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MONITORING GRASSLAND BIRD POPULATIONS ON FORT CAMPBELL MILITARY RESERVATION, KENTUCKY-TENNESSEE, WITH A SPECIAL EMPHASIS ON BACHMAN'S SPARROW (Peucaea aestivalis)

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To the Graduate Council:

I am submitting herewith a thesis written by Emily Vera Hockman entitled "MONITORING GRASSLAND BIRD POPULATIONS ON FORT CAMPBELL MILITARY RESERVATION, KENTUCKY-TENNESSEE, WITH A SPECIAL EMPHASIS ON BACHMAN'S SPARROW (Peucaea aestivalis)." 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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MONITORING GRASSLAND BIRD POPULATIONS ON FORT CAMPBELL MILITARY RESERVATION, KENTUCKY-TENNESSEE, WITH A SPECIAL EMPHASIS ON BACHMAN'S SPARROW (*Peucaea aestivalis)*

A Thesis Presented for the Master of Science Degree

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ABSTRACT

Grassland birds have declined more in the past four decades than any other group, primarily because of the suppression of ecological disturbance. Fort Campbell Military Reservation (FCMR) has maintained large amounts of grasslands and oak (*Quercus* spp.) savannas because of military training and prescribed fires, and supports many grassland bird populations. I established a survey route to investigate vegetation influencing occupancy of grassland birds with an emphasis on Bachman's Sparrows (*Peucaea aestivalis*), and additionally described habitat selection of Bachman's Sparrows on FCMR. Bachman's Sparrow, Eastern Meadowlark (*Sturnella magna*), Henslow's Sparrow (*Ammodramus henslowii*), and Orchard Oriole *(Icterus spurius*) occupancy were positively related to grass cover (β [beta] = 10.02 ± [plus-minus] 2.80 SE, β = 9.93 ± 2.05 SE, β = 7.09 ± 2.35 SE, β = 17.12 ± 5.81 SE), whereas Blue Grosbeak (*Passerina caerulea*) and Northern Bobwhite (*Colinus virginianus*) occupancy were related to grass cohesion (β = 0.08 ± 0.03 SE, β = 0.08 ± 0.02 SE). Blue-winged Warbler (*Vermivora cyanoptera*) occupancy was positively related to shrub cover (β = 4.90 ± 1.85 SE), Prairie Warbler (*Setophaga discolor*) occupancy was positively related to interspersion and juxtaposition (β = 0.05 ± 0.02 SE), and Dickcissel (*Spiza americana*) occupancy was negatively related to tree cover (β = -7.28 ± 0.48 SE). Bachman's Sparrow territory size averaged 2.66 ha (± 0.57 SE); basal area was 2.25 m^2/ha [meters squared per hectacre] (± 0.57 SE). Occupied territories had greater cover of forbs than unoccupied savannas (27% ± 1.55 SE vs 22% ± 1.02 SE, p = 0.0001) and greater variance in litter (0.71 ± 0.03 SE vs 0.6 ± 0.02 SE, p = 0.01). There was less variance between occupied and unoccupied territory points for bareground (0.58 ± 0.02 SE vs 0.66 ±0.03 SE, p = 0.02), forbs (0.47 ± 0.01 SE vs 0.53 ± 0.02 SE, p = 0.02), and woody

species (0.85 ± 0.03 SE vs 0.96 ± 0.04, $p = 0.03$). Our goal is to use these data to develop a conservation strategy to monitor and enhance Bachman's Sparrows and other high-priority species at FCMR and elsewhere in the region.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Bird species that rely on native grasslands and savannas are experiencing the most significant population decline for any group of birds monitored by the North American Breeding Bird Survey since 1966 (Sauer et al. 2011). Widespread suppression of fire, land use changes, woody encroachment, fragmentation, lack of natural ephemeral ecological disturbances, and use of exotic forages are primarily responsible for the loss of grasslands and avian species that depend on them (Dunning and Watts 1990, Vickery et al. 1999, Johnson and Igl 2001, Vickery and Herkert 2001). These influences have caused a decline in the total area and particularly the quality of native grasslands in the East; grassland birds are experiencing a similar, steady decline.

Landscapes that experience frequent or ephemeral disturbance support a gradient of vegetation types from open grasslands to forested woodlands. This variety of cover types can support an assortment of grassland bird species with diverse habitat requirements. Grasslands developed and maintained by humans and primarily comprised of native perennial grasses often support this gradient and mixture of vegetation types (Baskin et al. 1994, Heikens and Robertson 1994). Frequent anthropological disturbances over extensive periods of time and particularly in poor soil types of the southeastern barrens promoted the dominance of grasses and forbs, although the climax vegetation of these types of grasslands is typically forest (Heikens and Robertson 1994). The composition of grasses in southeastern barrens is comparable to those found in the midwestern prairies, and include grasses in the *Schizachyrium*, *Andropogon*, and *Panicum* genera (DeSelm 1994). Barrens today are maintained nearly exclusively by human activity and thus are much more dependent on man-made disturbance compared with the midwestern grasslands they resemble; remnant patches of barrens serve as vital habitat for many grassland birds species in the eastern United States (DeSelm 1994, Heikens and Robertson 1994).

Fort Campbell Military Reservation (FCMR) on the Tennessee-Kentucky border within the Big Barrens eco-region has some of the largest remnant native grasslands in the eastern United States (Moss 2001, Giocomo et al. 2008). Pre-settlement fires, periodic drought, shallow soils, and grazing kept the Big Barrens in grassland or early successional vegetation instead of the climax oak-hardwood forest found in the surrounding areas (DeSelm 1994, Chester et al. 1997). By the early 1900s, however, most of the land had been converted to agriculture and only small remnants of native vegetation remained. FCMR was created at the onset of World War II to maintain open land for military training, and established a regular burning regime to do so. Native species still found in the seed-bank were able to regenerate historic barrens-like vegetation (Chester et al. 1997, Giocomo et al. 2008).

FCMR is currently used extensively for military training both on the ground and in the air. Grassland and savanna vegetation covers approximately 30% of the base whereas the remainder is oak-hickory (*Quercus* spp.- *Carya* spp.) woodlands and forests (Giocomo et al. 2008). Floristic studies confirmed that the composition of these grasslands are unique to the barrens of this region although they closely resemble tallgrass prairie systems found further west (Chester et al. 1997). Frequent prescribed fires set specifically for military training to improve visibility and create landing areas reduce fuel for accidental fires, and create a mosaic of open grasslands of the Big Barrens and closed-canopy forests.

The unique vegetation on FCMR is home to a rapidly declining species: the Bachman's Sparrow (*Peucaea aestivalis*). Bachman's Sparrows use the oak savannas created by regular burning on FCMR even though they are more typically associated with mature pine savannas of the Southeastern Coastal Plain. Bachman's Sparrows are ground-nesting grassland birds whose typical habitat is comprised of a patchy herbaceous layer dominated by native warm-season grasses, forbs, bare ground, and litter, characteristic of both pine and oak savannas (Chester et al. 1997, Dunning 2006). In addition to the grass-dominated understory, Bachman's Sparrows also require a scattered woody overstory mostly used for territorial singing. This sparse woody component is lost without frequent burning; Bachman's Sparrows vacate a savanna habitat within 2-5 years after fire regimes are interrupted (Tucker et al. 2004, Cox and Jones 2007;2009).

Populations of Bachman's Sparrows have been decreasing 3.2% per year since 1966 (Sauer et al. 2011). Bachman's Sparrows were previously listed by the U.S. Fish and Wildlife Service as a Category 2 candidate species: one which had some indication that they should be listed as threatened or endangered but whose listing was never proposed because of insufficient data. Bachman's Sparrows are currently listed as birds of National Conservation Concern (USFWS 2008). They are classified as near threatened on the IUCN Red List and are on the Partners in Flight Watchlist and are listed as Endangered in Tennessee and Threatened in Kentucky.

Like many grassland species, the main cause of Bachman's Sparrow population decline is habitat loss and degradation (Dunning and Watts 1990). Their current range stretches from the

Gulf of Mexico and Florida to as far north as Virginia, Kentucky, and Illinois, although Bachman's Sparrows were found much further north in the past (Brooks 1938, Dunning 2006). Historical data document a northerly expansion in their range that peaked in the early 20th Century, but the range and population size have contracted since that time. Bachman's Sparrow population contraction in the northerly limits of their range through was noted through the middle of the 20th century (Weston 1968).

FCMR was a perfect location to study Bachman's Sparrows because of its proximity to the current limits of the species' range and the occurrence of extensive oak savannas and other native grasslands. Very few studies have investigated the habitat requirements of Bachman's Sparrows in hardwood savannas . We used this unique landscape structure, composition, and location to answer specific questions about Bachman's Sparrows and other declining grassland birds. Our objectives were as follows:

Chapter 1

1) utilize a point-count route to monitor Bachman's Sparrows and other declining grassland and savanna species;
2) determine which vegetation and spatial characteristics best describe occupancy and detectability for a suite of grassland birds at Fort Campbell;
3) examine the effectiveness of playback as a tool for detecting Bachman's Sparrows.

Chapter 2

4) document the size and extent of the accessible Bachman's Sparrow population on Fort Campbell;
5) describe the vegetation composition in Bachman's Sparrow territories in terms of percent cover, vertical structure, and landscape features; and
6) determine the main factors associated with Bachman's Sparrow habitat selection in the woodland-oak savanna-grassland mosaic.

CHAPTER 1: OCCUPANCY AND DETECTABILITY OF GRASSLAND BIRDS USING HABITAT AND LAND COVER RELATIONSHIPS ON FORT CAMPBELL MILITARY RESERVATION, TENNESSEE-KENTUCKY

Abstract

The Department of Defense manages more than 10 million ha in the United States that has become unintentional refugia for wildlife. Grassland birds, which are experiencing the largest decline of any group of breeding birds in North America, benefit from open vegetation created and maintained for military training. I used a point-count route around the impact area on Fort Campbell Military Reservation (FCMR), Tennessee-Kentucky to investigate the use of native warm season grasslands and oak savannas by a suite of declining grassland birds. I evaluated the relationship between vegetation cover and arrangement on species' occupancy along the route. Bachman's Sparrows (*Peuacea aestivalis*) were of particular interest because of the small but persistent and isolated population found on FCMR in the northern-most reaches of the species' range. The most common species recorded on point-count surveys in 2009-2010 were Northern Bobwhite (*Colinus virginianus*) and Prairie Warblers (*Setophaga discolor*) (n = 492, 466 respectively; both years combined). Bachman's Sparrow occupancy was the lowest across both years (⍰=0.08 ± 0.02, n = 18), and occupancy did not increase with use of playback. Bachman's Sparrow, Eastern Meadowlark (*Sturnella magna*) Henslow's Sparrow (*Ammodramus henslowii*), and Orchard Oriole (*Icterus spurius*) occupancy were positively related to grass cover (β = 10.02 ± 2.80 SE, β = 9.93 ± 2.05 SE, β = 7.09 ± 2.35 SE, and β = 17.12 ± 5.81 SE, respectively), whereas Blue Grosbeak (*Passerina caerulea*) and Northern Bobwhite occupancy were positively related to grass cohesion (β = 0.08 ± 0.03 SE and β = 0.08 ± 0.02 SE). Blue-winged Warbler (*Vermivora cyanoptera*) occupancy was positively related to shrub cover (β = 4.90 ± 1.85 SE). Prairie Warblers had a positive relationship with interspersion and juxtaposition (β = 0.05 ± 0.02 SE), and Dickcissels (*Spiza Americana*) were more likely to occupy

an area with less tree cover (β = -7.28 ± 0.48 SE). The variety of vegetation structure and composition present in the impact area on FCMR illustrates the importance of anthropogenic disturbances in grassland bird conservation.

INTRODUCTION

Grassland birds are experiencing the most significant population decline of any group of birds monitored by the North American Breeding Bird Survey (Sauer et al. 2011). Widespread suppression of fire, land use changes, woody encroachment, fragmentation, and use of exotic forages are primarily responsible for the loss of grasslands and avian species that depend on them (Dunning and Watts 1990, Vickery et al. 1999, Johnson and Igl 2001, Vickery and Herkert 2001). Furthermore, the lack of extensive natural and man-made disturbances required to create, maintain and restore grasslands, prairies, and savannas diminishes the available habitat for grassland birds (Mlot 1990, Brawn et al. 2001, Van Lear et al. 2005). These factors combined have caused a decline in the total area and especially the quality of native grasslands in the East and as a result, grassland birds are experiencing a similar, steady decline.

Bachman's Sparrow populations have been decreasing 3.2% per year since 1966 (Sauer et al. 2011). Like many grassland species, the main cause of population decline of the Bachman's Sparrow is habitat loss and degradation (Dunning and Watts 1990). The current range of the Bachman's Sparrow stretches from the Gulf of Mexico and Florida to as far north as Virginia, Kentucky, and Illinois, although they were found much further north in the past (Brooks 1938, Dunning 2006). Historical data document a northerly expansion in their range that peaked in the early 20th century, but the range and population size have contracted since that time (Weston 1968) and successive population declines have caused concern.

Bachman's Sparrows were previously listed by the U.S. Fish and Wildlife Service as a Category 2 candidate species: one which had some indication that listing as threatened or endangered was warranted but whose listing was never proposed because of insufficient data. They are currently listed as a Bird of National Conservation Concern (USFWS 2008). Bachman's Sparrows are classified as near threatened on the IUCN Red List and are on the Partners in Flight Watchlist. They are listed as Endangered in Tennessee and Threatened in Kentucky at the state level.

Fort Campbell Military Reservation on the Tennessee-Kentucky border within the Big Barrens eco-region has some of the largest remnant native grasslands and oak (*Quercus* spp.) savannas in the eastern United States (Moss 2001, Giocomo et al. 2008) (Figure 1-1). Pre-settlement fires, periodic drought, shallow soils, and grazing prevented succession of the Big Barrens grasslands and other types of early successional vegetation to the climax oak-hickory (*Carya* spp.) forest found in the surrounding areas (DeSelm 1994, Chester et al. 1997). By the early 1900s, however, most of the land had been converted to agriculture and only small remnants of native vegetation remained. FCMR was created at the onset of World War II to maintain open land for military training, and established a regular burning regime to do so.

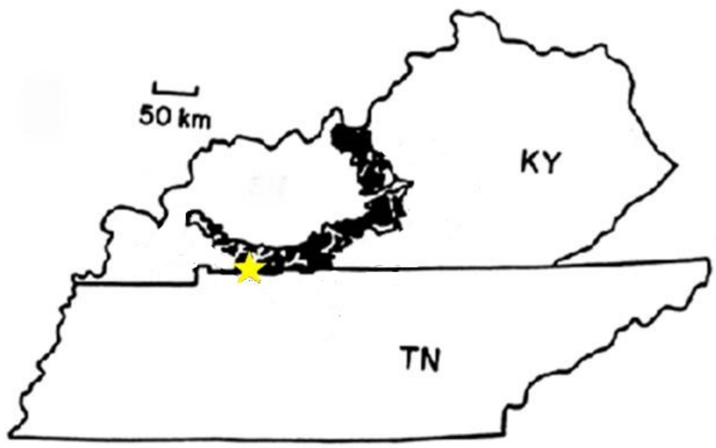


Figure 1 - 1: The location of Fort Campbell Military Reservation within the historical occurrence of the Big Barrens Region of Kentucky and Tennessee (Baskin et al. 1994a).

Native plant species still present in the seed-bank responded positively to prescribed burning, restoring areas to historic barrens-like vegetation (Chester et al. 1997, Giocomo et al. 2008).

Bachman's Sparrows typically occur in southern pine savannas, but also occur in oak savannas, like those created by management at FCMR in the northern part of its range (Figure 1-2). Bachman's Sparrows are ground-nesting grassland birds whose typical habitat is comprised of a herbaceous layer dominated by native warm-season grasses, forbs, bare ground, and litter, characteristic of both pine and oak savannas (Chester et al. 1997, Dunning 2006). In addition to the grass-dominated understory, Bachman's Sparrows also require a scattered woody overstory mostly used for territorial singing (Dunning and Watts 1990, Haggerty 1998). Spacing between trees needs to be wide enough to enable sunlight to penetrate most of the savanna floor, promoting development of the herbaceous layer. This sparse woody component is lost without frequent burning; Bachman's Sparrows vacate an area 2-5 years post-burn (Tucker et al. 2004, Cox and Jones 2008, Cox and Jones 2009). Bachman's Sparrows will occasionally use abandoned fields or young even-aged pine stands if vegetation structure is suitable, but they will leave in the absence of disturbance.

The effects of landscape fragmentation have been well researched for many declining grassland species. For example, Henslow's Sparrows show a strong negative relationship with grassland patch size whereas Dickcissels respond more strongly to habitat quality than patch size (Herkert 1994). Fragmentation is often studied at the landscape scale and not at finer, territory size scales (Brennan and Schnell 2005, Cunningham and Johnson 2006, Renfrew and Ribic 2008). The arrangement of grass cover or shrub cover within a 1-2 ha area may be as

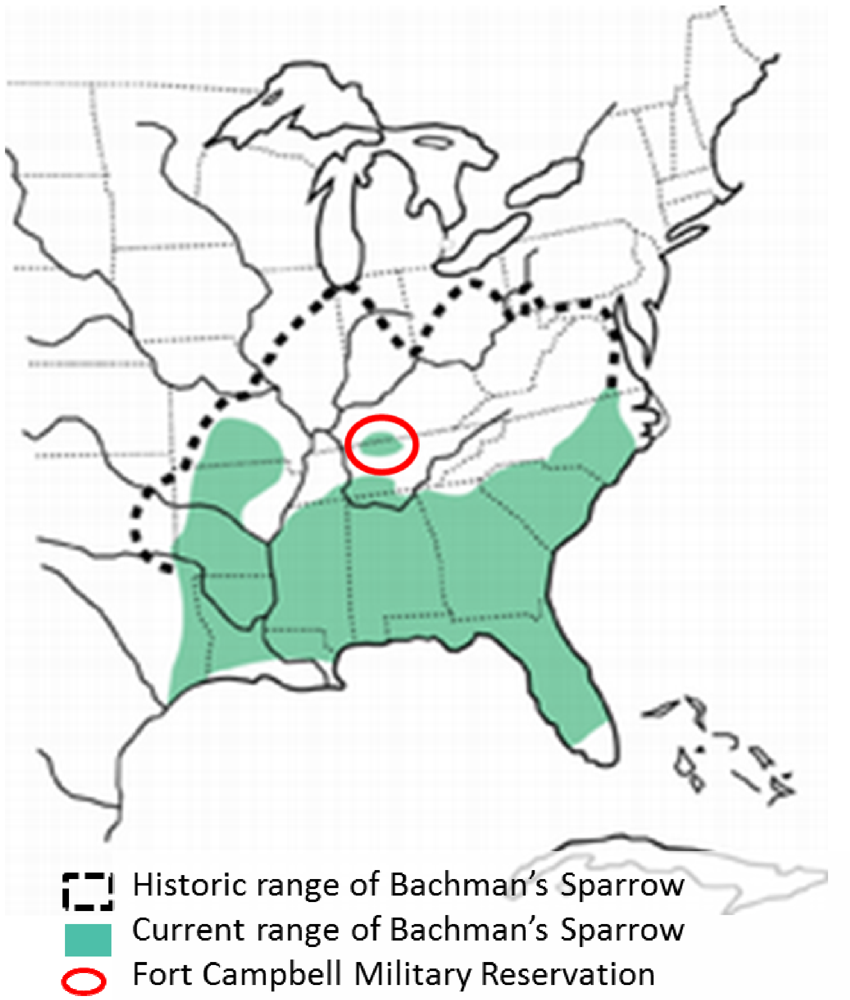


Figure 1 - 2: The location of Fort Campbell Military Reservation within the historic and current range of Bachman's Sparrow (Dunning 2006).

important as landscape characteristics that cover multiple square kilometers or entire study sites. I used land-cover classification created from aerial photography of FCMR within the radius of individual point counts to explore relationships between vegetation arrangement and composition and their use by grassland and savanna birds.

Bachman's Sparrows were the main focus of this study. However I was also interested in other grassland birds that benefit from land management at FCMR and share similar habitat characteristics. I additionally monitored Grasshopper Sparrows (*Ammodramus savannarum*), Henslow's Sparrows, Eastern Meadowlarks, and Dickcissels to investigate how relationships with vegetative cover and arrangement of patches on the landscape affect other grassland-obligate bird species (Vickery 1996, Herkert et al. 2002, Temple 2002, Jaster et al. 2012). I monitored Blue Grosbeaks, Orchard Orioles, Prairie Warblers, Blue-winged Warblers, and Red-Headed Woodpeckers (*Melanerpes erythrocephalus*) to investigate the role of vegetation patch shape and composition on shrub-scrub birds (Nolan et al. 1999, Smith et al. 2000, Gill et al. 2001, Scharf and Kren 2010, Lowther and Ingold 2011). Lastly, I modeled vegetation cover, the presence of bare ground, and patch arrangement with Bachman's Sparrow and Northern Bobwhite occupancy. Both species are associated with some amount of bare ground either as open patches or beneath an herbaceous canopy (Guthery 1997, Brennan 1999, Dunning 2006).

Given the landscape structure and composition of the grasslands at FCMR and the various grassland bird species occurring there, my objectives were as follows:

1) utilize a point-count route to monitor Bachman's Sparrows and other declining grassland and savanna species;
2) determine which vegetation structural characteristics best describe occupancy and detectability for a suite of grassland birds at FCMR; and
3) examine the effectiveness of playback as a tool for improving detection of Bachman's Sparrows.

STUDY AREA

FCMR is home to the U. S. Army's 101st Airborne Division and is used extensively for ground-based and aerial military training. Grassland and savanna vegetation covers roughly 30% of the base while the remainder is oak-hickory woodlands and forests (Giocomo et al. 2008). Composition of the grasslands resembles tallgrass prairies found further west, although floristic studies confirmed that the composition of these grasslands are unique to the barrens of this region (Baskin et al. 1994, Chester et al. 1997). Fifty-five percent of the flora on FCMR are in the Asteraceae, Poacaea, Fabaceae, Rosaceae, Cyperaceae, and Lamiaceae families, while the genera with the highest number of taxa included *Panicum, Quercus, Eupatorium, Helianthus, Hypericum, Lespedeza, Carex, Asclepias,* and *Solidago* (Chester et al. 1997*).* Oak trees were the most common tree genera on FCMR, specifically Southern Red Oak (*Quercus falcata*) and Post Oak (*Quercus stellata*).

Frequent prescribed fires set specifically for military training to improve visibility and create landing areas, reduced fuel for accidental fires, and maintained early seral stages of vegetation communities. Fires promote a mosaic of vegetation types between open grasslands and closed-canopy forests on FCMR. The most frequently burned section of FCMR was the impact area, a large 5 km by 8 km section of the base used for large munitions practice. This impact area was typically burned on an annual basis to decrease occurrence of fire caused by munitions explosions. Consequently, it contained the majority of the oak savanna land cover on FCMR. I focused on the accessible areas and perimeter of the impact area for this study.

METHODS

Point Counts

I established a roadside point-count route around the impact area at FCMR to monitor species of interest in a gradient from grasslands to savannas and open woodlands (Figure 1-3). This section provided the largest accessible area of grassland bird habitat and is where the majority of Bachman's Sparrows have been found in the past (D. Moss, pers. comm.). The 50-km long point-count route had a total of 100 survey locations spaced at 500-m intervals along accessible roads. I altered the route slightly in 2009 after roads were improved that allowed access to additional grassland habitat. I divided the route into six sections and delegated one observer one morning to survey each section. We surveyed three times during each summer for a total of 18 point-count mornings, and each section was surveyed once during a two-week window in a random order. Direction of travel for each portion of the route changed for subsequent surveys. Data were collected between sunrise and up to four hours past sunrise coinciding with peak singing activity.

Point counts were ten minutes in duration, split into two five-minute periods. The first five minutes followed a removal model method with the time first seen, location, and type of

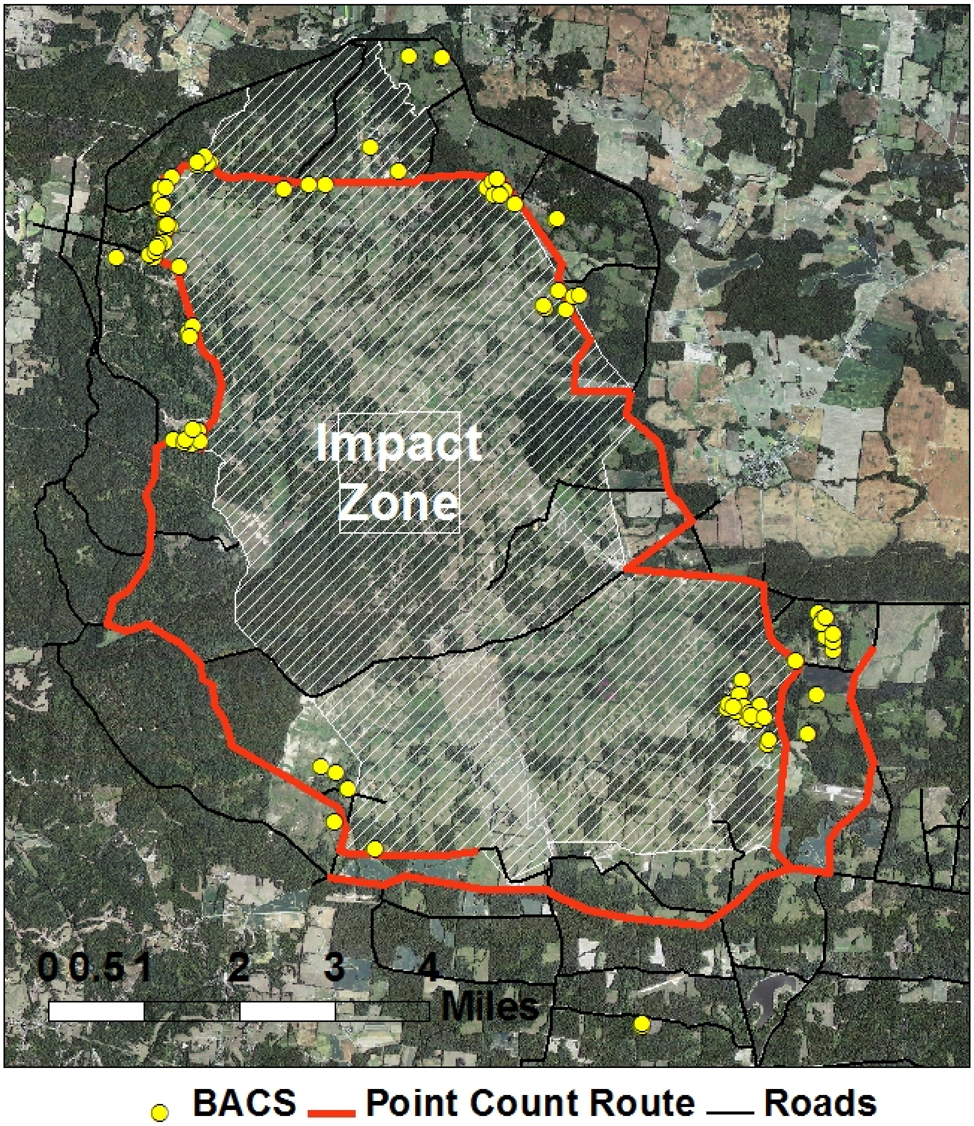


Figure 1 - 3: The point-count route used to monitor Bachman's Sparrows (BACS) and other grassland birds on Fort Campbell, Tennessee-Kentucky 2009-2010. Yellow dots represent locations where territorial male Bachman's Sparrows were observed by management staff from 1999 through 2008.

observation (visual, song, or fly-over) recorded for each individual grassland bird detected (Farnsworth et al. 2002). Focal species included Bachman's Sparrow, Blue Grosbeak, Blue-Winged Warbler, Dickcissel, Eastern Meadowlark, Grasshopper Sparrow, Henslow's Sparrow, Northern Bobwhite, Orchard Oriole, Prairie Warbler, and Red-Headed Woodpeckers. We recorded all species within a 250-m radius of each point, except North Bobwhite which were recorded within a 500-m radius to accommodate the larger detection distance (Brennan 1999). Locations of detected birds were recorded on 0.3-m (0.09m^2) resolution field maps and then distances were measured in ArcMAP to minimize measurement error.

I designed the second five-minute period of each count to enhance Bachman's Sparrow detection. Bachman's Sparrow male territorial song recordings from FCMR were broadcasted using an MP3 player and speakers for three minutes, followed by a passive listening period during the final two minutes. Data were recorded as presence or absence of Bachman's Sparrows during this five-minute period.

Landcover

Satellite imagery from 2009 with 0.3-m resolution obtained from the Department of Defense was used to create a digitized land-cover map of FCMR. I classified each pixel as bare ground, grass-herbaceous cover, shrub cover, or tree canopy cover using supervised classification in ERDAS Imagine 2010 and spatial analyst tools in ArcMAP 9.3. Ground-truthing was conducted by randomly choosing thirty locations for each cover type across the installation. Each location represented a specific land-cover patch that covered an area larger than the error rate of a handheld GPS unit (± 3-m). Multiple iterations of supervised classification were run until the 3-m radius around each central point of these patches was at least 75% accurate. I included the percent cover of the various land-cover classes as covariates for all species in the analysis. The spatial arrangement and composition of the different cover types within each point-count radius were further characterized through analysis in FRAGSTATS (McGarigal et al. 2002) (Table 1-1). Landscape-level metrics included Shannon's diversity index, total edge, contagion, and the interspersion and juxtaposition index (IJI). Both contagion and the IJI measure the extent to which vegetation types are aggregated in a landscape, but IJI looks at patches within the landscape whereas contagion measures individual cell placement. I also characterized clumpiness (class-level contagion or aggregation index), connectivity (physically connected borders between cells of the same vegetation class), and cohesion (a class-level perimeter to area ratio) for bare-ground and grass cover types because of their potential to play a larger part in Bachman's Sparrow habitat selection. I excluded metrics with a correlation > 0.7 to another variable from the analysis to minimize redundancy.

All landscape-level metrics in FRAGSTATS were generated using land-cover data created from the satellite imagery within 90 m of each point count center. The high resolution of the original image (0.3 m) made it difficult to physically execute FRAGSTAT metrics in a timely manner; however the area covered by a 90-m radius represents the average territory size of Bachman's Sparrows on Fort Campbell in 2009 and 2010. Furthermore, previous studies across a range of grassland species have shown that up to 60% of individuals are missed by observers at distances >100 m, so a 90-m radius represented the vegetation used by the majority of birds I detected (Emlen 1971, Diefenbach et al. 2003). Class-level metrics (clumpiness, connection, and cohesion) were calculated within the entire 250-m radius of the point counts because the

Table 1 - 1: Land-cover and FRAGSTAT covariates calculated for occupancy detection on Fort Campbell Military Reservation Tennessee-Kentucky, 2009-2010.

Variable	Variable Description	Selected radius from point (m)	Value range on Fort Campbell Military Reservation
Bare ground	Percent cover of bareground around point center	90 and 250	0 - 0.29 and 0 - 0.33
Bare ground Clumpiness	Frequency with which pixels of bare ground landcover appear side-by-side on a map	250	0.47 - 0.93
Bare ground Cohesion	Standardized perimeter-area ratio for bare ground landcover	250	15 - 98
Bare ground Connection	Number of fuctional joinings between pixels or patches of the bare ground based on Euclidian distance	250	35 - 100
Contagion*	A measure of class aggregationwithin the landscape at the cell level	90	32.2 - 79.42
Grass**	Percent cover of grass around point count center	90 and 250	0 - 53%
Grass Clumpiness*	Frequency with which pixels of grass landcover appear side-by-side on a map		
Grass Cohesion	Standardized perimeter-area ratio for grass landcover	250	37 - 99
Grass Connection	Number of fuctional joinngs between pixels or patches of grass cover based on Euclidian distance	250	51 - 86
Interspersion and Juxtaposition Index	A measure of the intermixing of all landscape types based on patch adjacencies	90	20 - 84
Row Crop	Percent cover of agricultural leases planted in row crops around point count center	250	0 - 37 %
Shannon's Diversity Index*	Measure of patch diversity across the landscape	90	0.13 - 1.34
Shrub	Percent cover of shrubs around point count center	250	0 - 64 %
Total Edge	The sum of the length of all edge segments in the landscape	90	1611 - 7523
Tree	Percent cover of trees around point count center	250	0 -88%

** Covariates removed from analysis after correlation analysis*

*** Grass cover at 90m was removed only due to correlation analysis*

90-m radius was too small to reliably generate these particular class-level metrics with the land-cover map I had generated.

Data Analysis

I calculated occupancy (ψ) and detectability (*p*) for all species using the occupancy estimation function with detection < 1 in Program MARK. This a closed system model that assumes independency between sites. I modeled three encounter histories per year (representing the three visits to each point count location) and grouped by year to allow for different detection histories between seasons. Individual land-cover and spatial arrangement covariates were included to explain the site-specific probability of occupancy, and I used one covariate per model. I only used single covariates to ascertain the importance of specific vegetation cover and arrangement variables on occupancy of each species individually. This allowed me to compare the relationships across all species.

Results were compared using an information-theoretic approach adjusted for small sample bias (i.e. AIC_c) (Akaike 1973, Hurvich and Tsai 1989). I calculated detectability for each survey period group separately if this improved the fit of the model, and occupancy rates were similarly calculated for each year separately if it improved model fit for a given species. Anderson (2008) suggested that an arbitrary cutoff for model selection should not be used (i.e. $\Delta AIC_c \leq 2$). I retained all models that had AIC_c values lower than the null, where occupancy and detectability were modeled without covariates, regardless of the actual ΔAIC_c value.

RESULTS

A total of 1,348 individual birds of all focal species were recorded during point counts for this study (Table 1-2). Northern Bobwhite and Prairie Warblers were recorded most commonly across both years. Grasshopper Sparrows and Red-headed Woodpeckers were rarely encountered during my sampling, so they were excluded from the data analysis. Bachman's Sparrows were never found during point counts within 250 m of fields planted in row crops and we did not have sufficient detections to evaluate differences among years so I excluded agriculture and year from the analysis. Complete Program MARK model outputs for all species are included in the appendix.

Nine Bachman's Sparrows were detected during point counts prior to playback each year, for a total of 18 detections over the entire study. Out of these 18 birds, 15 were also detected during the second five minute count period that included playback. No additional individuals were recorded during the second five minutes with playback that were not observed during the first five minutes. I analyzed Bachman's Sparrow occupancy for the first five minutes and the entire ten minutes separately. However, I could not use the five minutes with playback alone due to small sample sizes (MacKenzie 2006). Occupancy was the same for Bachman's Sparrows between the five and ten minute point count (⍰ = 0.07 ± 0.02 SE and ⍰ = 0.08 ± 0.02 SE), and detection did not differ with (p_1 = 0.41 ± 0.15 SE, p_2 = 0.63 ± 0.17 SE, p_3 = 0.19 ± 0.10 SE) and without playback (p_1 = 0.39 ± 0.15 SE, p_2 = 0.72 ± 0.16 SE, p_3 = 0.22 ± 0.12 SE) across survey periods.

Table 1 - 2: Grassland and scrub-shrub bird species detections by survey at Fort Campbell Military Reservation, TN-KY, May-July, 2009-2010.

	Bachman's Sparrow	Bachman's Sparrow with playback	Blue Grosbeak	Blue-winged Warbler	Dickcissel	Eastern Meadowlark	Grashopper Sparrow	Henslow's Sparrow	Northern Bobwhite	Orchard Oriole	Prairie Warbler	Red-headed Woodpecker
2009 Survey 1	2	3	5	17	12	12	0	7	49	8	80	0
2009 Survey 2	5	5	8	9	28	14	1	5	78	12	82	3
2009 Survey 3	2	1	12	1	27	7	0	6	72	6	53	0
2009 Total	9	9	25	27	67	33	1	18	199	26	215	3
2010 Survey 1	3	2	3	19	7	16	1	5	41	6	136	0
2010 Survey 2	5	3	3	6	25	12	3	2	127	3	78	2
2010 Survey 3	1	1	2	2	37	11	0	6	125	1	37	0
2010 Total	9	6	8	27	69	39	4	13	293	10	251	2
Total	18	15	33	54	136	72	5	31	492	36	466	5

Prairie Warblers and Northern Bobwhite occupied 80% (± 0.03 SE) and 74% (± 0.04 SE) of all point count locations, respectively (Table 1-3). Occupancy of the next most common bird, the Blue-winged Warbler, was nearly half of the first two at 39% (± 0.11 SE). Dickcissels, Eastern Meadowlarks, Blue Grosbeaks, and Orchard Orioles all had occupancy values between 20 and 38%. Henslow's Sparrow was the least common species (⍰ = 0.12), aside from Bachman's Sparrows.

Detectability over all three survey periods was greatest for Prairie Warblers, Northern Bobwhite, and Dickcissels (p = 0.59, 0.53, and 0.51, respectively); the same species with the greatest number of recorded individuals. Bachman's Sparrows and Henslow's Sparrows did have disproportionately high detectability (p = 0.40, 0.33) considering the total number of individuals recorded. The remainder of the species decreased in detectability as the total number of individuals decreased.

The specific questions we asked regarding the relationship between vegetation and distribution generated a complex set of data (Table 1-4). The models which best fit Bachman's Sparrow, Eastern Meadowlark, Henslow's Sparrow, and Orchard Oriole occupancy were positively related to grass cover (⍰ = 10.02 ± 2.80 SE, 9.93 ± 2.05 SE, 7.09 ± 2.35 SE, and 17.12 ± 5.81 SE, respectively). Blue Grosbeak and Northern Bobwhite occupancy were most strongly positively related to grass cohesion (β = 0.08 ± 0.03 SE and 0.08 ± 0.02 SE), whereas Prairie Warbler occupancy was positively related to the interspersion and juxtaposition index (β = 0.05 ± 0.02 SE). Blue-winged Warbler occupancy had a positive relationship with shrub cover (β =

Table 1 - 3: Occupancy (±SE) and detectability (±SE) of grassland and shrub-scrub bird species for point counts on Fort Campbell Military Reservation Tennessee-Kentucky, 2009-2010.

Species	Occupancy ($\psi_{year\ 1}$, $\psi_{year\ 2}$)*		Detectability ($p_{survey\ 1}$, $p_{survey\ 2}$, $p_{survey\ 3}$) **		
Bachman's Sparrow	0.08 ± 0.02	- - -	0.39 ± 0.15	0.72 ± 0.16	0.22 ± 0.12
Blue Grosbeak	0.38 ± 0.14	0.15 ± 0.07	0.18 ± 0.07	- - -	- - -
Blue-winged Warbler	0.39 ± 0.11	- - -	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03
Dickcissel	0.23 ± 0.03	- - -	0.26 ± 0.07	0.59 ± 0.08	0.75 ± 0.08
Eastern Meadowlark	0.23 ± 0.04	- - -	0.43 ± 0.09	0.45 ± 0.09	0.25 ± 0.07
Henslow's Sparrow	0.12 ± 0.04	- - -	0.33 ± 0.09	- - -	- - -
Northern Bobwhite	0.74 ± 0.04	- - -	0.36 ± 0.04	0.63 ± 0.04	0.63 ± 0.04
Orchard Oriole	0.37 ± 0.14	0.20 ± 0.09	0.18 ± 0.07	- - -	- - -
Prairie Warbler	0.80 ± 0.03	- - -	0.75 ± 0.04	0.66 ± 0.04	0.39 ± 0.04

* Occupancy across both years is shown together if the model had a lower AIC value than that with each year modeled separately.

** Detectability across all surveys is shown if the model had a lower AIC value than that with each survey modeled separately.

Table 1 - 4: The effect of vegetation distribution and arrangement on the occupancy (±SE) and detectability (±SE) of grassland birds monitored during point counts at Fort Campbell Military Reservation, TN-KY, May-July, 2009 and 2010.

	QUESTION		BACS	BLGR	BWWA	DICK	EAME	HESP	NOBO	OROR	PRAW
LANDCOVER	Does an increase in bare ground cover influence occupancy (90 meters)?	⍰	0.05 ± 0.02			0.20 ± 0.03	0.20 ± 0.04		0.73 ± 0.04	0.26 ± 0.09	0.79 ± 0.03
		p1	0.38 ± 0.15			0.27 ± 0.07	0.43 ± 0.09		0.37 ± 0.04		0.75 ± 0.04
		p2	0.70 ± 0.18	No	No	0.60 ± 0.08	0.45 ± 0.09	No	0.64 ± 0.04	0.19 ± 0.06	0.66 ± 0.04
		p3	0.21 ± 0.11			0.75 ± 0.07	0.25 ± 0.07		0.63 ± 0.04		0.39 ± 0.04
		ΔAIC	4.44			16.64	9.88		30.66	16.53	11.9
		β	14.98 ± 4.86			13.66 ± 3.62	38.18 ± 10.06		10.27* ± 5.40	12.05 ± 5.93	6.66* ± 5.38
	Does an increase in bare ground cover influence occupancy (250 meters)?	⍰				0.21 ± 0.03	0.20 ± 0.04			0.31 ± 0.11	
		p1				0.26 ± 0.07	0.42 ± 0.09				
		p2	No	No	No	0.60 ± 0.08	0.44 ± 0.09	No	No	0.17 ± 0.06	No
		p3				0.75 ± 0.08	0.24 ± 0.07				
		ΔAIC				25.13	8.55			18.31	
		β				13.60 ± 5.43	21.14 ± 6.54			23.43* ± 12.19	
	Does an increase in grass cover influence occupancy (250 meters)?	⍰	**0.04 ± 0.02**	0.26 ± 0.10		0.17 ± 0.03	**0.16 ± 0.04**	**0.09 ± 0.03**	0.77 ± 0.04	**0.28 ± 0.11**	0.85 ± 0.05
		p1	**0.38 ± 0.15**	0.18 ± 0.07		0.26 ± 0.07	**0.45 ± 0.09**		0.37 ± 0.04		0.74 ± 0.04
		p2	**0.71 ± 0.17**		No	0.59 ± 0.08	**0.47 ± 0.09**	**0.32 ± 0.09**	0.65 ± 0.04	**0.15 ± 0.04**	0.64 ± 0.04
		p3	**0.21 ± 0.12**			0.75 ± 0.08	**0.26 ± 0.07**		0.64 ± 0.04		0.39 ± 0.04
		ΔAIC	**0.00**	2.36		0.15	**0.00**	**0.00**	1.73	**0.00**	1.09
		β	**10.02 ± 2.80**	6.64 ± 2.99		8.69 ± 0.73	**9.93 ± 2.05**	**7.09 ± 2.35**	10.25 ± 2.18	**17.12 ± 5.81**	8.87 ± 3.82
	Does a linear increase in shrub cover influence occupancy (250 meters)?	⍰		0.27 ± 0.11	**0.30 ± 0.09**		0.21 ± 0.04		0.77 ± 0.06		0.80 ± 0.04
		p1			**0.44 ± 0.12**		0.42 ± 0.09		0.35 ± 0.04		0.75 ± 0.04
		p2	No	0.18 ± 0.07	**0.22 ± 0.07**	No	0.45 ± 0.09	No	0.62 ± 0.05	No	0.65 ± 0.04
		p3			**0.05 ± 0.03**		0.25 ± 0.07		0.61 ± 0.05		0.39 ± 0.04
		ΔAIC		8.01	**0.00**		28.68		18.31		11.79
		β		-2.96* ± 0.94	**4.90 ± 1.85**		-2.99 ± 0.52		-5.87 ± 1.82		2.28* ± 1.70
	Does an increase in tree cover influence occupancy (250 meters)?	⍰				**0.17 ± 0.03**	0.20 ± 0.04	0.11 ± 0.03		1.00 ± 0.00	0.80 ± 0.03
		p1				**0.26 ± 0.07**	0.43 ± 0.09				0.75 ± 0.04
		p	No	No	No	**0.59 ± 0.08**	0.45 ± 0.09	0.33 ± 0.09	No	0.07 ± 0.01	0.65 ± 0.04
		p3				**0.75 ± 0.08**	0.25 ± 0.07				0.39 ± 0.04
		ΔAIC				**0.00**	25.37	7.52		4.45	11.23
		β				**-7.28 ± 0.48**	-3.42 ± 0.32	-2.98* ± 1.70		-16125.40 ± 2552.81	-1.91* ± 1.16
	Does an increase in row crop cover influence occupancy (250 meters)?	⍰			0.28 ± 0.08	0.21 ± 0.03					0.80 ± 0.03
		p1			0.45 ± 0.12	0.26 ± 0.07					0.75 ± 0.04
		p2	No	No	0.22 ± 0.07	0.59 ± 0.08	No	No	No	No	0.66 ± 0.04
		p3			0.05 ± 0.03	0.75 ± 0.08					0.39 ± 0.04
		ΔAIC			3.43	30.18					8.35
		β			-7.41 ± 3.43	3.21 ± 1.51					-3.83 ± 1.55
	Does an increase in bare ground cohesion influence occupancy?	⍰	0.03 ± 0.02			0.21 ± 0.03	0.19 ± 0.04			0.26 ± 0.01	0.80 ± 0.03
		p1	0.39 ± 0.15			0.26 ± 0.07	0.43 ± 0.09				0.75 ± 0.04
		p2	0.73 ± 0.16	No	No	0.60 ± 0.08	0.45 ± 0.09	No	No	0.18 ± 0.07	0.66 ± 0.04
		p3	0.22 ± 0.12			0.75 ± 0.08	0.25 ± 0.07				0.39 ± 0.04
		ΔAIC	5.71			29.99	23.25			17.43	6.27
		β	0.14 ± 0.06			0.03* ± 0.01	0.05 ± 0.02			0.05 ± 0.02	0.04 ± 0.01
YEAR	Where there significant differences in occupancy between years?	⍰ year 1		0.38 ± 0.15						0.37 ± 0.14	0.76 ± 0.05
		⍰ year 2		0.15 ± 0.07						0.20 ± 0.09	0.82 ± 0.04
		p	No		No	No	No	No	No		0.75 ± 0.04
		p								0.18 ± 0.07	0.66 ± 0.04
		p									0.39 ± 0.04
		ΔAIC		5.03						20.43	12.99
FRAGSTATS	Does an increase in bare ground connection influence occupancy?	⍰							0.73 ± 0.04		
		p1							0.36 ± 0.04		
		p2	No	No	No	No	No	No	0.63 ± 0.04	No	No
		p3							0.63 ± 0.04		
		ΔAIC							33.33		
		β							-0.03* ± 0.02		
	Does an increase in grass connection influence occupancy?	⍰		0.28 ± 0.12							
		p1									
		p2	No	0.17 ± 0.07	No	No	No	No	No	No	No
		p3									
		ΔAIC		6.19							
		β		0.08* ± 0.05							

Table 1- 4. Continued.

	QUESTION		BACS	BLGR	BWWA	DICK	EAME	HESP	NOBO	OROR	PRAW
FRAGSTAT metrics (continued)	Does an increase in grass cohesion influence occupancy?	⍰	0.00 ± 0.01	**0.23 ± 0.10**		0.18 ± 0.03	0.16 ± 0.04	0.09 ± 0.03	**0.75 ± 0.05**	0.21 ± 0.10	0.80 ± 0.03
		p1	0.39 ± 0.15			0.26 ± 0.07	0.43 ± 0.09		**0.36 ± 0.04**		0.75 ± 0.04
		p2	0.72 ± 0.17	**0.18 ± 0.07**	No	0.59 ± 0.08	0.45 ± 0.09	0.33 ± 0.09	**0.64 ± 0.04**	0.17 ± 0.07	0.66 ± 0.04
		p3	0.22 ± 0.12			0.75 ± 0.08	0.25 ± 0.07		**0.63 ± 0.04**		0.39 ± 0.04
		ΔAIC	0.10	**0.00**		18.86	13.90	3.54	**0.00**	7.90	3.31
		β	0.32 ± 0.15	**0.08 ± 0.03**		0.07 ± 0.02	0.10 ± 0.03	0.07 ± 0.04	**0.08 ± 0.02**	0.11 ± 0.04	0.04 ± 0.01
	Does an increase in interspersion and juxtiposition increase occupancy?	⍰	0.04 ± 0.02	0.27 ± 0.11		0.20 ± 0.03	0.18 ± 0.04		0.74 ± 0.04	0.27 ± 0.10	**0.82 ± 0.04**
		p1	0.39 ± 0.15			0.26 ± 0.07	0.43 ± 0.09		0.36 ± 0.04		**0.75 ± 0.04**
		p2	0.72 ± 0.17	0.17 ± 0.07	No	0.59 ± 0.08	0.45 ± 0.09	No	0.63 ± 0.04	0.18 ± 0.07	**0.65 ± 0.04**
		p3	0.22 ± 0.12			0.75 ± 0.08	0.25 ± 0.07		0.63 ± 0.04		**0.39 ± 0.04**
		ΔAIC	6.04	6.77		25.49	17.92		25.00	17.96	**0.00**
		β	0.09 ± 0.03	0.04* ± 0.02		0.04 ± 0.01	0.06 ± 0.02		0.04 ± 0.01	0.04 ± 0.02	**0.05* ± 0.02**
	Does an increase in total edge increase occupancy?	⍰			0.30 ± 0.08			0.11 ± 0.03			0.80 ± 0.04
		p1			0.44 ± 0.12						0.75 ± 0.04
		p2	No	No	0.22 ± 0.07	No	No	0.32 ± 0.09	No	No	0.65 ± 0.04
		p3			0.05 ± 0.03						0.39 ± 0.04
		ΔAIC			3.69			5.47			6.52
		β			0.00 ± 0.00			-0.00* ± 0.00			0.00 ± 0.00

Occupancy, detectability, ΔAIC, and β values (and SEs) for each model are shown only if the AICc value was less than that of the null model. A 'no' for a given species implies that including the given covariate did not improve model fit compared to the null model.

** 95% confidence interval crosses zero*

AICc = Akaike's Information Criteria with small sample bias adjustment

ΔAICc = Difference in AICc value between the current model and the best-fitting model

AICc weight= the conditional probability of each model

⍰ = Occupancy estimation

P = Detectability estimation

4.90 ± 1.85 SE), and Dickcissel occupancy was negatively related to tree cover (β = -7.28 ± 0.48 SE).

All species except for Blue-Winged Warblers had positive relationships with percent grass cover within 250 meters and grass cohesion. The two species with the greatest beta values for both these covariates were Orchard Oriole (β = 17.12 ± 5.81 SE and β = 0.11 ± 0.04 SE, respectively) and Bachman's Sparrow (β = 10.02 ± 2.80 SE and β = 0.32 ± 0.15 SE, respectively). All species except for Blue-winged Warblers and Henslow's Sparrows showed positive relationships with an increase in the interspersion and juxtaposition index. In contrast, only Northern Bobwhite had a relationship with bareground connection (β = -0.03 ± 0.02 SE), and only Blue Grosbeak occupancy was related to grass connection (β = 0.08 ± 0.05 SE). Henslow's Sparrows, Prairie Warblers, and Blue-Winged warblers all had models including total edge that were greater than the null model, but the confidence intervals for the associated beta values all included 0.00.

Average grass, shrub, and tree cover at occupied points illustrates the main habitat components for each species. The resulting image showed three distinct groups (Figure 1-4). Dickcissels, Eastern Meadowlarks, Henslow's Sparrows, and Orchard Orioles all had a high percent cover of grasses with varying amounts of tree and shrub cover, whereas Blue-winged Warblers, Prairie Warblers, Blue Grosbeaks, and Northern Bobwhite had similar, high percent cover of trees with most of the variation coming from the amount of shrub cover available. Bachman's Sparrows appeared to be unique in their pattern of habitat association, with the a)

Species	Grass	Shrubs	Trees
Bachman's Sparrow	31	27	35
Blue Grosbeak	23	28	36
Blue-winged Warbler	17	37	37
Dickcissel	27	31	27
Eastern Meadowlark	28	29	30
Henslow's Sparrow	28	29	30
Northern Bobwhite	20	28	38
Orchard Oriole	27	29	32
Prairie Warbler	19	32	37

b)

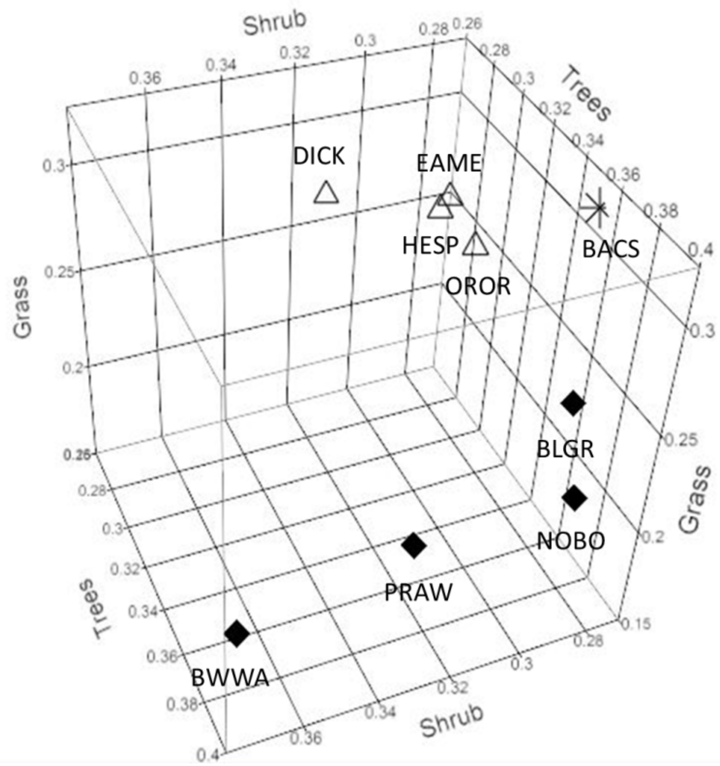


Figure 1 - 4: Average percent cover of grass, shrubs, and trees for grassland and shrub-scrub birds for occupied point counts on Fort Campbell TN-KY, 2009-2010 (a). Species shown in the 3D graph are Bachman's Sparrow (BACS), Blue-winged Warbler (BWWA), Blue Grosbeak (BLGR), Dickcissel (DICK), Eastern Meadowlark (EAME), Henslow's Sparrow (HESP), Northern Bobwhite (NOBO), Orchard Oriole (OROR), and Prairie Warbler (PRAW) (b).

greatest amount of grass cover per occupied point, but also one of the greatest percent covers of trees, and virtually no shrub cover.

The group of species related to the highest amount of grass cover (Dickcissel, Eastern Meadowlark, Henslow's Sparrow, and Orchard Oriole) had similar relationships with the covariates, with a few exceptions. Dickcissels, Eastern Meadowlarks, and Orchard Orioles had positive relationships with bare ground and occupancy at both 90 (β = 13.66 ± 3.62 SE; β = 38.18 ± 10.06 SE; and β = 12.05 ± 5.93 SE, respectively) and 250 m (β = 13.60 ± 5.43 SE; β = 21.14 ± 6.54 SE; and β = 23.43 ± 12.19 SE, respectively) as well as bare ground cohesion (β = 0.03 ± 0.01 SE; β = 0.05 ± 0.02 SE; and β = 0.05 ± 0.02 SE, respectively). All four of these high-grass species had negative relationships between tree cover and occupancy. Only Eastern Meadowlarks had any relationship to shrub cover (β = -2.99 ± 0.52 SE), whereas Dickcissels alone among these species had a positive relationship with row crop cover (β = 3.21 ± 1.51 SE). Orchard Orioles were the only species that exhibited a difference in occupancy between 2009 and 2010 (□ = 0.37 ± 0.14 and □ = 0.20 ± 0.09, respectively).

Of the four species in the high tree canopy cover group, only Prairie Warbler occupancy showed any association to canopy cover that fit better than the null model (β = - 1.91 ± 1.16 SE). Relationships between occupancy and shrub cover were split between the group; those for Blue Grosbeak and Northern Bobwhite were negative (β = -2.96 ± 0.94 SE and β = -5.87 ± 1.82 SE) whereas shrub cover and Prairie Warbler and Blue-Winged Warbler occupancy were positively related (β = 2.28 ± 1.70 SE and β = 4.90 ± 1.85 SE). Northern Bobwhite and Prairie Warblers had weak but positive relationships between bare ground cover at 90 m (β = 10.27 ±

5.40 SE and β = 6.66 ± 5.38 SE), but only Prairie Warbler occupancy was related to bare ground cohesion (β = 0.04 ± 0.01 SE). Both Prairie and Blue-Winged Warblers had negative relationships with row crop cover (β = -3.83 ± 1.55 SE and β = -7.41 ± 3.43 SE).

Bachman's Sparrows didn't fall into either group based on average percent cover of occupied points, but they did exhibit habitat associations most characteristic of the high-grass group. In addition to a positive response to grass cover, grass cohesion, and the interspersion and juxtaposition index, they had the highest relationship between occupancy and bare ground at 90 m and bare ground cohesion (β = 14.98 ± 4.86 SE and β = 0.14 ± 0.06 SE).

DISCUSSION

Fort Campbell provided breeding-season habitat for a variety of grassland birds, many of which are species of national or regional conservation concern (USFWS 2008). The occupancy rates observed are a reflection of the habitat composition and structure along the survey route. The route was designed to survey a variety of grassland habitats by encircling the impact area, one of the largest native grasslands in the region. As such, the observed occupancy rates are reflective of the route but not necessarily the occupancy rates for grassland birds across all of FCMR.

The greatest occupancy rates for this route were for Prairie Warblers (⍰ = 0.80 ± 0.03 SE), a species that requires the shrubby open canopy created by woodland edges or barrens (Nolan et al. 1999), and Northern Bobwhite (⍰ = 0.74 ± 0.04 SE), a well-studied gamebird that use patchy habitat created by similar woodland and prairie edges (Stoddard 1932). Other species found in more open savannas with a native warm season grass understory, including

Bachman's Sparrows and Orchard Orioles (Dunning and Watts 1990, Scharf and Kren 2010), were less common (□ = 0.08 ± 0.02 SE; *n* = 18 and $□_{1,2}$ = 0.37 ± 0.14 SE, 0.20 ± 0.09; *n* = 36). Grassland-obligates that require large open grassland patches with minimal woody vegetation, such as Henslow's Sparrows, Eastern Meadowlarks, and Dickcissels (Zimmerman 1988, Giocomo et al. 2008), all had very low occupancy for the entire point-count route (□ = 0.12 ± 0.04 SE, □ = 0.23 ± 0.04 SE, and □ = 0.23 ± 0.03 SE, respectively). The route around the impact zone only surveyed the edges of the largest grassland patches (Figure 1-3); other large open landing zones and drop zones on FCMR support more grassland obligates (Moss 2001, Giocomo 2005).

The Bachman's Sparrow song is easily distinguishable when heard because it is clear, distinctive, and relatively loud for its genus; however their singing is also infrequent and highly variable (Borror 1971, Dunning et al. 1995a). This variability created detection rates that were relatively low for accurate occupancy estimation. My use of playback of male vocalizations did not facilitate additional detections. The relationship of conspecific density and singing rates has not been thoroughly studied for grassland birds (McShea and Rappole 1997). However, researchers in areas more heavily populated by Bachman's Sparrows have successfully used playback for both target netting and winter surveys of these sparrows (Seaman and Krementz 2001, Tucker et al. 2004, Cox and Jones 2008). Three minutes of playback may not be long enough in duration to induce an increase in singing or movement for individuals at FCMR with relatively low breeding densities. The extra effort and time associated with using playback or a longer point count were not justified for increasing the detection rate of Bachman's Sparrows on FCMR.

Bachman's Sparrows and Northern Bobwhite have been shown to utilize patchy vegetation with lots of exposed mineral soil for increased mobility (Hammerquist-Wilson and Crawford 1981, Dunning and Watts 1991, Liu et al. 1995, Guthery 1997). Bachman's Sparrows in particular often don't flush when startled but use the interstitial space between native warm season grass clumps to escape predators (Dunning 2006). Many Bachman's Sparrows on Fort Campbell during 2009 and 2010 had a large patch of bare ground within their territories created by disking, ephemeral streams, or military training. Several studies have mentioned the possibility of a relationship between percent cover of bare ground and species distribution for both Northern Bobwhites and Bachman's Sparrows (Blincoe 1921, Brooks 1938, Hammerquist-Wilson and Crawford 1981, Cox and Jones 2008). However, information on the effect of the arrangement, not just the presence, of bare ground patches is lacking for both species (Guthery 1997).

Both Bachman's Sparrow and Northern Bobwhite occupancies showed an increase related to an increase in bare ground at 90 m from each point ($\beta = 14.98 \pm 4.86$ SE and $\beta = 10.27 \pm 5.40$ SE) although the covariance confidence interval for Northern Bobwhite included zero. Of these two species, only Bachman's Sparrows showed a positive relationship between occupancy and bare ground cohesion, suggesting that Bachman's Sparrows may prefer larger patches of bare ground as opposed to or in addition to exposed bare ground between grass clumps. The same types of disturbances (e.g., disking) that created the larger patches of bare ground are recommended as beneficial for bobwhites both structurally and for increased food availability (Stoddard 1932, Rosene 1969, Rice et al. 1993). Bachman's Sparrows may be selecting for these large patches as well or, alternatively, are simply more tolerant of this intense disturbance than Northern Bobwhites. The effect of bare ground coverage within Bachman's Sparrow territories is discussed further in Chapter 2.

The high-grass group of species displayed associations between covariates and occupancy characteristic of grassland obligates (Winter 1999, Herkert et al. 2002, Jaster et al. 2012). These species had high positive responses to grass cover, grass cohesion (i.e. aggregation), and negative relationships to tree canopy cover and to a lesser degree, shrub cover. However, the confidence interval for the beta coefficient between tree cover and Henslow Sparrow occupancy included zero suggesting a weak relationship at best, and other covariates examined did not improve the Henslow's Sparrow models compared to the null model. For Henslow's Sparrow, the simple presence of grass and not its spatial arrangement seemed to be the most important factor related to its occupancy.

Orchard Oriole relationships between land cover and spatial arrangement were more similar to those of the high-grass group than of the high-tree group, despite the fact that they are considered savanna obligates (Scharf and Kren 2010). Like Bachman's Sparrows, Orchard Orioles had a strongly positive relationship with bare ground as well as grass within the hardwood matrix. Both the species appear to be selecting for a high amounts of herbaceous (grass) cover with less sensitivity to tree cover, as long as some trees are available.

The high-tree group of species (Blue Grosbeak, Northern Bobwhite, Prairie Warbler, and Blue-Winged Warbler) was observed in locations with the greatest tree cover, but it was their relationships with shrub cover that distinguished this group from the others. Only Prairie Warbler occupancy was related to tree canopy cover, but the beta coefficient for the covariate was small and negative (β = -1.91 ± 1.16). Blue Grosbeak and Northern Bobwhite occupancies were negatively related to shrub cover but the two warbler species displayed the opposite trend. Of these four species, Prairie Warblers are typically associated with a more shrubby habitat with limited tree canopy cover (Nolan et al. 1999). We expected the Prairie Warblers to be the most reliant on a shrubby or dense mid-story component compared to all the other species. Blue Grosbeaks, Northern Bobwhite, and Prairie Warblers had small but positive relationships with grass cohesion (β = 0.08 ±0.03 SE, β = 0.08 ± 0.02 SE, and β = 0.04 ± 0.01 SE, respectively) and the interspersion and juxtaposition index (β = 0.04 ± 0.02 SE, β = 0.04 ± 0.01 SE, and β = 0.05 ± 0.02 SE, respectively). In addition to their respective relationships with shrub cover, the aggregation of grass cover within a patchy landscape was important in occupancy across these three high-tree canopy species.

The relationships between Blue-winged Warbler occupancy and vegetation didn't follow the same trends of the other high-tree species. Blue-winged Warbler occupancy increased with increasing shrub cover and decreasing row crop cover (β = 4.90 ± 1.85 SE and β = -7.41 ± 3.43 SE). No other models fit the data for this species. Blue-Winged Warblers in particular seemed to have a very specialized niche and as such were not widely distributed. They were typically found in open woodlands or on the edge of forested areas that still retained an herbaceous understory. This species seems to be the definition of a scrub-shrub bird in that it really only responded to the presence of shrubs within a landscape and not the patchiness of that landscape (Gill et al. 2001, Comer et al. 2011).

I did not find that row crop cover had a very large overall affect related to species occupancy across the point count route. The average percent cover of row-crops was 23% across the 28 points that contained that cover type. Only Dickcissel occupancy was positively associated with the amount of row-crop cover ($\beta = 3.21 \pm 1.51$ SE), whereas both Prairie and Blue-Winged Warblers were negatively related ($\beta = -3.82 \pm 1.55$ SE and $\beta = -7.41 \pm 3.43$ SE). The strong relationship between these warbler species' occupancy with an increase in shrub cover and the homogenous nature of the row crop structure helps to explain why these two in particular are negatively associated with this cover type. Dickcissel's relationship with row crops may be spurious because it is unlikely Dickcissel's were actually using row-crop fields. Although row crops are being managed to benefit Northern Bobwhite on FCMR (G. Zirkle, pers. comm.), there did not appear to be any relationship (positive or negative) between bobwhite breeding season occupancy and row crop cover.

The point-count route I developed demonstrated the importance of anthropogenic disturbances, like those created by and for training purposes on FCMR, for generating habitat for declining grassland birds within a generally forested landscape. It additionally helped to describe how a suite of grassland species respond to anthropogenic and ecological disturbances in terms of the impact on vegetation composition and arrangement. Although access was prohibited to some of the best oak savannas and native warm season grasslands, the surveys around the periphery of the impact area illustrated the potential on FCMR for providing high-quality habitat for a number of declining bird species. The survey route and monitoring protocol developed for this study could be used for long term monitoring of grassland birds on FCMR. . The benefit of using this route, as opposed to other point-count monitoring already being conducted on FCMR, is that it could be used to specifically monitor Bachman's Sparrow distribution and abundance as well as other grassland species of conservation concern.

CHAPTER 2: BACHMAN'S SPARROW HABITAT USE AND TERRITORY SELECTION IN OAK SAVANNAS ON FORT CAMPBELL MILITARY RESERVATION, TENNESSEE-KENTUCKY

ABSTRACT

The Bachman's Sparrow (*Peucaea aestivalis*) is a species of national conservation concern due to declining populations and the loss of savanna ecosystems. Populations have averaged a 3.2% yearly decline from 1966 to 2009 based on analysis from the North American Breeding Bird Survey (Sauer et al. 2011). Bachman's Sparrows are traditionally found in pine (*Pinus* spp.) savannas in their core range along the Gulf and Atlantic coasts, but use oak (*Quercus* spp.) savannas on the outer limits of their range (Moss 2001, Giocomo 2005, Farley 2008). Fort Campbell Military Reservation (FCMR), located on the border of Tennessee and Kentucky, contains the largest known breeding population of Bachman's Sparrows in oak savanna habitat. We studied the population at Fort Campbell in 2009 and 2010 to document population size, habitat use, and breeding ecology. Forty-two Bachman's Sparrow territories were located during this study (18 in 2009 and 24 in 2010). Ten territories were accessible for habitat analysis. Territory size per bird was 2.66 ha ± 0.57 SE and basal area per territory was 2.25 m^2/ha ± 0.57 SE. Occupied territories had a greater percent cover of forbs than the adjacent unoccupied savannas over survey points (27% ± 1.55 SE vs 22% ± 1.02 SE, $p = 0.0001$), but did not differ in percent cover of native warm-season grasses (27% ± 1.00 SE vs 29% ± 1.03 SE, $p = 0.43$), standing-senescent grass (5% ± 0.40 SE vs 6% ± 0.42 SE, $p = 0.03$), woody species (12% ± 0.75 SE vs 9% ± 0.70 SE, $p = 0.05$), litter (12% ± 0.98 SE vs 14% ± 0.93 SE, $p = 0.17$), or bare ground (15% ± 0.77 SE vs 15% ± 1.02 SE, $p = 0.97$) after being adjusted for the false discovery rate. There were no significant differences between occupied and unoccupied territories at the territory level ($p > 0.05$). Occupied and unoccupied territories had greater variance within points for litter (0.71 ± 0.03 SE vs 0.6 ± 0.02 SE, $p = 0.01$) and less variance

between bare ground (0.58 ± 0.02 SE vs 0.66 ±0.03 SE, $p = 0.02$), forbs (0.47 ± 0.01 SE vs 0.53 ± 0.02 SE, $p = 0.02$), and woody species (0.85 ± 0.03 SE vs 0.96 ± 0.04, $p = 0.03$). The vegetation structure and composition created by both military training and land management activities have sustained Bachman's Sparrow habitat and a persistent breeding population at the northern limit of their current range. Our long-term goal is to use the knowledge gained from this study to develop a conservation strategy to both monitor and enhance populations of the high-priority species at FCMR and elsewhere in the region.

INTRODUCTION

Grassland bird populations have declined more in the last four decades than any other group of birds monitored by the North American Breeding Bird Survey (Sauer et al. 2011). Widespread suppression of fire, conversion to agricultural use, and urbanization are the primary causes of both habitat loss and the subsequent decline in grassland bird populations (Vickery et al. 1999, Vickery and Herkert 2001, Murphy 2003). The quality and quantity of grasslands is decreasing, favoring habitat generalists with less specific habitat requirements over more selective species (Johnson and Igl 2001).

The Department of Defense manages more than 10 million ha in the United States, which have become unintentional wildlife refugia throughout the country (Cohn 1996, Doresky et al. 2001, Giocomo 2005, Eberly and Keating 2006). The diversity and size of habitats supported on these lands create numerous unique opportunities for conservation, especially for grassland birds (Althoff et al. 2005). Military training exercises including ground navigation, vehicle maneuvers, artillery, and aerial training all benefit from large, open areas that are easy to maintain and can be kept open with minimal management once they are established (Giocomo et al. 2008). Military land management thus creates and maintains large patches of grasslands and open woodlands at a landscape scale that support a diversity of high-priority grassland bird species.

Bachman's Sparrows are an obligate savanna species that benefit from the grasslands mosaic created and maintained on Fort Campbell Military Reservation. They are most commonly found in mature pine savannas of the southeastern coastal plain, but are also occasionally found in clear-cuts, abandoned fields, and young even-aged pine stands for a short time until the understory becomes too thick (Brooks 1938, Dunning and Watts 1990, Haggerty 2000). FCMR supports one of only a few known populations in oak savannas, and little is known about their habitat requirements in this setting. Annual and biannual prescribed fires on Fort Campbell are used to limit wild fires started by training exercises and have maintained large patches of native warm-season grasses within an oak savanna landscape. Bachman's Sparrows have shown a total annual population decline of 3.2% since 1966 (Figure 2-1) and the declines are more pronounced in the more northerly regions of their range (Brooks 1938, Dunning 2006). Conservation of the species, especially in the northern regions where the population declines are greatest, is important.

Bachman's Sparrows require frequent disturbance to maintain open, grass-dominated habitats (Tucker et al. 2004, Dunning 2006). These ground-nesting sparrows spends the majority of their time foraging on the ground and skulk or dart through the vegetation instead of flushing when approached by predators; as a result they have very specific ground cover

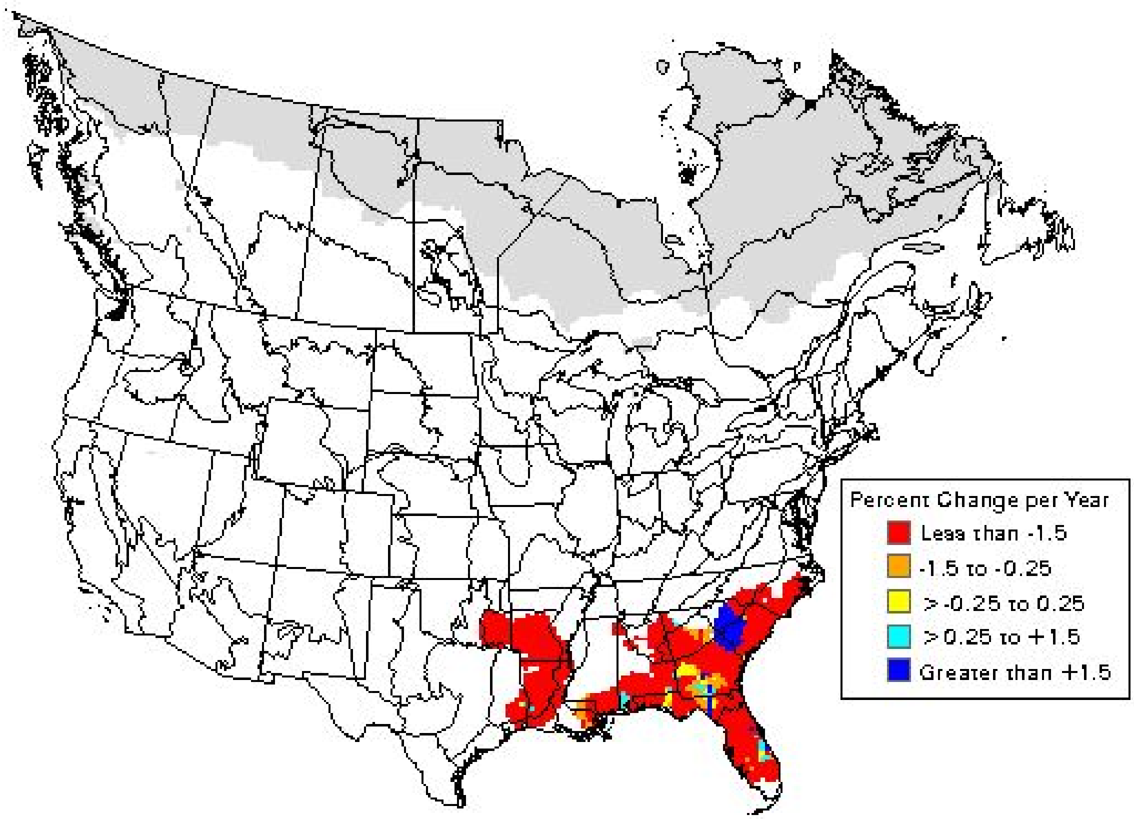


Figure 2 - 1: North American Breeding Bird Survey population trend for Bachman's Sparrows 1966-2010 (Sauer et al. 2011).

requirements (Brooks 1938, Dunning and Watts 1990). Total grass cover, litter depth, litter cover, forb cover, quadratic relationships with woody species, plant species diversity, shrub density, and landscape fragmentation have all been identified as explanatory factors in habitat selection, but the dichotomy between the types of ecosystems they use makes broad comparisons with any one of these factors difficult (Probasco 1978, Dunning et al. 1995a, Haggerty 1998, Watts et al. 1998, Conner et al. 2002, Tucker et al. 2004, Wood et al. 2004). Bachman's Sparrows will use young clear-cuts, even-aged pine stands under five to seven years old, and mature savannas, but have seldom been documented in intermediate-aged stands (Dunning and Watts 1990, Liu et al. 1995, Brooks and Stouffer 2011). Although many studies have examined Bachman's Sparrow habitat selection among these differing stages of vegetation, it has primarily been done within longleaf (*Pinus palustris*) or loblolly (*Pinus taeda*) pine systems. Little is known about Bachman's Sparrow vegetation associations in oak savannas such as those found on FCMR (Farley 2008). Objectives for this study were to

1) locate all accessible Bachman's Sparrow population on FCMR;
2) describe the vegetation structure in Bachman's Sparrow territories in terms of percent cover, vertical structure, and landscape features; and
3) determine the main factors associated with Bachman's Sparrow habitat selection in the woodland-oak savanna-grassland mosaic.

STUDY AREA

FCMR is home to the U. S. Army's 101st Airborne Division and continues to be used extensively for military training both on the ground and in the air. The installation was established in 1942 when the majority of the area was covered in agricultural fields; the Department of Defense (DOD) maintained this open quality of the vegetation with frequent prescribed fire upon taking control of the area. This eventually led to the reestablishment of native warm-season grasses from the seed bank that can now be found interspersed throughout the existing oak-hickory (*Carya* spp.) forest (Baskin et al. 1994, Chester et al. 1997). The mosaic of grasslands and oak-hickory savannas roughly covers 30% of FCMR and mimic vegetation maintained by Native Americans prior to European settlement (Baskin et al. 1994, Chester et al. 1997). Fort Campbell is an oasis of native species within a fragmented agricultural and urban landscape that holds great potential for conservation of grassland and scrub-shrub birds.

Frequent prescribed fires set specifically for military training to improve visibility and create landing areas, reduce fuel for accidental fires, and create wildlife habitat generates a mosaic of vegetation types between the open grasslands of the Big Barrens and closed-canopy forests on FCMR. The impact area is the most frequently burned areas of FCMR and is typically burned on an annual basis to decrease the occurrence of fire caused by munitions. Consequently, the impact area contains the majority of the open oak savanna habitat on FCMR. This inaccessible area is approximately 5 x 8 km and situated at the west end of the base. Small patches of grasslands or savannas ranging from 0.5 km^2 to over 2.5 km^2 can be found outside of the impact zone, but they frequently either contain agricultural row-crops or do not contain any interior mature trees(Moss 2001, Giocomo 2005). The impact area and surrounding savannas represents the best Bachman’s Sparrow habitat available on FCMR, and the majority of our research efforts were concentrated in and around this area.

METHODS

Color Banding

I made multiple attempts to locate, capture, and attach colored leg bands on all accessible male Bachman's Sparrows on Fort Campbell in 2009 and 2010. All recently burned fields, sites known to support Bachman's Sparrows in the past, and other potential habitat were visited on two or more occasions during the breeding season to locate male Bachman' s Sparrows. Once a bird was located, I set up a 12-m mist net near a song perch. I then played territorial male songs recorded previously on FCMR to attract the bird to the net area, and flushed it into the net if the bird approached close enough to capture. Each netted bird was given a USGS numbered aluminum band and a unique combination of three color bands for identification and subsequently released at the capture site.

Territory Mapping

Territories for all accessible males found in 2009 and 2010 were mapped using a 30-min burst sampling method (Barg et al. 2005). This method allowed me to collect large amounts of balanced data for all males quickly regardless of how often I was granted access to particular areas: I wasn't able to spend the same amount of time with each male due to military training activities on live fire ranges or in training areas. The identity of the individual was confirmed by colored leg bands (or frequently used singing perches if the bird was not banded) before each session was started and locations of the bird were recorded every sixty seconds for a total of thirty minutes. Each bird was visited until a minimum of thirty discrete observations were collected, with 2-7 days between each session. Birds found within the impact area were observed from within the safety zone via binoculars and spotting scopes. I plotted bird locations on printouts of 0.3-m resolution aerial images from 2007. Utilizing the detailed maps decreased potential distance estimation errors and improved the accuracy of location information. All territories were visited throughout the field season until fledglings were observed in a territory, or the target bird was not detected for one month. Minimum convex polygons were created by using Hawth's Tools in ArcMAP to delineate territories.

Habitat Analysis

Four to five transects spaced at least 20 m apart and parallel to the longest axis of each territory were established for vegetation measurements. Random numbers were used to determine the location of the first sampling point along the first transect and thirty points were systematically placed over the remaining distance. Percent cover of herbaceous vegetation at each point was visually estimated from above using a 1-m x 1-m Daubenmeyer frame divided into four 0.25 m^2 sub-points. Vegetation cover in each sub-point was categorized into native warm-season grasses, cool season grasses, standing dead grass, forbs, woody species, exposed bare ground, and litter. These factors have been shown to be important to Bachman's Sparrow habitat selection in other studies (Dunning and Watts 1990, Haggerty 1998). I also included Sericea lespedeza (*Lespedeza cuneata*) in percent cover estimation as it is a common invasive weed on Fort Campbell that might negatively affect Bachman's Sparrows. Visual estimates of percent cover allowed me to conduct a relatively quick vegetation survey useful for when there was limited time at any particular location. I used the total average percent cover at each point as well as the average over entire territories to examine the differences driving habitat selection at two different scales.

Percent cover of shrubs below and above 1-m height within a 5-m radius of each point were visually estimated. I classified any woody species with a diameter at breast height (DBH) < 7 cm as a shrub (including tree saplings). Shrub percent cover was estimated to the nearest 5%. I also recorded the diameter at DBH of any tree > 7 cm within an 11.3-m radius (0.04 ha) of each point. Each tree was identified to species. A Robel pole was used to characterize vegetation density at each point. The observer stood 4 m from point center and, with their head 1 m off the ground, recorded the lowest height on the pole not obscured by vegetation. Data were recorded in 5-cm intervals.

To characterize potential unoccupied habitat, I measured the herbaceous vegetation, shrub cover, and tree cover in the closest accessible but unused area adjacent to each territory following the same methods as mentioned above. I visited these unused areas a minimum of two mornings during each field season to ensure that they were not being used by breeding Bachman's Sparrows during this study, and used playback to detect any individual that might be present but not singing. Each unused territory was located > 150 m from the boundary of the nearest occupied territory. If there was no available unused field near a given territory, I used fields where Bachman's Sparrows had been found in recent years. By choosing previously used fields or those adjacent to occupied sites I was attempting to identify the key differences that discriminated between occupied and unoccupied Bachman's Sparrow habitat. Randomly distributed survey locations across FCMR would have revealed differences between Bachman's Sparrow habitat and all other vegetation types across FCMR (including woodlands, open prairie, and agriculture fields). However, I was interested in finer scale habitat selection within oak savanna vegetation because it would be potentially more valuable information for understanding where and why Bachman's Sparrows occur on FCMR.

Landcover analysis

I used DOD 2007 satellite imagery with 0.3-m resolution to create a digitized land-cover map of FCMR. Each pixel was categorized as bare ground, herbaceous cover, shrub cover, or tree canopy cover using supervised classification in ERDAS Imagine 2010 and spatial analyst tools in ArcMAP 9.3. Ground truthing was conducted by randomly choosing thirty patches for each cover type across the installation. Locations were homogenous representations of one vegetation type and each patch had a larger radius than the error of a handheld global positioning system unit (± 3 m). I conducted multiple iterations of supervised classification until the 3 m radius around each central point of these patches was at least 75% accurate in ArcMAP.

The spatial arrangement and composition of the different cover types within each occupied and unoccupied territories were further characterized through analysis with FRAGSTAT software (McGarigal et al. 2002) (Table 2-1). Landscape-level metrics included Shannon's diversity index, contagion, and the interspersion and juxtaposition index (IJI). Both contagion and the IJI measure the extent to which vegetation types are aggregated in a landscape, but IJI looks at patches within the landscape whereas contagion measures individual cell placement. I also characterized clumpiness (class-level contagion or aggregation index), connectivity (physically connected borders between cells of the same vegetation class), and

Table 2 - 1: Landscape-level vegetation comparisons between occupied and unoccupied Bachman's Sparrow territories on Fort Camp bell, Tennessee-Kentucky, 2009-2010.

Landcover or Metric	Occupied	Unoccupied	*p*-value	Variable Description	Measurement Radius	Variable Range
Bare ground Cover (%)	3.08	3.99	0.393	Percent cover of bare ground around territory center	90	0 - 29
Grass Cover (%)	42.83	43.1	0.967	Percent cover of grass around territory center	90	0 - 60
Shrub Cover (%)	29.09	36.71	0.108	Percent cover of shrubs around territory center	90	7 - 65
Tree Cover (%)	22.19	12.33	0.017*	Percent cover of trees around territory center	90	2 - 82
Bare ground Clumpiness	0.49	-0.03	0.140	Frequency with which pixels of bare ground landcover appear side-by-side on a map	250	-0.47 - 0.93
Grass Clumpiness	0.45	0.42	0.431	Frequency with which pixels of grass landcover appear side-by-side on a map	250	0.41 - 0.91
Bare ground Cohesion	34.39	24.71	0.428	Standardized perimeter-area ratio for bare ground landcover	250	15 - 98
Grass Cohesion	89.77	87.28	0.640	Standardized perimeter-area ratio for grass landcover	250	37 - 99
Bare ground Connection	74.3	48.35	0.140	Number of functional joinings between pixels or patches of the bare ground based on Euclidian distance	250	35 - 100
Grass Connection	78.85	75.16	0.316	Number of functional joinings between pixels or patches of the grass cover based on Euclidian distance	250	51 - 86
Cantagion	27.66	30.64	0.523	A measure of class aggregation within the landscape at the cell level	90	20 - 79.4
Interspersion and Juxtaposition Index	66.91	54.57	0.053	A measure of the intermixing of all landscape types based on patch adjacencies	90	20 - 84
Shannon's Diversity Index	1.07	0.87	0.19	Measure of patch diversity across the landscape	90	0.20- 1.30

** = significant after using the false discovery rate to adjust for multiple comparisons*

p-values generated from two-tailed student t-tests cohesion (a class-level perimeter to area ratio) for bare-ground and herbaceous cover types because of their potential importance in Bachman's Sparrow habitat selection.

I generated landscape level FRAGSTAT metrics using land cover data within a 90-m radius centered in the middle of each used and available territory. Landscape in this case refers to analyzing all cover types within a specified area, not analysis over the entire study-site. The 90-m radius represented the same size as the average Bachman's Sparrow territory delineated on FCMR during this study (2.6 ha). Class-level metrics for bare ground and grass cover only (clumpiness, connection, and cohesion) were calculated within the entire 250-m radius of the territory centers because the 90-m radius was too small to reliably compute these particular class-level metrics.

Data Analysis

Percent cover data of all vegetation components at the point and territory levels were analyzed separately to examine variables relevant to Bachman's Sparrow habitat selection at a range of scales. I used the Proc Logistic procedure to analyze logistic regression for binary data between occupied and unoccupied territories in program SAS (SAS Institute, Inc, Cary, NC). The continuous vegetation variables were used to describe the probability of each measurement belonging to either an occupied or unoccupied territory. Bachman's Sparrows are thought to be attracted to the patchiness of frequently burned savannas (Cox and Jones 2008); consequently I also compared the coefficient of variation for vegetation components within each territory and between territories using the same methods.

I used the false discovery rate (FDR) procedure to account for multiple comparisons at each analysis level (Pike 2011). This method is a less conservative way of minimizing type I error when conducting multiple analyses compared to Bonferroni-type multiple comparisons, and do not undergo the same loss of power as more traditional multiple comparison adjustments. Miller (1966) proposed simply diving α by the number of comparisons to create an adjusted cut-off for rejecting the null hypothesis. However, when using FDR each p-value is ranked starting with the most significant result, and increasingly larger thresholds are calculated for each ranking dependent on the number of comparisons.

I compared landscape-level percent cover and FRAGSTAT metrics between occupied and unoccupied territories using two-tailed student t-tests, adjusted for multiple comparisons. These metrics represented either the average land cover within a 90 m radius of the center of each territory or the value for each FRAGSTAT metric centered in each territory.

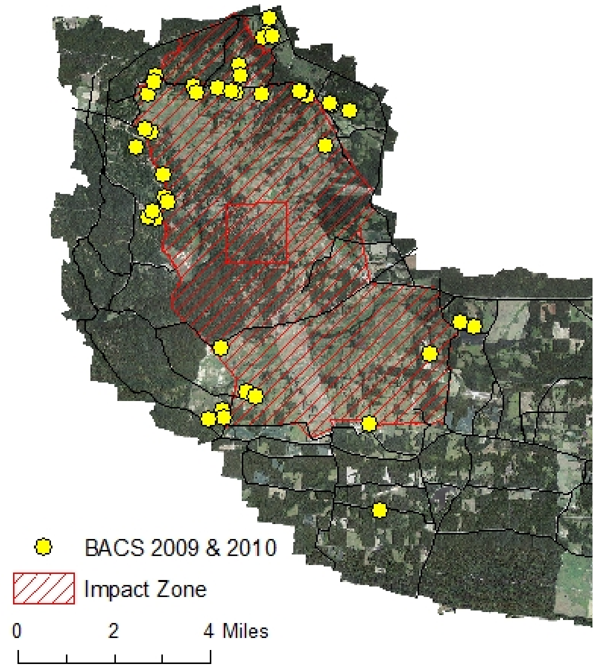
RESULTS

Color Banding

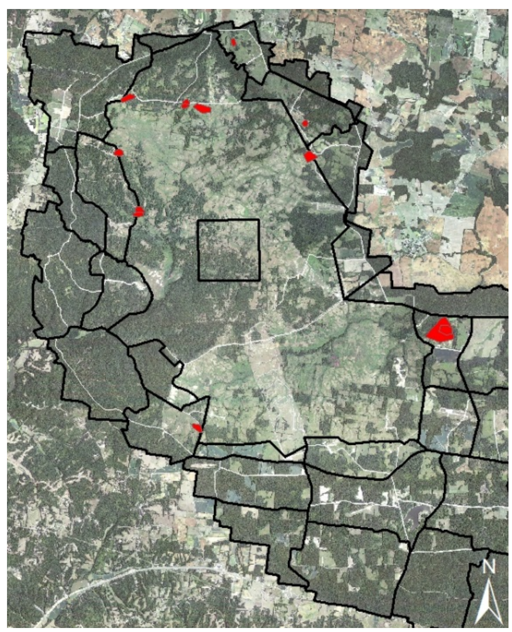
I located a total of forty-two adult male Bachman's Sparrows on FCMR (18 in 2009 and 24 in 2010) and banded thirty with unique color combinations (Table 2-2). Only one bird was captured after the first attempt despite multiple efforts to catch every territorial bird. The majority of the males were found in ranges or training areas surrounding the large impact area on the west end of the base (Figure 2-2a). One female, three hatch-year birds, and four nestlings were also banded during this study. One hatch-year bird banded in 2009 was re-

Table 2 - 2: Bachman's Sparrows banded on Fort Campbell Military Reservation, Tennessee-Kentucky, 2009-2010.

Location	Date	Color Combination	Sex	Age
OP 13	8-Jun-09	YE/SI:RD/DG	M	AHY
OP 8a	17-May-09	MV/SI:DB/YE	M	AHY
Range 41	18-May-10	RD/SI:OR/PI	M	AHY
	31-May-10	DB/SI:GR/YE	M	AHY
Range 42	25-May-09	MV/SI:BL/YE	M	AHY
Range 42c near	30-Jun-10	MV/MV:DB/SI	M	AHY
	16-Jul-09	WH/WH:RD/SI	U	AHY
	16-Jul-09	DB/SI:YE/BK	M	AHY
	16-Jul-09	GR/SI:DB/PI	U	HY
Range 44	23-May-09	YE/DG:DG/SI	M	AHY
Range 51	18-Jun-10	BK/BK:YE/SI	M	AHY
Range 52	7-Jul-09	DB/DB:GR/SI	M	AHY
Range 53	23-May-09	RD/SI:BL/BK	M	AHY
	29-Jun-09	PI/YE:DG/SI	M	AHY
	27-May-10	DG/SI:PI/GR	M	AHY
Range 54	22-May-10	BL/SI:YE/YE	M	AHY
	23-May-10	OR/SI:BK/OR	M	AHY
Range 55	23-May-09	WH/OR:YE/SI	M	AHY
	9-Jul-09	GR/GR:PI/SI	U	HY
	15-May-10	DB/SI:DG/BL	M	AHY
	15-May-10	MV/WH:OR/SI	M	AHY
	15-May-10	BK/DG:MV/SI	M	AHY
	10-Jun-10	PI/PI:BL/SI	M	AHY
TA 14	5-Jun-10	BL/SI:GR/BL	M	AHY
TA 27	10-May-09	PI/BL:DG/SI	M	AHY
	31-May-09	RD/RD:OR/SI	M	AHY
	4-Jul-09	NB/BL:NB/SI	U	HY
	4-Jul-09	NB/WH:NB/SI	U	HY
	4-Jul-09	NB/PI:NB/SI	U	HY
	4-Jul-09	NB/DB:NB/SI	U	HY
	4-Jul-09	NB/GR:NB/SI	U	HY
TA 32	18-Jun-10	DB/PI:BK/SI	M	AHY
TA 43a	17-May-09	BK/PI:OR/SI	F	AHY
	18-May-09	WH/DG:RD/SI	M	AHY
	18-May-10	YE/BL:MV/SI	M	AHY
	18-May-10	PI/WH:BK/SI	M	AHY
TA 48	11-May-09	RD/DB:YE/SI	M	AHY
	20-May-09	GR/SI:PI/WH	M	AHY



a)



b)

Figure 2 - 2: Bachman's Sparrows (BACS) located on Fort Campbell (a) and fully delineated Bachman’s Sparrows territories (b) on Fort Campbell Military Reservation, Tennessee-Kentucky in 2009 and 2010.

sighted in 2010 approximately 2.5 km from where it was banded, but no other previously banded bird was resighted in 2010.

Territory Mapping

A sufficient number of locations were collected to delineate ten territories in 2009 and sixteen territories in 2010 (Figure 2-2b). Territory size of Bachman's Sparrows on FCMR ranged from 0.8 to 8.1 ha ($\bar{x}$ = 2.6 ha, n = 26). The majority of these territories were located on the northwest portion of FCMR, where there has been extensive prescribed burning in and around the impact area. Six fields were used by Bachman's Sparrows in both 2009 and 2010, but never by the same bird in both years. All of the territories were in training areas or ranges that had been burned at least once in the last two years and at least four times in the last decade. The sparrows did not typically use recently mowed areas, but in three training areas they were observed using small strips of recently disked ground or patches of grass torn up by military vehicles.

Habitat Analysis

Six territories in 2009 and four territories in 2010 were accessible to collect complete vegetation data. An additional four territories in 2009 and three in 2010 were partially located in the impact area, so only vegetation at accessible locations within these territories was evaluated. Not all available unoccupied locations immediately adjacent to established territories were accessible in 2010 because of military access restrictions, but the majority were measured. *Sericea lespedeza* was rarely encountered in occupied or unoccupied fields so it was omitted from further analyses.

Occupied Bachman's Sparrows territories were characterized, on average, by 27% grass cover, 28% forb cover, 15% bare ground, 12% litter, 12% woody cover, and 5% standing dead grass (Table 2-3). Forb cover was greater at the point level within occupied territories compared to unoccupied territories (27% ± 1.55 SE vs 22% ± 1.02, $p = 0.0001$) and percent cover of standing dead grass was marginally less in occupied territories compared to the unoccupied territories at the point level after adjusting for the false discovery rate (5% ± 0.40 SE vs 6%, $p = 0.03$ [the cut-off for this p-value with FDR is 0.01]). Cover did not differ between occupied and unoccupied sites with respect to native warm-season grasses (27% ± 1.00 SE vs 29% ± 1.03 SE, $p = 0.43$), woody species (12% ± 0.75 SE vs 9% ± 0.70 SE, $p = 0.05$), litter (12% ± 0.98 SE vs 14% ± 0.93 SE, $p = 0.17$), or bare ground (15% ± 0.77 SE vs 15% ± 1.02 SE, $p = 0.97$) after being adjusted for the false discovery rate. Occupied territories had more variance within points compared to unoccupied territories for litter (0.71 ± 0.03 SE vs 0.6 ± 0.02 SE, $p = 0.01$) and less variance between bare ground (0.58 ± 0.02 SE vs 0.66 ±0.03 SE, $p = 0.02$), forbs (0.47 ± 0.01 SE vs 0.53 ± 0.02 SE, $p = 0.02$), and woody species (0.85 ± 0.03 SE vs 0.96 ± 0.04, $p = 0.03$). I found no significant differences between percent cover or variance at the territory level.

Landscape analysis using the computer-generated vegetation cover maps characterized the average Bachman's Sparrow territory as 3% bare ground, 43% grassy or herbaceous cover, 29% shrub cover, and 22% tree canopy cover. The only differences between occupied and unoccupied territories occurred between percent tree cover (22 vs 12%, $P = 0.017$). Basal area for occupied territories averaged 2.41 m^2/ha ± 0.37 SE and ranged from 0 (partial territory) to 4.71 m^2/ha (a two year old male that paired with a female late in the season). Average basal area in unoccupied territories was 1.39 m^2/ha ± 0.32 SE and the variance for basal area was

Table 2 - 3: Habitat comparisons at point territory sampling levels for occupied and unoccupied Bachman's Sparrow territories on Fort Campbell Military Reservation, 2009-2010.

	Measurement	Occupied					Unoccupied					Parameter	*p*-value	q-value[b]
		Mean	±	S.E.	Min	Max	Mean	±	S.E.	Min	Max	Estimate		
Point	Grass	27.42	±	1.00	0	88	28.56	±	1.03	0	79.5	0.0039	0.4284	0.55
	Standing dead grass	4.97	±	0.40	0	37.5	6.25	±	0.42	0	35	0.0263	0.0313	0.12
	Forbs	27.41	±	1.55	1	95.25	21.5	±	1.02	0	77.3	-0.0192	0.0001*	0.0009*
	Litter	11.98	±	0.98	0	78.75	13.9	±	0.93	0	88.8	0.0072	0.1652	0.30
	Bare ground	15	±	0.77	0	96	14.85	±	1.02	0	91.3	0.0133	0.91	0.91
	Woody Species	11.42	±	0.75	0	66.5	9.38	±	0.70	0	63	-0.0136	0.0527	0.12
	Robel Pole[a]	35.04	±	1.13	5	100	37.12	±	1.33	5	100	0.0049	0.23	0.35
	Shrub cover under 1 m	12.57	±	0.65	0	90	10.56	±	0.75	0	70	-0.0152	0.05	0.12
	Shrub cover over 1 m	11.58	±	1.14	0	95	12.01	±	1.35	0	100	0.001	0.80	0.90
Territory	Grass	27.43	±	2.83	13	60.39	28.63	±	2.24	18.42	42.4	0.0137	0.76	0.97
	Standing dead grass	4.5	±	1.02	0	12.46	6.76	±	1.42	1.75	15.9	0.139	0.20	0.84
	Forbs	27.64	±	2.18	15	40.25	20.19	±	2.99	8.1	37.4	-0.1095	0.07	0.63
	Litter	11.88	±	3.05	0	35.06	13.94	±	2.50	6.9	25.5	0.0291	0.56	0.84
	Bare ground	17.3	±	2.24	3	33.69	15.06	±	2.55	4.7	24.7	-0.0352	0.51	0.84
	Woody Species	9.41	±	1.32	2	20.39	9.6	±	1.18	3.63	15	0.0096	0.92	0.97
	Robel Pole[a]	32.83	±	2.66	17	51.5	37.05	±	2.91	22.58	50.3	0.0471	0.31	0.84
	Shrub cover under 1 m	11.77	±	1.05	3	19.67	10.62	±	1.82	5.17	20	-0.0586	0.54	0.84
	Shrub cover over 1 m	11.58	±	3.49	0	53.18	11.76	±	2.37	3.67	25.3	0.0015	0.97	0.97
CV over point	Grass	0.5	±	0.02	0	2	0.45	±	0.02	0	2	-0.3212	0.18	0.22
	Standing dead grass	0.68	±	0.03	0	2	0.69	±	0.03	0	2	0.0477	0.75	0.75
	Forbs	0.47	±	0.01	0.01	1.49	0.53	±	0.02	0	2	0.6832	0.02*	0.04*
	Litter	0.71	±	0.03	0	2	0.6	±	0.02	0	2	-0.5043	0.01*	0.04*
	Bare ground	0.58	±	0.02	0	2	0.66	±	0.03	0	2	0.51	0.02*	0.04*
	Woody Species	0.85	±	0.03	0	2	0.96	±	0.04	0	2	0.2933	0.03*	0.05*
CV over territory	Grass	0.61	±	0.05	0.28	1.04	0.53	±	0.16	0.38	0.78	0.6384	0.50	0.50
	Standing dead grass	1.1	±	0.11	0.71	2.36	0.83	±	0.22	0.53	1.22	4.4954	0.06	0.41
	Forbs	0.62	±	0.04	0.3	0.83.	0.67	±	0.16	0.45	0.99	-1.7698	0.26	0.46
	Litter	1.25	±	0.12	0.61	0.98	1.04	±	0.47	0.39	1.69	1.6869	0.21	0.46
	Bare ground	0.78	±	0.14	0.16	2.52	1.11	±	0.54	0.64	2.47	-2.7612	0.09	0.41
	Woody Species	1.25	±	0.08	0.78	.0	1.17	±	0.20	0.86	1.48	2.24466	0.41	0.46
	Robel Pole[a]	2.36	±	0.09	1.26	6.16	1.96	±	0.04	1.47	2.43	-0.6593	0.37	0.46
	Shrub cover under 1 m	1.52	±	0.05	0.68	3.17	1.21	±	0.03	0.84	1.88	-1.2535	0.25	0.46
	Shrub cover over 1 m	0.74	±	0.03	0.35	2.15	0.6	±	0.02	0.31	0.84	-1.5862	0.40	0.46

All results are from the Proc Logistic model in program SAS

a= Robel pole measurements were made to the nearest 5cm

b=False Discovery Rate (FDR) adjusted p-value (0.05 is the cut-off for significance) (Pike 2011)

**=Models are significant after being adjusted for FDR multiple comparisons* greater for the unoccupied territories (3.64 vs 2.62, $P = 0.025$). The most common tree species in occupied territories were Southern Red Oak , Post Oak (*Q. stellata*), and standing dead snags.

DISCUSSION

Bachman's Sparrows on Fort Campbell in 2009-2010 were found in routinely burned areas in or around the impact area. Only one bird banded in 2009 was re-sighted in 2010 despite the repeated use of three territories across both years. The apparent return rates thus are very low although these results are confounded by the presence of the impact area. If returning males seek new territories in the impact zone, they would be missed by our routine surveys on the periphery. The reuse of territories in 2010 which were occupied in 2009 by different individuals suggests that the sparrows show consistent habitat selection patterns. Recurrent use of those territories was not precluded by apparent changes in habitat suitability. Based on eBird data, a citizen-science based program operated by the Cornell Lab of Ornithology, the next nearest Bachman's Sparrow sighting in the last decade was >100 km from Fort Campbell. The continued use of Fort Campbell by Bachman's Sparrows for over 10 years (D. Moss, unpublished data) suggests that this population is sustainable, primarily because the vegetation has been reliably managed to produce appropriate savanna-like structure and composition.

My observed average 2.6 ha ($n = 16$) territory size at FCMR was comparable to the average based on minimum convex polygon analysis (0.62 to 2.5 ha) and 95% fixed kernel analyses (1.74 to 3.5 ha) from other studies across the specie's range (Hardin et al. 1982, Haggerty 1988, Dunning and Watts 1990, Cox and Jones 2007, Farley 2008, Jones 2008). Comparisons of territory size within specific studies in Georgia, South Carolina, and Florida supported the food value theory: territories were smaller than average when there was an abundance of available seeds or arthropods because of either recent fire (within 12 months) or lack of succession (Brown 1964, Hixon 1980, Stober and Krementz 2006, Cox and Jones 2007, Jones 2008). If territory size is a good indication of territory quality, with smaller territories suggestive of greater quality (Lack 1964), habitat quality at FCMR should be considered comparable to that from southern pine savanna sites which reported similar territory sizes.

The ground cover of occupied territories on Fort Campbell was dominated by native warm-season grasses and forbs, consistent with habitat descriptions from other studies across Bachman's Sparrow range. Previous studies of Bachman's Sparrow habitat selection in mature pine stands of Alabama, Florida, and Arkansas recorded the percent cover of grass along transects in occupied territories as 73%, 76%, and 60%, respectively, whereas percent cover of forbs was lower at 25%, 55%, and 18%. (Haggerty 1998, Plentovich et al. 1998, Tucker et al. 2004). Grass and forb percent cover in stands occupied by Bachman's Sparrows but managed for Red-cockaded Woodpeckers in Florida were 74% and 38%, respectively (Plentovich et al. 1998). All studies found that amounts of grass and forb cover were the greatest compared to all other vegetation types. The ratio of grass cover to forb cover from these studies ranged from 1.4 to 3.3, however the ratio of grass to forb percent cover at FCMR was approximately 1:1, much less grass cover than at other sites.

Grass cover has frequently been documented as the most important factor in Bachman's Sparrow habitat selection, whereas forb cover varies widely in abundance and importance to habitat selection (Haggerty 1998, Plentovich et al. 1998, Tucker et al. 1998, Dunning et al. 2000, Haggerty 2000). Grass cover dominated the herbaceous layer at FCMR, however, forb cover was greater between occupied and unoccupied points within territories. The frequent fires on Fort Campbell may have generated a landscape where forbs are the limiting factor in habitat selection. If grass cover is generally sufficient throughout available habitat at Fort Campbell, then other features may become important in fine-scale habitat selection. Previous research has found increased abundance of available arthropod biomass in native warm-season grasslands with greater forb cover, frequent fires, and recent disking (Southwood et al. 1979, Fettinger et al. 2002, Gruchy 2007). Bachman's Sparrows may be selecting for more forb cover at FCMR to increase the diversity and amount of food available to them. Lower percent cover of standing dead grass may additionally be an indicator of more territory-wide disturbance compared to adjacent fields. The greater amount of forb cover and therefore potentially greater amount of food, and frequent disturbance in general may explain why Bachman's Sparrows continue to use FCMR year after year.

Vertical structure and density of woody cover in Bachman's Sparrow's territories has been shown to be important in habitat selection: they are drawn specifically to a high amount of vegetation under 1 m but low amounts over 1 m (Dunning and Watts 1990, Plentovich et al. 1998). I did not detect any differences between occupied and unoccupied territories for woody percent cover, percent cover of shrubs under 1 m, or percent cover of shrubs over 1 m. The adjacency of occupied and unoccupied territories to each other probably left little room for large differences in fire effects to be expressed by different levels of woody structure. In this case it is probably the species composition, particularly forbs, within the first meter above the ground that is driving habitat selection.

The basal area for occupied territories at Fort Campbell (2.41 m^2/ha ± 0.57 SE) was much lower than that reported for Bachman's Sparrows in pine savannas (11.1 to 13.6 m^2/ha). Tree distribution as well as the vegetative density in savannas is very patchy because of fire behavior. Bachman's Sparrows are generally selective in the amount and arrangement of trees in their territories (Mitchell 1998, Dunning et al. 2000, Brooks and Stouffer 2011). They will not occupy areas with even optimal herbaceous cover if there is no standing woody vegetation to use for perches, nor will they use thick woodlands that don't let enough light in to stimulate the growth of a thick herbaceous layer (Cox and Jones 2007, Cox and Jones 2008). The frequent prescribed fire on Fort Campbell has created a much more open habitat with greater light penetration compared to that in pine savannas, but the vegetation still supports a persistent population. The landcover analysis showed that Bachman's Sparrows were selecting territories with more tree cover than the neighboring fields, suggesting that the basal area levels found on Fort Campbell are on the low end of what the species will use within an oak savanna matrix.

I attempted to characterize the 'patchiness' inherent in fire-adapted ecosystems by examining the coefficient of variation among cover types within and across occupied and unused territories. Nest sites are typically located in an open grass-dominated patch for concealed movement to and from the nest, whereas woody vegetation for song perches is also essential (Gainer 1921, Dunning and Watts 1990, Cox and Jones 2008). Presumably, the patchier the habitat, the more likely Bachman's Sparrows will find all the vegetation components they require within a given territory. Variance of litter cover was higher in occupied territories, and this may reflect the patchy distribution of the tree cover (and dead leaves) in the preferred habitat. However, the variance between territory points was lower for forbs, bare ground, and woody vegetation in occupied territories. Bachman's Sparrows may be selecting for a more homogeneous mixture of vegetation within their habitat in oak savannas than previously assumed.

Other studies examined patchiness of grasslands within a larger landscape and how it relates to dispersal, but none have studied patchiness between territories (Dunning et al. 1995b, Dunning et al. 2000, Brooks and Stouffer 2010). I didn't find differences in this type of patchiness, but my study was not specifically designed to examine such differences. Importance of inter-territorial patchiness may need further investigation not only for Bachman's Sparrow habitat selection but also for other shrub-scrub birds that rely on frequent disturbances.

Early reports describing Bachman's Sparrow habitat in the northern portions of their range described eroded slopes and ravines with exposed patches of soil (Blincoe 1921, Brooks 1938). Bare ground is also associated with their nests, as it allows for easy access and escape from predators (Dunning and Watts 1990, Cox and Jones 2008). Many Bachman's Sparrows found during this study and by FCMR wildlife staff in the past had some type of large bare ground patches from roads, vehicle movement, erosion, or disking. We expected to see differences in the area of bare ground between occupied and unoccupied territories in our analysis either as greater average percent cover of bare ground or as greater variation within territories (i.e., patchiness). However, the only relationship we found was a lesser coefficient of variation for bare ground in occupied vs. unoccupied territories. The fact that the unoccupied territories had more variation suggests that Bachman's Sparrows may be selective in the amount of bare ground they need, but less so in the patchiness. More studies are needed to continue looking into this aspect of territory selection.

The oak savannas on Fort Campbell represent unique Bachman's Sparrow habitat in some of the most critically declining areas of their range. The population estimate of about 20 breeding male Bachman's Sparrows per year should be considered a minimum, because thousands of hectares of potential habitat occur in adjacent inaccessible impact areas on FCMR. The breeding population at FCMR is likely the largest northern population using oak savannas. Although the oak savannas on FCMR may not look the exactly like their more distinctive pine counterparts, they have many of the same important vegetation composition and structural characteristics important in territory selection. The vegetation components, as well as the continued use of the geographically-isolated location, support the conclusion that military activity on FCMR plays a vital role in Bachman's Sparrow conservation.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Fort Campbell Military Reservation (FCMR) has sustained a unique population of Bachman's Sparrows and a variety of other grassland and savanna species while supporting the military mission. I have some recommendations to enhance conservation of grassland birds on FCMR will continue into the future.

The point count route we developed to monitor grassland and shrub-scrub birds around the impact area demonstrated the variety of complex vegetation cover and arrangements related to species occupancy. Anthropogenic disturbances at FCMR, including prescribed fire, disking, and military training, are beneficial and should be maintained if maintaining open areas for these declining species is a management goal. The area around the impact area may not be ideal for species such as Henslow's or Grasshopper Sparrows that prefer small areas of woody vegetation, but they are supported in larger number elsewhere on the base. By having these large treeless areas as well as the frequently burned impact area, FCMR supports a range of declining grassland species. Biologists may consider which species they want to provide habitat for when making decisions regarding changes in grassland management. Extending the prescribed fire regime into woodlands adjacent to the impact zone may increase available habitat for species such as Prairie Warblers and Blue-Winged Warblers by opening up the canopy and increasing mid-story shrub cover, whereas increasing fire within the existing impact zone could increase the population of Henslow's and Grasshopper Sparrows by discouraging the growth of the already sparse tree and shrub cover. Continuing to utilize the point count route we established around the impact zone would help in understanding vegetation relationships beneficial for these species and a useful tool in monitoring these types of interactions.

Habitat analysis of Bachman's Sparrow territories indicates that management techniques which promote the growth of native warm season grasses and forbs, such as prescribed fire, are necessary to maintain the current population. Frequent burns during any season would be beneficial to maintain the appropriate composition in the herbaceous layer. If additional habitat is desired, opening up existing oak-hickory woodlands to approximately thirty five percent canopy cover and introducing annual fire to stimulate herbaceous growth may be effective.

The point-count route was developed around the impact zone on FCMR because the high frequency of prescribed fire is known to support a small population of Bachman's Sparrows. However, we did fail to detect any individuals in a few areas with overgrown vegetation that had been home to Bachman's Sparrows in the past. The lack of suitable disturbance caused a local extirpation of individuals from the area. Prescribed fire can be patchy, unpredictable, and variable so it is natural for some patches to remain undisturbed even with frequent fires on the landscape as a whole. If the goal is to maintain habitat for Bachman's Sparrows in these areas, we recommend using more direct disturbance such as disking or an increase in troop movement to knock back succession. This should not only keep the areas useable for all grassland species, but would also generate aggregations of exposed dirt that could attract those species positively related to bare ground cover and FRAGSTAT metrics including Bachman's Sparrows, Eastern Meadowlarks, Orchard Orioles, and Northern Bobwhite.

The variability of Bachman's Sparrows song is not conducive to a typical point count, and we did not increase detection with playback or longer counts. A five minute window may be appropriate for detecting more Bachman's Sparrows if it is conducted either more frequently during the breeding season or if it was accompanied by supplementary monitoring of potential habitat. Shortening the time spent at each point count to five minutes without playback would greatly shorten the time required to run the entire route from eighteen person-mornings to only nine or ten. Additionally, those species whose detectability was modeled by group and not averaged over the summer (Bachman's Sparrow, Blue-Winged Warbler, Dickcissel, Eastern Meadowlark, Northern Bobwhite, and Prairie Warbler) all had different survey periods for their highest detectability value. If biologists want to minimize the time spent on point counts or maximize the number of runs to increase total detections, they can do so without sacrificing potential Bachman's Sparrow observations.

This study did not show support for the use of row crops to increase occupancy of Northern Bobwhite or other grassland and shrub-scrub birds. If an increase in the number of Bobwhite around the impact area is desired, I would recommend using techniques like disking or bush-hogging to decrease the amount of shrub cover and increase grass cover and patch size. These management types have the potential to be especially useful if implemented around the outer boundaries of current grassland bird habitat or in areas where the prescribed fire does not adequately maintain open vegetation.

Anthropogenic and natural disturbances on FCMR have created a mosaic of vegetation types used by a number of declining grassland species. Continuing to monitor and analyze landcover relationships for this suite of species would increase understanding of their distribution across the installation, provide information about responses of species to changes in vegetation, and help in future management planning.

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APPENDIX

Appendix Table 1: Correlation results for point count covariates generated from ERDAS supervised classification and FRAGSTATS metrics.

	Total Edge	Contagion*	Interspersion and Juxtaposition	Bareground Clumpy	Grass Clumpy*	Bareground Connect	Grass Connect	Bareground Cohesion	Grass Cohesion	Bareground Cover 250m	Grass Cover 250m	Shrub Cover 250m	Tree Cover 250m	Row Crops 250m	Bareground Cover 90m	Grass Cover 90m*
Shannon's Diversity Index*	0.372358	0.060551	0.724255	0.294328	0.498573	-0.08136	-0.13029	0.404205	0.716674	0.309184	0.460292	-0.29609	-0.03533	0.045456	0.462834	0.528399
Total Edge		-0.11283	0.202517	0.06397	0.051495	-0.07561	-0.44102	0.20616	0.19827	0.138198	0.17725	0.237361	-0.00137	-0.16595	0.179843	0.307553
Contagion*			0.063295	0.072191	0.062318	-0.07694	0.227397	0.075393	0.029057	-0.00566	-0.00598	-0.10156	-0.07553	0.880911	-0.01671	-0.05311
Interspersion and Justiposition				0.341369	0.489335	-0.0883	-0.00924	0.559722	0.663282	0.365694	0.460401	-0.44011	0.053467	0.047055	0.595046	0.431369
Bareground Clumpy					0.265505	0.028767	-0.08598	0.300334	0.282525	0.434003	0.254704	-0.26292	-0.00818	0.059063	0.423824	0.225712
Grass Clumpy*						-0.05124	-0.10193	-0.02421	0.736213	0.054336	0.627157	-0.4829	0.020382	0.082148	0.173133	0.554624
Bareground Connect							0.154552	0.127763	-0.10749	-0.0526	-0.00895	-0.13424	0.18877	-0.07537	0.07617	0.03775
Grass Connect								-0.08152	-0.0637	-0.08448	-0.19961	-0.18834	0.128107	0.205776	-0.04012	-0.20378
Bareground Cohesion									0.162704	0.289076	0.197046	-0.0617	-0.04873	0.088359	0.520234	0.239135
Grass Cohesion										0.176424	0.619131	-0.45197	-0.03988	0.022632	0.297147	0.670656
Bareground Cover 250m											0.2704	-0.00957	-0.25723	-0.02532	0.525381	0.155186
Grass Cover 250m												-0.12488	-0.45037	-0.03146	0.340887	0.733804
Shrub Cover 250m													-0.58702	-0.14847	-0.15811	-0.21093
Tree Cover 250m														-0.04929	-0.07804	-0.20422
Row Crops 250m															-0.03625	-0.08631
Bareground Cover 90m																0.319393

** Metrics were dropped from analysis due to correlation with other variables. Boxes show high correlation values.*

Appendix Table 2: Modeling results for occupancy (±SE) and detectability (±SE) using percent cover and FRAGSTAT vegetation covariates for Bachman's Sparrows on Fort Campbell Military Reservation, Tennessee-Kentucky, May-July, 2009-2010.

Model	**AICc**	**ΔAICc**	**AICc Weight**	**Model Likelihood**	**⍰**	**p_1**	**p_2**	**p_3**	**β x**
⍰ (Grass 250m) p (survey)	122.08	0.00	0.34	1.00	0.04 ± 0.02	0.38 ± 0.15	0.71 ± 0.17	0.21 ± 0.12	10.02 ± 2.80
⍰ (Grass cohesion) p (survey)	122.18	0.10	0.32	0.95	0.00 ± 0.01	0.39 ± 0.15	0.72 ± 0.17	0.22 ± 0.12	0.32 ± 0.15
⍰ (Bare ground clumpy) p (survey)	124.88	2.80	0.08	0.25	0.03 ± 0.02	0.39 ± 0.15	0.73 ± 0.16	0.22 ± 0.12	15.00 ± 5.08
⍰ (Bare ground 90m) p (survey)	126.52	4.44	0.04	0.11	0.05 ± 0.02	0.38 ± 0.15	0.70 ± 0.18	0.21 ± 0.11	14.98 ± 4.86
⍰ (Bare ground cohesion) p (survey)	127.79	5.71	0.02	0.06	0.03 ± 0.02	0.39 ± 0.15	0.73 ± 0.16	0.22 ± 0.12	0.14 ± 0.06
⍰ (Interspersion and Juxtiposition) p (survey)	128.12	6.04	0.02	0.05	0.04 ± 0.02	0.39 ± 0.15	0.72 ± 0.17	0.22 ± 0.12	0.09 ± 0.03
⍰ (.) p (survey)	**136.49**	**14.41**	**0.00**	**0.00**	**0.07 ± 0.02**	**0.39 ± 0.15**	**0.72 ± 0.16**	**0.22 ± 0.12**	---
⍰ (Grass connect) p (survey)	137.19	15.11	0.00	0.00	0.06 ± 0.02	0.39 ± 0.15	0.72 ± 0.17	0.22 ± 0.12	-0.05* ± 0.04
⍰ (Total edge) p (survey)	137.43	15.35	0.00	0.00	0.07 ± 0.02	0.39 ± 0.15	0.72 ± 0.16	0.22 ± 0.12	0.00* ± 0.00
⍰ (Bare ground connection) p (survey)	137.59	15.51	0.00	0.00	0.07 ± 0.02	0.39 ± 0.15	0.72 ± 0.16	0.22 ± 0.12	0.03* ± 0.03
⍰ (Bare ground 250m) p (survey)	137.66	15.58	0.00	0.00	0.07 ± 0.02	0.39 ± 0.15	0.72 ± 0.17	0.22 ± 0.12	5.62* ± 5.28
⍰ (Shrub) p (survey)	137.71	15.63	0.00	0.00	0.07 ± 0.02	0.39 ± 0.15	0.72 ± 0.17	0.22 ± 0.12	-2.01* ± 2.22
⍰ (Tree) p (survey)	138.01	15.93	0.00	0.00	0.07 ± 0.02	0.39 ± 0.15	0.72 ± 0.17	0.22 ± 0.12	-1.37* ± 1.82
⍰ (Year) p (survey)	138.59	16.51	0.00	0.00	0.07 ± 0.03, 0.07 ± 0.03	0.39 ± 0.15	0.72 ± 0.16	0.22 ± 0.12	---

** 95% confidence interval crosses zero*

AICc = Akaike's Information Criteria with small sample bias adjustment

ΔAICc = Difference in AICc value between the current model and the best-fitting model

AICc weight= the conditional probability of each model

⍰ = Occupancy estimation

p = Detectability estimation

Appendix Table 3: Modeling results for occupancy (±SE) and detectability (±SE) of Bachman's Sparrows over 10-minute point counts on Fort Campbell Military Reservation, Tennessee-Kentucky, May-July, 2009-2010 with playback using percent cover and FRAGSTAT vegetation covariates.

Model	**AICc**	**ΔAICc**	**AICc Weight**	**Model Likelihood**	**⍰**	**p_1**	**p_2**	**p_3**	**β x**
⍰ (Grass cohesion) p (survey)	131.73	0.00	0.43	1.00	0.01 ± 0.01	0.40 ± 0.15	0.63 ± 0.17	0.19 **± 0.10**	0.28 ± 0.13
⍰ (Grass 250m) p (survey)	133.13	1.41	0.21	0.49	0.05 ± 0.02	0.40 ± 0.15	0.62 ± 0.17	0.19 ± 0.10	9.27 ± 2.68
⍰ (Bare ground clumpy) p (survey)	135.34	3.61	0.07	0.16	0.04 ± 0.02	0.41 ± 0.15	0.64 ± 0.16	0.19 ± 0.10	13.58 ± 4.65
⍰ (Bare ground 90m) p (survey)	137.64	5.91	0.02	0.05	0.06 ± 0.02	0.40 ± 0.15	0.62 ± 0.17	0.19 ± 0.10	14.05 ± 4.85
⍰ (Interspersion and Juxtiposition) p (survey)	139.83	8.10	0.01	0.02	0.05 ± 0.02	0.41 ± 0.15	0.63 ± 0.17	0.19 ± 0.10	0.07 ± 0.03
⍰ (Bare ground cohesion) p (survey)	140.98	9.25	0.00	0.01	0.05 ± 0.02	0.41 ± 0.15	0.64 ± 0.17	0.19 ± 0.10	0.09 ± 0.04
⍰ (.) p (survey)	**146.16**	**14.43**	**0.00**	**0.00**	**0.08 ± 0.02**	**0.41 ± 0.15**	**0.63 ± 0.17**	**0.19 ± 0.10**	---
⍰ (Shrub) p (survey)	147.44	15.71	0.00	0.00	0.08 ± 0.02	0.41 ± 0.15	0.63 ± 0.17	0.19 ± 0.10	-1.87 ± 2.13
⍰ (Bare ground 250m) p (survey)	147.49	15.77	0.00	0.00	0.08 ± 0.02	0.40 ± 0.15	0.63 ± 0.17	0.19 ± 0.10	5.14* ± 5.42
⍰ (Total edge) p (survey)	147.55	15.82	0.00	0.00	0.08 ± 0.02	0.41 ± 0.15	0.63 ± 0.17	0.19 ± 0.10	0.00* ± 0.00
⍰ (Grass connect) p (survey)	147.74	16.01	0.00	0.00	0.08 ± 0.02	0.41 ± 0.15	0.63 ± 0.17	0.19 ± 0.10	=-0.02* ± 0.04
⍰ (Bare ground connection) p (survey)	147.76	16.04	0.00	0.00	0.08 ± 0.02	0.41 ± 0.15	0.63 ± 0.17	0.19 ± 0.10	0.02* ± 0.03
⍰ (Tree) p (survey)	147.88	16.15	0.00	0.00	0.08 ± 0.02	0.41 ± 0.15	0.63 ± 0.17	0.19 ± 0.10	-1.07* ± 1.74
⍰ (Year) p (survey)	148.21	16.48	0.00	0.00	0.08 ± 0.03; 0.07 ± 0.03	0.41 ± 0.15	0.63 ± 0.17	0.19 ± 0.10	---

** 95% confidence interval crosses zero*

AICc = Akaike's Information Criteria with small sample bias adjustment

ΔAICc = Difference in AICc value between the current model and the best-fitting model

AICc weight= the conditional probability of each model

⍰ = Occupancy estimation

p = Detectability estimation

Appendix Table 4: Modeling results for occupancy (±SE) and detectability (±SE) using percent cover and FRAGSTAT vegetation covariates for Blue Grosbeaks on Fort Campbell Military Reservation, Tennessee-Kentucky, May-July, 2009-2010.

Model	AICc	ΔAICc	AICc Weights	Model Likelihood	⍰	p	β x
⍰ (Grass cohesion) p (.)	227.55	0.00	0.50	1.00	0.23 ± 0.10	0.18 ± 0.07	0.08 ± 0.03
⍰ (Grass 250m) p (.)	229.91	2.36	0.15	0.31	0.26 ± 0.10	0.18 ± 0.07	6.64 ± 2.99
⍰ (Bare ground clumpy) p (.)	231.02	3.47	0.09	0.18	0.25 ± 0.10	0.18 ± 0.07	7.32 ± 3.23
⍰ (Year) p (.)	232.57	5.03	0.04	0.08	0.38 ± 0.14, 0.15 ± 0.07	0.18 ± 0.07	---
⍰ (Grass connect) p (.)	233.74	6.19	0.02	0.05	0.28 ± 0.12	0..17 ± 0.07	0.08* ± 0.05
⍰ (Interspersion and Juxtiposition) p (.)	234.31	6.77	0.02	0.03	0.27 ± 0.11	0.17 ± 0.07	0.04* ± 0.02
⍰ (Shrub) p (.)	235.56	8.01	0.01	0.02	0.27 ± 0.11	0.18 ± 0.07	-2.96* ± 0.94
⍰ (.) p (.)	**235.84**	**8.29**	**0.01**	**0.02**	**0.27 ± 0.10**	**0.18 ± 0.07**	**---**
⍰ (Bare ground connection) p (.)	237.01	9.47	0.00	0.01	0.27 ± 0.10	0.18 ± 0.07	0.02* ± 0.02
⍰ (Tree) p (.)	237.30	9.75	0.00	0.01	0.27 ± 0.10	0.18 ± 0.07	-1.22* ± 1.59
⍰ (Row crop) p (.)	237.38	9.83	0.00	0.01	0.27 ± 0.10	0.18 ± 0.07	1.55* ± 2.17
⍰ (Total edge) p (.)	237.55	10.00	0.00	0.01	0.27 ± 0.10	0.18 ± 0.07	0.00* ± 0.00
⍰ (Bare ground 250m) p (.)	237.66	10.11	0.00	0.01	0.27 ± 0.10	0.18 ± 0.07	-3.71* ± 8.01
⍰ (Bare ground cohesion) p (.)	237.89	10.34	0.00	0.01	0.27 ± 0.10	0.18 ± 0.07	0.00* ± 0.02
⍰ (Bare ground 90m) p (.)	237.89	10.34	0.00	0.01	0.27 ± 0.10	0.18 ± 0.07	0.41* ± 4.97

** 95% confidence interval crosses zero*

AICc = Akaike's Information Criteria with small sample bias adjustment

ΔAICc = Difference in AICc value between the current model and the best-fitting model

AICc weight= the conditional probability of each model

⍰ = Occupancy estimation

p = Detectability estimation

Appendix Table 5: Modeling results for occupancy (±SE) and detectability (±SE) using percent cover and FRAGSTAT vegetation covariates for Blue-winged Warblers on Fort Campbell Military Reservation, Tennessee-Kentucky, May-July, 2009-2010.

Model	**AICc**	**ΔAICc**	**AICc Weights**	**Model Likelihood**	**ψ**	**p_1**	**p_2**	**p_3**	**β x**
ψ (Shrub) p (survey)	284.12	0.00	0.69	1.00	0.30 ± 0.09	0.44 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	4.90 ± 1.85
ψ (Row crop) p (survey)	287.55	3.43	0.12	0.18	0.28 ± 0.08	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	-7.41 ± 3.43
ψ (Total edge) p (survey)	287.81	3.69	0.11	0.16	0.30 ± 0.08	0.44 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	0.00 ± 0.00
ψ (.) p (survey)	**292.75**	**8.64**	**0.01**	**0.01**	**0.31 ± 0.08**	**0.45 ± 0.12**	**0.22 ± 0.07**	**0.05 ± 0.03**	---
ψ (Tree) p (survey)	293.10	8.99	0.01	0.01	0.31 ± 0.08	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	-1.69* ± 1.31
ψ (Interspersion and Juxtiposition) p (survey)	293.97	9.86	0.01	0.01	0.31 ± 0.08	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	-0.01* 0.02
ψ (Grass cohesion) p (survey)	294.22	10.10	0.00	0.01	0.31 ± 0.08	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	0.01* ± 0.02
ψ (Bare ground cohesion) p (survey)	294.31	10.19	0.00	0.01	0.31 ± 0.08	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	0.01* ± 0.01
ψ (Bare ground connection) p (survey)	294.51	10.40	0.00	0.01	0.31 ± 0.08	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	-0.01* ± 0.02
ψ (Grass connect) p (survey)	294.56	10.44	0.00	0.01	0.31 ± 0.08	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	-0.02* ± 0.03
ψ (Year) p (survey)	294.64	10.52	0.00	0.00	0.33 ± 0.09, 0.29 ± 0.09	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	---
ψ (Bare ground 250m) p (survey)	294.77	10.66	0.00	0.00	0.31 ± 0.08	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	-1.68* ± 5.89
ψ (Grass) p (survey)	294.83	10.72	0.00	0.00	0.31 ± 0.08	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	-0.29* ± 1.78
ψ (Bare ground clumpy) p (survey)	294.84	10.72	0.00	0.00	0.31 ± 0.08	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	-0.29* ± 2.02
ψ (Bare ground 90m) p (survey)	294.86	10.74	0.00	0.00	0.31 ± 0.08	0.45 ± 0.12	0.22 ± 0.07	0.05 ± 0.03	0.67* ± 1.69

** 95% confidence interval crosses zero*

AICc = Akaike's Information Criteria with small sample bias adjustment

ΔAICc = Difference in AICc value between the current model and the best-fitting model

AICc weight= the conditional probability of each model

ψ = Occupancy estimation

p = Detectability estimation

Appendix Table 6: Modeling results for occupancy (±SE) and detectability (±SE) using percent cover and FRAGSTAT vegetation covariates for Dickcissels on Fort Campbell Military Reservation, Tennessee-Kentucky, May-July, 2009-2010.

Model	**AICc**	**ΔAICc**	**AICc Weights**	**Model Likelihood**	****	**p_1**	**p_2**	**p_3**	**β x**
(Tree) p (survey)	325.76	0.00	0.64	1.00	0.17 ± 0.03	0.26 ± 0.07	0.59 ± 0.08	0.75 ± 0.08	-7.28 ± 0.48
(Grass 250m) p (survey)	326.90	0.15	0.36	0.56	0.17 ± 0.03	0.26 ± 0.07	0.59 ± 0.08	0.75 ± 0.08	8.69 ± 0.73
(Bare ground clumpy) p (survey)	335.45	9.70	0.00	0.01	0.17 ± 0.03	0.26 ± 0.07	0.59 ± 0.08	0.75 ± 0.08	10.50 ± 2.49
(Bare ground 90m) p (survey)	342.40	16.64	0.00	0.00	0.20 ± 0.03	0.27 ± 0.07	0.60 ± 0.08	0.75 ± 0.07	13.66 ± 3.62
(Grass cohesion) p (survey)	344.62	18.86	0.00	0.00	0.18 ± 0.03	0.26 ± 0.07	0.59 ± 0.08	0.75 ± 0.08	0.07 ± 0.02
(Bare ground 250m) p (survey)	350.89	25.13	0.00	0.00	0.21 ± 0.03	0.26 ± 0.07	0.60 ± 0.08	0.75 ± 0.08	13.60 ± 5.43
(Interspersion and Juxtiposition) p (survey)	351.25	25.49	0.00	0.00	0.20 ± 0.03	0.26 ± 0.07	0.59 ± 0.08	0.75 ± 0.08	0.04 ± 0.01
(Bare ground cohesion) p (survey)	355.75	29.99	0.00	0.00	0.21 ± 0.03	0.26 ± 0.07	0.60 ± 0.08	0.75 ± 0.08	0.03* ± 0.01
(Row crop) p (survey)	355.94	30.18	0.00	0.00	0.21 ± 0.03	0.26 ± 0.07	0.59 ± 0.08	0.745 ± 0.08	3.21 ± 1.51
** (.) p (survey)**	**358.20**	**32.44**	**0.00**	**0.00**	**0.22 ± 0.03**	**0.26 ± 0.07**	**0.59 ± 0.08**	**0.75 ± 0.08**	---
(Total edge) p (survey)	358.76	33.01	0.00	0.00	0.22 ± 0.03	0.26 ± 0.07	0.59 ± 0.08	0.75 ± 0.08	0.00* ± 0.00
(Grass connect) p (survey)	360.02	34.27	0.00	0.00	0.22 ± 0.03	0.26 ± 0.07	0.59 ± 0.08	0.75 ± 0.08	0.01* ± 0.02
(Bare ground connection) p (survey)	360.11	34.35	0.00	0.00	0.22 ± 0.03	0.26 ± 0.07	0.59 ± 0.08	0.75 ± 0.08	0.00* ± 0.01
(Year) p (survey)	360.13	34.37	0.00	0.00	0.23 ± 0.04, 0.21 ± 0.04	0.26 ± 0.07	0.59 ± 0.08	0.75 ± 0.08	---
(Shrub) p (survey)	360.28	34.53	0.00	0.00	0.22 ± 0.03	0.26 ± 0.07	0.59 ± 0.08	0.75 ± 0.08	-0.14* ± 1.19

** 95% confidence interval crosses zero*

AICc = Akaike's Information Criteria with small sample bias adjustment

ΔAICc = Difference in AICc value between the current model and the best-fitting model

AICc weight= the conditional probability of each model

* = Occupancy estimation*

p = Detectability estimation

Appendix Table 7: Modeling results for occupancy (±SE) and detectability (±SE) using percent cover and FRAGSTAT vegetation covariates for Eastern Meadowlarks on Fort Campbell Military Reservation, Tennessee-Kentucky, May-July, 2009-2010.

Model	AICc	ΔAICc	AICc Weights	Model Likelihood	ψ	p_1	p_2	p_3	β x
ψ (Grass 250m) p (survey)	238.44	0.00	0.78	1.00	0.16 ± 0.04	0.45 ± 0.09	0.47 ± 0.09	0.26 ± 0.07	9.93 ± 2.05
ψ (Bare ground clumpy) p (survey)	286.13	2.69	0.20	0.26	0.14 ± 0.04	0.42 ± 0.09	0.44 ± 0.10	0.24 ± 0.07	14.80 ± 3.64
ψ (Bare ground 250m) p (survey)	292.00	8.55	0.01	0.01	0.20 ± 0.04	0.43 ± 0.09	0.45 ± 0.09	0.25 ± 0.07	38.18 ± 10.06
ψ (Bare ground 90m) p (survey)	293.32	9.88	0.01	0.00	0.20 ± 0.04	0.42 ± 0.09	0.44 ± 0.09	0.24 ± 0.07	21.14 ± 6.54
ψ (Grass cohesion) p (survey)	297.34	13.90	0.00	0.00	0.16 ± 0.04	0.43 ± 0.09	0.45 ± 0.09	0.25 ± 0.07	0.10 ± 0.03
ψ (Interspersion and Juxtiposition) p (survey)	301.06	17.92	0.00	0.00	0.18 ± 0.04	0.43 ± 0.09	0.45 ± 0.09	0.25 ± 0.07	0.06 ± 0.02
ψ (Bare ground cohesion) p (survey)	306.69	23.25	0.00	0.00	0.19 ± 0.04	0.43 ± 0.09	0.45 ± 0.09	0.25 ± 0.07	0.05 ± 0.02
ψ (Tree) p (survey)	308.81	25.37	0.00	0.00	0.20 ± 0.04	0.43 ± 0.09	0.45 ± 0.09	0.25 ± 0.07	-3.42 ± 0.32
ψ (Shrub) p (survey)	309.44	28.68	0.00	0.00	0.21 ± 0.04	0.42 ± 0.09	0.45 ± 0.09	0.25 ± 0.07	-2.99 ± 0.52
ψ (.) p (survey)	**314.32**	**30.88**	**0.00**	**0.00**	**0.22 ± 0.04**	**0.43 ± 0.09**	**0.45 ± 0.09**	**0.25 ± 0.07**	---
ψ (Row crop) p (survey)	314.98	32.33	0.00	0.00	0.22 ± 0.04	0.43 ± 0.09	0.45 ± 0.09	0.25 ± 0.07	-1.64* ± 2.10
ψ (Grass connect) p (survey)	315.92	32.48	0.00	0.00	0.22 ± 0.04	0.42 ± 0.09	0.45 ± 0.09	0.25 ± 0.07	-0.02* ± 0.03
ψ (Bare ground connection) p (survey)	316.11	32.67	0.00	0.00	0.22 ± 0.04	0.43 ± 0.09	0.45 ± 0.09	0.25 ± 0.07	0.00* ± 0.02
ψ (Year) p (survey)	316.36	32.92	0.00	0.00	0.23 ± 0.05, 0.21 ± 0.05	0.43 ± 0.09	0.45 ± 0.09	0.25 ± 0.07	---
ψ (Total edge) p (survey)	316.41	32.95	0.00	0.00	0.22 ± 0.04	0.43 ± 0.09	0.45 ± 0.09	0.25 ± 0.07	0.00* ± 0.00

** 95% confidence interval crosses zero*

AICc = Akaike's Information Criteria with small sample bias adjustment

ΔAICc = Difference in AICc value between the current model and the best-fitting model

AICc weight= the conditional probability of each model

ψ = Occupancy estimation

p = Detectability estimation

Appendix Table 8: Modeling results for occupancy (±SE) and detectability (±SE) using percent cover and FRAGSTAT vegetation covariates for Henslow's Sparrows on Fort Campbell Military Reservation, Tennessee-Kentucky, May-July, 2009-2010.

Model	AICc	ΔAICc	AICc Weights	Model Likelihood		p	β x
(Grass 250m) p (.)	174.72	0.00	0.65	1.00	0.09 ± 0.03	0.32 ± 0.09	7.09 ± 2.35
(Grass cohesion) p (.)	178.26	3.54	0.10	0.17	0.09 ± 0.03	0.33 ± 0.09	0.07 ± 0.04
(Bare ground clumpy) p (.)	179.20	4.48	0.06	0.11	0.10 ± 0.03	0.33 ± 0.09	7.44 ± 3.27
(Total edge) p (.)	180.19	5.47	0.04	0.07	0.11 ± 0.03	0.32 ± 0.09	-0.00* ± 0.00
(Tree) p (.)	182.24	7.52	0.01	0.02	0.11 ± 0.03	0.33 ± 0.09	-2.98* ± 1.70
** (.) p (.)**	**183.55**	**8.83**	**0.01**	**0.01**	**0.12 ± 0.04**	**0.33 ± 0.09**	---
(Bare ground 90m) p (.)	183.86	9.14	0.01	0.01	0.12 ± 0.03	0.33 ± 0.09	5.85* ± 4.29
(Bare ground connection) p (.)	183.94	9.22	0.01	0.01	0.12 ± 0.03	0.33 ± 0.09	0.03* ± 0.02
(Interspersion and Juxtiposition) p (.)	184.87	9.79	0.00	0.01	0.12 ± 0.04	0.33 ± 0.09	0.02* ± 0.02
(Grass connect) p (.)	184.91	10.15	0.00	0.01	0.12 ± 0.04	0.33 ± 0.09	0.03* ± 0.04
(Bare ground 250m) p (.)	184.91	10.19	0.00	0.01	0.12 ± 0.04	0.33 ± 0.09	4.07* ± 5.06
(Shrub) p (.)	185.38	10.19	0.00	0.01	0.12 ± 0.04	0.33 ± 0.09	-0.87* ± 1.82
(Year) p (.)	185.52	10.80	0.00	0.00	0.11 ± 0.04, 0.13 ± 0.05	0.33 ± 0.09	---
(Row crop) p (.)	185.59	10.87	0.00	0.00	0.12 ± 0.04	0.33 ± 0.09	-0.35* ± 2.55
(Bare ground cohesion) p (.)	185.61	10.89	0.00	0.00	0.12 ± 0.04	0.33 ± 0.09	0.00* ± 0.02

** 95% confidence interval crosses zero*

AICc = Akaike's Information Criteria with small sample bias adjustment

ΔAICc = Difference in AICc value between the current model and the best-fitting model

AICc weight= the conditional probability of each model

* = Occupancy estimation*

p = Detectability estimation

Appendix Table 9: Modeling results for occupancy (±SE) and detectability (±SE) using percent cover and FRAGSTAT vegetation covariates for Northern Bobwhite on Fort Campbell Military Reservation, Tennessee-Kentucky, May-July, 2009-2010.

Model	**AICc**	**ΔAICc**	**AICc Weights**	**Model Likelihood**	**▯**	**p_1**	**p_2**	**p_3**	**β x**
▯ (Grass cohesion) p (survey)	725.46	0.00	0.67	1.00	0.75 ± 0.05	0.36 ± 0.4	0.64 ± 0.04	0.63 ± 0.04	0.08 ± 0.02
▯ (Grass 250m) p (survey)	727.20	1.73	0.28	0.42	0.77 ± 0.04	0.37 ± 0.04	0.65 ± 0.04	0.64 ± 0.04	10.25 ± 2.18
▯ (Shrub) p (survey)	743.77	18.31	0.00	0.00	0.77 ± 0.06	0.35 ± 0.04	0.62 ± 0.05	0.61 ± 0.05	-5.87 ± 1.82
▯ (Interspersion and Juxtiposition) p (survey)	750.47	25.00	0.00	0.00	0.74 ± 0.04	0.36 ± 0.04	0.63 ± 0.04	0.63 ± 0.04	0.04 ± 0.01
▯ (Bare ground clumpy) p (survey)	752.44	26.09	0.00	0.00	0.73 ± 0.04	0.36 ± 0.04	0.64 ± 0.04	0.63 ± 0.04	5.11 ± 1.74
▯ (Bare ground 90m) p (survey)	756.12	30.66	0.00	0.00	0.73 ± 0.04	0.37 ± 0.04	0.64 ± 0.04	0.63 ± 0.04	10.27* ± 5.40
▯ (Bare ground connection) p (survey)	758.80	33.33	0.00	0.00	0.73 ± 0.04	0.36 ± 0.04	0.63 ± 0.04	0.63 ± 0.04	-0.03* ± 0.02
▯ (.) p (survey)	**759.54**	**34.08**	**0.00**	**0.00**	**0.72 ± 0.04**	**0.36 ± 0.04**	**0.63 ± 0.04**	**0.63 ± 0.04**	---
▯ (Bare ground 250m) p (survey)	760.70	35.24	0.00	0.00	0.72 ± 0.04	0.36 ± 0.04	0.63 ± 0.04	0.93 ± 0.04	4.89 ± 5.66
▯ (Row crop) p (survey)	760.86	35.40	0.00	0.00	0.72 ± 0.04	0.36 ± 0.04	0.63 ± 0.04	0.63 ± 0.04	1.58 ± 0.89
▯ (Total edge) p (survey)	761.10	35.63	0.00	0.00	0.72 ± 0.04	0.36 ± 0.04	0.63 ± 0.04	0.63 ± 0.04	0.00* ± 0.00
▯ (Grass connect) p (survey)	761.43	35.97	0.00	0.00	0.72 ± 0.04	0.36 ± 0.04	0.63 ± 0.04	0.63 ± 0.04	-0.01* ± 0.02
▯ (Tree) p (survey)	761.58	36.12	0.00	0.00	0.72 ± 0.04	0.36 ± 0.04	0.63 ± 0.04	0.63 ± 0.04	-0.25* ± 1.04
▯ (Bare ground cohesion) p (survey)	761.60	36.14	0.00	0.00	0.72 ± 0.04	0.36 ± 0.04	0.63 ± 0.04	0.63 ± 0.04	-0.002* ± 0.01
▯ (Year) p (survey)	761.64	36.18	0.00	0.00	0.72 ± 0.05, 0.72 ± 0.05	0.36 ± 0.04	0.633 ± 0.04	0.63 ± 0.04	---

** 95% confidence interval crosses zero*

AICc = Akaike's Information Criteria with small sample bias adjustment

ΔAICc = Difference in AICc value between the current model and the best-fitting model

AICc weight= the conditional probability of each model

▯ = Occupancy estimation

p = Detectability estimation

Appendix Table 10: Modeling results for occupancy (±SE) and detectability (±SE) using percent cover and FRAGSTAT vegetation covariates for Orchard Orioles on Fort Campbell Military Reservation, Tennessee-Kentucky, May-July, 2009-2010.

Model	AICc	ΔAICc	AICc Weights	Model Likelihood	?	p	β x
? (Grass 250m) p(.)	221.36	0.00	0.88	1.00	0.28 ± 0.11	0.15 ± 0.04	17.12 ± 5.81
? (Tree) p (.)	225.82	4.45	0.09	0.11	1.00 ± 0.00	0.07 ± 0.01	-16125.40 ± 2552.81
? (Grass cohesion) p (.)	229.26	7.90	0.02	0.02	0.21 ± 0.10	0.17 ± 0.07	0.11 ± 0.04
? (Bare ground clumpy) p (.)	236.50	15.14	0.00	0.00	0.28 ± 0.13	0.16 ± 0.07	8.41 ± 3.92
? (Bare ground 90m) p (.)	237.90	16.53	0.00	0.00	0.26 ± 0.09	0.19 ± 0.06	12.05 ± 5.93
? (Bare ground cohesion) p (.)	238.80	17.43	0.00	0.00	0.26 ± 0.01	0.18 ± 0.07	0.05 ± 0.02
? (Interspersion and Juxtiposition) p (.)	239.33	17.96	0.00	0.00	0.27 ± 0.10	0.18 ± 0.07	0.04 ± 0.02
? (Bare ground 250m) p (.)	237.67	18.31	0.00	0.00	0.31 ± 0.11	0.17 ± 0.06	23.43* ± 12.19
? (Year) p (.)	241.80	20.43	0.00	0.00	0.37 ± 0.14, 0.20 ± 0.09	0.18 ± 0.07	---
? (.) p (.)	**242.34**	**20.97**	**0.00**	**0.00**	**0.29 ± 0.10**	**0.18 ± 0.07**	---
? (Grass connect) p (.)	243.06	21.70	0.00	0.00	0.29 ± 0.11	0.18 ± 0.07	-0.04* ± 0.04
? (Bare ground connection) p (.)	243.21	21.84	0.00	0.00	0.29 ± 0.11	0.17 ± 0.07	0.03* ± 0.03
? (Shrub) p (.)	243.30	21.94	0.00	0.00	0.29 ± 0.11	0.17 ± 0.07	-1.97* ± 1.96
? (Row crop) p (.)	244.36	23.00	0.00	0.00	0.29 ± 0.10	0.18 ± 0.07	0.46* ± 2.45
? (Total edge) p (.)	244.36	23.00	0.00	0.00	0.29 ± 0.10	0.18 ± 0.07	0.00* ± 0.00

** 95% confidence interval crosses zero*

AICc = Akaike's Information Criteria with small sample bias adjustment

ΔAICc = Difference in AICc value between the current model and the best-fitting model

AICc weight= the conditional probability of each model

? = Occupancy estimation

p = Detectability estimation

Appendix Table 11: Modeling results for occupancy (±SE) and detectability (±SE) using percent cover and FRAGSTAT vegetation covariates for Prairie Warblers on Fort Campbell Military Reservation, Tennessee-Kentucky, May-July, 2009-2010.

Model	**AICc**	**ΔAICc**	**AICc Weights**	**Model Likelihood**	**ψ**	**p_1**	**p_2**	**p_3**	**β x**
ψ (Interspersion and Juxtiposition) p (survey)	759.21	0	0.44	1.00	0.82 ± 0.04	0.75 ± 0.04	0.65 ± 0.04	0.39 ± 0.04	0.05* ± 0.02
ψ (Grass 250m) p (survey)	760.30	1.09	0.26	0.52	0.85 ± 0.05	0.74 ± 0.04	0.64 ± 0.04	0.39 ± 0.04	8.87 ± 3.82
ψ (Grass cohesion) p (survey)	762.52	3.31	0.08	0.19	0.80 ± 0.03	0.75 ± 0.04	0.66 ± 0.04	0.39 ± 0.04	0.04 ± 0.01
ψ (Bare ground cohesion) p (survey)	765.48	6.27	0.02	0.04	0.80 ± 0.03	0.75 ± 0.04	0.66 ± 0.04	0.39 ± 0.04	0.04 ± 0.01
ψ (Total edge) p (survey)	765.73	6.52	0.02	0.04	0.80 ± 0.04	0.75 ± 0.04	0.65 ± 0.04	0.39 ± 0.04	0.00 ± 0.00
ψ (Row crop) p (survey)	767.57	8.35	0.00	0.02	0.80 ± 0.03	0.75 ± 0.04	0.66 ± 0.04	0.39 ± 0.04	-3.83 ± 1.55
ψ (Tree) p (survey)	770.44	11.23	0.00	0.00	0.80 ± 0.03	0.75 ± 0.04	0.65 ± 0.04	0.39 ± 0.04	-1.91* ± 1.16
ψ (Shrub) p (survey)	771.00	11.79	0.00	0.00	0.80 ± 0.04	0.75 ± 0.04	0.65 ± 0.04	0.39 ± 0.04	2.28* ± 1.70
ψ (Bare ground 90m) p (survey)	771.11	11.90	0.00	0.00	0.79 ± 0.03	0.75 ± 0.04	0.66 ± 0.04	0.39 ± 0.04	6.66* ± 5.38
ψ (.) p (survey)	**771.13**	**11.91**	**0.00**	**0.00**	**0.80 ± 0.03**	**0.75 ± 0.04**	**0.66 ± 0.04**	**0.39 ± 0.04**	**- - -**
ψ (Bare ground connection) p (survey)	771.48	12.26	0.00	0.00	0.80 ± 0.03	0.75 ± 0.04	0.65 ± 0.04	0.39 ± 0.04	-0.02* ± 0.02
ψ (Year) p (survey)	772.20	12.99	0.00	0.00	0.76 ± 0.05, 0.82 ± 0.04	0.75 ± 0.04	0.66 ± 0.04	0.39 ± 0.04	- - -
ψ (Bare ground clumpy) p (survey)	772.93	13.41	0.00	0.00	0.80 ± 0.03	0.75 ± 0.04	0.66 ± 0.04	0.39 ± 0.04	1.42* ± 1.82
ψ (Bare ground 250m) p (survey)	772.80	13.67	0.00	0.00	0.80 ± 0.03	0.75 ± 0.04	0.66 ± 0.04	0.39 ± 0.04	3.87* ± 6.71
ψ (Grass connect) p (survey)	772.89	13.37	0.00	0.00	0.80 ± 0.03	0.75 ± 0.04	0.66 ± 0.04	0.39 ± 0.04	-0.02* ± 0.03

** 95% confidence interval crosses zero*

AICc = Akaike's Information Criteria with small sample bias adjustment

ΔAICc = Difference in AICc value between the current model and the best-fitting model

AICc weight= the conditional probability of each model

ψ = Occupancy estimation

p = Detectability estimation

VITA

Emily Hockman was born in Brandon, Wisconsin, to Floyd and Loine Hockman. After graduating in 2001 from Laconia High School, Emily attended the University of Wisconsin-Eau Claire where she earned a Bachelor's Degree in Biology and a minor in Natural Sciences. She continued to explore and refine her field skills at a number of intern technician positions including working with prairie biodiversity in Minnesota, macaws and parrots in Peru, Golden-winged Warblers in Kentucky, Mississippi Sandhill Cranes in Mississippi, Golden-cheeked Warblers in Texas, bird banding in North Carolina, owl banding in Idaho, and bison and antelope grazing in South Dakota before accepting this graduate position at the University of Tennessee under Dr. David Buehler. She is continuing her education under the same advisor studying the use of aerial acoustic technology for monitoring avian species on military bases.