0.008^{AB}	0.085	0.255^{A}	0.068	0.000^{B}	0.000
Henslow's Sparrow	0.4051^{A}	0.081	0.4478^{A}	0.064	0.000^{B}	0.000
Indigo Bunting	0.443	0.086	0.613	0.067	0.689	0.113
Northrn Bobwhite	0.159	0.035	0.088	0.026	0.079	0.047
Prairie Warbler	0.000^{B}	0.000	0.264^{A}	0.053	0.141^{AB}	0.090
Red-winged Blackbird	0.761^{A}	0.107	0.067^{B}	0.085	0.357^{AB}	0.137
Yellow-breasted Chat	0.134	0.070	0.262	0.056	0.146	0.091

Table 2-5. Factor loadings for principal components analysis on vegetation variables measured in the Big Barrens, Tennessee and Kentucky, 2006-07. The loadings that are considered dominant for each principal component are shaded gray. Herbhgt, woodhgt, and grsshgt refer to the height of forbs, woody vegetation, and grass, respectively, within 1-m^2 plots. Avg_lit is the average litter depth and cbavg is an index of vegetation density (greater values indicate less dense vegetation). The last 7 variables are the proportion of ground covered by each of 7 cover types within the 1-m^2 plot.

Variable	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**
HerbHgt	-0.4869	-0.4580	-0.2095	0.2895	-0.2390	-0.0638
WoodHgt	-0.4980	0.4272	-0.6367	-0.0887	0.0547	-0.1200
GrssHgt	-0.7033	-0.0428	0.4284	0.1515	0.1735	0.0562
Avg_Lit	-0.5288	-0.1495	0.1830	-0.6629	-0.0950	-0.0169
CBAvg	0.5528	0.3963	0.0924	-0.3916	-0.1427	-0.0221
Litter	-0.1529	-0.1131	0.2837	-0.6946	-0.5017	-0.0299
Bare	0.6653	0.2093	-0.3239	-0.0148	-0.1159	-0.0297
Wood	-0.4795	0.4112	-0.6689	-0.1836	0.0378	-0.1488
DWood	-0.1073	0.1046	-0.2309	-0.0772	-0.0518	0.9562
CSG	0.0996	-0.2138	0.0727	-0.5118	0.7745	0.0205
WSG	-0.2304	0.6544	0.5626	0.4053	-0.0280	0.0286
Forbs	0.1342	-0.8530	-0.2715	0.1565	-0.0683	0.0231

Table 2-6. Notation for vegetation variables discussed in this Chapter 2.

Variable Name	**Description**
herbhgt	Forb height (cm)
grsshgt	Grass height (cm)
woodhgt	Woody vegetation height (cm)
cbavg	Inverse index of vertical vegetation density (range: 1-20)
avglit	Litter depth (cm)
litter	Proportion of ground covered in litter
bare	Proportion of ground covered in bare ground
wood	Proportion of ground covered in live woody vegetation
dwood	Proportion of ground covered in dead woody vegetation
csg	Proportion of ground covered in cool-season grass
wsg	Proportion of ground covered in warm-season grass
forbs	Proportion of ground covered in forbs

Table 2-7. Results of population density model selection for Dickcissels in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(avglit)	2	-40.72	0.00	0.214
S(dwood)	2	-39.77	0.95	0.133
S(grsshgt)	2	-39.68	1.04	0.127
S(.)	1	-39.22	1.50	0.101
S(woodhgt+dwood)	3	-39.13	1.59	0.097
S(woodhgt)	2	-38.72	2.00	0.079
S(bare)	2	-38.70	2.02	0.078
S(herbhgt)	2	-38.41	2.31	0.067
S(herbhgt+woodhgt)	3	-38.19	2.53	0.060
S(global)	7	-37.54	3.18	0.044

Table 2-8. Results of population density model selection for Grasshopper Sparrows in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(avglit)	2	-84.35	0.00	0.285
S(.)	1	-82.75	1.61	0.128
S(litter)	2	-82.66	1.70	0.122
S(wood)	2	-82.41	1.95	0.108
S(wsg)	2	-81.98	2.37	0.087
S(litter+csg)	3	-81.33	3.03	0.063
S(csg)	2	-81.09	3.27	0.056
S(herbhgt)	2	-80.82	3.54	0.049
S(cbavg)	2	-80.77	3.58	0.048
S(wood+cbavg)	3	-80.59	3.77	0.043
S(global)	8	-78.19	6.16	0.013

Table 2-9. Results of population density model selection for Henslow's Sparrows in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(wsg)	2	-58.27	0.00	0.174
S(wood)	2	-57.94	0.33	0.148
S(.)	1	-57.70	0.57	0.131
S(litter+wsg)	3	-57.41	0.87	0.113
S(bare)	2	-56.97	1.30	0.091
S(avglit)	2	-56.73	1.54	0.081
S(herbhgt)	2	-56.52	1.75	0.073
S(grsshgt)	2	-56.12	2.15	0.059
S(forbs)	2	-56.03	2.24	0.057
S(csg)	2	-55.72	2.55	0.049
S(csg+grsshght+avglit)	4	-53.49	4.78	0.016
S(global)	9	-52.56	5.71	0.010

Table 2-10. Results of population density model selection for Red-winged Blackbirds in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(woodhgt)	2	-48.18	0.00	0.265
S(litter)	2	-46.31	1.87	0.104
S(wood)	2	-45.97	2.20	0.088
S(.)	1	-45.88	2.30	0.084
S(wsg)	2	-45.86	2.32	0.083
S(cbavg)	2	-44.96	3.22	0.053
S(avglit)	2	-44.67	3.51	0.046
S(bare)	2	-44.67	3.51	0.046
S(herbhgt)	2	-44.36	3.82	0.039
S(forbs)	2	-44.18	4.00	0.036
S(grsshgt)	2	-44.13	4.05	0.035
S(csg)	2	-44.05	4.13	0.034
S(dwood)	2	-43.93	4.25	0.032
S(global)	13	-43.57	4.61	0.026
S(grsshgt+wood+csg)	4	-42.50	5.68	0.015
S(dwood+forbs)	3	-42.23	5.95	0.014

Table 2-11. Results of population density model selection for American Goldfinches in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(forbs)	2	-121.71	0.00	0.235
S(litter)	2	-119.91	1.80	0.095
S(woodhgt)	2	-119.68	2.03	0.085
S(woodhgt+bare)	3	-119.48	2.23	0.077
S(.)	1	-119.40	2.31	0.074
S(bare)	2	-119.33	2.38	0.071
S(cbavg)	2	-118.98	2.73	0.060
S(herbhgt)	2	-118.67	3.04	0.051
S(grsshgt)	2	-118.45	3.27	0.046
S(cbavg+forbs+dwood)	4	-118.38	3.33	0.044
S(wood)	2	-118.05	3.67	0.038
S(csg)	2	-117.87	3.84	0.034
S(dwood)	2	-117.68	4.04	0.031
S(wsg)	2	-117.62	4.09	0.030
S(avglit)	2	-117.41	4.30	0.027
S(global)	13	-110.63	11.08	0.001

Table 2-12. Results of population density model selection for Blue Grosbeaks in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(cbavg)	2	-178.35	0.00	0.586
S(cbavg+forbs+dwood)	4	-176.63	1.72	0.248
S(herbhgt)	2	-174.21	4.14	0.074
S(forbs)	2	-171.66	6.69	0.021
S(.)	1	-170.56	7.79	0.012
S(dwood)	2	-170.48	7.87	0.011
S(avglit)	2	-169.55	8.79	0.007
S(bare)	2	-169.28	9.07	0.006
S(wsg)	2	-169.14	9.21	0.006
S(grsshgt)	2	-168.97	9.38	0.005
S(litter)	2	-168.95	9.39	0.005
S(wood)	2	-168.64	9.70	0.005
S(woodhgt)	2	-168.57	9.78	0.004
S(csg)	2	-168.56	9.79	0.004
S(woodhgt+bare)	3	-167.28	11.07	0.002
S(global)	13	-166.87	11.48	0.002

Table 2-13. Results of population density model selection for Common Yellowthroats in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(woodhgt)	2	-67.13	0.00	0.204
S(woodhgt+bare)	3	-66.80	0.33	0.173
S(csg)	2	-65.81	1.32	0.105
S(.)	1	-65.43	1.70	0.087
S(bare)	2	-65.22	1.91	0.078
S(litter)	2	-64.63	2.50	0.058
S(forbs)	2	-64.00	3.13	0.043
S(wsg)	2	-63.85	3.28	0.040
S(avglit)	2	-63.66	3.47	0.036
S(dwood)	2	-63.58	3.55	0.035
S(herbhgt)	2	-63.53	3.60	0.034
S(cbavg)	2	-63.50	3.64	0.033
S(grsshgt)	2	-63.47	3.66	0.033
S(wood)	2	-63.45	3.68	0.032
S(cbavg+forbs+dwood)	4	-60.15	6.98	0.006
S(global)	13	-57.79	9.34	0.002

Table 2-14. Results of population density model selection for Field Sparrows in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(csg)	2	-49.66	0.00	0.325
S(woodhgt)	2	-47.84	1.82	0.131
S(wood)	2	-47.60	2.06	0.116
S(woodhgt+dwood)	3	-46.96	2.70	0.084
S(grsshgt+wood)	3	-46.86	2.79	0.080
S(.)	1	-46.22	3.43	0.058
S(bare)	2	-45.86	3.80	0.049
S(dwood)	2	-45.49	4.17	0.040
S(cbavg)	2	-45.01	4.64	0.032
S(global)	8	-44.83	4.83	0.029
S(avglit)	2	-44.79	4.87	0.028
S(grsshgt)	2	-44.73	4.93	0.028

Table 2-15. Results of population density model selection for Indigo Buntings in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(herbhgt)	2	-76.43	0.00	0.468
S(global)	13	-75.44	0.99	0.285
S(csg)	2	-73.92	2.51	0.133
S(avglit)	2	-70.50	5.93	0.024
S(litter)	2	-69.57	6.87	0.015
S(.)	1	-69.29	7.14	0.013
S(woodhgt)	2	-69.19	7.24	0.012
S(wsg)	2	-68.74	7.70	0.010
S(cbavg)	2	-67.92	8.51	0.007
S(wood)	2	-67.76	8.67	0.006
S(dwood)	2	-67.55	8.89	0.005
S(forbs)	2	-67.50	8.93	0.005
S(grsshgt)	2	-67.42	9.02	0.005
S(bare)	2	-67.36	9.07	0.005
S(woodhgt+bare)	3	-67.23	9.21	0.005
S(cbavg+forbs+dwood)	4	-64.14	12.29	0.001

Table 2-16. Results of population density model selection for Northern Bobwhites in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(wsg)	2	-114.09	0.00	0.183
S(woodhgt+bare)	3	-113.13	0.96	0.113
S(woodhgt)	2	-113.11	0.98	0.112
S(wood)	2	-113.02	1.08	0.106
S(.)	1	-112.34	1.75	0.076
S(bare)	2	-111.96	2.14	0.063
S(grsshgt)	2	-111.90	2.19	0.061
S(avglit)	2	-111.77	2.33	0.057
S(cbavg)	2	-111.68	2.41	0.055
S(csg)	2	-111.36	2.74	0.046
S(herbhgt)	2	-110.66	3.43	0.033
S(forbs)	2	-110.59	3.50	0.032
S(litter)	2	-110.40	3.70	0.029
S(dwood)	2	-110.34	3.75	0.028
S(cbavg+forbs+dwood)	4	-107.72	6.38	0.008
S(global)	13	-100.18	13.91	0.000

Table 2-17. Results of population density model selection for Prairie Warblers in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(.)	1	-70.46	0.00	0.149
S(cbavg)	2	-70.01	0.45	0.119
S(dwood)	2	-69.10	1.36	0.075
S(woodhgt)	2	-68.93	1.53	0.069
S(herbhgt)	2	-68.81	1.65	0.065
S(grsshgt)	2	-68.79	1.67	0.064
S(forbs)	2	-68.77	1.68	0.064
S(wsg)	2	-68.74	1.72	0.063
S(litter)	2	-68.51	1.95	0.056
S(wood)	2	-68.50	1.96	0.056
S(avglit)	2	-68.49	1.97	0.056
S(bare)	2	-68.48	1.97	0.055
S(csg)	2	-68.46	1.99	0.055
S(cbavg+forbs+dwood)	4	-67.06	3.40	0.027
S(woodhgt+bare)	3	-66.95	3.51	0.026
S(global)	13	-52.05	18.41	0.000

Table 2-18. Results of population density model selection for Yellow-breasted Chats in the Big Barrens, Tennessee and Kentucky, 2006-07. S(global) contains all variables represented in the single variable models. S(.), the null model, contains only the intercept. Variable notation is described in Table 2-6.

Model	**K**	**AIC**	**ΔAIC**	w_i
S(wood)	2	-95.44	0.00	0.964
S(woodhgt)	2	-85.20	10.24	0.006
S(cbavg+forbs+dwood)	4	-85.06	10.38	0.005
S(csg)	2	-84.82	10.61	0.005
S(forbs)	2	-84.40	11.04	0.004
S(.)	1	-84.03	11.41	0.003
S(bare)	2	-83.05	12.38	0.002
S(litter)	2	-82.73	12.71	0.002
S(wsg)	2	-82.60	12.84	0.002
S(cbavg)	2	-82.49	12.95	0.001
S(dwood)	2	-82.46	12.98	0.001
S(grsshgt)	2	-82.22	13.21	0.001
S(herbhgt)	2	-82.19	13.25	0.001
S(avglit)	2	-82.15	13.29	0.001
S(global)	13	-80.93	14.50	0.001
S(woodhgt+bare)	3	-80.63	14.81	0.001

Table 2-19. Summary of β estimates for retained population density models for grassland birds, Big Barrens, Tennessee and Kentucky, 2006-07. The sign of each β estimate is given as well as the level of significance (* $P < 0.10$, ** $P < 0.05$, *** $P < 0.01$).

Species / Model	K	AIC	ΔAIC	w_i	herbhgt	grsshgt	woodhgt	cbavg	avglit	litter	bare	wood	dwood	csg	wsg	forbs
Dickcissel																
S(avglit)	2	-40.72	0.00	0.214					-*							
S(dwood)	2	-39.77	0.95	0.133									-			
S(grsshgt)	2	-39.68	1.04	0.127		-										
S(.)	1	-39.22	1.50	0.101												
S(woodhgt+dwood)	3	-39.13	1.59	0.097			-						-			
Grasshopper Sparrow																
S(avglit)	2	-84.35	0.00	0.285					-*							
S(.)	1	-82.75	1.61	0.128												
S(litter)	2	-82.66	1.70	0.122						-						
S(wood)	2	-82.41	1.95	0.108								-				
Henslow's Sparrow																
S(wsg)	2	-58.27	0.00	0.174											+	
S(wood)	2	-57.94	0.33	0.148								-				
S(.)	1	-57.70	0.57	0.131												
S(litter+wsg)	3	-57.41	0.87	0.113						-					+	
S(bare)	2	-56.97	1.30	0.091							-					
S(avglit)	2	-56.73	1.54	0.081					-							
S(herbhgt)	2	-56.52	1.75	0.073	-											
Red-winged Blackbird																
S(woodhgt)	2	-48.18	0.00	0.265			-**									
S(litter)	2	-46.31	1.87	0.104						+						

Table 2-20. Summary of β estimates for retained population density models for shrub/scrub birds, Big Barrens, Tennessee and Kentucky, 2006-07. The sign of each β estimate is given as well as the level of significance (* $P < 0.10$, ** $P < 0.05$, *** $P < 0.01$).

Species / Model	K	AIC	ΔAIC	w_i	herbhgt	grsshgt	woodhgt	cbavg	avglit	litter	bare	wood	dwood	csg	wsg	forbs
American Goldfinch																
S(forbs)	2	-121.71	0.00	0.235												+**
S(litter)	2	-119.91	1.80	0.095						+						
Blue Grosbeak																
S(cbavg)	2	-178.35	0.00	0.586				+***								
S(cbavg+forbs+dwood)	4	-176.63	1.72	0.248				+**					+			-
Common Yellowthroat																
S(woodhgt)	2	-67.13	0.00	0.204			+*									
S(woodhgt+bare)	3	-66.80	0.33	0.173			+*				-					
S(csg)	2	-65.81	1.32	0.105										-		
S(.)	1	-65.43	1.70	0.087												
S(bare)	2	-65.22	1.91	0.078							-					
Field Sparrow																
S(lncsg)	2	-49.66	0.00	0.325										-**		
S(woodhgt)	2	-47.84	1.82	0.131			+*									
Indigo Bunting																
S(herbhgt)	2	-76.43	0.00	0.468	+***											
S(global)	13	-75.44	0.99	0.285	+***	-	+*	+	-	+	+	+	+	+	+	+

Species / Model	K	AIC	ΔAIC	*w i*	herbhgt	grsshgt	woodhgt	cbavg	avglit	litter	bare	wood	dwood	csg	wsg	forbs
Northern Bobwhite																
S(wsg)	2	-114.09	0.00	0.183											+*	
S(woodhgt+bare)	3	-113.13	0.96	0.113			-*				-					
S(woodhgt)	2	-113.11	0.98	0.112			-									
S(wood)	2	-113.02	1.08	0.106								-				
S(.)	1	-112.34	1.75	0.076												
Prairie Warbler																
S(.)	1	-70.46	0.00	0.149												
S(cbavg)	2	-70.01	0.45	0.119				+								
S(dwood)	2	-69.10	1.36	0.075									-			
S(woodhgt)	2	-68.93	1.53	0.069			+									
S(herbhgt)	2	-68.81	1.65	0.065	-											
S(grsshgt)	2	-68.79	1.67	0.064		-										
S(forbs)	2	-68.77	1.68	0.064												-
S(wsg)	2	-68.74	1.72	0.063											+	
S(litter)	2	-68.51	1.95	0.056						-						
S(wood)	2	-68.50	1.96	0.056								+				
S(avglit)	2	-68.49	1.97	0.056					-							
S(bare)	2	-68.48	1.97	0.055							-					
S(csg)	2	-68.46	1.99	0.055										-		
Yellow-breasted Chat																
S(wood)	2	-95.44	0.00	0.964								+***				

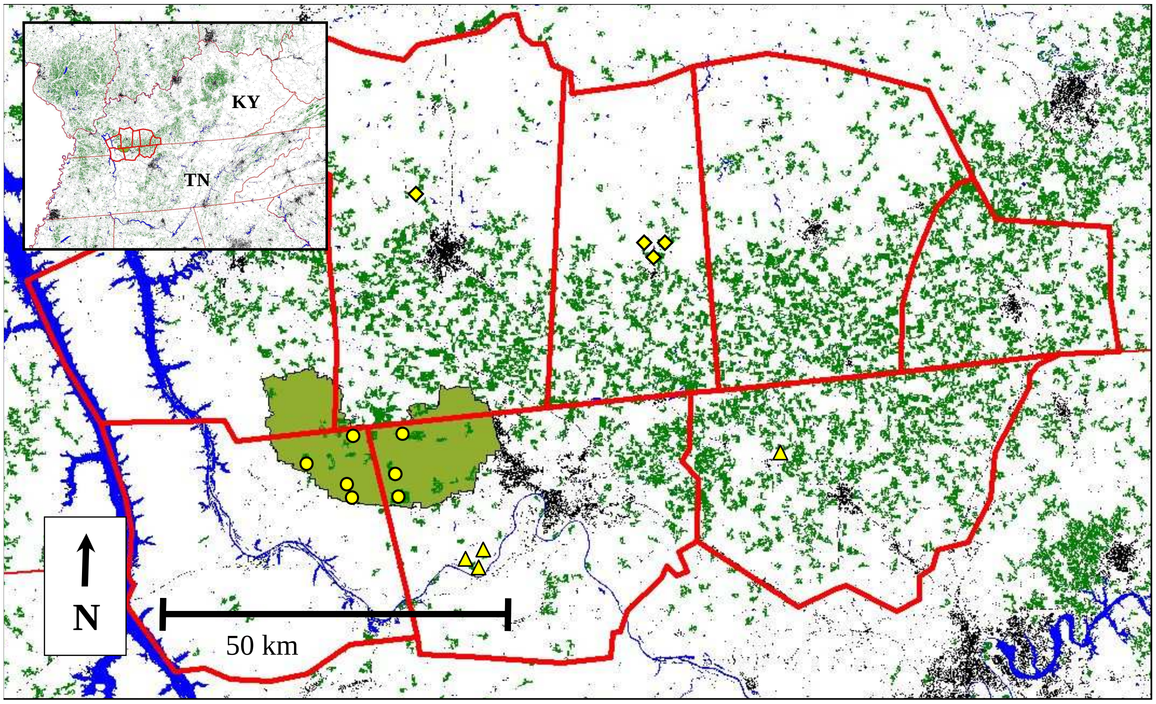

Figure 2-1. Study sites for nest searching in the Big Barrens, Tennessee and Kentucky, 2006-07. Yellow circles represent FCMR fields, yellow diamonds are CRP fields, and yellow triangles are TWRA fields. Black pixels indicate developed areas, dark green pixels are fields of >40 ha in total size, blue areas are standing water, and the pea green region shows the area covered by FCMR. The Big Barrens is visible as the green band across the middle of the figure. Red lines indicate the border between Tennessee and Kentucky as well as the 8 counties that make up the study area. The northern 5 counties (left to right: Trigg, Christian, Todd, Logan, and Simpson) are in Kentucky and the southern 3 (left to right: Stewart, Montgomery, and Robertson) are in Tennessee.

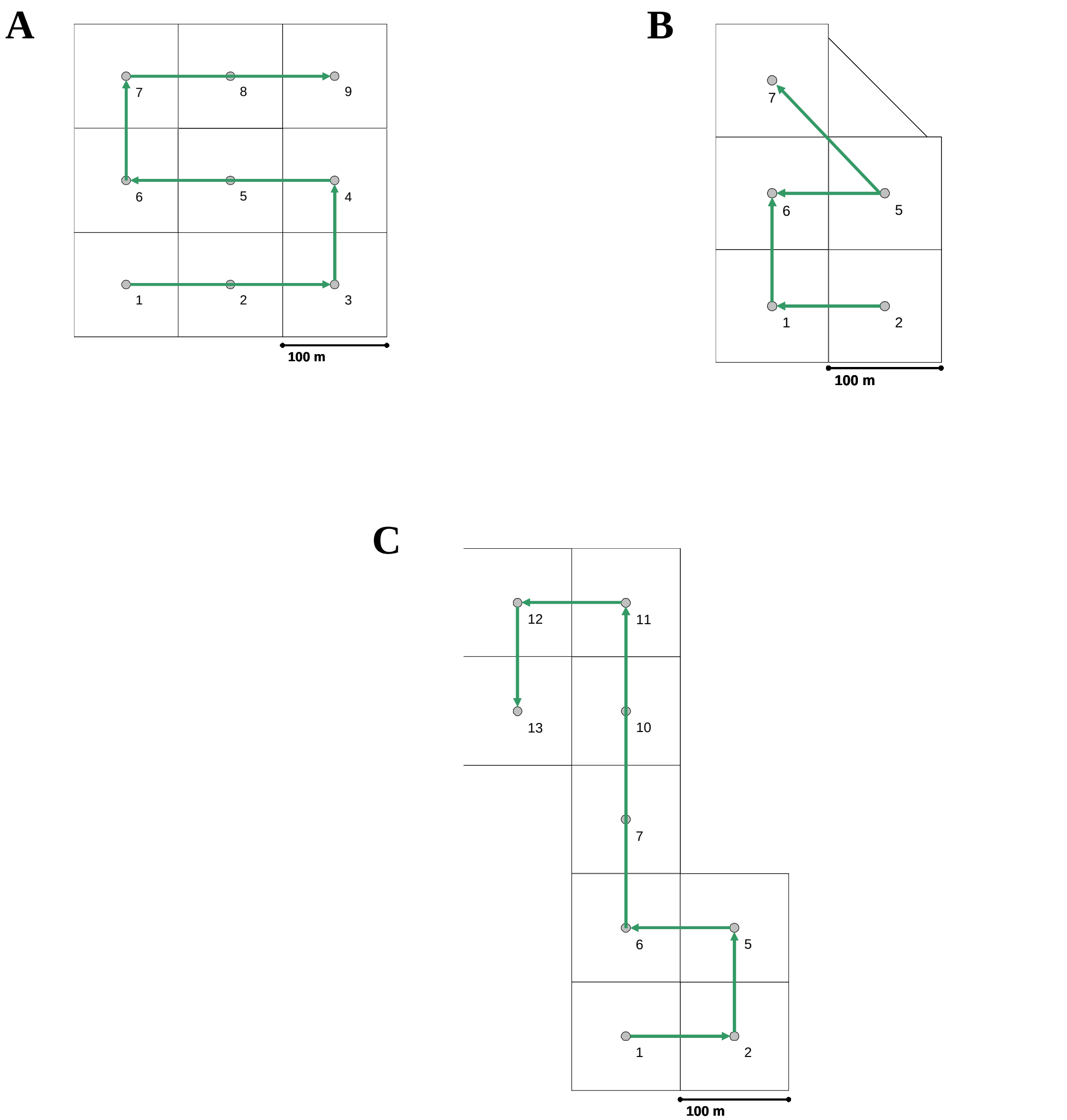

Figure 2-2. Examples of plot designs used to sample grassland bird density. The basic design (A) is a 3×3 grid of points with each point in the center of a 1-ha. square. The arrows indicate a possible path along which the observer walked to sample the grid. Modifications of the basic design were necessary if a field was too small (B) or too irregularly shaped (C) for the basic design.

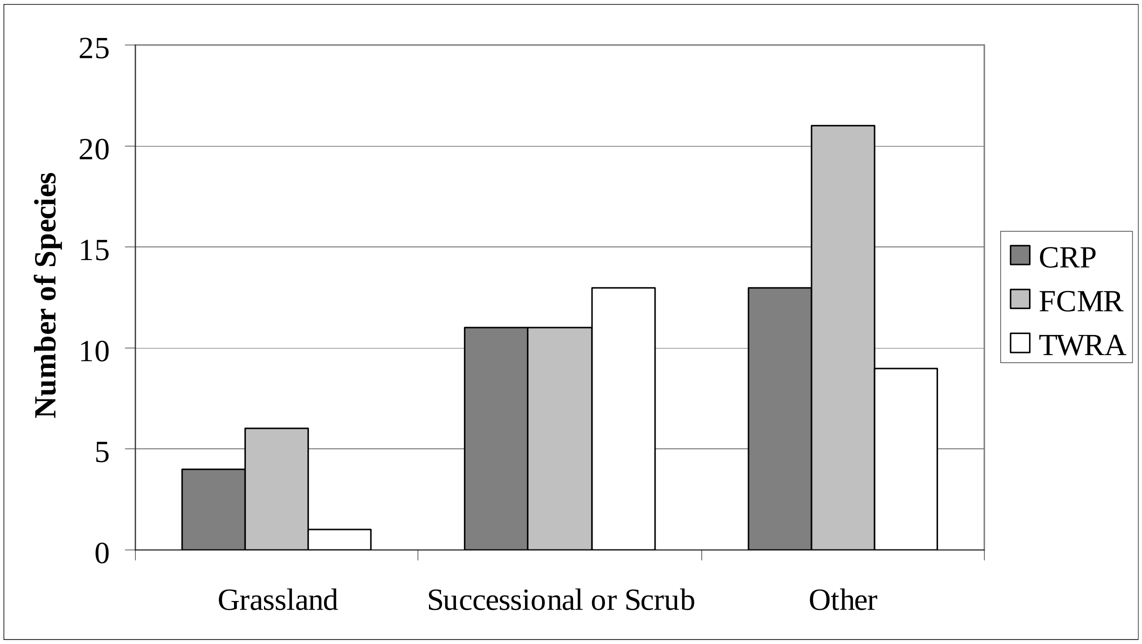

Figure 2-3. Number of species observed by field ownership and habitat association of the species (from Sauer et al. 2005). Lists of the species observed in the grassland and successional or scrub groups are found in Table 2-1.

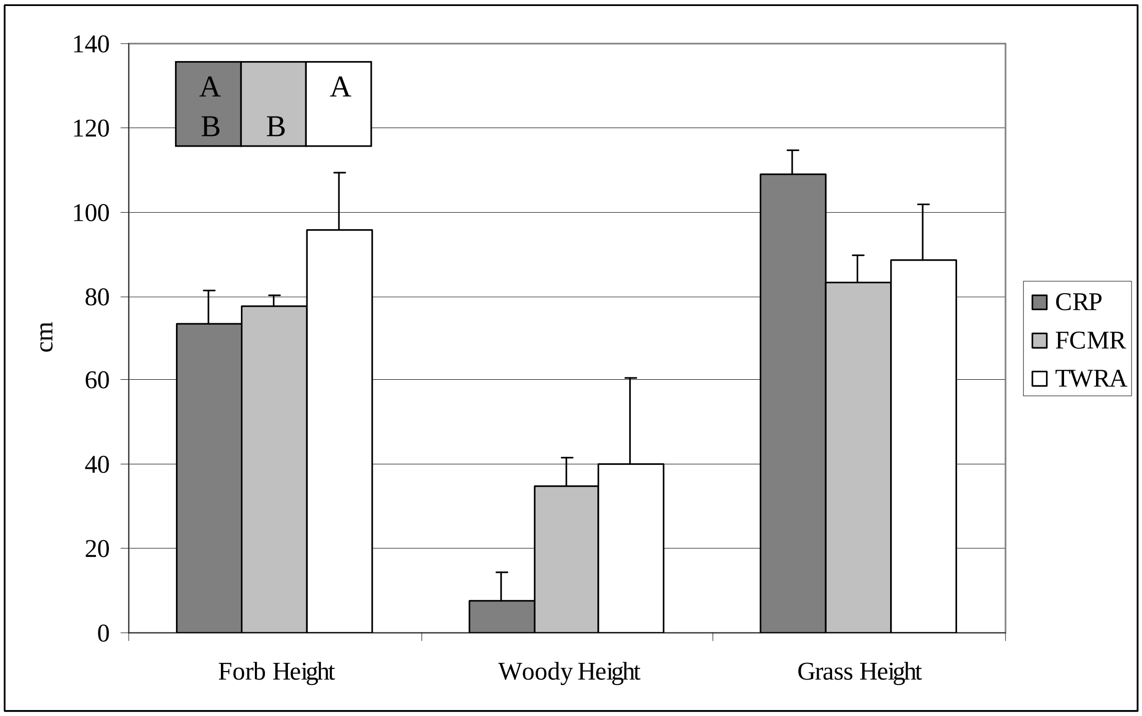

Figure 2-4. Average height of vegetation by vegetation type and field ownership type. Error bars indicate 1 standard error. The box above forb height indicates a significant difference in forb height between TWRA and FCMR.

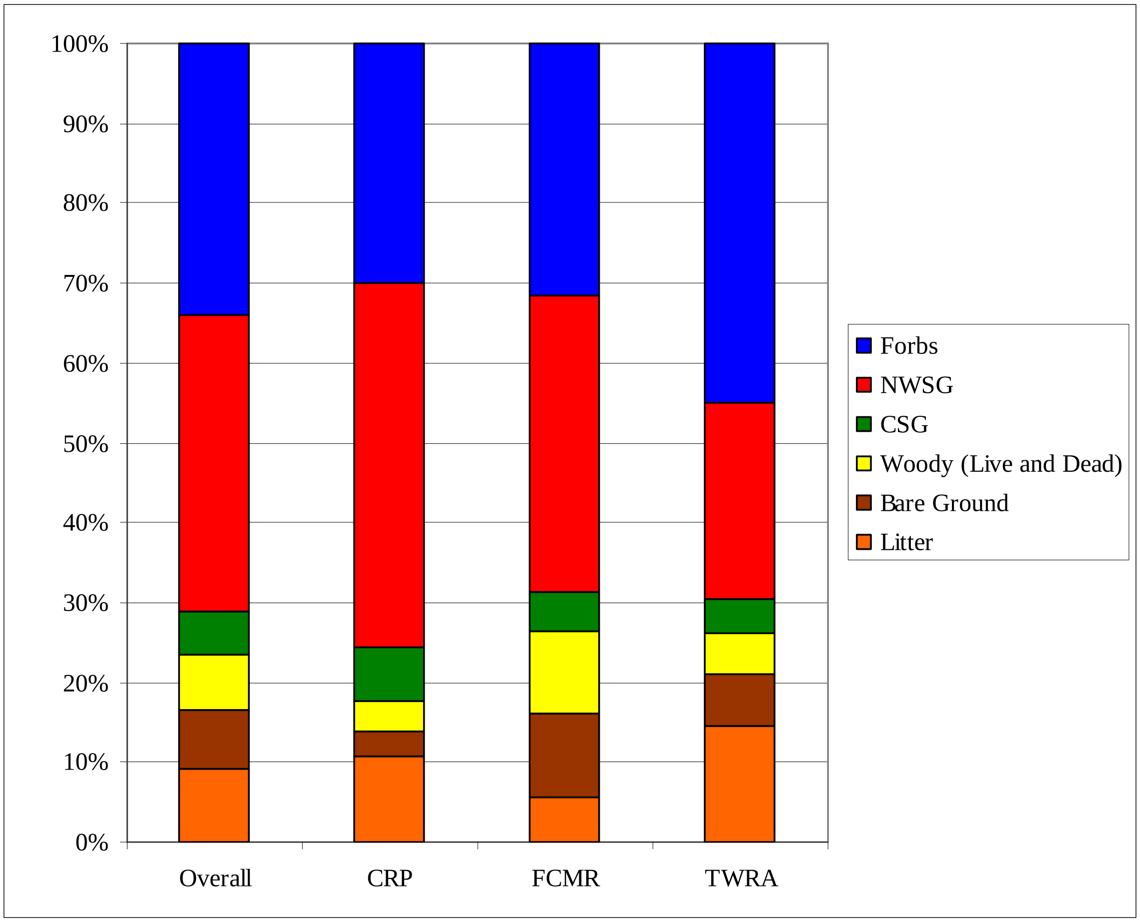

Figure 2-5. Proportion of ground cover in 6 vegetation types by ownership type in the Big Barrens, Tennessee and Kentucky, 2006-07. The dead woody and woody categories were combined in this figure. Native warm-season grass was significantly greater on FCMR and CRP fields than on TWRA. Litter was significantly greater on CRP fields than on FCMR fields.

Chapter 3

CHAPTER 3

NESTING SUCCESS OF HENSLOW'S AND FIELD SPARROWS ON FORT CAMPBELL MILITARY RESERVATION AND IN THE SURROUNDING LANDSCAPE

Introduction

Henslow's Sparrows (*Ammodramus henslowii*) have a greater estimated rate of decline than any other grassland bird species breeding in eastern North America from 1966-2006 (-6.3% annual population trend; Sauer et al. 2007). The estimated global population of Henslow's Sparrows is about 80,000 (Rich et al. 2004), which also gives cause for conservation concern. This species is listed as Near Threatened by the IUCN (BirdLife International 2004) and as a bird of conservation concern by the United States Fish and Wildlife Service (2002). Habitat loss and degradation are likely the principal causes of decline (Pruitt 1996, Burhans 2002, Herkert et al. 2002, Herkert 2007). There is evidence that the Henslow's Sparrow population may be increasing over the last 2 decades in response to habitat created through the United States Department of Agriculture's Conservation Reserve Program (CRP; Herkert 1997, 2007a, 2007b, Wells 2007) and reclamation of surface coal mines (Bajema et al. 2001). In fact, in and around the Big Barrens, Henslow's Sparrows appear to have increased >1.5% annually from 1966-2003 (Figure 3-1; Sauer et al. 2007).

Field Sparrows (*Spizella pusilla*) also have also exhibited a significant decline from 1966-2006; the mean annual population change estimate for this species is -2.9% (Figure 3-2; Sauer et al. 2007). Carey et al. (1994) identified habitat loss as the primary cause of the decline of Field Sparrow populations. Despite the population decline, the

Field Sparrow is typically not thought of as a species of conservation concern because its global population estimate of 8,200,000 (Rich et al. 2004) is about 100 times more abundant than Henslow's Sparrows. The Field Sparrow also makes use of a broader range of habitats, including small forest openings and habitat with fairly dense woody growth (e.g. Christmas tree farms; Carey et al. 1994, Burhans 1997, McWilliams and Brauning 2000). Field Sparrows do not typically occur in habitat where there is not at least sparse woody vegetation (Carey et al. 1994).

Many factors may influence the nesting success of Henslow's and Field Sparrows in the Big Barrens. Proximity to habitat edge has been shown to have a negative effect on nest success for grassland birds through increased rates of predation and parasitism by Brown-headed Cowbirds (*Molothrus ater*; Zimmerman 1971, Johnson and Temple 1990, Paton 1994, Helzer and Jelinski 1999, Winter and Faaborg 1999, Winter et al. 2000, Herkert et al. 2003), although recent research suggests those trends may not be present for some grassland birds (Winter et al. 2006). Henslow's Sparrows favor habitats with greater standing dead vegetation and less woody vegetation (Zimmerman 1988, Giocomo 2005; Table 2-6). Giocomo et al. (2008) also observed less bare ground, more cool and warm-season grass, less forb cover, and greater litter depth at Henslow's Sparrow nests than at random points.

Although nest success is usually low for both of these species, both species typically raise multiple broods per breeding season. Henslow's Sparrows appear to be at least double-brooded (Ehrlich et al. 1988, Winter 1999); this species could potentially complete more than 2 broods because its breeding season starts in early May and can last until late August (Hyde 1939, Robins 1971, Herkert et al. 2002, Giocomo 2005). Field

Sparrows are usually double-brooded (Best 1978, Giocomo 2005), but can successfully complete up to 3 broods in 1 breeding season (Best 1974a, Carey et al. 1994). Best (1974a) observed a single female that made 10 unsuccessful nesting attempts during one breeding season. Like Henslow's Sparrow, the Field Sparrow breeding season lasts from May until late August (Walkinshaw 1936).

Moss (2001) and Giocomo (2005) estimated demographic parameters for Henslow's and Field Sparrows nesting on Fort Campbell Military Reserve (FCMR), Tennessee and Kentucky, in 1999-2000 and 2001-03, respectively. Both Henslow's Sparrows and Field Sparrows have relatively low documented nest success rates, a trait that is common among grassland and shrub/scrub nesting birds (Nolan 1963, Gottfried and Thompson 1978, Martin 1993). Giocomo (2005) compared Mayfield nest success estimates for Henslow's and Field Sparrows breeding on FCMR from 2001-03 to the range of estimates represented in the literature. FCMR nest success for Henslow's Sparrows (27%) was in the middle of the documented range for that species (7-46%), but the estimated FCMR nest success for Field Sparrows (20%) was below the published range (21-47%).

I searched for Henslow's and Field Sparrow nests on FCMR fields as well as on 2 types of fields in the surrounding landscape: privately-owned fields enrolled in CRP and fields managed by the Tennessee Wildlife Resources Agency (TWRA). FCMR grasslands support an almost complete community of grassland and shrub nesting birds that were historically found in eastern grasslands (see Chapter 2), but it is unknown whether the habitat provided on the military base is actually higher quality from the standpoint of productivity. My main objectives were to identify microhabitat characteristics associated with nest site selection and, by modeling daily survival rate (DSR) of nests, to identify which habitat characteristics imparted an advantage to breeding grassland birds through increased fitness.

Methods

Study Area – The Big Barrens, part of the Pennyroyal Plain, is a 1.2-million-ha region of mostly open habitat in Kentucky and Tennessee (Figure 2-1). This area was once covered almost entirely by native grasslands but was shifted to a mostly forested landscape following European settlement (McInteer 1946). It has now shifted to a mosaic of forests and agriculture with patches of remnant or restored grassland (Chester et al. 1997). Big bluestem (*Andropogon gerardii*), broomsedge (*A. virginicus*), switchgrass (*Panicum virgatum*), little bluestem (*Schizachyrium scoparium*), and indiangrass (*Sorghastrum nutans*) are the predominant species of native warm-season grass occurring on FCMR (Moss 2001, Dykes 2005, Giocomo 2005). I searched for nests on fields with a significant NWSG component in the Big Barrens. Three different ownership types were investigated: military fields on FCMR, privately-owned land enrolled in CRP, and TWRA Wildlife Management Areas. TWRA-managed grasslands were sampled at Cedar Hill Swamp and Haynes Bottom Wildlife Management Areas.

Nest Searching and Monitoring – I searched for grassland bird nests from late April to late July in 2006 and 2007. Nests were located using search image, observations of parental behavior, and by flushing adults directly from the nest. Once located, nests were checked every 3-5 days until completion. Longer intervals were required occasionally when access was denied to FCMR fields because of their use for military training or hunting. Care was taken during nest checks to cause as little disturbance as possible to the vegetation around the nest. Contact between nest substrate and human skin or clothing was avoided during nest checks; a stick or ruler was used to hold vegetation aside when necessary. Observers walked away from the nest in a different direction than the path used to approach the nest to avoid leaving a physical or scent trail to the nest for potential predators to follow.

The primary target for nest searchers was Henslow's Sparrow. Henslow's Sparrow nests are particularly difficult to find because the nests are well hidden and adult behavior is cryptic. Field Sparrows were also of particular interest, but nests of this and any other species were usually found opportunistically while observers searched for Henslow's Sparrow nests. I monitored all nests that were found. Nest fate was determined for each nest based on nest contents, nest condition, parental behavior, and the presence of fledglings in the immediate vicinity (Martin and Geupel 1993, Moss 2001, Giocomo 2005). Hensler and Nichols (1981) recommended that a sample size of at least 20 is necessary to precisely estimate nest success, and I attempted to locate at least 20 Henslow's and Field Sparrow nests on each ownership type.

***Vegetation Sampling* –** Vegetation was sampled at each nest after the failure or successful completion of the nest. I also sampled vegetation at 5 systematically chosen points within each field in both years (2006-07), between 1 June and 20 July. If a field was large enough to contain the basic 9 ha, square-shaped plot, vegetation was sampled at the middle point and the four points closest to the corners of the plot (Figure 2-2, *a*; points 1, 3, 5, 7, and 9). On smaller or irregularly shaped plots (Figure 2-2, *b* and *c*, respectively), I sampled vegetation at a set of 5 points that were as spread out as possible but still on the points used for bird surveys. I sampled vegetation on 17 fields in 2006 and on 21 fields in 2007, for a total of 85 and 105 vegetation sampling plots, respectively. I averaged estimates for each variable for the 5 points on each field. Nest searching was not confined to the area sampled with systematically selected vegetation plots, but I collected the same vegetation data at each nest, after completion of the nest.

For each field, I recorded whether or not the field had been burned within the last year and whether or not it had been mowed. Other data were based on measurements on 1-m^2 plots. Within the 1-m^2 plot, I measured the tallest vegetation (cm) for each of 3 vegetation types: grass, woody, and forb. I measured depth (cm) of litter at each corner of the square plot and at the center of the plot. The percent ground cover was recorded in each of 8 cover types: litter, bare ground, live woody vegetation, dead woody vegetation, cool-season grass, warm-season grass, forbs, and other. To estimate the vertical density of the vegetation, I used a cover board marked with 20 100-cm^2 squares arranged in 2 columns and 10 rows. One observer held the board up while another looked back at the board from 10 m in each cardinal direction (Nudds 1977). I recorded the number of squares visible from each cardinal direction. Finally, I visually estimated the distance to the edge of the habitat and the distance to the nearest tree for each vegetation sampling point. Before the field seasons, I practiced estimating distances and checked my estimates with a laser range finder to increase the accuracy and precision of the estimates I made during the field season.

Nest Site Selection **–** I compared vegetation characteristics at systematically-selected vegetation plots with vegetation sampled at Henslow's and Field Sparrow nest sites. I used the full set of vegetation variables measured for this portion of the analysis. I used the ANOVA procedure in SAS 9.1.3 (SAS Institute, Inc. 2003) and used a Bonferroni correction on the results of the ANOVA tests to constrain overall error rate at $\alpha = 0.05$. I compared values for 11 variables (height of forbs, woody vegetation, and grass; vertical vegetation density; litter depth, and proportion of ground in 6 cover types, litter, bare ground, woody vegetation, cool-season grass, warm-season grass, and forbs), so $\alpha_{Bonferroni} = 0.0047$. Tukey's Honestly Significant Difference test was used to control overall error rate on pairwise comparisons among vegetation plots, Henslow's Sparrow nests, and Field Sparrow nests for each vegetation variable.

Modeling of Daily Survival Rate **–** I calculated nest exposure days as the sampling unit to estimate daily survival rate (DSR) of nests (Mayfield 1961, 1975); this method provides a more conservative DSR estimate than calculation of apparent nest success (number of successful nests divided by total nests). Use of nests as sampling units can lead to overestimation of nest success rates because nests that fail early are less likely to be located by observers than nests that are successful or fail late in the nesting cycle (Mayfield 1961, 1975). DSR, taken to the power of the number of days necessary for a successful nest, yields a Mayfield nest success estimate. I assumed the Henslow's Sparrow required 4, 11, and 9 days for the laying, incubation, and brooding stages, respectively (Graber 1968, Ehrlich 1988). I used the same values for Field Sparrows for the laying and brooding stages, but 12 days is a more appropriate incubation estimate for that species (Walkinshaw 1968, Best 1978, Ehrlich 1988). Therefore, the total length of time assumed necessary for successful completion of a nesting cycle was 24 days for Henslow's Sparrow and 25 days for Field Sparrow.

Regression models comparing DSR to vegetation and field covariates for both Henslow's and Field Sparrows were developed *a priori* for each species and were analyzed using Program MARK (White and Burnham 1999, Rotella 2008). Models were compared using the information theoretic approach, which allows comparisons of several models with each other, rather than testing each alternate hypothesis against a null hypothesis with a probability threshold that is essentially arbitrary (Akaike 1974, Johnson and Omland 2004). I used the logit link function in Program MARK because it is appropriate for analysis of nest survival data (Rotella 2008).

I reduced the total pool of covariates for nest success regression by removing all variables that were direct linear combinations of other variables, such as average concealment (Nudds 1977), which was the mean of concealment estimates from the 4 cardinal directions. Correlation among remaining variables was tested with the corr procedure in SAS 9.1.3 (SAS Institute, Inc. 2003). I removed variables liberally to reduce the set to a more manageable number; I removed a variable from each pair of variables for which $R > 0.50$. Separate correlation analyses were used for Henslow's and Field Sparrow vegetation data.

I selected models using a hierarchical approach based on the methods outlined in Bulluck and Buehler (2008, in press). Covariates were separated into the following 4 categories: ownership class, temporal, field-level, and microhabitat-level. An initial suite of models (Suite I) was developed for Henslow's Sparrow (Table 3-1) and Field Sparrow (Table 3-2) based on ownership class and temporal covariates. The top model from Suite I was treated as the null model for analysis of Suite II models, which were based on field-level covariates. Microhabitat-level variables were addressed in the models comprising

Suite III, which used the top model from Suite II as the null model. In addition to the models laid out in Tables 3-1 and 3-2, a global model was tested for each model suite that contained all the covariates represented in that suite. This hierarchical approach aims to simulate the decisions of an individual bird selecting a nest site, moving from more general to more specific site characteristics. I retained all models with $\Delta AIC_c \leq 2.0$ in Suite III for each species as being important to describe the variation in DSR.

Results

***Nest-site Selection* –** Vegetation height differed among random vegetation plots and bird nests for forbs ($F = 6.73$, $df = 2, 325$, $P = 0.001$), woody vegetation ($F = 10.10$, $df = 2, 325$, $P < 0.001$), and grass ($F = 5.66$, $df = 2, 325$, $P = 0.004$; Figure 3-7). Mean forb height at Henslow's Sparrow nests (61.2 ± 4.9 cm) was lower than forb height at vegetation plots (78.9 ± 2.0 cm; $P_{Tukey} = 0.003$) and Field Sparrow nests (81.4 ± 2.7 cm; $P_{Tukey} = 0.001$). Woody vegetation height was much taller at Field Sparrow nests (54.5 ± 5.1 cm) than at vegetation plots (29.5 ± 3.8 cm; $P_{Tukey} < 0.001$) or Henslow's Sparrow nests (17.1 ± 9.1 cm; $P_{Tukey} = 0.001$). Grass was shorter at vegetation plots (87.0 ± 2.8 cm) than at Henslow's (105.2 ± 6.7 cm; $P_{Tukey} = 0.034$) or Field Sparrow nests (99.9 ± 3.7 cm; $P_{Tukey} = 0.017$; Figure 3-7).

There was also a difference among vegetation plots and bird nests for vegetation density ($F = 6.21$, $df = 2, 324$, $P = 0.002$). Because I recorded the number of squares visible out of 20 on the cover board, vegetation density varied inversely with the index measured. Therefore, vegetation density was lower at Henslow's Sparrow nests (15.6 ±

0.7 cm) than at vegetation plots (13.0 ± 0.3 visible squares; $P_{Tukey} = 0.002$) and Field Sparrow nests (13.1 ± 0.4 visible squares; $P_{Tukey} = 0.006$).

Proportion of ground cover differed among vegetation plots, Henslow's Sparrow nests, and Field Sparrow nests for 3 of 6 ground cover variables (Figure 3-8): bare ground ($F = 10.14$, df = 2, 325, $P < 0.001$), woody vegetation ($F = 8.50$, df = 2, 325, $P < 0.001$), and warm-season grass ($F = 10.18$, df = 2, 325, $P < 0.001$). Bare ground coverage was greater at vegetation plots (7.9 ± 0.8 %) than at Field Sparrow nests (1.8 ± 1.1 %; $P_{Tukey} < 0.001$), but bare ground coverage at systematically-selected plots and Field Sparrow nests did not differ with Henslow's Sparrow nests (2.7 ± 2.0 %). Woody vegetation coverage was greater at Field Sparrow nests (14.0 ± 1.6 %) than at vegetation plots (7.6 ± 1.2 %; $P_{Tukey} = 0.004$) or Henslow's Sparrow nests (2.0 ± 2.9 %; $P_{Tukey} = 0.001$). Warm-season grass coverage was greater at Henslow's Sparrow nests (58.3 ± 4.5 %) than at vegetation plots (36.5 ± 1.9 %; $P_{Tukey} < 0.001$) or Field Sparrow nests (37.8 ± 2.5 %; $P_{Tukey} < 0.001$; Figure 3-8).

Nest Success – I monitored 286 nests of 17 species, including 39 Henslow's Sparrow nests and 122 Field Sparrow nests (Table 3-3). The Mayfield nest success estimate for Henslow's Sparrow was 23.8% (95% CI = 10.7 – 40.5%; Table 3-4) and apparent nest success (successful nests / all nests) was 48.7%. Field Sparrow Mayfield nest success was 15.4% (95% CI = 9.5 – 23.1%; Table 3-5) and apparent nest success was 44.3%. The 95% confidence intervals did not overlap for daily survival rate of Field Sparrow nests in incubation (DSR = 0.908; 95% CI = 0.881 – 0.929) and brooding (DSR = 0.961; 95% CI = 0.936 – 0.977; Table 3-5) stages.

The earliest estimated date for initiation within a breeding season for Henslow's Sparrow was 6 May; the last observed nesting activity for Henslow's Sparrow was a successful nest that was completed on 7 July. The number of known active Henslow's Sparrow nests peaked at 13 nests in the 6th week (3-9 June) of the field season in 2006 and at 7 nests in the 4th week (20-26 May) in 2007 (Figure 3-3). The earliest known nest initiation date for Field Sparrow was 30 April, and the last known nesting activity was a successful nest completed on 21 July. Known active Field Sparrow nests peaked during the 4th week (20-26 May) in both 2006 (25 nests) and 2007 (21 nests; Figure 3-4). A 2nd peak of lesser magnitude was observed in the 8th and 9th weeks (17-30 June) of the field season (Figure 3-4).

Predation was the apparent cause of nest failure for 20 Henslow's Sparrow nests (100% of failures) and 63 Field Sparrow (92.6%) nests based on evidence of nest disturbance. Parental abandonment was the cause of the other 5 nest failure events (7.4%) for Field Sparrow, and 3 of those 5 (60.0%) were apparently related to parasitism by Brown-headed Cowbirds. Cowbirds parasitized 16 Field Sparrow nests (13.2% of total). Brown-headed Cowbird parasitism was not observed in Henslow's Sparrow nests.

Modeling Daily Survival Rate **–** The null model (S(.), w_i = 0.272; see Table 3-1 for Henslow's Sparrow model notation), containing only the intercept, was the top model in Suite I for Henslow's Sparrow nests (Table 3-6). However, a relatively large proportion of the variation was described by the quadratic temporal model (S(T+TT), ΔAIC_c = 0.06, w_i = 0.264). Based on the significance of this parameter, I chose to retain S(T+TT) as the null model for Suite II. The linear temporal (S(T), ΔAIC_c = 0.89, w_i = 0.175) and stage models (S(stage), ΔAIC_c = 1.62, w_i = 0.121) were also important in Suite I. S(T+TT) (w_i

= 0.494) was the top model in Suite II and was retained as the null model for Suite III. S(T+TT+dist_edge) (ΔAIC_c = 1.45, w_i = 0.239) was the only other important model in Suite II. S(T+TT) was the top model for Suite III (w_i = 0.293). Other important models included S(T+TT) (ΔAIC_c = 1.04, w_i = 0.175; the null model for Suite III) and S(T+TT+bare) (ΔAIC_c = 1.83, w_i = 0.117). With the exception of the β estimate for quadratic time in S(T+TT) and S(T+TT+bare), the 95% confidence interval of each β estimate included zero in each of the retained models for Henslow's Sparrow DSR (Table 3-7). Linear time had negative and quadratic time had positive β estimates for all models (Table 3-7).

The stage model was the top model in Suite I for Field Sparrow (S(stage), w_i = 0.959), and it was retained as the null model for Suite II (Table 3-8). S(stage+field_size) (w_i = 0.466) was the best model in Suite II, and S(stage) (ΔAIC_c = 1.19, w_i = 0.257) was the only other model with $\Delta AIC_c < 2.0$. S(stage+field_size) was used as the null model for Suite III, and it was the best model in that suite (w_i = 0.232). Five other models met the $\Delta AIC_c < 2.0$ criterion in Suite III for the Field Sparrow; each of those models included stage and field size as well as the following parameters: ht_live (ΔAIC_c = 0.46, w_i = 0.184), cb_avg (ΔAIC_c = 1.21, w_i = 0.126), wsg (ΔAIC_c = 1.34, w_i = 0.118), wood (ΔAIC_c = 1.84, w_i = 0.092), and both wood and ht_live (ΔAIC_c = 1.99, w_i = 0.086; Table 3-8).

Stage had a negative β estimate in all models, which indicated greater DSR in the brooding stage than in the incubation stage (Table 3-9). Estimates of β for height of live vegetation and vertical vegetation density were also negative, but the vegetation density variable is an inverse index of the parameter, suggesting a positive relationship with vegetation density (neither of those β estimates were significant). Field size had a positive relationship with Field Sparrow nest DSR in all models. The 95% confidence interval of the β estimate for the stage variable did not include zero in any of the 4 retained models, and the confidence interval of the β estimate included zero in 1 of the 6 retained models (S(stage+field_size)); however, the stage variable was the only variable for which the 95% confidence interval of the β estimate did not contain zero (Table 3-9).

Discussion

Most of the differences between Henslow's Sparrow nests and systematically-selected vegetation points were the same in this study as those identified by Giocomo et al. (2008), including greater grass height (Figure 3-7) and greater coverage by warm-season grass (Figure 3-8). I also found a negative β estimate for cool-season grass coverage on DST for one of the retained models from Suite III, S(T+TT+csg), although the 95% confidence interval for that estimate contained zero, suggesting that this is not a strong relationship (Table 3-7). An increase of 10% of the proportion of ground covered with cool-season grass corresponds to a decrease in Henslow's Sparrow nest DSR of 0.34 ± 0.19. Greater levels of ground coverage in cool-season grass are often indicative of habitats in an earlier stage of succession that may not have a developed warm-season grass component. A link between apparent preferences for nest placement and DSR suggests that Henslow's Sparrows that select for greater warm-season grass coverage are actually increasing their fitness through greater DSR.

I did not observe any difference between Henslow's Sparrow nests and vegetation plots for cool-season grass coverage (Figure 3-8). However, the second best model in Suite III, S(T+TT+csg) (Table 3-6), contained a negative β estimate for cool-season grass coverage. The most common cool-season grass on FCMR and throughout the Big Barrens is tall fescue (*Festuca arundinacea*), which does not have the same type of structure as the native warm-season grasses (little bluestem, big bluestem, broomsedge, indiangrass, and switchgrass) in which I observed Henslow's Sparrow nests. Tall fescue grows in dense, homogeneous patches; the native warm-season grasses listed above grow in dense clumps, often surrounded by comparatively open space. Henslow's Sparrows seem to prefer habitats dominated by native warm-season bunchgrasses with dead standing vegetation (Zimmerman 1988, Scott et al. 2002), but in some cases cool-season grasses can be used for nesting (McCoy et al. 2001).

One relationship that I observed for Henslow's Sparrow nest-site selection was contrary to what Giocomo (2005) observed: I found greater forb height at Henslow's Sparrow nests, while Giocomo found greater forb height at vegetation plots. This may suggest that forb height is not as important a condition as grass height and warm-season grass coverage. Furthermore, in my nest-site analysis, I did not observe greater litter depth at Henslow's Sparrow nest sites, a site characteristic that is fairly consistently reported in the literature (Hyde 1939, Hanson 1994, Cully and Michaels 2000, Herkert et al. 2002, Giocomo 2005) and in fields occupied by Henslow's Sparrows (Scott et al. 2002). Formation of a thick litter layer on FCMR fields is likely hindered by the biennial burning regime. A positive β estimate for litter depth in model S(T+TT+lit_avg) (Table 3-7) provides some evidence that greater litter depth increases DSR for nests of this species, even if I did not find evidence suggesting that Henslow's Sparrows were selecting sites with greater litter depth than the average for vegetation plots. Interestingly, Moss (2001) observed greater litter depth at successful Henslow's Sparrow nests than at unsuccessful nests while also finding greater litter depth at vegetation plots than at nests of that species. Perhaps this species is selecting nest sites and territories with what they perceive as an appropriate amount of litter, regardless of the average litter depth on the whole field.

Field Sparrow nest sites differed from systematically-selected vegetation plots in having greater woody vegetation and grass height (Figure 3-7), greater coverage by woody vegetation, and less coverage by bare ground (Figure 3-8). None of those variables are reflected in the Field Sparrow nest DSR models retained in Suite III (Table 3-9). This suggests that there is a disconnect between nest-site characteristics selected and factors affecting DSR and overall productivity. The β estimate for height of live vegetation was negative in S(stage+field_size+ht_live), which may be related to the apparent preference for sites with lower forb height; however, woody vegetation height was greater at Field Sparrow nests than at vegetation plots. The tallest live vegetation was almost always woody vegetation or forbs because growing warm-season grasses continue to gain stature through the field season and do not reach peak height until August or September (Voigt 1959, Dalrymple and Dwyer 1967). The β estimate for live vegetation height was difficult to interpret because it may have been influenced by an apparent preference for both taller woody vegetation and shorter forbs. Nest height was correlated with both woody vegetation and forb height for Field Sparrow. Previous studies have demonstrated correlations between greater nest concealment (Burhans and Thompson 1998) and lower predation rates (Burhans et al. 2002) with greater nest height.

Daily nest survival did not differ among ownership types for Field Sparrows. However, Field Sparrows are more of a habitat generalist than Henslow's Sparrows (Carey et al. 1994, Burhans 1997, McWilliams and Brauning 2000). Because Henslow's Sparrows did not occur on the TWRA fields (Chapter 2), it was impossible to compare DSRs with the FCMR fields. Henslow's Sparrow nests were found on the CRP fields but in insufficient numbers to make comparison with FCMR possible.

The importance of quadratic time in describing variation in DSR through the nesting season is apparent (Figure 3-5). Estimated DSR decreases from 0.967 (± 0.020) on 7 May, the first day a Henslow's Sparrow nest was observed, to 0.902 (± 0.050) on 6 July. The rate of decline of DSR is 1.35 times as fast over the 2^{nd} half of that interval than over the 1^{st} half. Further research could validate the importance of this trend and identify the probable cause, such as increased predation or lower food availability as the breeding season progresses. While disturbances such as mowing and burning of grasslands during the breeding season will always have a negative effect on productivity for grassland birds (Rodenhouse et al. 1995, Giocomo 2005), Henslow's Sparrows should benefit in such a situation from having the greatest productivity early in the breeding season. Time of season did not seem to have an effect on DSR for Field Sparrow nests (Figure 3-6).

One surprising finding was that DSR was lower for Field Sparrows during the incubation stage than during the brooding stage (Table 3-5), contrary to the hypothesis of Skutch (1949) that increased parental activity at the nest during the brooding stage leads to lower DSR. Skutch's hypothesis has been supported by many investigators (Young 1963, Best 1978, Thompson et al. 1999, Martin et al. 2000), but not by others in a variety of settings (Best and Stauffer 1980, Farnsworth and Simons 1999, Renfrew et al. 2005). Conway and Martin (2000) actually found a negative relationship between frequency of nest visits and proportion of nests depredated. They also found a positive relationship between the length of incubation bouts and nest predation. As Martin et al. (2000) proposed, nests that are poorly hidden from predators are more likely to be found early in the nesting cycle, during the incubation stage, and nests that escape predation long enough for the eggs to hatch will tend to have higher DSR. Furthermore, the predominant predator on the nests of any bird species may differ among the laying, incubation, and brooding stages (Liebezeit and George 2002).

DSR estimates across the Big Barrens in 2006-07 were very similar to 5-year estimates on FCMR from 1999-2003 (Moss 2001, Giocomo 2005) for both Henslow's Sparrow (0.942 ± .013, 39 nests, 2006-07; 1999-2003 estimate: 0.938 ± 0.009, 113 nests; Table 3-4) and Field Sparrow (0.928 ± 0.008, 122 nests, 2006-07; 1999-2003 estimate: 0.926 ± 0.006, 276 nests; Table 3-5). The coefficient of variation for the 6 years for which DSR was estimated was 1.3% (includes 2000-03 and 2006-07, the sample size of Henslow's Sparrow nests was too small to calculate DSR for 1999). DSR estimates for 2000-03 ranged from 0.940 (± 0.022; 2002) to 0.958 (± 0.013; 2001; Giocomo et al. 2008), which contained the 2 years discussed in this study, 2006 (0.941 ± 0.017) and 2007 (0.943 ± 0.019). The closeness of these estimates suggests that habitat quality for breeding grassland birds on FCMR has been fairly consistent through the last decade. I found no difference among ownership types for DSR of Field Sparrow nests (Table 3-5), the only species with a sufficiently large sample size on all ownership types.

Double brooding was likely for the Field Sparrow (Figure 3-4), as evidenced by the double peaked pattern in both years of the number of nests monitored by week. Although my data did not show the same pattern for Henslow's Sparrow (Figure 3-3), double brooding has been documented for that species (Winter 1999, Giocomo 2005). Furthermore, the length of time that I observed Henslow's Sparrows involved in nesting activity (61 days) is more than twice the 24-day (includes laying stage, but not post-fledging parental care) nesting cycle of the Henslow's Sparrow.

Snakes were likely responsible for many of the predation events on grassland bird nests in this study. Snakes are among the most prevalent predators of grassland bird nests in the mid-South and midwestern United States (Thompson and Nolan 1973, Best 1974b, Best 1978, Wray et al. 1982, Thompson et al. 1999, Thompson and Burhans 2004). Henslow's Sparrow nests may be particularly susceptible to snake predation (Graber 1968, Herkert et al. 2002). Thompson et al. (1999) directly observed predation at 16 Field Sparrow and and 7 Indigo Bunting (*Passerina cyanea*) nests in central Missouri using a video camera. For 16 of their 23 observations (69.6%), the predator was a snake, and all 4 of the snake species observed by Thompson et al. (1999), black rat snake (*Elaphe obsoleta*), prairie kingsnake (*Lampropeltis calligaster*), black racer (*Coluber constrictor*), and garter snake (*Thamnophis* sp.), were observed on my study sites. On 4 occasions during the 2006 and 2007 field seasons, I observed a snake (3 black rat and 1 rough green [*Opheodrys aestivus*]), within 1 m of a recently depredated nest. Furthermore, there was little damage to most depredated nests, a characteristic suggestive of snake-depredated nests (Thompson and Nolan 1973). Increased snake predation may not account for decreasing DSR in Henslow's Sparrow, however, because snake activity may decrease through the breeding season (Klimstra 1958). Other documented predators of grassland bird nests that occur in the Big Barrens included American Crow (*Corvus brachyrhynchos*; Wray et al. 1982), raccoon (*Procyon lotor*; Renfrew and Ribic 2003), striped skunk (*Mephitis mephitis*; Vickery et al. 1992), and rodents (Order Rodentia; Pietz and Granfors 2000, Winter et al. 2000). A more complete understanding of the roles of different nest predators on grassland bird nesting success remains an important research need.

Appendix

Table 3-1. Models tested for Henslow's Sparrow nest daily survival rate for nests monitored in the Big Barrens, Tennessee and Kentucky, 2006-07. The top models from Suites I and II were used as the null models for Suites II and III, respectively. In addition to the models listed, I also tested a global model for each suite containing all of the covariates in that suite.

Model Suite	**Model**	**Notation**
I. Temporal and Nuisance Models	Year	$S_{(year)}$
	Nest stage (Incubation/Brood)	$S_{(stage)}$
	Linear time	$S_{(T)}$
	Quadratic time	$S_{(T+TT)}$
II. Field-level variables	Field size	$S_{(field\_size)}$
	Distance to edge	$S_{(dist\_edge)}$
III. Microhabitat-level variables	Height of dead vegetation	$S_{(ht\_dead)}$
	Litter depth	$S_{(lit\_avg)}$
	Woody vegetation coverage	$S_{(cb\_avg)}$
	Bare ground coverage	$S_{(bare)}$
	Cool season grass coverage	$S_{(csg)}$
	Warm season grass coverage	$S_{(wsg)}$
	Ht.of dead vegetation and bare ground cov.	$S_{(ht\_dead+bare)}$
	Ht. of dead vegetation and warm season grass cov.	$S_{(ht\_dead+wsg)}$
	Litter depth and warm season grass coverage	$S_{(lit\_avg+wsg)}$

Table 3-2. Models tested for Field Sparrow nest daily survival rate for nests monitored in the Big Barrens, Tennessee and Kentucky, 2006-07. The top models from Suites I and II were used as the null models for Suites II and III, respectively. In addition to the models listed, I also tested a global model for each suite containing all of the covariates in that suite.

Model Suite	Model	Notation
I. Temporal and Nuisance Models	Ownership Class	$S_{(owner)}$
	Year	$S_{(year)}$
	Nest stage (Incubation/Brood)	$S_{(stage)}$
	Linear time	$S_{(T)}$
	Quadratic time	$S_{(T+TT)}$
II. Field-level variables	Field size	$S_{(field\_size)}$
	Distance to edge	$S_{(dist\_edge)}$
III. Microhabitat-level variables	Height of live vegetation	$S_{(ht\_live)}$
	Vegetation thickness	$S_{(cb\_avg)}$
	Warm season grass coverage	$S_{(wsg)}$
	Bare ground coverage	$S_{(bare)}$
	Woody vegetation coverage	$S_{(wood)}$
	Woody vegetation cov. and live vegetation ht.	$S_{(wood+ht\_live)}$
	Woody vegetation cov. and vegetation thickness	$S_{(wood+cb\_avg)}$
	Woody veg. and bare ground cov., veg. thickness, and live veg. ht.	$S_{(wood+bare+cb\_avg+ht\_live)}$

Table 3-3. Number of nests monitored in the Big Barrens, Tennessee and Kentucky, 2006-07. The 286 observed nests are broken down by species, field ownership, and year. Species are presented in alphabetical order by common name.

Species	Year	Total	FCMR	CRP	TWRA
Bell's Vireo	2006	0	0	0	0
Vireo belli	2007	1	1	0	0
	Both Years	1	1	0	0
Blue Grosbeak	2006	3	3	0	0
Passerina caerulea	2007	1	1	0	0
	Both Years	4	4	0	0
Blue-gray Gnatcatcher	2006	0	0	0	0
Polioptila caerulea	2007	2	0	0	2
	Both Years	2	0	0	2
Common Yellowthroat	2006	2	2	0	0
Geothlypis trichas	2007	4	4	0	0
	Both Years	6	6	0	0
Dickcissel	2006	15	14	1	0
Spiza americana	2007	8	4	2	2
	Both Years	23	18	3	2
Eastern Meadowlark	2006	2	2	0	0
Sturnella magna	2007	2	0	2	0
	Both Years	4	2	2	0
Field Sparrow	2006	62	23	14	25
Spizella pusilla	2007	60	20	22	18
	Both Years	122	43	36	43
Henslow's Sparrow	2006	21	19	2	0
Ammodramus henslowii	2007	18	13	5	0
	Both Years	39	32	7	0
Indigo Bunting	2006	15	7	6	2
Passerina cyanea	2007	9	5	0	4
	Both Years	24	12	6	6
Mourning Dove	2006	0	0	0	0
Zenaida macroura	2007	1	0	1	0
	Both Years	1	0	1	0
Northern Cardinal	2006	3	0	0	3
Cardinalis cardinalis	2007	1	0	0	1
	Both Years	4	0	0	4
Northern Mockingbird	2006	0	0	0	0
Mimus polyglottos	2007	1	0	0	1
	Both Years	1	0	0	1
Prairie Warbler	2006	22	20	1	1
Dendroica discolor	2007	13	12	0	1
	Both Years	35	32	1	2
Red-winged Blackbird	2006	1	0	1	0
Agelaius phoeniceus	2007	6	0	3	3
	Both Years	7	0	4	3
White-eyed Vireo	2006	0	0	0	0
Vireo griseus	2007	1	1	0	0
	Both Years	1	1	0	0
Wild Turkey	2006	2	1	0	1
Meleagris gallopavo	2007	2	1	1	0
	Both Years	4	2	1	1
Yellow-breasted Chat	2006	3	1	0	2
Icteria virens	2007	5	4	0	1
	Both Years	8	5	0	3
Total	2006	151	92	25	34
	2007	135	66	36	33
	Both Years	286	158	61	67

Table 3-4. Estimates of daily survival rate (DSR) for Henslow's Sparrow nests in the Big Barrens, Tennessee and Kentucky, 2006-07.

Parameter		**Mean DSR**	**SE**	**95%CI**	
				Lower	**Upper**
Year	**2006**	0.941	0.017	0.897	0.967
	2007	0.943	0.019	0.891	0.972
Stage	**Incubation**	0.936	0.017	0.892	0.962
	Brood	0.952	0.019	0.898	0.979
Overall		0.942	0.013	0.911	0.963

Table 3-5. Estimates of daily survival rate (DSR) for Field Sparrow nests in the Big Barrens, Tennessee and Kentucky, 2006-07. Owner refers to ownership class, and the abbreviations stand for Fort Campbell Military Reserve (FCMR), privately owned fields enrolled in the Conservation Reserve Program (CRP), and Tennessee Wildlife Resources Agency (TWRA).

Parameter		Mean DSR	SE	95%CI	
				Lower	Upper
Year	**2006**	0.936	0.011	0.910	0.955
	2007	0.921	0.012	0.894	0.942
Stage	**Incubation**	0.908	0.012	0.881	0.929
	Brood	0.961	0.010	0.936	0.977
Owner	**FCMR**	0.933	0.014	0.901	0.956
	CRP	0.928	0.015	0.891	0.953
	TWRA	0.924	0.014	0.890	0.948
Overall		0.928	0.008	0.910	0.943

Table 3-6. Results of daily survival rate model selection for Henslow's Sparrow nests in the Big Barrens, Tennessee and Kentucky, 2006-07. See Table 3-1 for a description of model notation.

Model Suite I

Model	**K**	**AIC$_c$**	**ΔAIC$_c$**	w_i
S(.)	1	92.74	0.00	0.272
S(T+TT)	3	92.80	0.06	0.264
S(T)	2	93.62	0.89	0.175
S(stage)	2	94.36	1.62	0.121
S(year)	2	94.76	2.02	0.099
S(global)	5	95.44	2.70	0.070

Model Suite II

Model	**K**	**AIC$_c$**	**ΔAIC$_c$**	w_i
S(T+TT,null)	3	92.80	0.00	0.494
S(T+TT+dist_edge)	4	94.25	1.45	0.239
S(T+TT+field_size)	4	94.81	2.01	0.181
S(T+TT+field_size+dist_edge)	5	96.31	3.51	0.085

Model Suite III

Model	**K**	**AIC$_c$**	**ΔAIC$_c$**	w_i
S(T+TT+csg)	4	91.76	0.00	0.293
S(T+TT,null)	3	92.80	1.04	0.175
S(T+TT+bare)	4	93.59	1.83	0.117
S(T+TT+wood)	4	94.09	2.33	0.091
S(T+TT+lit_avg)	4	94.45	2.69	0.076
S(T+TT+ht_dead)	4	94.72	2.95	0.067
S(T+TT+wsg)	4	94.78	3.02	0.065
S(T+TT+bare+ht_dead)	5	95.57	3.81	0.044
S(T+TT+wsg+lit_avg)	5	96.45	4.69	0.028
S(T+TT+wsg+ht_dead)	5	96.76	5.00	0.024
S(global)	9	97.22	5.46	0.019

Table 3-7. Beta estimates for parameters in final set of models retained in Suite III (Table 3-6) for daily survival rate of Henslow's Sparrow nests in the Big Barrens, Tennessee and Kentucky, 2006-07. Model notation is described in Table 3-1.

Model	**Parameter**	**Estimate**	**SE**	**95% CI**	
				Upper	**Lower**
S(T+TT+csg)	intercept	5.996	2.050	1.977	10.015
	linear time	-0.201	0.131	-0.459	0.056
	quadratic time	0.003	0.002	-0.001	0.007
	cool season grass coverage	-0.034	0.019	-0.071	0.002
S(T+TT,null)	intercept	5.974	1.978	2.096	9.851
	linear time	-0.200	0.125	-0.446	0.045
	quadratic time	0.003	0.002	8.93×10^{-4}	0.006
S(T+TT+bare)	intercept	5.617	1.988	1.722	9.513
	linear time	-0.190	0.125	-0.436	0.055
	quadratic time	0.003	0.002	9.82×10^{-4}	0.006
	bare ground coverage	0.050	0.053	-0.054	0.154

Table 3-8. Results of daily survival rate model selection for Field Sparrow nests in the Big Barrens, Tennessee and Kentucky, 2006-07. See Table 3-2 for a description of model notation.

Model Suite I

Model	**K**	**AIC_c**	**ΔAIC_c**	**w_i**
S(stage)	2	302.23	0.00	0.959
S(.)	1	310.63	8.41	0.014
S(global)	7	311.63	9.40	0.009
S(year)	2	311.83	9.60	0.008
S(T)	2	312.57	10.35	0.005
S(T+TT)	3	313.98	11.75	0.003
S(owner)	3	314.42	12.20	0.002

Model Suite II

Model	**K**	**AIC_c**	**ΔAIC_c**	**w_i**
S(stage+field_size)	3	301.03	0.00	0.466
S(stage,null)	2	302.23	1.19	0.257
S(global)	4	303.04	2.01	0.171
S(stage+dist_edge)	3	303.99	2.96	0.106

Model Suite III

Model	**K**	**AIC_c**	**ΔAIC_c**	**w_i**
S(stage+field_size,null)	3	301.03	0.00	0.232
S(stage+field_size+ht_live)	4	301.49	0.46	0.184
S(stage+field_size+cb_avg)	4	302.24	1.21	0.126
S(stage+field_size+wsg)	4	302.38	1.34	0.118
S(stage+field_size+wood)	4	302.87	1.84	0.092
S(stage+field_size+wood+ht_live)	5	303.02	1.99	0.086
S(stage+field_size+bare)	4	303.04	2.01	0.085
S(stage+field_size+wood+cb_avg)	5	304.19	3.16	0.048
S(stage+field_size+wood+bare+cb_avg+ht_live)	7	306.13	5.10	0.018
S(global)	8	307.33	6.29	0.010

Table 3-9. Beta estimates for parameters in final set of models retained in Suite III (Table 3-8) for daily survival rate of Field Sparrow nests in the Big Barrens, Tennessee and Kentucky, 2006-07. Field Sparrow model notation is described in Table 3-2.

Model	**Parameter**	**Estimate**	**SE**	**95% CI**	
				Upper	**Lower**
S(stage+field_size,null)	intercept	2.934	0.310	2.326	3.543
	stage	-0.902	0.309	-1.508	-0.296
	field size	0.001	7.12×10^{-4}	-1.58×10^{-4}	0.003
S(stage+field_size+ht_live)	intercept	3.263	0.407	2.465	4.061
	stage	-0.892	0.309	-1.499	-0.286
	field size	0.002	7.50×10^{-4}	3.08×10^{-5}	0.003
	ht. of live vegetation	-0.005	0.004	-0.012	0.003
S(stage+field_size+cb_avg)	intercept	3.387	0.598	2.214	4.559
	stage	-0.902	0.309	-1.508	-0.296
	field size	0.001	7.11×10^{-4}	2.18×10^{-4}	0.003
	vegetation thickness	-0.033	0.037	-0.106	0.040
S(stage+field_size+wsg)	intercept	2.802	0.348	2.120	3.484
	stage	-0.891	0.310	-1.497	-0.284
	field size	0.001	7.35×10^{-4}	3.52×10^{-4}	0.002
	wsg coverage	0.004	0.005	-0.006	0.015
S(stage+field_size+wood)	intercept	2.903	0.318	2.279	3.528
	stage	-0.906	0.309	-1.512	-2.998
	field size	0.001	7.11×10^{-4}	1.47×10^{-4}	0.003
	woody veg. coverage	0.003	0.006	-0.010	0.015
S(stage+field_size+wood+ht_live)	intercept	3.252	0.408	2.452	4.051
	stage	-0.899	0.310	-1.506	-0.292
	field size	0.002	7.50×10^{-4}	6.97×10^{-5}	0.003
	woody veg. coverage	0.004	0.006	-0.008	0.017
	ht. of live vegetation	-0.005	0.004	-0.013	0.002

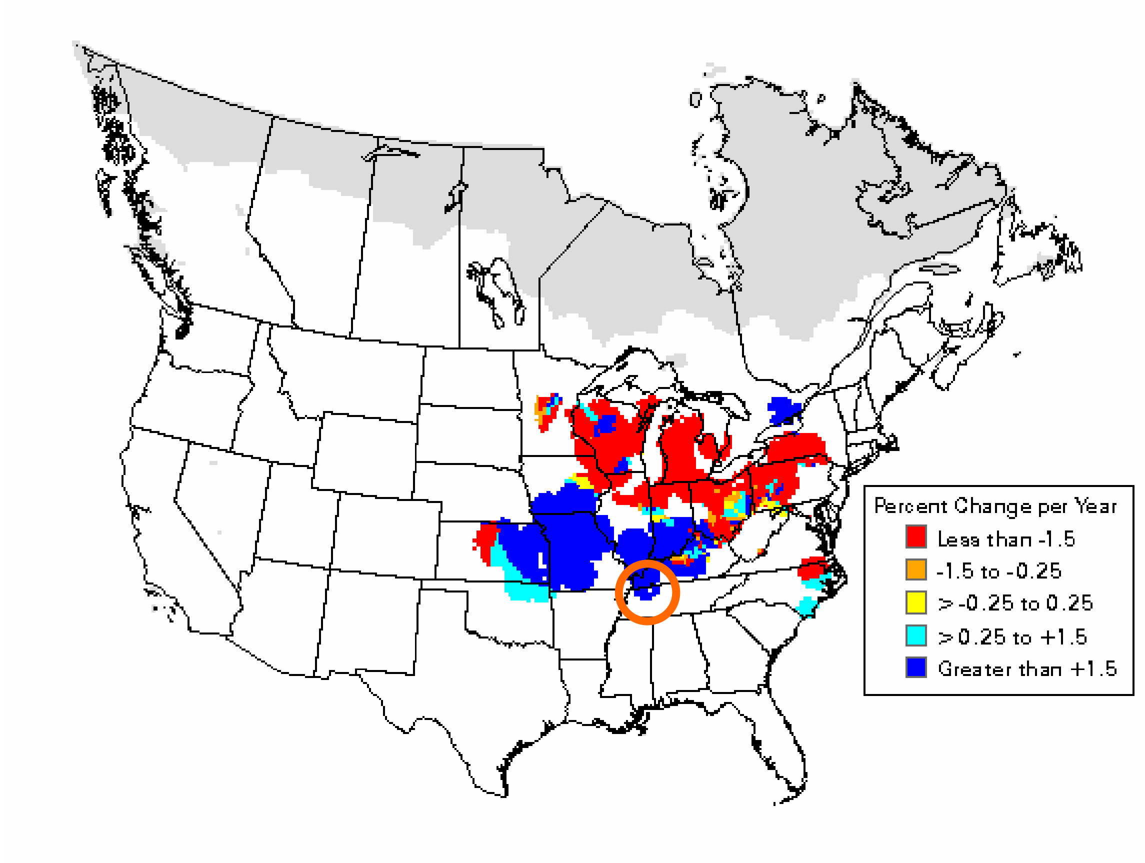

Figure 3-1. Breeding Bird Survey trend map for Henslow's Sparrow, 1966-2003 (Sauer et al. 2007). Gray areas are outside the range of the Breeding Bird Survey. The orange circle indicates the approximate location of the Big Barrens, Tennessee and Kentucky.

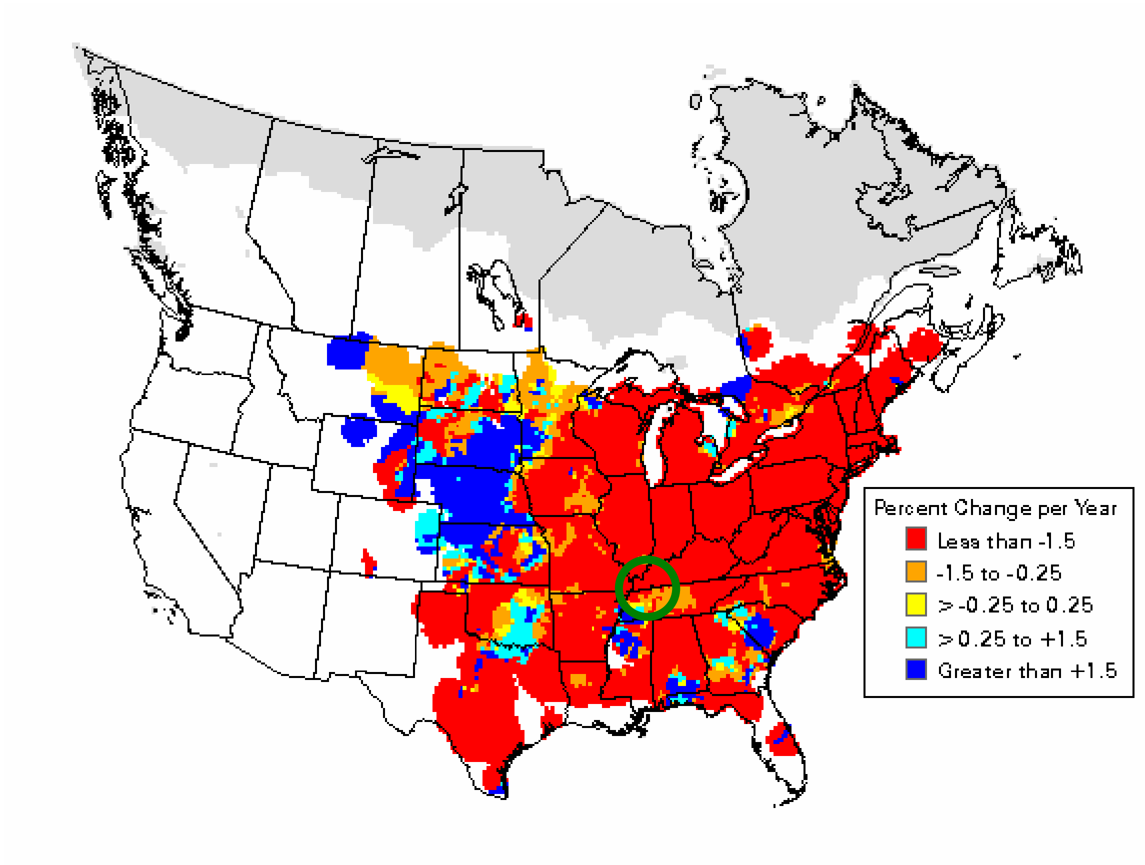

Figure 3-2. Breeding Bird Survey trend map for Field Sparrow, 1966-2003 (Sauer et al. 2007). Gray areas are outside the range of the Breeding Bird Survey. The green circle indicates the approximate location of the Big Barrens, Tennessee and Kentucky.

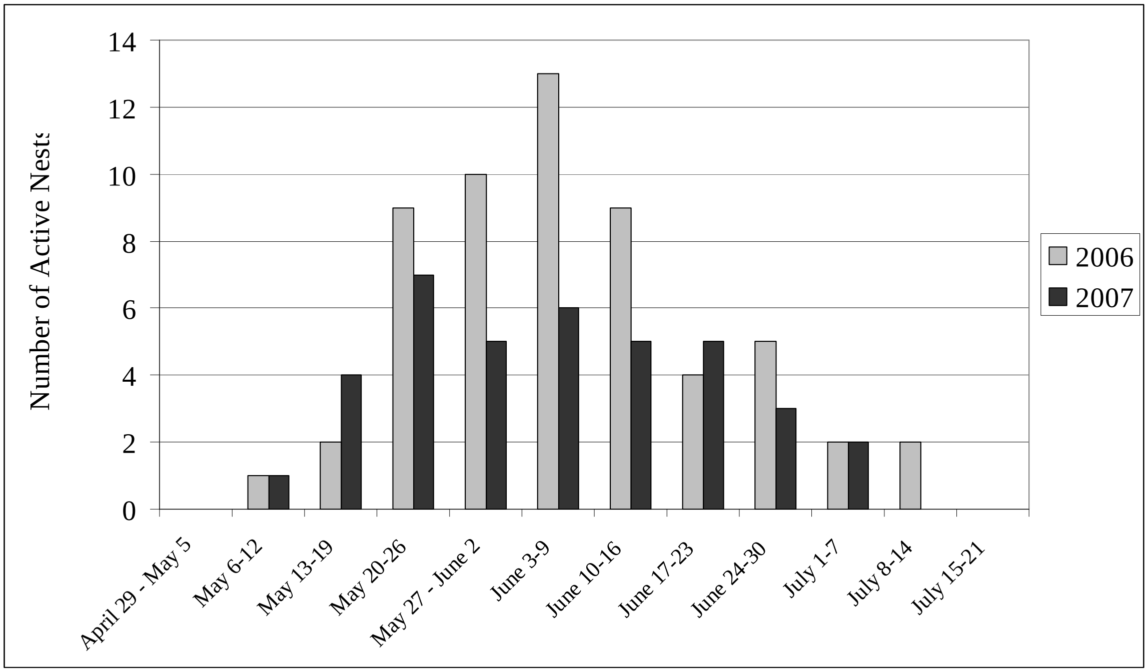

Figure 3-3. Number of Henslow's Sparrow nests monitored per week in the Big Barrens, Tennessee and Kentucky, 2006-07.

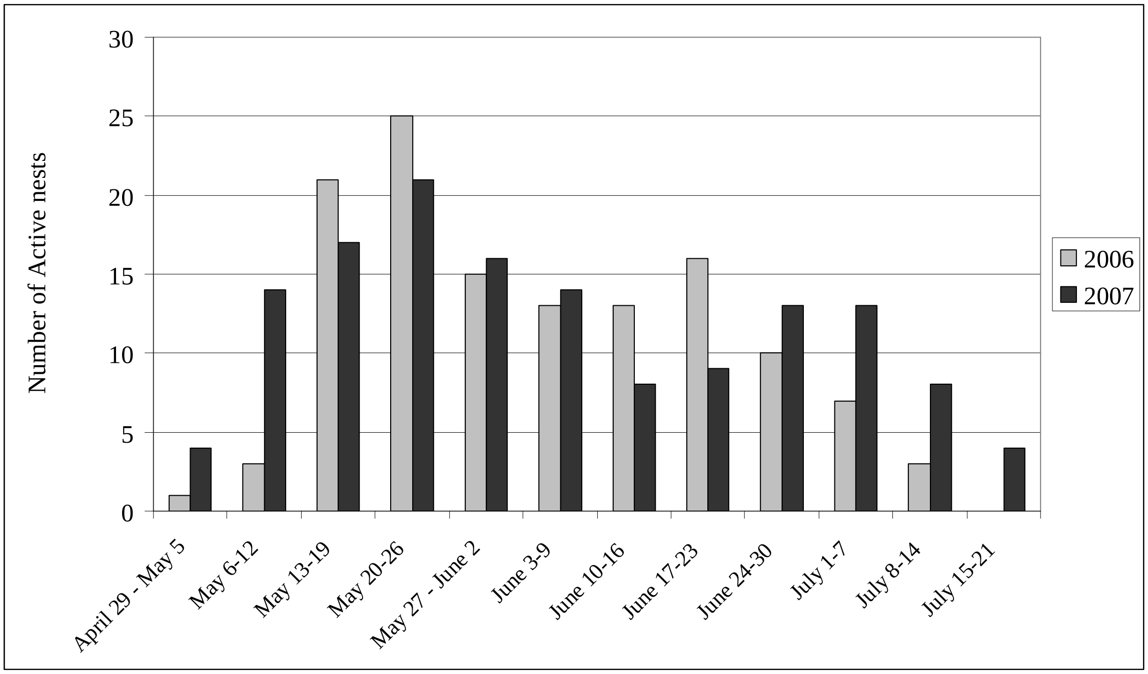

Figure 3-4. Number of Field Sparrow nests monitored per week in the Big Barrens, Tennessee and Kentucky, 2006-07.

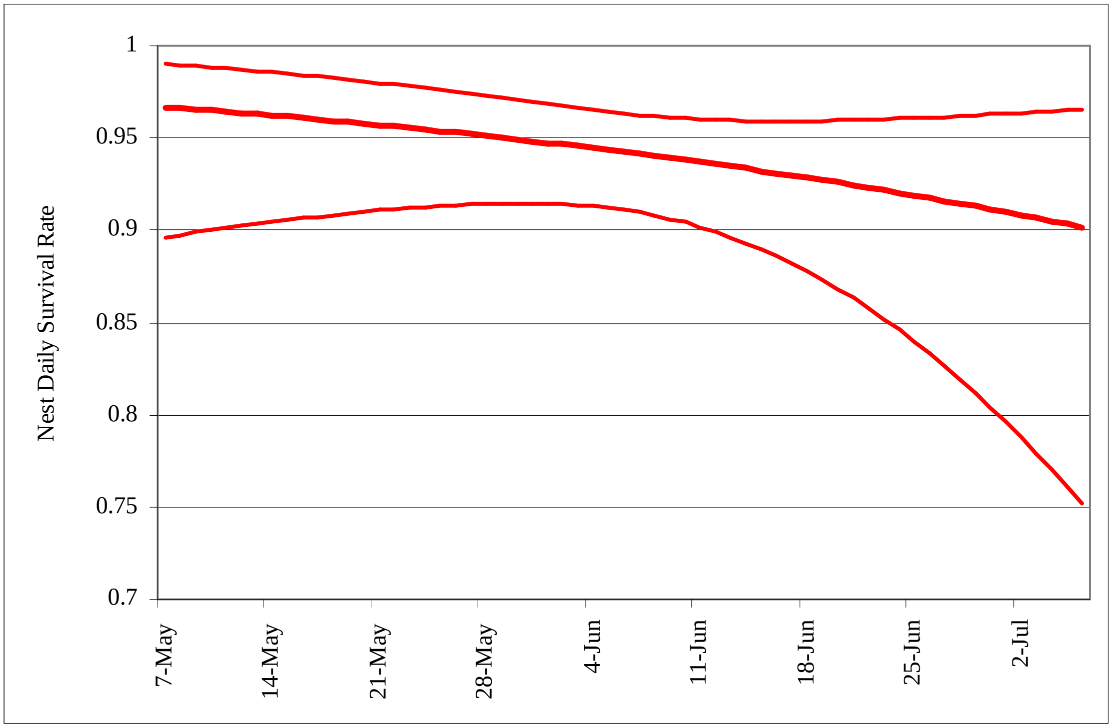

Figure 3-5. Estimated daily survival rate (DSR) of Henslow's Sparrow nests across the observed breeding season in the Big Barrens, Tennessee and Kentucky, 2006-07. The top models selected for this species included quadratic time as an important parameter in describing variation in DSR.

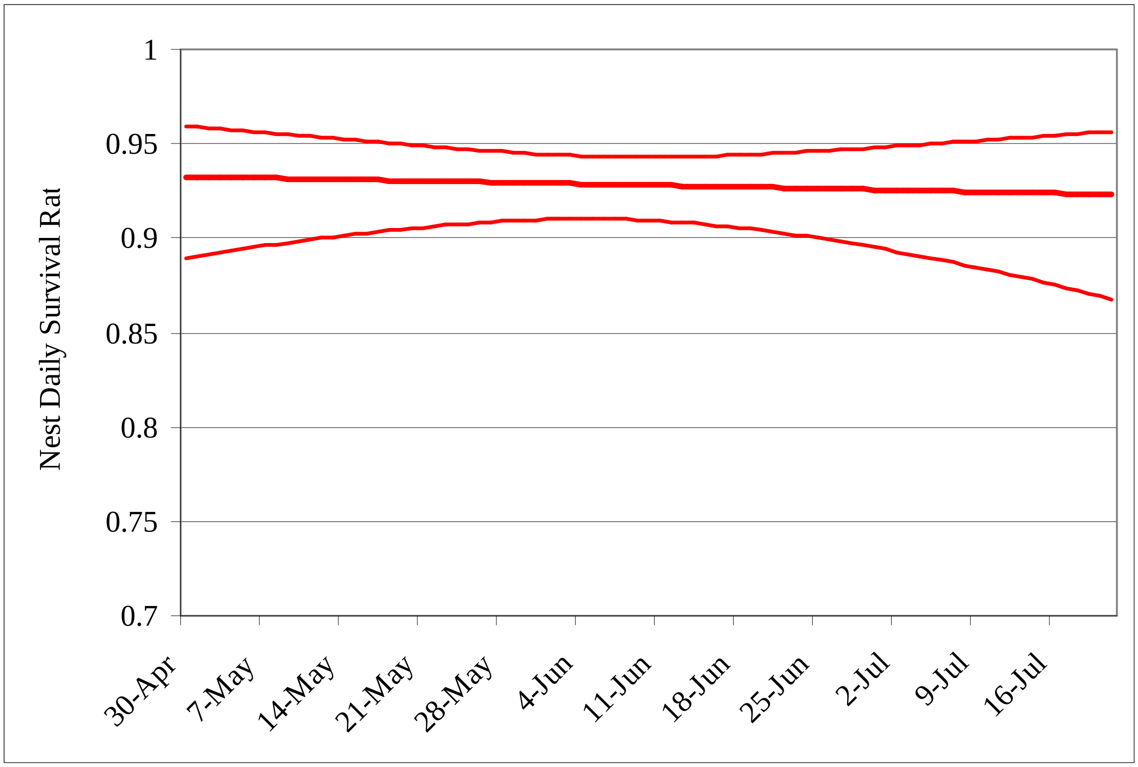

Figure 3-6. Estimated daily survival rate (DSR) of Field Sparrow nests across the observed breeding season in the Big Barrens, Tennessee and Kentucky, 2006-07. Temporal variables were not found to be important in describing variation in DSR for this species.

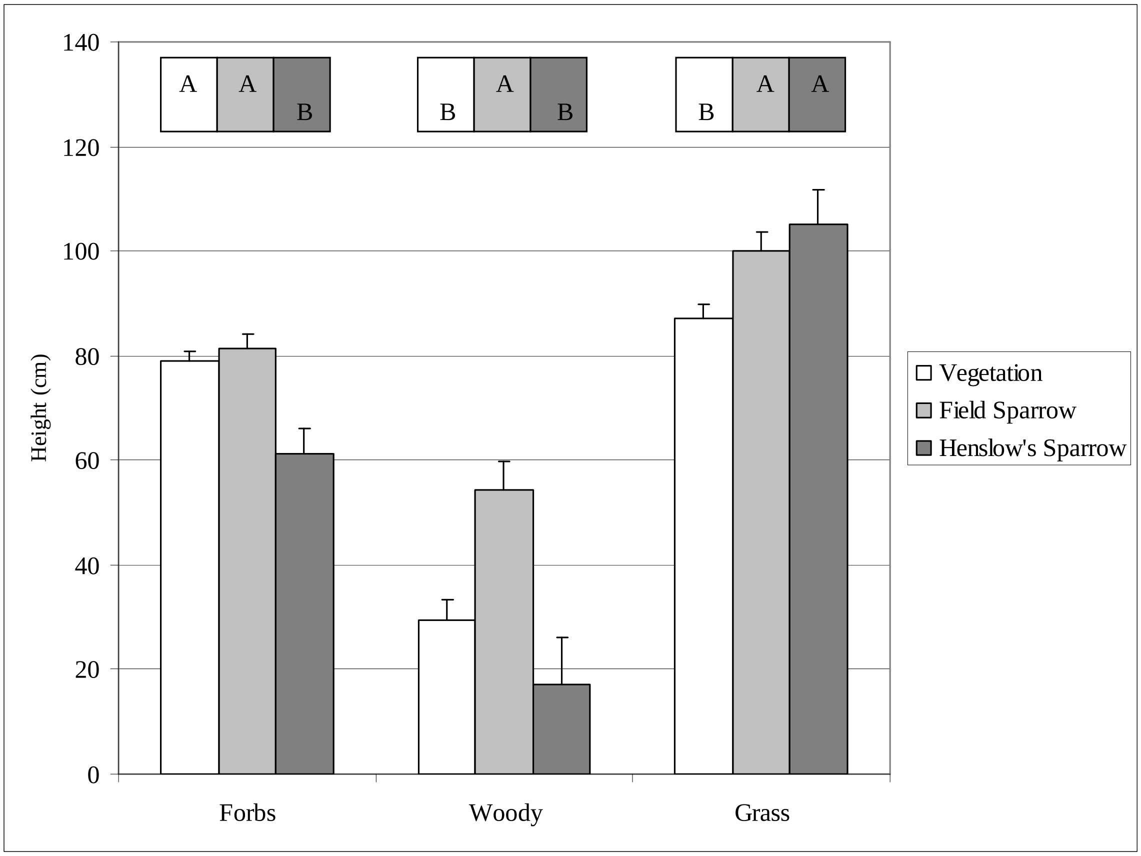

Figure 3-7. Height of 3 vegetation types at systematically selected vegetation sampling points, Field Sparrow nests, and Henslow's Sparrow nests in the Big Barrens, Tennessee and Kentucky, 2006-07. Error bars indicate one standard error. Different letters in the boxes above the bars indicate significantly different groups within each vegetation type. Overall error rate was controlled with a Bonferroni correction across all vegetation variables. Comparisons among vegetation points and the 2 types of bird nest were adjusted with Tukey's Honestly Significant Difference to control error rate.

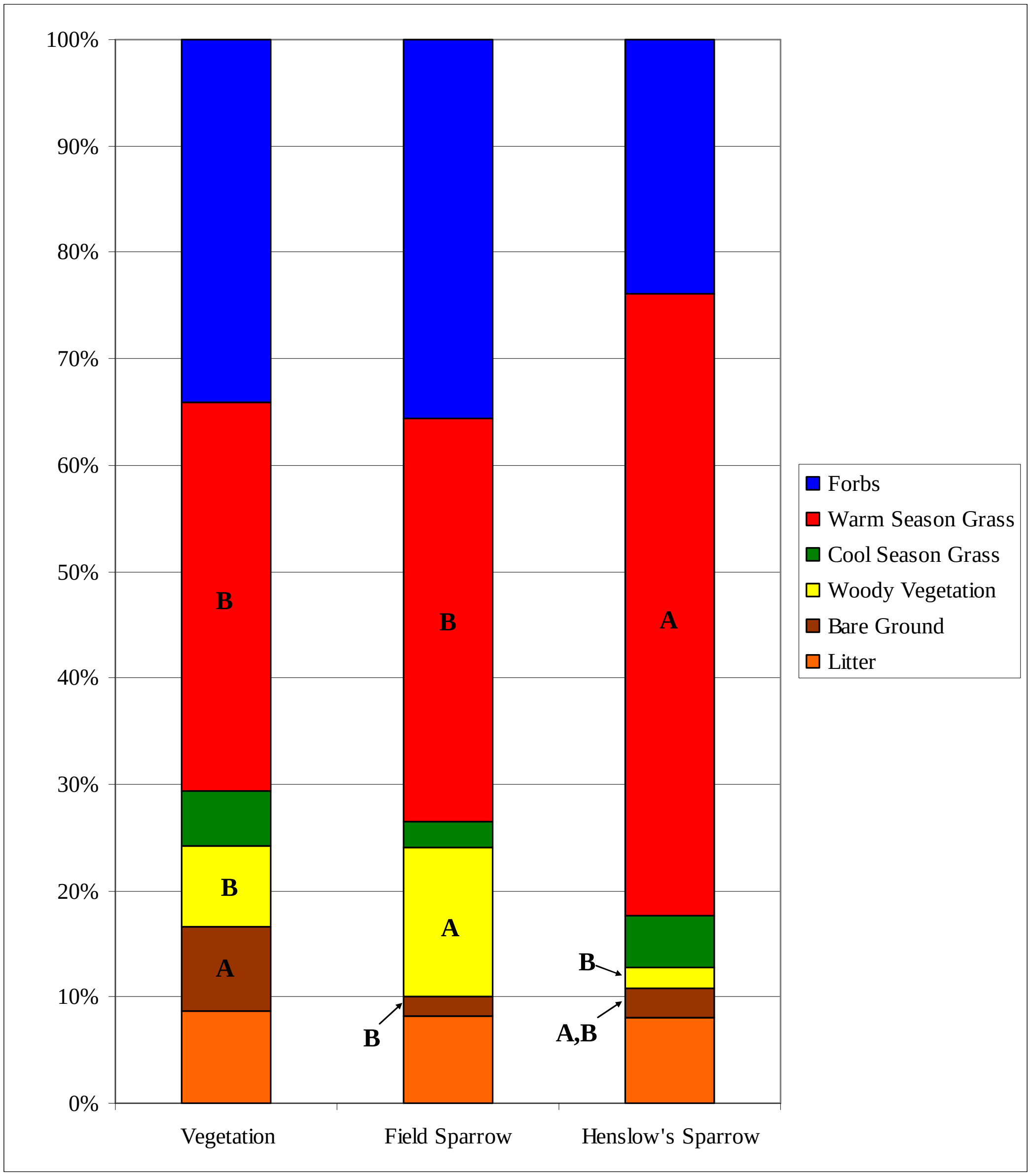

Figure 3-8. Proportion of 1-m^2 plot covered in each of 6 ground cover types at vegetation plots, Henslow's Sparrow nests, and Field Sparrow nests in the Big Barrens, Tennessee and Kentucky, 2006-07. Different letters signify estimates that differ based on pairwise comparisons with $\alpha = 0.05$; overall error rate was controlled with Tukey's Honestly Significant Difference.

Chapter 4

CHAPTER 4

ECOLOGY AND MANAGEMENT OF GRASSLAND BIRDS IN WINTER IN THE MID SOUTH

Introduction

Grassland bird species populations have been declining throughout eastern North America for several decades. Of the 14 species in this group occurring in the eastern United States, 11 have significantly negative population trends since the beginning of the Breeding Bird Survey (BBS) in 1966 (Sauer et al. 2005). Using BBS data, Herkert (1995) estimated an average annual population change of -1.4 ± 0.7% for 13 grassland bird species in the Midwest. Population declines have largely been attributed to habitat loss and degradation, perhaps exacerbated by area sensitivity for many of the species (Herkert 1994, Warner 1994, Johnson and Igl 2001, Bakker et al. 2002, Renfrew et al. 2005). Many of the grassland birds that breed in the eastern United States also winter in that region, so there are opportunities to manage that group of species throughout the life cycle (Vickery et al. 2000). Loss of native grassland habitats to intensive agriculture or other agricultural uses that reduce habitat quality has been linked with declines for this group of birds (Murphy 2003). However, for many grassland species, it is unknown which habitat characteristics are important in determining habitat quality (Peterjohn 2003).

There has been extensive grassland loss in the mid-South. The Big Barrens, part of the Pennyroyal Plain, is a 1.2-million-ha region of mostly open habitat in Kentucky and Tennessee. This area was once covered almost entirely by native grasslands but was shifted to a mostly forested landscape following European settlement (McInteer 1946). The Big Barrens has now shifted to a mosaic of forests and agriculture with widely scattered patches of remnant or restored grassland (Chester et al. 1997). Habitat loss is expected to continue in this region and may be accelerated by the increased use of land for the production of switchgrass (*Panicum virgatum*) and corn for biofuel production (Tolbert and Downing 1995). Eastern Tennessee, in a region called the Great Valley, also historically hosted large areas of open habitat, especially along large rivers (Lorimer 2001).

There is an especially great need for studies focused on birds that use open habitats during the non-breeding season (Vickery and Herkert 2001, Peterjohn 2003). Most grassland bird research to date has dealt with the breeding season. The winter grassland bird community differs from the breeding bird community in most areas (Best et al. 1998). Loss or changes of grassland habitat on the wintering grounds has been put forth as a possible cause of population declines for some bird species (Lymn and Temple 1991, Herkert and Knopf 1998). Birds that use early successional habitat in the non-breeding season have received little management or research attention in the mid-South. Few species of grassland birds winter north of this region. Several priority species that do not occur in the mid-South in winter include Sedge Wren (*Cistothorus platensis*), Henslow's Sparrow (*Ammodramus henslowii*), Le Conte's Sparrow (*A. leconteii*), Bachman's Sparrow (*Aimophila aestivalis*), which winter in the Gulf Coastal Plain in pine savannas.

Many grassland bird species winter in the mid-South. Most of the passerines are sparrows (family *Emberizidae*), including Eastern Towhee (*Pipilo erythrophthalmus*), Song Sparrow (*Melospiza melodia*), Swamp Sparrow (*M. georgiana*), Savannah Sparrow (*Passerculus sandwichensis*), Field Sparrow (*Spizella pusilla*), Dark-eyed Junco (*Junco hyemalis*), White-throated Sparrow (*Zonotrichia albicollis*), and White-crowned Sparrow (*Zonotrichia leucophrys*). Non-emberizid passerines include Loggerhead Shrike (*Lanius ludovicianus*), Horned Lark (*Eremophila alpestris*), and American Pipit (*Anthus rubescens*). Northern Bobwhite (*Colinus virginianus*), American Kestrel (*Falco sparverius*), and Northern Harrier (*Circus cyaneus*) are also linked to open habitats throughout the region during the winter. One possible reason for the limited attention paid to this community of birds is that few of the species are of high continental conservation concern based on Partners in Flight conservation scores (Rich et al. 2004); a notable exception is the Short-eared Owl (*Asio flammeus*), a Watch List species (Ford et al. 2000). Additionally, 4 of the species listed above, Northern Bobwhite, Loggerhead Shrike, Eastern Towhee, and Field Sparrow, are listed as species of regional concern for the Central Hardwoods Bird Conservation Region (Rocky Mountain Bird Observatory 2005).

***Food and Cover* –** The diets of winter grassland passerines consists primarily of seeds, particularly for cardinals (family *Cardinalidae*), finches (family *Fringillidae*), and sparrows (Martin et al. 1951, Allaire and Fisher 1975). Wiens (1973) presented data collected by Baldwin (pers. comm.) on changes in the diet of Horned Lark between seasons. Baldwin analyzed Horned Lark diet on a biweekly basis and found the proportion of dry weight of the stomach contents represented by seed and animal prey. Horned Lark diet was >55% animal prey from April to early August, but was >90% seeds from October to January. Baldwin also observed a high percentage of animal prey items in the breeding season diet of an emberizid, the Lark Bunting (*Calamospiza melanocorys*), although that species does not occur on my study area during the winter. The chief animal prey of grassland passerines is invertebrates, which are largely dormant or inaccessible during the winter. Over 90% of the winter diets of 5 species of sparrows and finches in North Carolina were composed of vegetable matter (Pulliam and Enders 1971).

Predation risk is greater in some potential foraging areas than for others. An organism feeding in a landscape with heterogeneous distribution of food and predators will likely seek a foraging strategy that optimizes its position in a trade off between those two factors, based at least partially on the method for which that organism is adapted for predator avoidance (Lima 1998). Ecological niches can be partitioned between species in many different ways. Historically, competition was viewed as the major determining factor, but direct and indirect effects of predation can also be important in defining niche characteristics (Sih et al. 1985). Thus, partitioning of food resources may be accomplished by winter grassland birds partly by their different predator escape behaviors.

Several studies have shown an apparent trade off between food and cover for individual species or groups of species. Schneider (1984) suggested that this tradeoff is an example of optimal foraging theory described by MacArthur and Pianka (1966), but in this case overall survival is optimized, incorporating both foraging efficiency and predation risk. For example, wintering White-throated Sparrows foraged preferentially on food closer to thick cover in an experimental winter study in New Jersey (Schneider 1984). Watts (1990) described a similar tradeoff between cover and food for wintering

Song and Savannah Sparrows in central Georgia. In southeastern Arizona, Lima and Valone (1991) demonstrated experimentally that the whole winter grassland bird community was different in fields with a high density of cover than in fields with relatively little cover. They found that species such as Chipping (*Spizella passerina*) and Vesper Sparrow (*Pooecetes gramineus*) were abundant in high cover areas but nearly absent from low cover areas; meadowlarks (*Sturnella* sp.) and Horned Larks showed the opposite relationship to cover density. The authors theorized that the relationships observed were related to different predator escape strategies for the different bird species because the type and density of food was not thought to differ between the two habitat types. A similar spatial pattern of bird distribution was observed in England with an emberizid (Yellowhammer, *Emberiza citrinella*) and an alaudid (Skylark, *Alauda arvensis*; Robinson and Sutherland 1999).

Habitat differences have been observed among sparrow species that winter in the mid-South based on the density and proximity of areas of thick cover. Five species of common winter sparrows in the mid-South (Field Sparrow, Savannah Sparrow, Song Sparrow, Swamp Sparrow, and White-throated Sparrow) demonstrate such differences. Savannah Sparrows use open habitats with short vegetation like cultivated fields and grasslands with sparse vegetation (Wheelwright and Rising 1993, Ginter and Desmond 2005). Swamp Sparrows are often found in habitats with taller and thicker vegetation, in many cases near water (Mowbray 1997). Song Sparrow habitat is similar to Swamp Sparrow habitat (without an apparent affinity for habitats near water), but they also occur in brushy field edges and in non-native shrubs in suburban areas (Arcese et al. 2002). White-throated Sparrows are often found in flocks with Song Sparrows during the winter

(Pulliam and Enders 1971, Arcese et al. 2002), but they usually remain in thick, brushy vegetation and rarely occur in more open habitats (Falls and Kopachena 1994). Field Sparrows occur in both open habitats and along brushy edges, making it something of a habitat generalist (Allaire and Fisher 1975, Carey et al. 1994).

Another important function of cover for birds is its use for thermal purposes, which allows birds to minimize energy expenditure to maintain an appropriate body temperature. As the name implies, thermal cover is useful to birds, in part, for insulation from cold temperatures, but protection from wind chill effects may actually be more important for passerines (Elkins 1983). The use of thermal cover has been documented during the winter in both American Tree Sparrows (*Spizella arborea*) and Dark-eyed Juncos (Best et al. 1998). Smith et al. (2005) contended that field edges can be managed to provide food, thermal cover, and predator cover. They demonstrated some of those effects on fields in Mississippi enrolled in the Conservation Reserve Program, but their comments on thermal cover were essentially hypotheses. House Sparrows (*Passer domesticus*) also exhibited a tradeoff between cover types with different levels of protection from predators and thermal value (Grubb and Greenwald 1982). Marcus et al. (2000) observed greater densities of sparrows in shrubby field edges than in mowed field edges in North Carolina, and all of the sparrows that they observed were species that winter in open habitats in the mid-South. They hypothesized that the difference in density between the two field edge types was a result of brushy edges providing better predator escape and thermal cover.

Flocking Behavior – A conspicuous behavior of some wintering grassland birds is the tendency of these species to form foraging flocks. Flocking behavior is negatively correlated with temperature throughout the year (Emlen 1952). One of the greatest benefits of flocking comes from the decreased need for each individual to scan for predators, allowing more time for foraging (Pulliam 1973). Caraco (1979) observed an increased rate of pecking for each bird with increased group size for Yellow-eyed Junco (*Junco phaeonotus*), but he also observed higher rates of aggression between members of the flock.

The principle negative effect of flocking is increased aggression. During the winter, Song Sparrows exhibit intraspecific aggression, with males typically dominating encounters with females (Smith et al. 1980, Wagner and Gauthreaux 1990). Aggression between members of a flock may be lessened by morphological and behavioral cues that help establish a dominance hierarchy, as has been observed in White-crowned Sparrow (Parsons and Baptista 1980). Interspecific interactions are also important. Song Sparrows are dominant in most interactions with White-throated Sparrows (Wagner and Gauthreaux 1990, Arcese et al. 2002), Swamp Sparrows, and Savannah Sparrows (Young 1990).

In some situations, decreased individual predation risk may not be the primary motivation for flock formation; Lindström (1989) found that increased flock size did not decrease individual predation risk for two species of finches in Sweden and he hypothesized that flocking behavior was driven by patchy resource distribution. Emlen (1952) hypothesized that differences in flock density and size are likely related to the negative and positive effects of flocking for different species in different situations, that is, species are unique in the circumstance in which they will form or join flocks.

***Objectives* –** I sampled the winter grassland bird community in the mid-South with a variety of methods. My primary objective was to describe ecological characteristics of that bird community, such as the spatial and temporal distributions of bird species, habitat associations of each species, and the population densities of birds using different open habitats. In addition to my primary objective, I was able to compare the effectiveness of the various methods used.

Methods

***Study Area* –** I conducted winter grassland bird research in 2 regions in Tennessee and Kentucky, the Big Barrens region in 2005-06, and the Great Valley of eastern Tennessee in 2006-07. The study areas were located in different Partners in Flight (PIF) Bird Conservation Regions (BCR), Central Hardwoods for the 1^{st} field season and Appalachian Mountains for the 2^{nd}. The region used for breeding bird research (Chapters 2 and 3), Fort Campbell Military Reserve (FCMR) and the Big Barrens, was used from December 2005 to February 2006. The Big Barrens, part of the Pennyroyal Plain, is a 1.2-million-ha region of mostly open habitat in Kentucky and Tennessee. FCMR fields are burned regularly (typically biennially) and have been shown to support almost all of the grassland bird species that occur in the region (Moss 2001, Giocomo 2005). For each of the methods used on FCMR, I chose fields to sample opportunistically. I began sampling each day on fields with which I was familiar and, each time I finished sampling a field, I moved to the nearest available field with the appropriate conditions.

From January to March 2007, I used 6 properties in eastern Tennessee, including Seven Islands Wildlife Refuge (a Knox County park), private fields in Grainger County, and 4 Tennessee Wildlife Resources Agency (TWRA) Wildlife Management Areas (WMA): Freel's Bend at Oak Ridge, Kyker Bottoms, Lick Creek, and Yuchi Refuge at Smith Bend. The grasslands on eastern Tennessee support a floristic community similar to that found in the Big Barrens and other parts of the Central Hardwoods BCR, but fields were generally smaller (DeSelm et al. 1969). I selected fields in eastern Tennessee opportunistically wherever I could find at least 1each of a burned field, a native grass field, and a harvested crop field.

***Big Barrens* –** Three methods were used to sample bird distribution and abundance in the Big Barrens: mist nets, point counts, and rope dragging. I used mist nets to generate a list of the species wintering in FCMR fields. Some netting was done passively, but I also tried to increase capture rate by driving birds into the net. Drives involved 2 or more observers walking parallel lines towards one side of the net. The observers dragged a rope between them to increase flush rates when there was little woody vegetation present to resist movement of the rope.

Point counts were distributed systematically across the Big Barrens in an attempt to determine which grassland bird species were present in the region. Points were set on a grid of 5 min latitude (~9.5 km) by 5 min longitude (~7.5 km), on maps by DeLorme (2004). I recorded all of the birds that I observed, but focused on the open habitats near each point. Time spent at points was not uniform because of the goals of this method, but at least 10 min were spent at each point to allow birds to adjust to the presence of observers. Less common species, such as Northern Harrier, American Kestrel, Merlin

(*Falco columbarius*), Short-eared Owl, and Loggerhead Shrike, were also recorded when observed during travel between point counts.

Rope dragging surveys were conducted along the long axis of opportunistically-selected fields on FCMR. Two rope lengths were used in different surveys, 25 m when only 2 observers were present and 50 m when more than 2 observers were present. Two observers each held an end of the rope and dragged it across the top of the vegetation. Additional observers, when present, were spaced evenly along the length of the rope. All the birds that were observed inside each survey area (rectangular areas defined by the length of the rope by the distance walked), were identified to the most specific taxon possible. I estimated density for each species by dividing the number of individuals of that species observed by the area sampled. Analysis focused largely on sparrows because it was often difficult to identify members of that family to species. Observers communicated throughout the survey to avoid counting the same individual more than once. Four types of habitat were sampled with the rope dragging method, harvested agriculture fields, un-mowed fescue fields (hay fields in the FCMR agricultural-lease program), mowed fields (average vegetation height < 15 cm), and grasslands dominated by native vegetation.

***Eastern Tennessee Transects* –** I used transects to sample birds in eastern Tennessee on 3 different types of open habitat: harvested crop fields, grasslands dominated by native vegetation, and grasslands dominated by native vegetation that had been burned in the same winter. Transects were 200 m long and positioned so that no point was within 50 m of a road or hard edge. Variable-width transects were used to sample the winter bird community because of demonstrated problems with fixed-area methods and with the point-count method in general (Buckland 2006). Furthermore, biased distance measurements have a lesser effect on line-transects than on point counts (Gregory et al. 2004, Buckland 2006). The relatively patchy distributions of grassland birds in winter and the inconspicuous behavior of many species also favor transect sampling over point counts. For each bird observed, I recorded the species, perpendicular distance from the line transect, and, to the nearest meter, the point on the transect that was closest to the bird. The use of distance data allows for correction of lower detectability of birds with greater distance from the line transect, assuming that 100% of the individuals on the line were recorded (Burnham and Anderson 1984, Rosenstock et al. 2002). Marked differences in vegetation structure between the sampled habitats also necessitated the estimation of detection probability by habitat type (MacKenzie and Kendall 2002). Samples were taken at any time of day because time of day is not a great source of bias in bird sampling during the winter (Rollfinke and Yahner 1990). No sampling took place when precipitation was perceptible or when the wind speed was greater than ~10 km/h.

***Eastern Tennessee Bird Banding* –** Birds were captured in mist nets near the middle of a native grass field at Seven Islands Wildlife Refuge in February-April in 2003 and 2004. In December-January, 2005-06, and March-April 2006, we set up a mist net perpendicular to a brush line on the edge of a native grass field at Seven Islands. For both the nets in the middle of the field and the nets on the edge of the field, we used a combination of passive netting and drive netting to increase capture rate. Effort was not equivalent in the 2 netting locations.

***Statistical Analysis* –** I used program Distance (Thomas et al. 2006) for estimation of bird density from line transect data with a correction based on changes in the probability that an individual will be detected based on how far it is from the line. A Bonferroni correction on the confidence intervals was used for conservation of overall error rate.

Sample size was not sufficiently large to compare density for individual species using program Distance, so density estimates for Field Sparrow, Savannah Sparrow, Song Sparrow, and Swamp Sparrow, the 4 species for which the most individuals were observed, were compared with SAS statistical software (SAS 2003) and without correction for detection probabilities. Overall error rate was controlled using Tukey's Honestly Significant Difference test. I used Dunnett's 2-sided multiple comparison test to compare sparrow density among habitat types with the rope dragging data. An overall $\alpha = 0.05$ was used for each of the tests outlined above.

Results

Big Barrens Mist Netting – We banded 202 birds from December 2005 to February 2006 on FCMR. Five species were captured (Table 4-1); over half of the individuals captured were Song Sparrows. The other 4 species captured were Common Yellowthroat (*Geothlypis trichas*), Swamp Sparrow, Savannah Sparrow, and White-crowned Sparrow. Four of the banded individuals (1.5%), 1 Song Sparrow and 3 Swamp Sparrows, were recaptured during the field season.

Big Barrens Point Counts – More species were observed using the point-count method than any of the other 2 methods. Of 49 total species observed with all methods, 36 (73.5%) were observed using the point-count method (Table 4-1).

***Big Barrens Rope Dragging* –** Twenty species of birds were observed using the rope dragging method at FCMR, including 9 species of sparrows (Table 4-1). In addition to those 20 species, 4 other species that were observed flying overhead were not included in analyses. Those species were Northern Harrier, Sandhill Crane (*Grus canadensis*), Red-winged Blackbird (*Agelaius phoeniceus*), and Common Grackle (*Quiscalus quiscula*). Across all species, 985 individuals were observed during rope dragging, of which 444 (45.1%) were sparrows. Using rope dragging, I observed an overall density of 20.8 birds/ha and a sparrow density of 9.4 birds/ha (Table 4-2). Sparrow density differed among field types ($F = 4.97$, $df = 3$, $P = 0.01$). Using Dunnett's 2-sided multiple comparison test, sparrow density was greater on fields with native vegetation than on agriculture fields or mowed fields ($t = 2.56$, $df = 19$, $P = 0.01$). There were no differences among field types for overall bird density.

***Eastern Tennessee Transects* –** Based on program Distance (Thomas et al. 2006), estimates of detection probability were most strongly affected for native grass fields, followed by burned fields and then by harvested crop fields. Detection probability dropped to 50% at about 14 m from the line transect in grasslands dominated by native vegetation, about 29 m on burned fields, and about 37 m in harvested crop fields (Figure 4-2). When corrected for differences in detection probabilities, overall observed bird density was greatest on grasslands dominated by native vegetation (18.92 birds/ha; 95% $CI_{Bonferroni}$ = 12.70 – 28.19 birds/ha), followed by burned fields (7.86 birds/ha; 95% $CI_{Bonferroni}$ = 4.26 – 14.53 birds/ha) and then by agricultural fields (2.51 birds/ha; 95% $CI_{Bonferroni}$ = 0.97 – 6.52 birds/ha). Grasslands dominated by native vegetation had greater bird densities than agricultural fields based on non-overlapping confidence intervals.

Sample sizes were not sufficiently large to estimate bird density by species in program Distance. I compared the number of birds observed per transect for the 4 most commonly observed species, Field Sparrow, Savannah Sparrow, Song Sparrow, and Swamp Sparrow (Figure 4-3). Differences were found among habitat types for 2 species (with $\alpha_{Bonferroni} = 0.013$), Song Sparrow ($F = 9.79$; df = 2, 52; $P < 0.001$) and Swamp Sparrow ($F = 10.38$; df = 2, 52; $P < 0.001$). Song Sparrow density was greater in grasslands dominated by native vegetation than in harvested crop fields ($t = -4.00$, df = 52, $P_{Tukey} < 0.001$) and in burned fields ($t = -3.42$, df = 52, $P_{Tukey} = 0.035$). Swamp Sparrow density was also greater in grasslands dominated by native vegetation than in harvested crop fields ($t = -3.90$, df = 52, $P_{Tukey} < 0.001$) and in burned fields ($t = -3.79$, df = 52, $P_{Tukey} = 0.001$). Savannah Sparrows were not observed in grasslands dominated by native vegetation.

Different bird communities were observed in the 3 habitat types, based on the proportion of observed individuals represented by each species. Common birds (defined here as those species represented among the minimum number of species necessary to represent ≥ 50% of the individuals observed) for agricultural fields were Savannah Sparrow (49 individuals, 42.6% of individuals) and Common Grackle (15, 13.0%). Common birds on burned fields were Field Sparrow (34, 36.2%), Savannah Sparrow (11, 11.7%), and Mourning Dove (10, 10.6%). The most commonly observed birds on grasslands dominated by native vegetation were Swamp Sparrow (95, 44.2%) and Song Sparrow (60, 27.9%; Table 4-3).

There were also apparent differences in species richness at different times in the winter. Observed species richness on grasslands dominated by native vegetation increased as the wintering season progressed (Figure 4-4). Furthermore, the proportion of total observed individuals represented by Song and Swamp Sparrow on grasslands dominated by native vegetation appeared to decline in the late winter season (Figure 4-5).

***Eastern Tennessee Mist Netting* –** In open fields during February-April, 2003 and 2004, we banded 151 birds of 5 species: Field Sparrow, Savannah Sparrow, Song Sparrow, Swamp Sparrow, and White-crowned Sparrow. Song Sparrow (54 individuals) and Swamp Sparrow (50) were the most abundant species in the field interior by number of captures (Figure 4-6). Furthermore, there was an apparent temporal change in the bird community of field interiors at Seven Islands Wildlife Refuge; Song Sparrow and Swamp Sparrow abundances decreased through the season (Figure 4-7). All recaptures in the field interior were on the day of the original capture.

Along the field edge in December-January, 2005-06, and March-April, 2006, we banded 109 individuals of 8 species: Carolina Wren (*Thryothorus ludovicianus*), Field Sparrow, Grasshopper Sparrow, Northern Cardinal (*Cardinalis cardinalis*), Savannah Sparrow, Song Sparrow, Swamp Sparrow, and White-crowned Sparrow. Field Sparrow (39 individuals) and White-crowned Sparrows were the most abundant species on the field edge by number of individuals captured (Figure 4-8). Recaptures have been documented between seasons along field edges on Seven Islands Wildlife Refuge. A direct comparison of the bird communities in the field interior and on the field edge indicated that there were 2 different groups of birds making use of the different habitats within the same field (Figure 4-9).

Discussion

A review of the literature on winter grassland birds in the mid-South (Tennessee and Kentucky, as well as parts of northern Mississippi, Alabama, and Georgia) yields more questions than answers. Most of the research cited in this review was conducted in other regions or on species that do not occur in the mid-South. Such articles are referenced because they illustrate general ecology and trends in habitat use by grassland birds in the winter; however, the results of those studies are important mainly as starting points for hypothesis formulation in the mid-South. Some of the research referenced could also be used in management planning, in the absence of any other guidance for managers, mostly in the case of studies that focused on mid-South species. A major theme, a trade off between food and cover, prevailed through the literature on wintering grassland birds. The literature also highlights that individual species balance the food-cover equation in different ways. The primary goal of a grassland bird in the winter is to survive the non-breeding season and enter the breeding season in the best possible condition to set the stage for successful reproduction. Management should focus on providing both food and cover in close proximity on a scale meaningful to the birds of management interest. However, the need for further research on mid-South wintering grassland birds is the main concern evident in the literature.

***Winter Ecology of Grassland Birds* –** Based on results from different methods on different study sites, native grass habitat across the mid-South supported greater bird densities than harvested crop fields or other habitat types with short vegetation and little cover. Rope dragging data showed a greater density of sparrows in fields with native grassland vegetation than on mowed fields or harvested crop fields (Table 4-2).

Grasslands dominated by native vegetation had the thickest cover and the tallest vegetation. Mowed fescue fields have essentially no food and no cover for most grassland songbirds; harvested crop fields have food (waste grain) but little cover. However, the main agricultural crops grown on FCMR are wheat (*Triticum* sp.), soybean (*Glycine max*), and corn (*Zea mays*), and none of these crops make up more than 2 to 5% of the winter diet of any of the sparrow species observed (Martin et al. 1951).

A similar pattern was observed for overall bird density on grasslands dominated by native vegetation using the transect data in eastern Tennessee, corrected for different detection probabilities. Song and Swamp Sparrows in particular seem to thrive in grasslands dominated by native vegetation. Although sample sizes were not sufficiently large to compare densities for these species with corrections for detection probabilities, the greatest density for each species was observed on the habitat type with the lowest detection probabilities (Figure 4-2, 4-3). Despite its apparent value for supporting the over-wintering bird community, managing for grasslands dominated by native vegetation alone may be detrimental to some open-habitat species. Different groups of species were observed on the 3 habitat types monitored. Native grasses are not preferred by species like Horned Lark and American Pipit. Savannah Sparrows have been observed incidentally in grasslands dominated by native vegetation on Seven Islands Wildlife Refuge, but in small numbers; grasslands dominated by native vegetation may be marginal habitat for Savannah Sparrows. It may be important for some species to have more open habitats available in the landscape. However, if a landscape is already dominated by agriculture, it may not be necessary for managers to maintain such habitats.

It is also important to take into account within field habitat variation. Bird banding data from Seven Islands Wildlife Refuge indicated that there were different communities of birds using field interiors and field edges during the winter. The 2 most frequently captured species on field edges were Field Sparrow (35.8% of captures) and White-crowned Sparrows (30.3%); Field Sparrows were less common in field interiors (13.2%) and White-crowned Sparrows were not captured at all in field interiors (Figure 4-9). There were 3 other species that were captured along the field edge but not in the interior: Carolina Wren, Grasshopper Sparrow, and Northern Cardinal. Grasshopper Sparrow is particularly interesting in this case, because that species uses open habitats with short vegetation and little cover during both the breeding season (Vickery 1996, Dykes 2005, Giocomo 2005) and the winter (Vickery 1996). Brush lines should be managed along the field edges, regardless of field type, to provide habitat for a variety of open habitat birds during the winter. Furthermore, the birds using brushy habitat on field edges may stay in the same location more than field-interior birds, as evidenced by the total lack of between-day recaptures in open fields while some birds returned to the same brush line a year after their original capture (J. Giocomo, unpublished data).

Temporal changes in bird community composition in grasslands dominated by native vegetation are another factor important in understanding the habitat needs of birds wintering in the mid-South. With both line transect (Figure 4-5) and mist netting data (Figure 4-7), I observed changes in composition near the end of the winter, from February to April. In both cases, the number of individuals and the proportion of individuals observed decreased at the end of the winter for Song Sparrow and Swamp Sparrow. The opposite trend was observed for Field Sparrow. All 3 of these species are short-distance migrants, and the changes in community composition my reflect birds leaving their wintering grounds for migration; Swamp Sparrows do not breed in Tennessee, so logically, their numbers must decline at the end of winter.

The breeding habitat for some species is not the same as the winter habitat. Field Sparrows appear to favor brush lines and field edges during the winter (Allaire and Fisher 1975) while using a broader set of habitat types during the breeding season (Carey et al. 1994). Swamp Sparrows, which do not breed in Tennessee, are described by Mowbray (1997) as using wetland habitats during both the breeding season and winter, but this study provides evidence that they also make use of drier upland grasslands during the winter. Because winter habitat differs from breeding habitat for these, and perhaps other, species, effective management of wintering grassland birds cannot be based solely on demonstrated breeding season habitat needs.

***Management Implications* –** No single habitat type is sufficient to support the entire suite of grassland birds native to the mid-South during the winter. Effective management should focus on several types of habitat, including grasslands dominated by native vegetation, burned fields, and agricultural fields. However, in a landscape in which the most common type of open habitat is agriculture, management should favor natural habitat types. It is also important to schedule disturbances fairly late in the winter (i.e., late March or early April) whenever possible to maximize the amount of habitat in the landscape. On grasslands dominated by native vegetation, species richness may increase during the last couple months of the wintering season (Figure 4-4); grasslands dominated by native vegetation may be important stopover sites for migrating species like Purple Martin (*Progne subis*) and Tree Swallow (*Tachycineta bicolor*) at the end of the winter.

I did not sample fields with standing crops. An unharvested field planted with small grains (e.g., wheat or grain sorghum) might provide favorable habitat conditions for some wintering bird species with both dense cover and food, at least in the early part of the winter. Martin et al. (1951) observed < 5% of small grains in the diets of wintering Song Sparrows and Swamp Sparrows, but they did not comment on the distribution of habitat types included in their sample. Researchers in Europe have observed greater densities of wintering birds on unharvested crop fields than on grasslands dominated by native vegetation (Henderson et al. 2004, Orlowski 2006). The quality of habitat for breeding birds should also be taken into account when managing unharvested crop fields. Murphy (2003) observed a decrease in populations of most grassland birds with an increase in the proportion of the landscape in unharvested cover crops.

***Effectiveness of Methods* –** Future research is needed for the winter grassland bird community of the mid-South; therefore, it is important to review the methods discussed in this chapter and assess their effectiveness in measuring features of the avian community. Such assessment can lead to more efficient use of time and resources in future research and monitoring endeavors. It is also necessary to understand the limitations of interpretation of results gained from those methods.

One of my hopes for the mist-netting method was that it would provide a nearly complete list of the common species of birds using grassland habitat in the winter. Coloration and behavior of grassland bird species can be very cryptic in the winter, and the use of mist nets, especially when coupled with drives, could have been effective in capturing all of the passerines present in a given habitat patch. Unfortunately, this method yielded only 5 of the 49 (10.2%) species observed with all 4 methods combined

(Table 4-1). A Common Yellowthroat was captured and that species was not observed using any of the other 3 methods, but this species is not a common winter resident of the mid-South (Guzy and Ritchison 1999). The individual was captured late in the winter field season and was likely an early migrant.

In contrast to the mist-netting method, the point-count method was very effective in identifying a large proportion (73.5%) of the open-habitat species observed across all 4 methods. The point-count method was particularly useful in including some of the larger species, such as Red-shouldered Hawk (*Buteo lineatus*), Red-tailed Hawk (*B. jamaicensis*), American Kestrel, and Northern Harrier, that have larger home ranges; however, Short-eared Owl was not observed with this method. Less common species, like the Loggerhead Shrike, were also observed with this method and none of the others; however, Loggerhead Shrikes were only observed during travel between point counts and they did not occur at any of the sampled points. The main weakness of this method, as it was applied in this study, was that it was not carried out in a standardized, repeatable manner. It was used as an initial attempt to determine which species were present in the Big Barrens.

The rope dragging method is elegant in that the survey covers a well defined area in which nearly 100% of the individuals should be observed. The chief difficulty in executing this method is the problem with identification of the birds. In many cases, sparrows flushed at a distance of 25 m, flew directly away from the observer, and landed in the nearest cover. The problem was compounded for the 2 observers holding the end of the rope because binoculars could not be held steadily to identify some individuals. A greater proportion of individuals could be identified if at least 1 observer walked behind the rope, focused solely on identification.

Of the 4 methods used in this study, the transect method in eastern Tennessee was the most repeatable and the most uniformly applied. Had a larger sample size been collected with this method, a thorough analysis would have been possible. One weakness of this method was that it did not account for habitat heterogeneity. For example, White-throated and White-crowned Sparrows were common winter residents in the mid-South (National Audubon Society 2002) but were not observed using transects. Both species use habitats with thick cover, especially on field edges (Falls and Kopachena 1994, Chilton et al. 1995), and the transect method, as it was implemented in this study, focused on field interiors.

Future Research Opportunities **–** Many research opportunities are available for winter grassland birds in the mid-South. Future research in the mid-South should focus on developing effective management strategies for the conservation of winter grassland birds. In some cases the specific habitat affinities are not known for many members of this group of species (Herkert and Knopf 1998). That and a better understanding of the spatial and temporal patterns of different habitat types for different bird species would alone aid conservation and management efforts enormously. Answers to the following specific research questions should improve management of grassland birds in the future:

- How do specific habitat characteristics effect the survival and fitness of open-habitat birds wintering in the mid-South?
- Does site fidelity differ between different types of open habitat in the mid-South?

- What mechanism drives temporal changes in bird community composition during the winter season? Are several factors at work?
- Do some habitat features increase the probability that an individual bird will survive a severe winter weather event, such as an ice storm or extremely low temperatures?

Unfortunately, several factors make research of these birds difficult. Many different types of habitat are used during the winter by open-habitat birds, and many species utilize several types of habitat. Foraging flocks and individuals may behave nomadically, leading to a high level of temporal variation in field use. Underlying all of these issues is the fact that none of the species that commonly winter in grasslands in the mid-South are of high conservation concern. Other than for game species like the Northern Bobwhite or charismatic species like the raptors, research funding may be hard to come by for studying wintering grassland birds in the mid-South.

Appendix

Table 4-1. Bird species observed with 4 sampling methods in Tennessee and Kentucky, winter of 2005-06 and 2006-07. Percent of observed species indicates the proportion of total species observed across all methods that were observed with each method. Entries in the table are alphabetized by species common name.

		Big Barrens			E. Tennessee
Common Name	**Scientific Name**	**Mist Nets**	**Point Counts**	**Rope Dragging**	**Transects**
American Crow	*Corvus brachyrhynchos*	No	No	**Yes**	No
American Goldfinch	*Carduelis tristis*	No	No	**Yes**	**Yes**
American Kestrel	*Falco sparverius*	No	**Yes**	No	No
American Pipit	*Anthus rubescens*	No	**Yes**	**Yes**	No
American Robin	*Turdus migratorius*	No	**Yes**	**Yes**	**Yes**
Brown Thrasher	*Toxostoma rufum*	No	**Yes**	No	No
Brown-headed Cowbird	*Molothrus ater*	No	No	No	**Yes**
Blue Jay	*Cyanocitta cristata*	No	**Yes**	No	**Yes**
Canada Goose	*Branta canadensis*	No	**Yes**	No	No
Carolina Wren	*Thryothorus ludovicianus*	No	**Yes**	No	No
Cedar Waxwing	*Bombycilla cedrorum*	No	**Yes**	**Yes**	No
Chipping Sparrow	*Spizella passerina*	No	**Yes**	No	No
Common Grackle	*Quiscalus quiscula*	No	No	No	**Yes**
Common Yellowthroat	*Geothlypis trichas*	**Yes**	No	No	No
Dark-eyed Junco	*Junco hyemalis*	No	**Yes**	**Yes**	No
Eastern Bluebird	*Sialia sialis*	No	**Yes**	No	**Yes**
Eastern Meadowlark	*Sturnella magna*	No	**Yes**	**Yes**	No
Eastern Phoebe	*Sayornis phoebe*	No	**Yes**	No	No
Eastern Towhee	*Pipilo erythrophthalmus*	No	**Yes**	No	**Yes**
European Starling	*Sturnus vulgaris*	No	**Yes**	No	No
Field Sparrow	*Spizella pusilla*	No	**Yes**	**Yes**	**Yes**
Fox Sparrow	*Passerella iliaca*	No	**Yes**	No	No
Horned Lark	*Eremophila alpestris*	No	**Yes**	**Yes**	No
House Finch	*Carpodacus mexicanus*	No	**Yes**	No	No
Killdeer	*Charadrius vociferus*	No	**Yes**	No	No
Lincoln's Sparrow	*Melospiza lincolnii*	No	No	No	No
Loggerhead Shrike	*Lanius ludovicianus*	No	**Yes**	No	No
Mourning Dove	*Zenaida macroura*	No	**Yes**	**Yes**	**Yes**
Northern Bobwhite	*Colinus virginianus*	No	No	**Yes**	No
Northern Cardinal	*Cardinalis cardinalis*	No	**Yes**	No	**Yes**
Northern Flicker	*Colaptes auratus*	No	**Yes**	No	No
Northern Harrier	*Circus cyaneus*	No	**Yes**	**Yes**	**Yes**
Northern Mockingbird	*Mimus polyglottos*	No	**Yes**	No	**Yes**
Purple Martin	*Progne subis*	No	No	No	**Yes**
Red-shouldered Hawk	*Buteo lineatus*	No	**Yes**	No	No
Red-tailed Hawk	*Buteo jamaicensis*	No	**Yes**	No	No
Red-winged Blackbird	*Agelaius phoeniceus*	No	**Yes**	No	No
Rock Pigeon	*Columba livia*	No	**Yes**	No	No
Savannah Sparrow	*Passerculus sandwichensis*	No	**Yes**	**Yes**	**Yes**
Short-eared Owl	*Asio flammeus*	No	No	**Yes**	No
Snow Goose	*Chen caerulescens*	No	**Yes**	No	No
Song Sparrow	*Melospiza melodia*	**Yes**	**Yes**	**Yes**	**Yes**
Swamp Sparrow	*Melospiza georgiana*	**Yes**	**Yes**	**Yes**	**Yes**
Tree Swallow	*Tachycineta bicolor*	No	No	No	**Yes**
Vesper Sparrow	*Pooecetes gramineus*	No	No	**Yes**	No
White-crowned Sparrow	*Zonotrichia leucophrys*	**Yes**	No	**Yes**	No
White-throated Sparrow	*Zonotrichia albicollis*	**Yes**	**Yes**	**Yes**	No
Wild Turkey	*Meleagris gallopavo*	No	No	No	**Yes**
Yellow-rumped Warbler	*Dendroica coronata*	No	**Yes**	No	No
Total (overall = 49)		**5**	**36**	**19**	**18**
Percent of total observed species		**10.2%**	**73.5%**	**38.8%**	**36.7%**

Table 4-2. Results of rope dragging at Fort Campbell (December 2005 – February 2006). AG includes harvested soybean, corn, and winter wheat fields. Ag-lease includes areas in the agricultural lease program that are unmowed fescue hay (*Festuca* sp.). Mowed includes ag-lease areas where the grass height was less than 15 cm. Native includes areas set aside for wildlife management including a mix of native warm-season grasses, woody vegetation, forbs, and cool-season grasses (< 50%).

Field Type	Fields	Area (ha)	Species		Count		Density (Birds/Ha)	
			Sparrows	All	Sparrows	All	Sparrows*	All
AG	**7**	**21.2**	**3**	**10**	**12**	**492**	**0.6b**	**23.2**
Ag-lease	**4**	**6.5**	**2**	**2**	**79**	**109**	**12.1**	**16.7**
Mowed	**6**	**12.6**	**1**	**5**	**40**	**64**	**3.2b**	**5.1**
Native	**6**	**9.2**	**7**	**8**	**313**	**320**	**34.1a**	**34.8**
TOTAL	**23**	**47.4**	**8**	**20**	**444**	**985**	**9.4**	**20.8**

*(ANOVA: F = 4.97, df = 3, P = 0.01)

[a,b] Letters indicate significantly different field types (Dunnett's 2-sided multiple comparison test: t = 2.556, df = 19, P = 0.01)

Table 4-3. Birds observed during winter transect sampling in eastern Tennessee (February – March 2007) on 3 field types. The number of individuals of each species is presented by field type as well as the proportion of individuals on each field type that is represented by each species. For each field type, values are in gray boxes for the minimum number of species necessary to represent ≥ 50% of the individuals observed.

	Agricultural		Burned		Native	
Species	**#**	**%**	**#**	**%**	**#**	**%**
American Goldfinch	8	7.0%	0		4	1.9%
American Robin	10	8.7%	2	2.1%	0	0.0%
Brown-headed Cowbird	0		1	1.1%	0	
Blue Jay	0		1	1.1%	2	0.9%
Common Grackle	15	13.0%	2	2.1%	0	
Eastern Bluebird	0		3	3.2%	0	
Eastern Towhee	0		8	8.5%	0	
Field Sparrow	4	3.5%	34	36.2%	21	9.8%
Mourning Dove	13	11.3%	10	10.6%	0	
Northern Cardinal	0		5	5.3%	11	5.1%
Northern Harrier	0		0		2	0.9%
Northern Mockingbird	0		2	2.1%	0	
Purple Martin	0		0		7	3.3%
Savannah Sparrow	49	42.6%	11	11.7%	0	
Song Sparrow	5	4.3%	6	6.4%	60	27.9%
Unidentified sparrow	0		0		7	3.3%
Swamp Sparrow	10	8.7%	4	4.3%	95	44.2%
Tree Swallow	1	0.9%	3	3.2%	6	2.8%
Wild Turkey	0		2	2.1%	0	
Total	**115**		**94**		**215**	

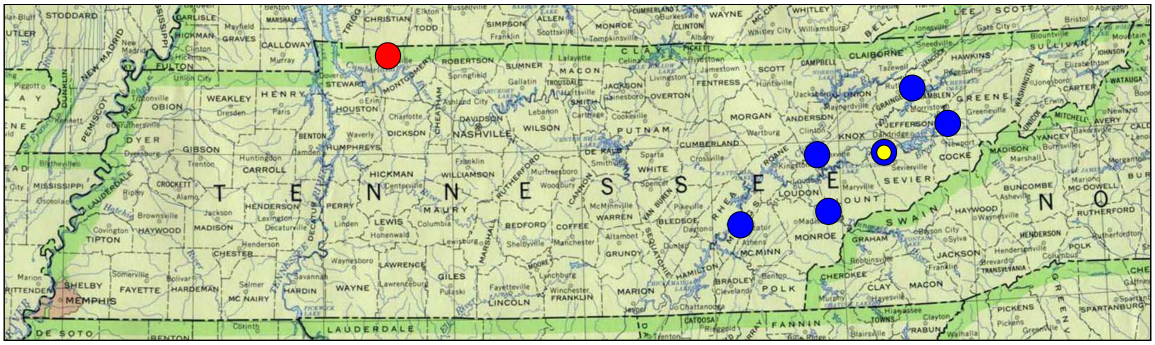

Figure 4-1. Study sites in the Big Barrens, Tennessee and Kentucky, and eastern Tennessee for grassland bird research in the winters of 2003-07. The Big Barrens and Fort Campbell Military Reserve are represented by the red point. Blue points indicate study sites in eastern Tennessee used for transect sampling. Seven Islands Wildlife Refuge, the yellow point, was used for both transect sampling and mist netting. Map source: University of Texas Libraries.

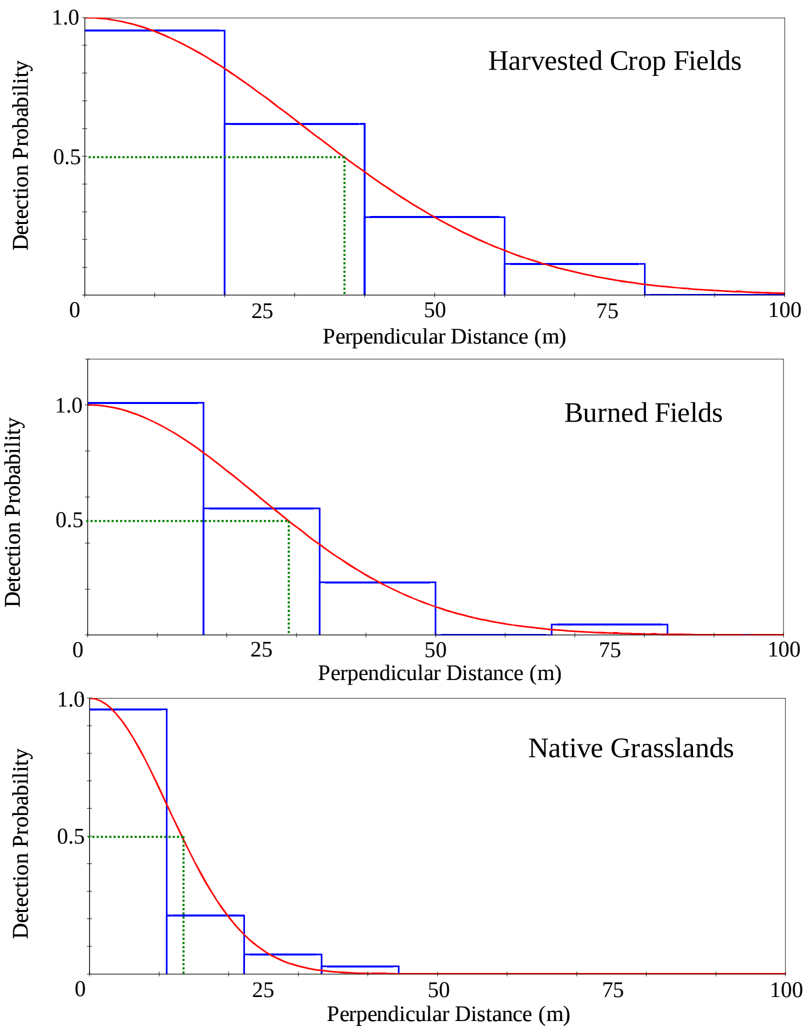

Figure 4-2. Changes in detection probability with greater distance from line transect for harvested crop fields, burned native grass fields, and unburned grasslands dominated by native vegetation in eastern Tennessee, February-April, 2007. Bars outlined in blue indicate the expected proportion of the birds within the given range that should be observed. The red line illustrates the function of change in detection probability with increased distance from the line transect. The dashed green lines indicate the distance from the line transect at which about 50% of the birds should be observed. This figure was prepared using the program Distance (Thomas et al. 2006).

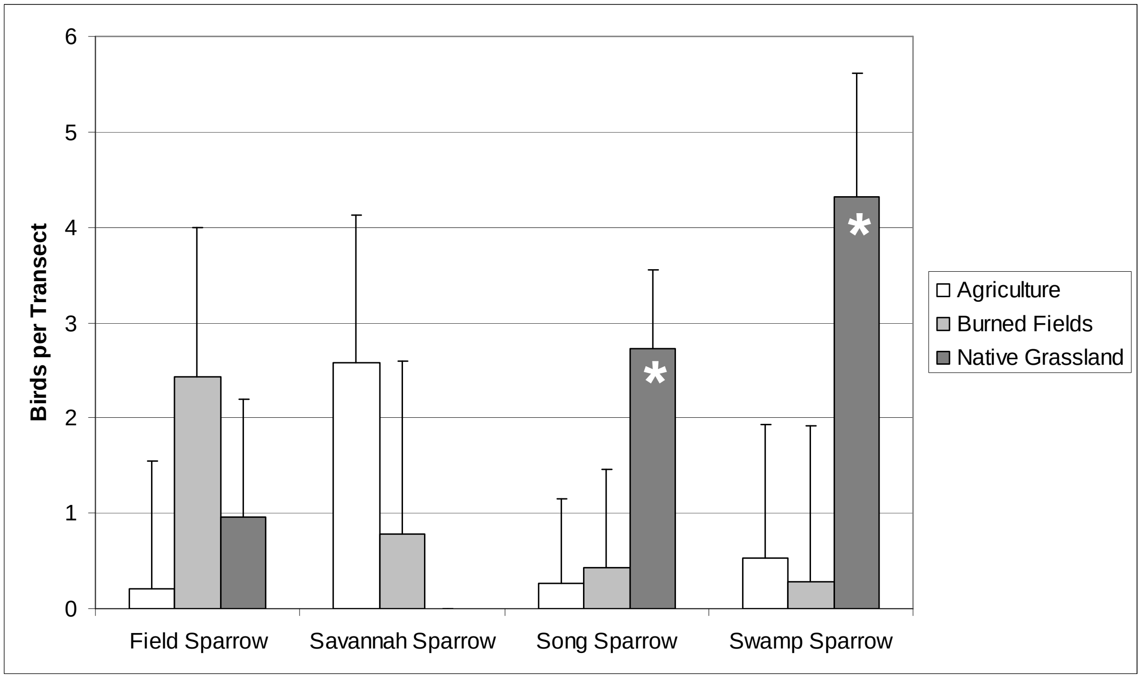

Figure 4-3. Number of birds observed per line transect by species and field type in eastern Tennessee, February-April, 2007. Error bars represent the upper portion of the 95% confidence interval. Bars with an asterisk enclosed within the bar represent a significant difference from the other habitat types for that species.

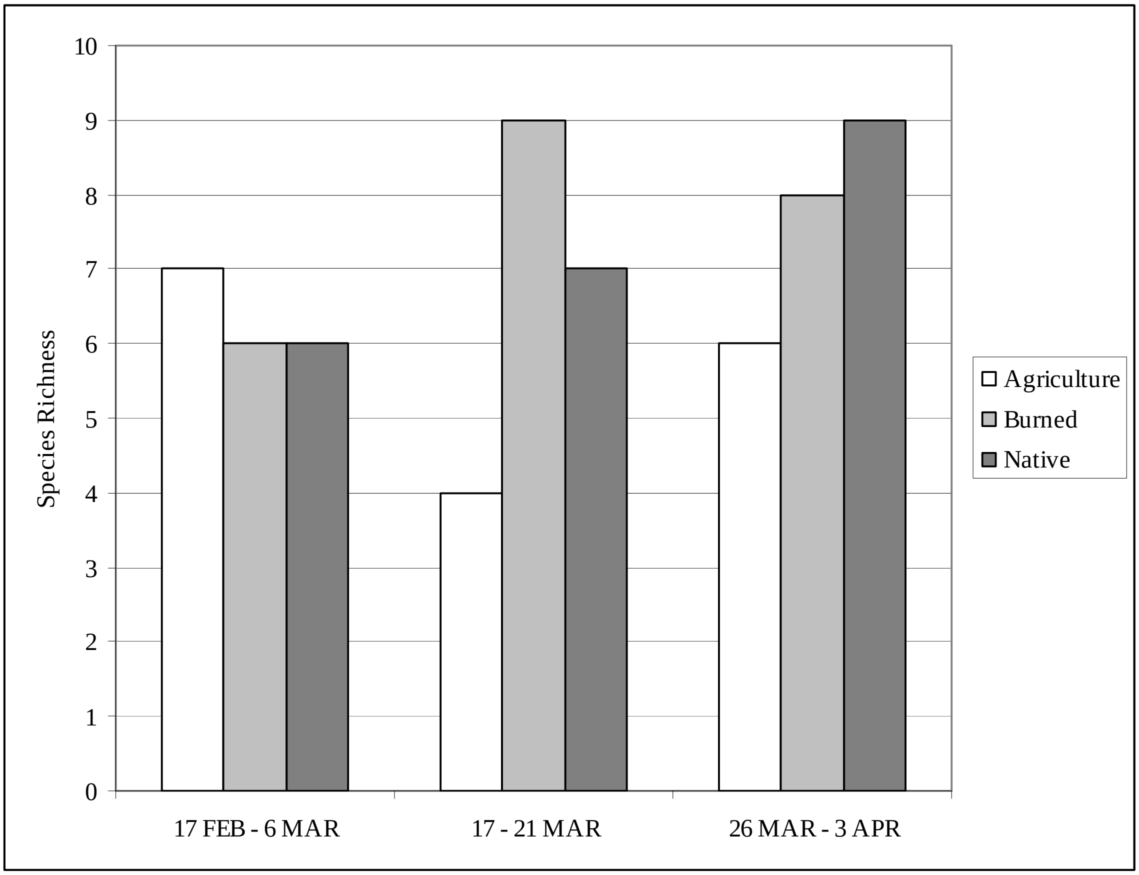

Figure 4-4. Observed species richness for line transect surveys in agricultural stubble, burned fields, and grasslands dominated by native vegetation in eastern Tennessee, February-April, 2007.

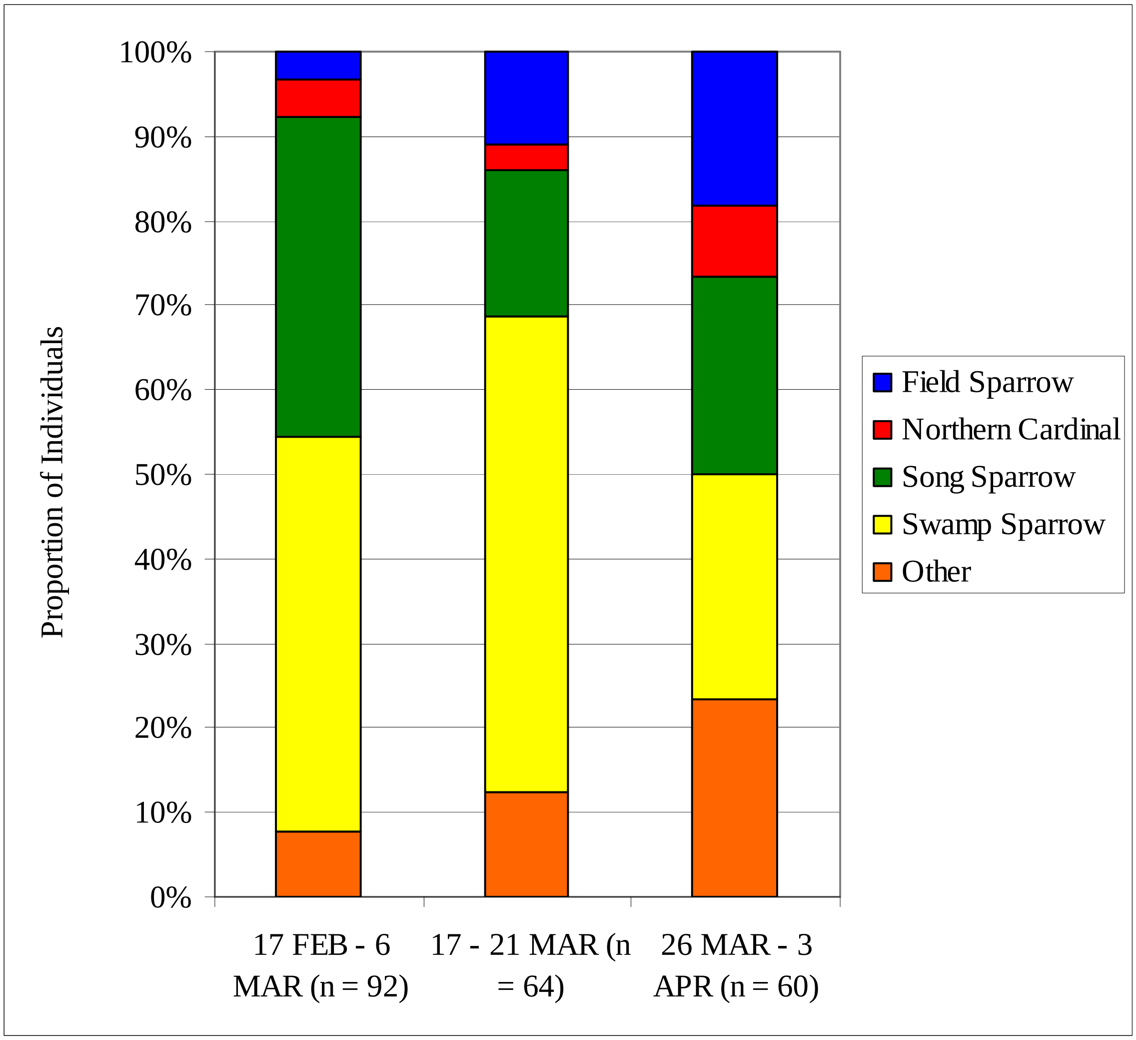

Figure 4-5. Changes in composition of bird community by proportion of birds observed on line transects in grasslands dominated by native vegetation in eastern Tennessee, February-April, 2007. The birds included in “Other” are American Goldfinch, Blue Jay, Northern Harrier, Purple Martin, Tree Swallow, and unidentified sparrows.

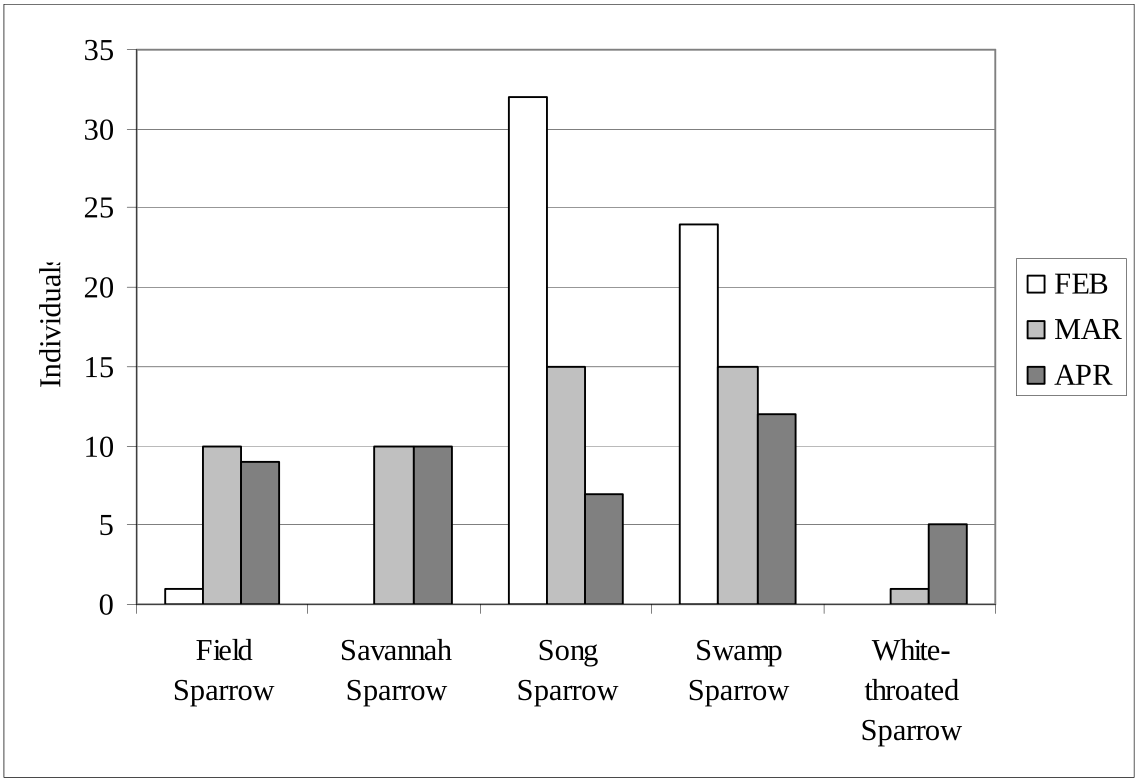

Figure 4-6. Number of birds captured in open native grass habitat at Seven Islands Wildlife Refuge, Knox County, Tennessee, February-April, 2003 and 2004.

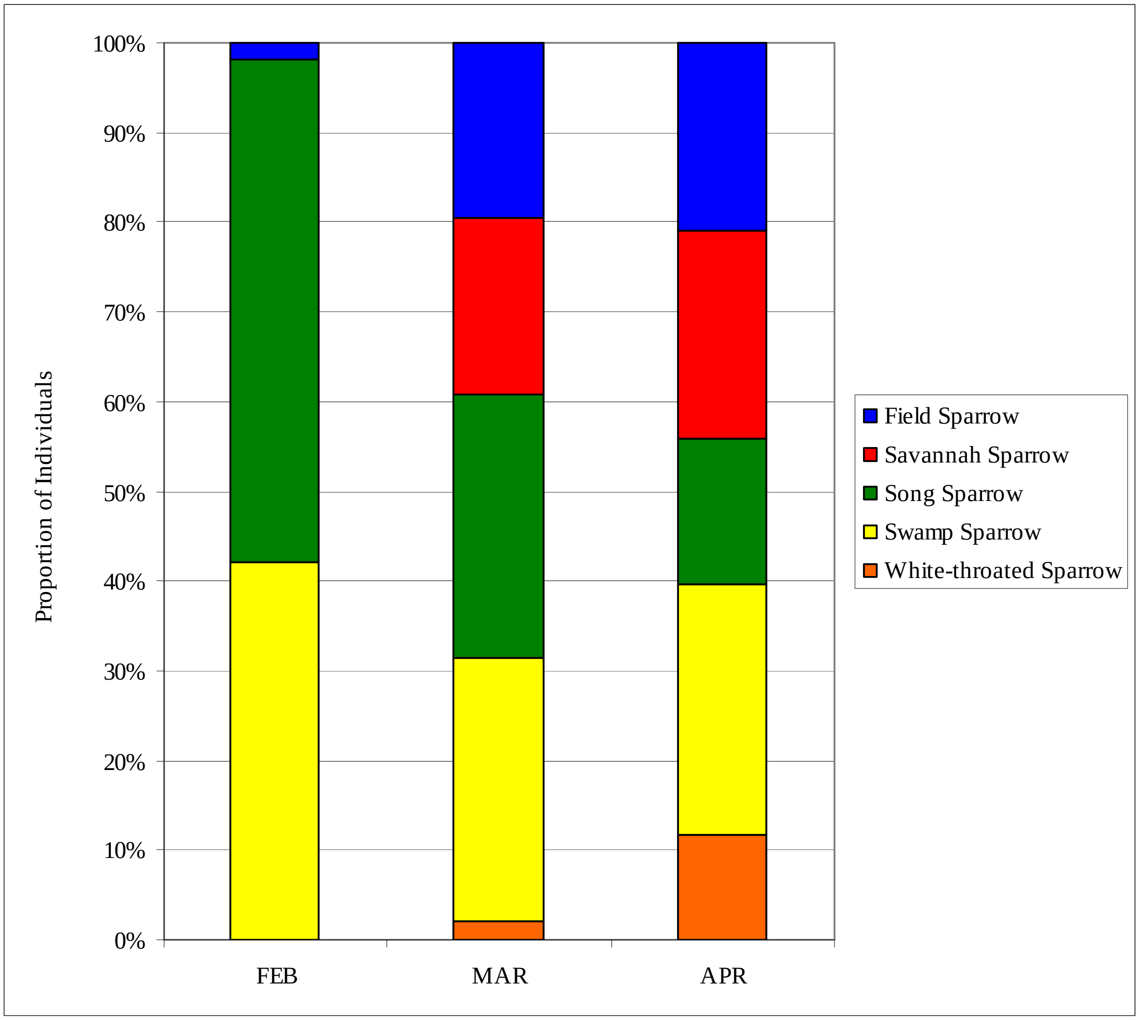

Figure 4-7. Changes in composition of bird community by proportion of birds captured in a field interior at Seven Islands Wildlife Refuge, Knox County, Tennessee, February-March, 2003 and 2004.

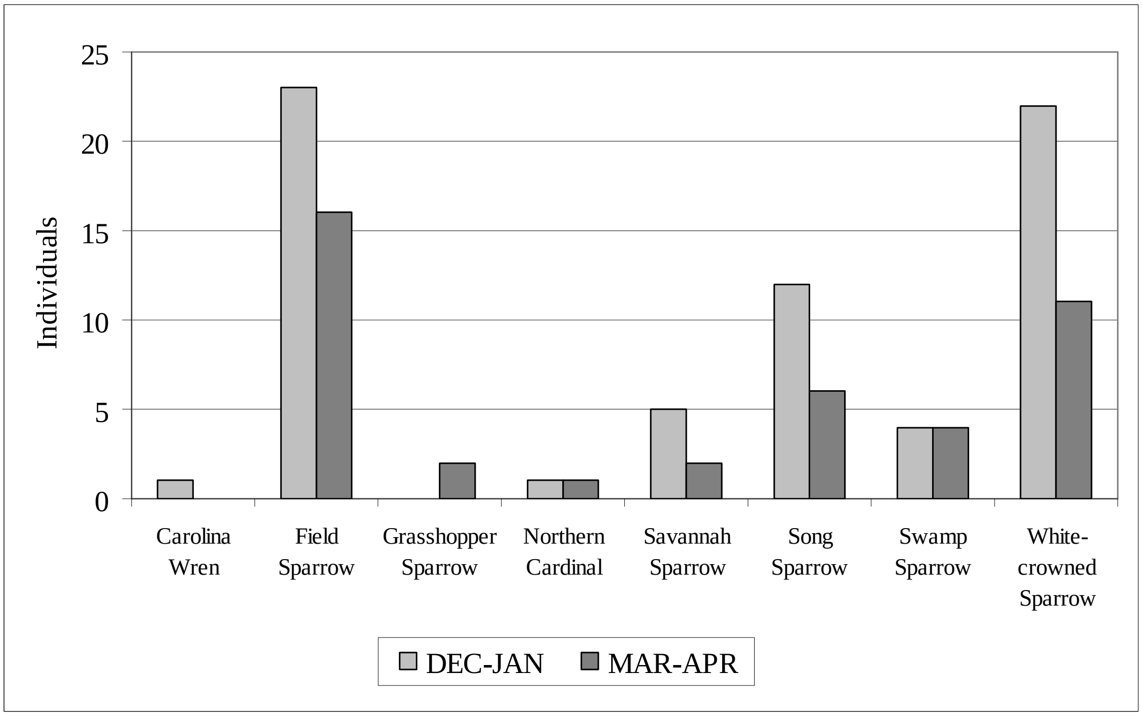

Figure 4-8. Number of birds captured in brushline on a field edge at Seven Islands Wildlife Refuge, Knox County, Tennessee, December-January and March-April, 2005-06.

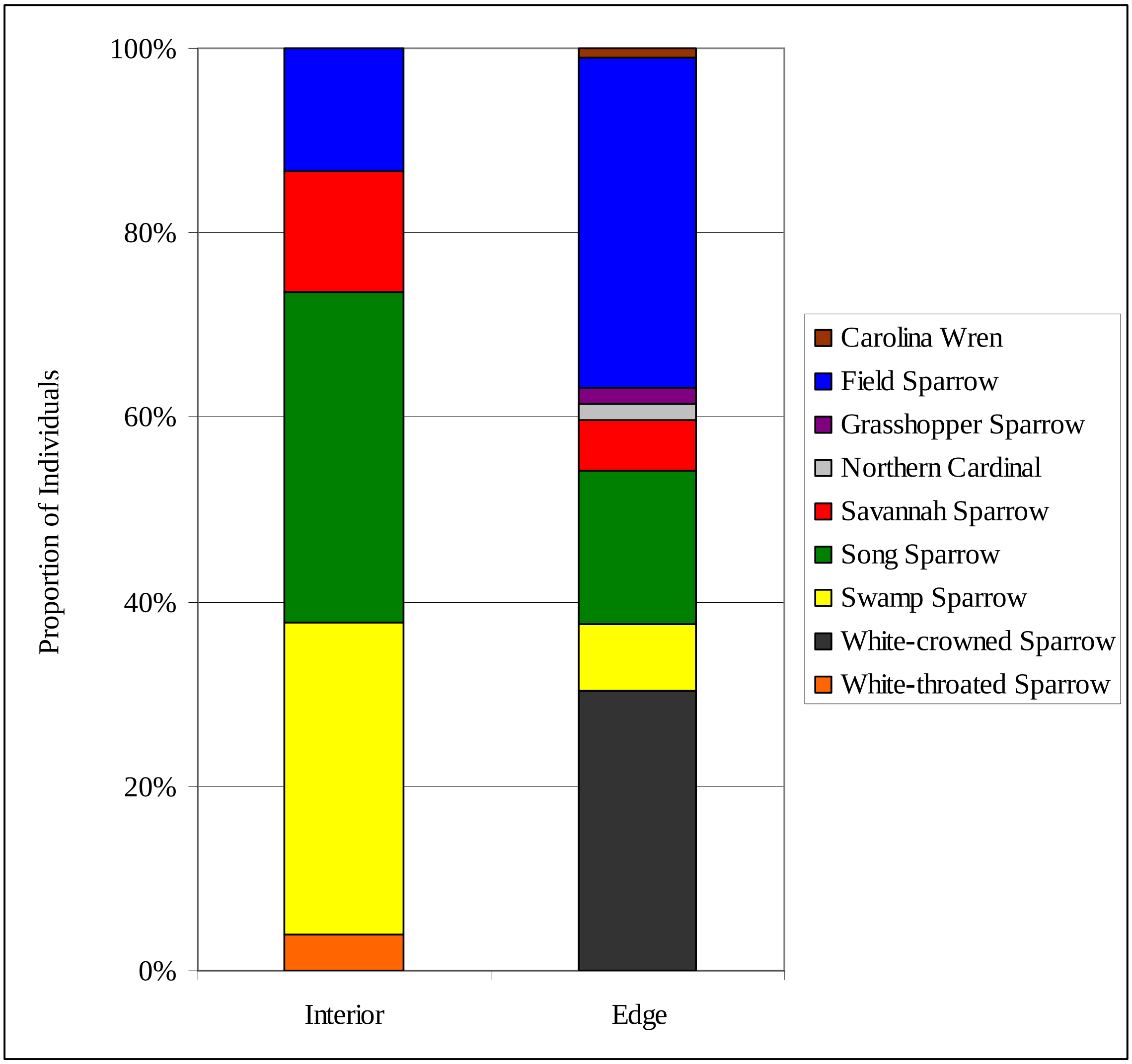

Figure 4-9. Composition of bird communities by proportion of birds banded in a native grass field interior (February-April, 2003 and 2004) and a field edge (December-January and March-April, 2005-06) at Seven Islands Wildlife Refuge, Knox County, Tennessee.

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VITA

Daniel Hinnebusch was born near Detroit, Michigan, in 1984, but was raised in Pittsburgh, Pennsylvania after his family moved in 1990. A childhood passion for the environment and an interest in bird watching led Daniel to earn a Bachelor of Science degree with honors in Wildlife and Fisheries Science, with a minor in Forest Science, from the Pennsylvania State University in May, 2006. While enrolled at the Pennsylvania State University, Daniel worked as a field technician on wildlife research projects in Arizona, Pennsylvania, and West Virginia, where he gained valuable research experience. Immediately after completion of his Bachelor's, Daniel began work at the University of Tennessee on a Master of Science degree in Wildlife and Fisheries Science with a minor in Statistics. Near the completion of his time in Tennessee, Daniel took a position as a Research Biologist at Hawk Mountain Sanctuary near Kempton, Pennsylvania. He plans to continue learning about birds and the natural world in the hope of contributing to the ongoing effort to conserve environmental resources and values.