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Breeding Bird Response to Post Oak Savanna Restoration Seven Years Post Management In Eastern Texas

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BREEDING BIRD RESPONSE TO POST OAK SAVANNA RESTORATION 7 YEARS POST MANAGEMENT IN EASTERN TEXAS

By

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ABSTRACT

Oak savannas were once an abundant vegetation type in the Midwestern United States that have now declined to <1% of their original distribution. Historically, natural disturbances such as periodic fire and grazing maintained oak savannas, but these have been reduced or eliminated, resulting in woody encroachment and subsequent habitat loss and degradation. In 2009-10, a baseline, pre-restoration study was completed to determine vegetation characteristics, breeding bird abundances, nest success, and nest site selection at the Gus Engeling Wildlife Management Area (GEWMA) in eastern Texas. The results showed a lack of savanna vegetation structure on degraded sites and few savanna or grassland obligate bird species. The goal of this study was to determine how breeding birds of oak savanna vegetation types in eastern Texas respond to restoration effects 7 years after initial management. Post-restoration surveys completed in 2016-17 showed a change in avian assemblages from a more woodland dominated community to grassland/savanna community. The presence and breeding of savanna obligate species dickcissel (*Spiza americana*) and lark sparrow (*Chondestes grammacus*) indicates that the restoration was successful. The presence of savanna species can be linked to the herbaceous vegetation that was restored to more closely resemble historic oak savanna structure and can quantify the success of restoration efforts.

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And at last Axe ‘em Jacks

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CHAPTER 1: INTRODUCTION

Once an abundant vegetation type in the Midwestern United States, oak (*Quercus* spp.) savannas have declined to <1% of their original distribution (Fig. 1-1; Berger & Keyser 2013). Oak savannas are generally characterized by having an oak dominated canopy cover of 10-70% with a well-developed herbaceous ground layer. The 70% canopy cover in these communities can be found in mottes (i.e. groups or clusters of trees), another key characteristic of oak savannas. Historically, natural disturbances such as frequent fire and grazing maintained oak savannas. These once common natural events have been reduced or eliminated on contemporary landscapes, facilitating encroachment by woody vegetation and subsequent habitat loss and degradation for associated wildlife (Harrington & Kathol 2008). This has led to oak savannas being considered among the most threatened vegetation types in North America (Berger & Keyser 2013). Thus, conservation of remaining oak savannas and restoration of degraded sites is considered of high importance.

With the loss and degradation of oak savannas, the associated wildlife populations of these vegetation types have seen declines. For instance, populations of nearly 60% of breeding bird species in oak savannas exhibited declines from 1966 – 1998 (Brawn et al. 2001). Most of these declines have continued through the last decade (Sauer et al. 2014). Declining species that are associated with oak savanna include: red-headed woodpecker (*Melanerpes erythrocephalus*), lark sparrow (*Chondestes grammacus*), northern bobwhite (*Colinus virginianus*), and eastern kingbird (*Tyrannus tyrannus*; Berger and Keyser 2013). Birds are the most noticeable component of oak savanna wildlife communities, are sensitive to vegetation changes, and are easily surveyed using standard methodologies (Ralph et al. 1993, Davis et al. 2000, Cantrell et al. 2011). Therefore, birds are useful when assessing the response of wildlife to oak savanna restoration.

The post oak savanna of Texas is the southernmost extension of the oak savanna ecoregion of the Midwest (Nuzzo 1985), and is the ecotone from the East Texas Pineywoods to the Blackland Prairie ecoregion to the west. Texas is divided into ten ecoregions, of which post oak savanna encompasses 31 counties and covers approximately 3.5 million hectares (Fig. 1-2; Texas Parks and Wildlife Department 2015). Only an estimated 10% of the historic Texas post oak savanna remains (Sampson & Knopf 1994).

Few studies have documented the success of restoration attempts in post oak savanna systems, especially regarding the resident bird communities (Davis et al. 2000). Fire, herbicide, and mechanical treatments have been used in oak savanna restoration and have been shown to be effective in creating appropriate habitat structure (Brawn et al. 2001). In most cases, oak savanna restoration begins with reducing the canopy cover to mimic more historic levels of 5-30% (Berger & Keyser 2013). The most common option is a commercial timber harvest where most trees and debris can be removed from the site. The open canopy and the reintroduction of fire are important to encourage the development of an herbaceous-dominated understory.

Timber harvests influence breeding bird communities by discouraging mature forest species such as Carolina chickadee (*Poecile carolinensis*) and favoring early successional or gap species such as yellow-breasted chat (*Icteria virens*) and hooded warbler (*Setophaga citrina*; Brawn et al. 2001). When fire has been used for an extended period, insectivorous bark-gleaning species such as red-headed woodpeckers and omnivorous ground or lower canopy feeding species such as indigo bunting (*Passerina cyanea*) and field sparrow (*Spizella pusilla*) increase in abundance (Davis et al. 2000). A fully restored oak savanna habitat in Texas would support a suite of typical avian species for the cover type; these species are intolerant to dense canopy cover or tree density and have evolved to inhabit grass-dominated systems. During the breeding season, regional bird species that are indicative of open-woodlands and savannas include: painted bunting (*Passerina ciris*), indigo buntings, dickcissel (*Spiza americana*), and lark sparrow (Holoubek & Jensen 2015).

The Gus Engeling Wildlife Management Area (GEWMA) is a state-owned post oak savanna research and demonstration area located in Anderson County, Texas. The property was acquired by Texas Parks & Wildlife Department (TPWD) from 1950-1960 under the Pittman-Robertson Act using Federal Aid in Wildlife Restoration Program funds. GEWMA is an isolated area of post oak savanna surrounded by coastal bermudagrass (*Cynodon dactylon*) pastures, second growth forests, and fragmented wildlife habitat. GEWMA has not been impacted as much as most of the surrounding area, with records showing that the area was moderately livestock grazed, but was not drastically cleared. Further evidence of reduced anthropogenic impacts includes mature bottomlands still found along the creeks and native tallgrasses still found in open woodlands and pastures.

Shortly after acquisition, nearly 200 hectares of the GEWMA property was restored to closely resemble historic oak savanna habitat by removing most of the large trees and shrub-oak understory. Prescribed fire and other forms of mechanical treatments have been used to maintain these patches of oak savanna since the late 1950’s (Texas Parks and Wildlife Department 2015a). In 2010, an additional 150 hectare post oak savanna restoration project was initiated. Overstory woody canopy was mechanically removed, reserving designated mottes, or groups of trees, to mimic historic vegetation structure. Since 2007, the restored area has been burned on a 2-3 year rotation and herbicide used as needed to control resprouting oaks and other woody vegetation.

Before the 2010 restoration began, a pre-restoration project was initiated to monitor the progress and success of the restoration by determining the baseline conditions. Specifically, avian diversity and abundance was measured in previously restored and encroached compartments to determine a baseline avian assemblage assessment and evaluate the success of management practices (e.g. fire, herbicide, and timber harvest) in maintaining savanna conditions (Comer & Lundberg 2011). The goal of the pre-restoration study was to conduct a baseline assessment of avian species composition and reproduction, specifically for grassland and early-successional songbirds to evaluate current and future restoration success for post oak savanna habitat at GEWMA. Although pre-restoration study showed an abundance of early successional generalists associated with oak savannas, such as indigo and painted buntings. There were few grassland or savanna obligate species, such as dickcissels and northern bobwhite, present during the breeding season.

An additional approximately 700 hectares of degraded post oak savanna was thinned in 2015 and fire was used on the area starting in winter of 2016 on a 2-4 year rotation. The thinning reduced the density from over 1,000 trees to around 300 trees per hectare. The expectation is that the heavy thinning will open the canopy enough to allow herbaceous vegetation in the seed bank to establish and flourish.

To complement and follow-up the baseline surveys, TPWD and Stephen F. Austin State University (SFASU) have collaborated to perform additional breeding bird and vegetation surveys. The project included comparing breeding bird data in restored, unrestored, and reference compartments with data from baseline surveys. The emphasis was placed on the expected change in avian communities from woodland and generalist species to grassland species.

In Chapter II, I determined avian abundance, density, species richness, and avian assemblage composition in restored post oak savannas in Eastern Texas. I also surveyed avian assemblages in reference savanna communities and adjacent, unrestored areas for comparative purposes. I conducted surveys during the breeding seasons (April—July) of 2016 and 2017. I also compared the avian assemblage to the results of pre-restoration surveys conducted in 2009 (Comer & Lundberg 2011). My expectations were that if the oak savanna restoration efforts achieved the desired outcomes, I would see an increase in abundances of birds typical of oak savannas, such as dickcissel and lark sparrow. Furthermore, I expected to see vegetation structural changes to more closely resemble historic oak savannas in the region, such as a well-developed herbaceous layer and reduced canopy cover

In Chapter III, I quantified avian reproductive success and nest site characteristics for target bird species in restored post oak savannas in Eastern Texas. I also searched reference savanna compartments and adjacent, unrestored areas for comparative purposes. I searched for nests during the breeding seasons (May—July) of 2016 and 2017. My expectations were that if oak savanna restoration efforts have achieved the desired outcome, I would see successful breeding of birds typical of oak savannas, such as dickcissel and painted bunting.

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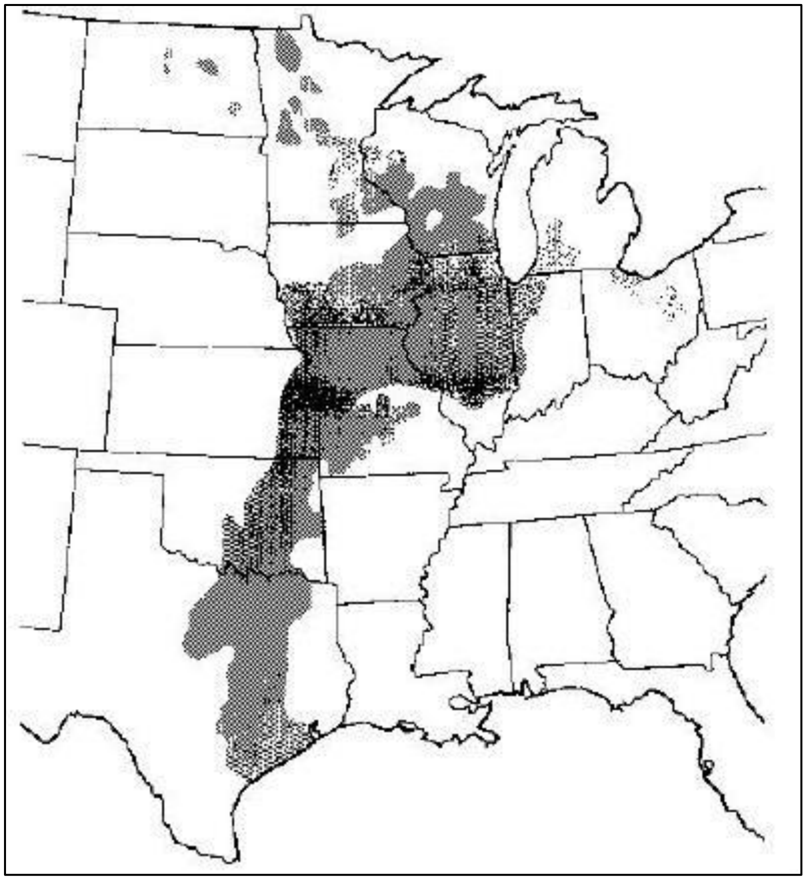

Figure 1-1. Estimated pre-settlement distribution of the midwestern oak savannas (Nuzzo 1985).

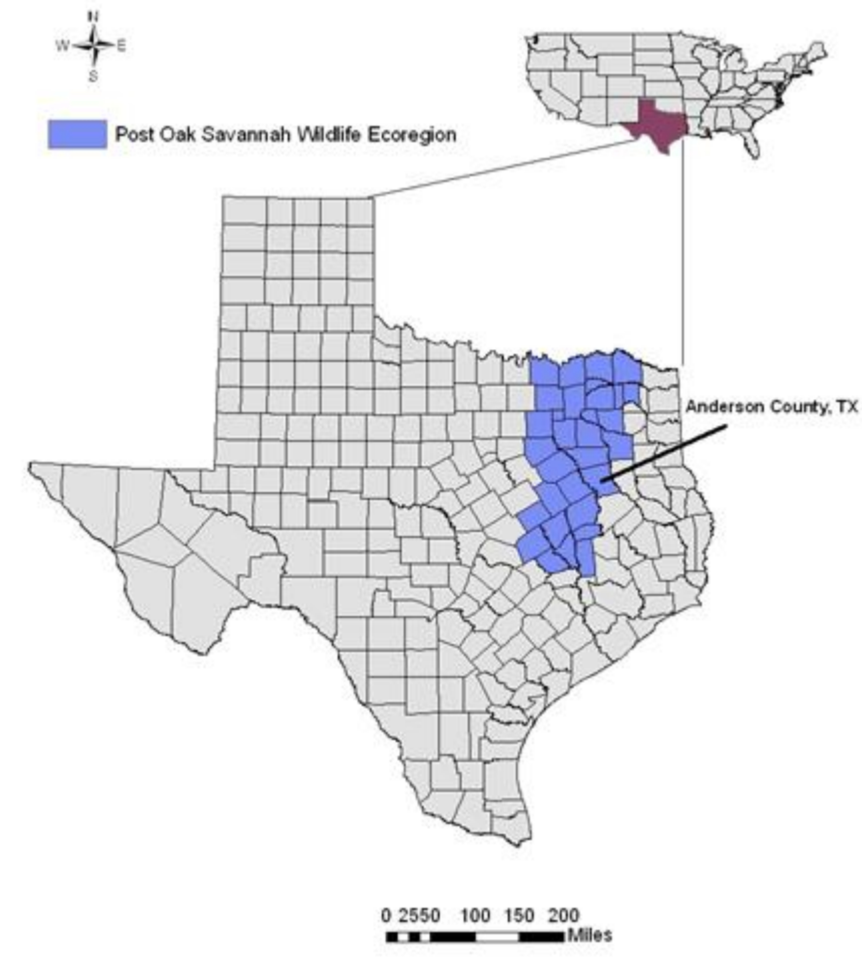

Figure 1-2. The Post Oak Savannah wildlife ecoregion encompasses 31 counties in east Texas, including Anderson County – where Gus Engeling Wildlife Management Area is located.

CHAPTER II

AVIAN ASSEMBLAGE RESPONSE TO POST OAK SAVANNA RESTORATION IN EASTERN TEXAS

ABSTRACT

Historically, oak savanna vegetation types covered some 46 million hectares (ha) of the Midwestern United States. Oak savannas are known for their open, park-like appearance, with large scattered oaks and a well-defined herbaceous-dominated understory. Oak savanna distribution can be linked to periodic disturbances such as fire, grazing, and drought that reverse or slow the closure of the canopy. In response to the regional loss and degradation of oak savannas, associated wildlife populations have experienced long-term declines that reflect loss of high-quality savanna communities. For example, 70% of disturbance-dependent bird species in the United States have experienced declines that have continued through the last decade. Most are associated with early successional habitats and can be found in grasslands, oak savannas, and open forest communities. Grassland breeding birds are highly susceptible to habitat fragmentation due to effects on nest success and reproductive rates. Few studies have documented the success of restoration attempts in post oak savanna systems, especially in regard to the resident bird assemblages. A fully restored oak savanna habitat in Texas should support a suite of typical avian species; these species are intolerant to dense canopy cover or tree density and have evolved to inhabit grass-dominated systems. In this study, I determined

avian abundance, density, species richness, and avian assemblage composition in restored post oak savannas at the Gus Engeling Wildlife Management Area (GEWMA) in Eastern Texas.

The 2010 restoration at GEWMA was at least partially successful, reflected in the vegetation changes that closely resemble historic characteristics. The avian assemblage also showed indications of successful restoration, as evidenced by the appearance of typical grassland obligate species following restoration efforts in 2010. Dickcissels (*Spiza americana*) had minor detections, one bird was detected in 2009, while lark sparrows were not detected during the breeding season in 2009. By 2017, dickcissel density in the restored sites was similar to densities recorded on tallgrass prairie and other high-quality habitat in the southern portion of its range. While I found the avian composition to be similar between the reference and restored treatments, the structure and composition of the herbaceous layer varied. The restored area had a significantly higher density of bunchgrasses, especially little bluestem. I observed a sparser herbaceous layer in the reference treatment. This could be linked to the amount of time since restoration in the reference and restored treatments. Overall the vegetation structure and avian assemblage resemble those expected for historic oak savanna communities. My observations of the vegetation and avian assemblage composition provides evidence that restoration was successful.

INTRODUCTION

Historically, oak savanna vegetation types covered some 46 million hectares (ha) of the Midwestern United States, extending from southern Wisconsin southward into Iowa, Illinois, Missouri, and across parts of eastern Kansas, Oklahoma, and Texas (Fig. 2-1; Temple 1998, Lorimer 2001). The canopy cover of oak savannas can range from 10-70%, and is dominated by fire-resistant oak species such as bur oak (*Quercus macrocarpa*) and post oak (*Quercus stellata*) with a well-developed, herbaceous layer dominated by a diverse assemblage of fire-adapted grasses and forbs (Brawn et al. 2001, Berger & Keyser 2013). This appearance suggests that oak savannas in North America are transitional ecotones between deciduous forests to the east and expansive prairies to the west (Temple 1998).

In savanna communities of the southern great plains, the herbaceous understory is typically comprised of tall grass prairie species (e.g., big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and indiangrass (*Sorghastrum nutans*) and a diverse forb community (Berger & Keyser 2013). The woody components of oak savannas are found in mottes that occur in wet or undisturbed areas. Tree species typically found in southern oak savannas include: post oak, southern red oak (Quercus falcata), black hickory

(*Carya texana*), and blackjack oak (*Quercus marilandica*). The understory in the wooded mottes differs from the open savanna (Berger & Keyser 2013) by having shade-tolerant trees and shrubs such as flowering dogwood (*Cornus florida*), American beautyberry (*Callicarpa americana*), and yaupon (*Ilex vomitoria*).

Oak savanna distribution can be linked to periodic disturbance such as fire, grazing, and drought that reverse or slow the closure of the canopy (Harrington & Kathol 2008). The natural fire regime of oak savanna was established by periodic lightning strikes and ignitions by Native Americans (Berger & Keyser 2013). Fires historically occurred in the post oak savanna region with a mean return interval of 6 years, until current anthropogenic activities altered the fire regime (Wolf 2004). Fire also plays a significant role in keeping the park-like structure of oak savannas and prevents them from becoming woodlands by eliminating woody regrowth. As a natural disturbance, fire increases native plant species richness and diversity by reducing the buildup of organic matter and encouraging new herbaceous growth. Fire plays a critical role in the productivity of native grasses by destroying excess organic matter and increasing mineral availability (Wolf 2004).

In response to the regional loss and degradation of oak savannas, associated wildlife populations have experienced long-term declines that reflect loss of high-quality savanna communities (Brawn et al. 2001). For example, 70% of disturbance-dependent bird species in the United States have experienced declines that have continued through the last decade according to the North American Breeding Bird Survey (BBS; Hunter et al. 2001, Sauer et al. 2014). Most are associated with early successional habitats and can be found in grasslands, oak savannas, and open forest communities (Hunter et al. 2001).

Birds that breed in oak savannas occupy a variety of niches and microhabitats, including tree canopies, oak regeneration, grasses, and mottes. Because they provide many microhabitats, oak savannas can support a high diversity of breeding birds. Grassland breeding birds are highly susceptible to habitat fragmentation due to effects on nest success and reproductive rates (Herkert et al. 2003). There has been growing evidence that relates patch size to the likelihood of grassland bird occurrence and species abundance, where reduced patch size is often associated with lower likelihood of occurrence or reduced abundance (Fletcher & Koford 2002).

Landscape structure can also affect grassland bird habitat use by affecting movements, altering interactions among species, and changing edge effects (Fletcher & Koford 2002). Landscape-scale analysis suggests that occurrence of 60% of bird species can be linked to the degree of canopy cover (Cantrell et al. 2011). With the recent emphasis on grassland and savanna restoration in the US, it is important to consider whether restored areas provide high quality habitat for breeding birds and to identify areas most suitable for restoration. For example, Shahan et al. (2017) discussed the importance of landscape context in evaluating areas for community restoration. Understanding the landscape around a focal patch can provide information about potential source populations and help decide which areas would benefit most from habitat restoration. They recommend that future restoration and habitat management plans should include an understanding of the landscape context surrounding the focal area by at least 4 km. The plan should include not only total area of various cover types but also information about their configuration (e.g., type and amount of edge), depending on target species' habitat preferences (Shahan et al. 2017). Oak savannas are a heterogeneous landscape; therefore, it is important to keep or restore the varied vegetation community to maintain a high diversity of species (Cantrell et al. 2011).

Few studies have documented the success of restoration attempts in post oak savanna systems, especially in regard to the resident bird communities (Davis et al. 2000). Canopy reduction and the reintroduction of fire are important to encourage the development of an herbaceous-dominated understory. The removal of overstory trees should influence breeding bird assemblages by discouraging mature forest species and favoring early successional, gap, and grassland species. In Texas, a fully restored oak savanna habitat should support a suite of typical avian species, that are intolerant to dense canopy cover or tree density and have evolved to inhabit grass-dominated systems. Bird species that are indicative of open-woodlands and savannas regionally during the breeding season include: painted bunting (*Passerina ciris*), indigo bunting (*Passerina cyanea*), dickcissel (*Spiza americana*), and lark sparrow (*Chondestes grammacus*; Holoubek & Jensen 2015).

In this study, I determined avian abundance, density, species richness, and avian assemblage composition in restored post oak savannas in Eastern Texas. I also surveyed avian assemblages in reference savanna compartments and adjacent, unrestored areas for comparative purposes. I conducted surveys during the breeding seasons (April-July) of 2016 and 2017, and I compared the avian assemblages to the results of pre-restoration surveys conducted in 2009 (Comer & Lundberg 2011). My expectations were that if the oak savanna restoration efforts achieved the desired outcomes, I would see an increase in abundances of birds typical of oak savannas, such as dickcissel and lark sparrow. Furthermore, I expected to see vegetation structural changes to more closely resemble historic oak savannas in the region, such as a well-developed herbaceous layer and reduced canopy cover. Along with the increase of typical oak savanna species, I expected to see a decline in woodland avian species and a decrease in woody understory cover.

METHODOLOGY

Study Site

The study was conducted at the Gus Engeling Wildlife Management Area (GEWMA), a state-owned post oak savanna research and demonstration area located in Anderson County, Texas (Fig. 2-2). GEWMA is an isolated area of remnant, restored, and degraded post oak savanna surrounded by coastal bermudagrass (*Cynodon dactylon*) pastures, second growth forests, and poor-quality habitat for many native wildlife species. Specifically, I conducted my study on the northwest section of the GEWMA, which is approximately 1,000 ha and broken into 9 compartments, 8 of which were utilized (Fig. 2-3). The northwest section of the GEWMA was chosen in 2007-8 for a savanna restoration project, primarily because of its soil and vegetative cover. Much this area is comprised of Darco fine sand soils and Tonkawa fine sands, which are somewhat excessively drained, have low water storage availability, and can support typical savanna vegetation types.

The eight compartments in the northwest section of GEWMA comprised three different treatments: reference, restored, and unrestored. Compartments F and G represented reference compartments of 62 ha and 112 ha, respectively, and served as reference areas for desired oak savanna conditions. These compartments were established shortly after acquisition in the 1950s and have been consistently maintained using prescribed fire, herbicide, and mechanical treatments (i.e. mowing, mulching, tree removal) for more than 50 years. These compartments contain mature scattered trees which have allowed the return of a well-developed herbaceous layer which includes bunchgrasses and a diverse forb component.

Compartments A and B were restored to post oak savanna conditions in 2010 and are 57 ha and 136 ha, respectively. Pre-2010 lack of disturbance in these compartments had resulted in an open woodland or forest structure, with dense mature trees in the overstory and an understory dominated by woody regeneration. As part of the restoration plan, a timber harvest was completed in these compartments in 2010 to remove woody overstory and reduce canopy cover, followed by regular herbicide and prescribed fire treatments to control woody regeneration and encourage an herbaceous understory. Currently these compartments contain mature scattered trees, mostly in designated mottes and a well-developed herbaceous understory comprised of mostly bunchgrasses.

The other six compartments range in size from 53-200 ha. These unrestored compartments are similar to pre-restoration conditions in the restored compartments. Specifically, they have been heavily encroached with woody vegetation and lack the desired herbaceous understory. They exceed typical canopy cover for an oak savanna but were subjected to a heavy thinning in 2015;

the canopy cover is now closer to the historic range, but still higher than the reference and restored compartments. The understory is still lacking the well-developed herbaceous component and instead consists of dense oak regeneration. Follow-up treatment with prescribed fire and herbicide have not yet been used on the unrestored compartments.

Breeding Bird Surveys

I determined breeding bird abundances in reference, restored, and unrestored compartments using distance sampling on line-transects (Comer & Lundberg 2011). Line transects create less bias, use less field time, and are considered the most efficient method to accurately survey avian populations (Buckland et al. 2006). Two, 500 meter (m) transects were placed in each compartment using a random point generator and random azimuth. Each transect was restricted to be >100 m from edges and roads, and >250 m from adjacent transects to reduce edge effects and ensure the independence of each survey (Fig. 2-4; Igl & Ballard 1999, Fritcher et al. 2004). The only exception was in reference compartment F, where the small portion composed of reference oak savanna did not allow for a 500-m transect that met the buffer requirements. In this compartment, I used two 150-m transects that were similarly randomly located. These transects were surveyed three times rather than once within a single survey period to account for the shorter transect lengths (Buckland et al. 2001).

I surveyed transects bi-weekly from 29 April to 10 July in 2016 and from 30 April to 8 July in 2017; transects were surveyed from 1 May to 15 July in 2009. I conducted surveys within the first 3.5 hours of daylight and completed the survey no faster than a pace of 1.0 km/hour (Igl & Ballard 1999, Thomas et al. 2002, Fritcher et al. 2004). I identified birds based on sight or sound, identified detected birds to species and estimated their position by taking an azimuth using a compass and estimating distance using an optical range finder. I used azimuth and distance to calculate perpendicular distances from bird sightings to transect lines. I also recorded the time, sex, and method of detection (sight or sound) for each individual (Buckland et al. 2001, Buckland 2006). Birds were only recorded at the location the individual was first detected. Birds seen flying over the site, but not landing, were not recorded (Buckland et al. 2001). Surveys were only completed on days with fair weather conditions and were not performed on days when weather was not suitable for bird activity or detection (e.g., rain, winds above 16 kilometers per hour, smoke or fog; Igl & Ballard 1999).

Vegetation Sampling

I conducted a vegetative assemblage assessment for each compartment to quantify the overall vegetation structural characteristics (N= 228 vegetation points total). I randomly placed 15 points within 250 m of each avian survey transect, except in compartment F, where nine points were placed on each short transect (Fig. 2-5). Vegetation characteristics for each compartment were measured within a 11.3 m radius circular plot (Fig. 2-6). I identified all woody stems ≥8-cm dbh within the 11.3 m radius plot and measured each diameter at breast height (dbh), to determine trees per hectare (TPH) and basal area per hectare.

I identified and counted all woody stems <8-cm dbh and ≥50-cm tall within a smaller 5-m radius plot centered inside the larger plot (Martin et al. 1997). Also, within each quadrant of the larger plot I used a randomly-located 1-m^2 quadrat to estimate percent herbaceous and woody ground cover. For each 1-m^2 quadrant, I recorded the 5 most dominant plant species based on six cover classes: 0-5%, 5-25%, 25-50%, 50-75%, 75-95%, and 95-100% (Daubenmire 1959). I also estimated canopy cover using a spherical densiometer at each cardinal direction and a mean value obtained (Lemmon 1957).

For pre-restoration vegetation assessment, Comer and Lundberg (2011) used 50 random plots in each compartment. Woody cover was estimated using the line-intercept method, which included a 25-m transect at a random azimuth. The herbaceous ground cover was measured using the 1-m^2 quadrant on alternating sides of the transect at 5-m intervals. The point-center-quarter method was used to quantify overstory vegetation. Basal area was also recorded at 5-m and 20-m using a 10-factor prism (Comer & Lundberg 2011).

Statistical Analysis

Using 2-way Analysis of Variance (ANOVA), I examined differences in herbaceous species by class (bunchgrasses, grasses/sedges/others, legumes, forbs, and woody), tree species richness, tree density (trees per hectare), andbasal area (m^2/ha) among treatments (reference, restored, and unrestored) and years (2009, 2016, 2017) using Statistical Analysis System (SAS) v.9.2 (Ribic et al. 2009). Data were tested for normality using the Shapiro-Wilks test and homogeneity using the Levene's test in SAS. Count data was transformed using square root and percent data was transformed using the arcsine when data did not meet the assumptions. Where initial ANOVAs suggested differences among treatments or years, I used Tukey's HSD post-hoc test to further identify those differences ($\alpha = 0.05$).

I estimated breeding bird densities using the program DISTANCE 7.0. Density is defined as the number of individuals per unit area, where *D* is density, *n* is the total number of individuals recorded within the compartment, and *a* is the total area of the compartment (Marques 2009);

$$D = \frac{n}{a},$$

However, this formula does not take into account individuals that are present during the transect surveys but not detected during the sampling period (Marques 2009). For this reason, I used program DISTANCE to estimate the probability of detecting an individual given that the individual is within the area of the transect survey. The program used the perpendicular distance of each detected bird from the transect line to create a histogram of the number of detections based on distance to the transect (Diefenbach et al. 2003). The detection function then fits a curve to the data and provides the detection probability, *P*, at any given distance from the transect (Buckland et al. 2001).

The first step in the distance data analysis is exploratory graphical analysis. A detection curve function was fitted to the most frequently detected bird species, as well as certain target species, using the raw detection data (Buckland et al. 2001, Rosenstock et al. 2002, Tucker et al. 2004). I classified abundant species as having over 200 detections. Target species included avian species that are considered grassland or savanna obligates (e.g., dickcissel, lark sparrow) and representative generalist early-successional species (e.g., painted and indigo buntings). I used the goodness-of-fit test and Akaike's Information Criterion corrected for small sample sizes (AIC_c), to verify the model fit and for model selection (Rosenstock et al. 2002, Burnham & Anderson 2004). I used the most parsimonious model for each species to calculate density in the reference, restored and unrestored compartments and for each sample year (Diefenbach et al. 2003).

I calculated richness and diversity of breeding bird assemblages found in restored and reference blocks (Jost 2006, Ott & Longnecker 2010). Given the before-and-after comparison of breeding bird abundances pre- and post-restoration, I used tests among treatments (reference, restored, and unrestored) and years (2009, 2016, 2017) to compare species detections (per 1,000 meters of transect surveyed) using Statistical Analysis System (SAS) v.9.2 (Ribic et al. 2009). For these analyses, I included species with insufficient detections to derive density estimates but that were detected in at least 4 compartments during at least 2 survey years. Data were square root transformed when data did not meet the normality or homogeneity assumptions of ANOVAS. I also compared total numbers of detections for several groups of bird species that were based on the Birds of North America species' accounts habitat preferences: woodland, open woodland, grassland, habitat generalist, and generalist early successional (The Birds of North America 2015).

RESULTS

Vegetation Assessment

I detected 66 species in the understory, versus 87 species in 2009 (Appendix 2-A). Bunchgrasses had the greatest percent cover (21%) in the restored treatment, while the unrestored treatments were dominated by woody vegetation and forbs had the most cover (19%) in the reference compartments (Table 2-1). The only vegetation class that did not differ among treatments or years was legumes, which were a minor component of vegetation cover (<10%, Table 2-1).

I detected nine tree species that made up the overstory basal area. The most dominant species were post oak (48%), black hickory (20%), and bluejack oak (18%; *Quercus incana*). The unrestored compartments had the highest average basal area at 8.3 m^2/ha, while both the reference and restored treatments had a basal area of 3.7 m^2/ha (Table 2-2). Treatment (P=0.0015) and year (P <0.0001) were all significant predictors for basal area following ANOVAS. Basal area in the reference compartments was similar in 2009 and post-restoration in 2016; however, basal area declined in restored and unrestored compartments from 2009 to 2016 (Table 2-2). Basal area was similar across treatments in 2016 (Table 2-2).

Tree stem density varied based on treatment (*P*=0.0291) and year (*P*=0.0042) based on ANOVAS. The unrestored compartments had the highest tree density of 150 trees per hectare (TPH), while the reference and restored treatments were 65 TPH and 70 TPH, respectively (Table 2-2). TPH in the reference compartments was similar in 2009 and post-restoration in 2016; however, TPH declined in restored and unrestored compartments from 2009 to 2016 (Table 2-2). TPH was similar across treatments in 2016. For canopy cover, treatment (*P*=0.0070) and year (*P*=<0.0001) were both significant following ANOVAS. The unrestored compartments had the highest canopy cover percentage of 39%, while the reference and restored treatments had canopy covers of 16% and 18%, respectively (Table 2-2). Canopy cover in the reference compartments was similar in 2009 and post-restoration in 2016; however, canopy cover declined in restored and unrestored compartments from 2009 to 2016 (Table 2-2). Canopy cover was similar across treatments in 2016.

Avian Assemblage

I encountered 52 bird species in 2016 and 49 bird species in 2017, compared to the 39 bird species detected in 2009 (Appendix 2-B). Species richness was similar across all treatments and years (Table 2-3). Mean species richness per compartment in 2016-2017 ranged from 23 (Compartment I) to 33 (Compartment A; Table 2-4).

I was able to derive density estimates for nine species: blue-gray gnatcatcher (*Polioptila caerulea*), brown-headed cowbird (*Molothrus ater*), Carolina chickadee (*Poecile carolinensis*), dickcissel, indigo bunting, northern cardinal (*Cardinalis cardinalis*), painted bunting, tufted titmouse (*Baeolophus bicolor*), and yellow-billed cuckoo (*Coccyzus americanus*; Table 2-5). Dickcissels were not detected in 2009 surveys, but increased to 2.9 birds/ha and 5.4 birds/ha in the reference and restored compartments, respectively in 2017 (Table 2-5). Blue-gray gnatcatcher density generally increased in all treatments from pre-restoration to post restoration; this was particularly evident in the restored compartments where density went from 1.4 to 6.4 birds/ha. Northern cardinals decreased slightly in density in the restored treatments but increased moderately in unrestored compartments. Yellow-billed cuckoos declined in density in all treatments and did not occur at all in reference areas post-restoration. Species that saw no change or inconsistent changes from 2009 to 2017 in the restored compartments included both woodland species (Carolina chickadee, tufted titmouse) and generalist early-successional species (indigo bunting, painted bunting, Table 2-5).

Based on detections (number of detections per 1,000 meters of transect surveyed) I ran ANOVAs for six species with three different habitat preferences. Open woodland species included blue grosbeak (*Passerina caerulea*), Carolina wren (*Thryothorus ludovicianus*), and great-crested flycatcher (*Myiarchus* *crinitus*). Grassland species included eastern kingbird (*Tyrannus tyrannus*) and scissor-tailed flycatcher (*Tyrannus forficatus*). The only true woodland species was summer tanager (*Piranga rubra*, Table 2-6). Two of the open woodland species (blue grosbeak and great-crested flycatcher) were not present in 2009. Scissor-tailed flycatchers were detected more frequently in restored and reference compartments than in unrestored compartments in both 2016 and 2017, and summer tanagers declined in 2017 in the restored compartments (Table 2-6).

I separated bird species based on their habitat preference and compartments using detections to get abundance indices (number of detections per 1,000 meters of transect) and richness (Fig. 2-7, Table 2-7, Appendix 2-B). There were more woodland species detected in all years than generalist early-successional or grassland species (Table 2-7). When broken down based on compartment, generalist early-successional and grassland birds combined were more species rich than woodland birds for restored and reference compartments in 2016 and 2017 (Table 2-7). When compared to 2009, there was an increase in grassland and open woodland species for both the reference and restored compartments in 2017, but a decrease in woodland species in same compartments (Fig. 2-7).

DISCUSSION

For effective habitat restoration the parameters of a successful community restoration must be defined with subsequent monitoring to determine which projects meet those objectives (Miller & Hobbs 2007). Specifically, it is important to conduct surveys both pre- and post-restoration and to have control (untreated) locations to quantify response to restoration activity (Brawn et al. 2001). At GEWMA, I expected to see an increase in abundance and occurrence of grassland birds in response to the restoration efforts initiated in 2010. This was true in that the grassland obligate dickcissel was present and abundant at the study site.

There is a considerable debate about the appropriate amount of canopy cover in a true oak savanna, but the widely accepted range is 10-40% (Asbjornsen et al. 2005). While canopy cover at GEWMA in 2017 ranged from 12% in compartment F (reference) to 59% in compartment J (unrestored), the mean canopy cover for both the reference and restored treatments fell within the typical range for an oak savanna (see Table 2-2). Similarly, basal area in the reference and restored compartments closely resembled historic oak savannas which typically had overstory basal area between 3 and 7 m2/ha (Barrioz et al. 2013, Berger & Keyser 2013). Unfortunately for comparison purposes, basal area, canopy cover, and woody understory cover in the unrestored treatment reflected the heavy thinning that was completed in 2015. This process changed the compartments from the pre-restoration baseline results; however, they still acted as degraded/unrestored treatments, since they had not been completely restored to historic vegetation characteristics.

I recorded many herbaceous species that are key components of oak savannas, including little bluestem, beggar tick (*Desmodium* spp.), lespedeza (*Lespedeza* spp.), and broomsedge (*Andropogon virginicus*; Appendix 2-A). However, the herbaceous layer differed among treatments. The restored compartments exhibited the most well-developed bunchgrass component, dominated by little bluestem. While the herbaceous layer in the reference compartments was more diverse, with fewer bunchgrasses and greater forb diversity. This may reflect the extremely deep, droughty sands that underlie the reference compartments and prevent the growth of dense grass cover. When comparing the soils in the reference and restored compartments, there is a distinct difference. The reference compartments are comprised of mostly of Tonkawa soil series, very deep, excessively drained sands that doesn't have the structure or water retention to support a diverse herbaceous understory. The restored compartments are comprised of mostly Darco soil series, deep loamy fine sands that is somewhat excessively drained that can better support the herbaceous understory of oak savannas (Fig 2-9). Finally, the vegetative response to the 2015 thinning in unrestored compartments consisted primarily of dense woody regeneration.

The 2010 restoration at GEWMA was at least partially successful, reflected in both the vegetation and avian assemblage. The strongest evidence of this was the appearance of typical grassland obligate species following restoration efforts in 2010. Dickcissels had minor detections, one bird was detected, while lark sparrows were not detected during the breeding season in 2009 (Comer & Lundberg 2011). Furthermore, in TPWD surveys from 2004-2010, dickcissels were not detected anywhere on the sites (C. Shackelford, Texas Parks and Wildlife Department, unpublished data). By 2017, dickcissel density in the restored sites was similar to densities recorded on tallgrass prairie and other high-quality habitat in the southern portion of its range (Dechant et al. 2002).

Interestingly, dickcissel density on the reference compartments went from non-detected in 2009 to nearly 3 per hectare in 2017 despite very little change in vegetation characteristics on these compartments. The precise reason that these grassland birds colonized the reference area is unknown, but it may reflect changes in total area of suitable habitat at the site. The dickcissel is considered “moderately area sensitive,” and the minimum grassland patch size for dickcissel occurrence was approximately 10 ha in Illinois and Nebraska (Herkert 1991, Helzer & Jelinski 1999). Positive relationships between patch size and abundance or reproduction have been seen in some studies (Swengel 1996, Winter 1996).

The 2009 pre-restoration oak savanna covered <200 ha, while the post-restoration oak savanna covered >400 ha after the 2010 restoration efforts. Although 200 ha is sufficient to support dickcissels, it may be that the larger area after 2010 was more attractive to these birds. In addition, the restored compartments may provide better nesting habitat for dickcissels than the reference compartments. Suitable nesting habitat varies across the range, but studies consistently identify dense, tall grassy cover as an important characteristic (Dechant et al. 2002). As my data and personal observations at the site show, grass cover was considerably denser and taller in the restored sites than on the reference sites; the presence of higher quality nesting habitat in the restored compartments may have attracted nesting dickcissels to the site.

The increased presence of dickcissels (and to a lesser extent lark sparrows) in 2016-17 is in contrast to another native savanna species. Bachman's sparrows (*Peucaea aestivalis*) have been present at the site during the breeding season at low abundance (<10 pairs) since at least 2004, primarily in the reference compartments (C. Shackelford, Texas Parks and Wildlife Department, unpublished data). This species is threatened in the state of Texas, and the hope was that increasing the area of suitable habitat would lead to an increase in abundance. However, I observed little change in abundance and these birds were only rarely observed in the restored compartments.

Bachman's sparrows are dependent on dense grassy understory and frequent fire for nesting; therefore, the restored compartments should be suitable for them. These birds are resident in the area and are relatively sedentary; therefore, it may be that the restored compartments were sufficiently far from existing populations that they were unable to colonize. There is approximately 1 km of unsuitable unrestored woodlands between the closest reference sites (with Bachman's sparrows) and the restored compartments, which is within the typical dispersal distance for this species (3 km; Taillie et al. 2015). The pre-restoration population of Bachman's sparrows was small and had low productivity (Comer & Lundberg 2011; C. Shackelford, Texas Parks and Wildlife Department, personal communication). Comparing the two species, dickcissels are a migratory species and have an average site fecundity of 60%, while Bachman's sparrows are local residents (Walk 2004 and Dunning 2018). Furthermore, the landscape surrounding GEWMA is such that the occurrence of potential source populations of Bachman's sparrows is extremely unlikely. In contrast, dickcissels and lark sparrows are common migrants throughout the region and have a source population migrating though each year.

While painted buntings are not grassland birds, they are a generalist early successional species and occupy a variety of habitats. They prefer habitats with a high edge-to-area ratio with nearby open areas for foraging such as treelines (Vasseur & Leberg 2015). Painted buntings occupy edges of tree clusters in otherwise open habitats (Kopachena & Crist 2000). Restoration left mottes which created edges and the oak regeneration provided varying amounts of woody growth which can be used for singing perches. These habitat characteristics may explain why the density of painted buntings increased from 2009 to 2017 even though they are not considered a grassland species.

Interestingly, the density of woodland species did not decrease in the restored treatment despite a reduction in basal area and canopy cover, but remained similar (Table 2-5; The Birds of North America 2015). This can be attributed to the mottes, groups or clusters of trees, that were not cleared or thinned during the 2010 restoration and provided the woody cover needed by these species. Woodland species were detected in, around, and traveling between the remaining mottes. Barrioz et al. (2013), modeled avian species response to oak savanna restoration and showed a lack of relationships between restoration and vegetation characteristics, but rather that the woodland species with a wide geographic range and presence of a gradient of sites can occupy habitats from mature woodlands to oak savannas. Vander et al. (2016), also found that while implementing open oak woodland and savanna restoration and management you are benefiting disturbance-dependent birds and have minimal negative impacts on the presence of late-successional woodland bird species.

The fact that woodland species did not decline after restoration supports oak savannas as ecological ecotones between forests and prairies and that they can provide habitat for both woodland and grassland species (Barrios et al. 2013).

While avian composition was similar between the reference and restored treatments, the structure and composition of the herbaceous layer varied. The restored area had a significantly higher density of bunchgrasses, especially little bluestem (Table 2-1), but I observed a sparser herbaceous layer in the reference treatment. This could be linked to the amount of time since restoration in the reference and restored treatments. Overall, the vegetation structure and avian assemblage resemble those expected for historic oak savanna communities.

The vegetation and avian assemblage composition provide evidence that restoration was successful. The future of disturbance-dependent and grassland bird conservation relies on the ability to create a mosaic of grassland habitats across the landscape (Davis et al. 2000 and Ribic et al. 2009). When selecting land to restore, it is very important to look at the surrounding landscapes and source populations for target avian species. Restoration areas that are larger in size and in close proximity to other restored or remnant savannas should have a higher priority to increase the function of the areas. While success can occur at isolated projects, such as the GEWMA, it is important to monitor the success of each area to understand the dynamics of restoration.

Restoring post oak savannas is a multi-step process that takes time and commitment. It is important to understand that the vegetation will represent an oak savanna while still not hosting obligate avian species. It is also important to note that even with restoring oak savanna, the current avian woodland species can still thrive and persist creating an even more diverse habitat while increasing species richness. This study provides insight into the results of vegetation cover following canopy reduction and heavy woody regeneration control. This study along with others can continue to make a difference and give us a better understanding of post oak savanna restoration.

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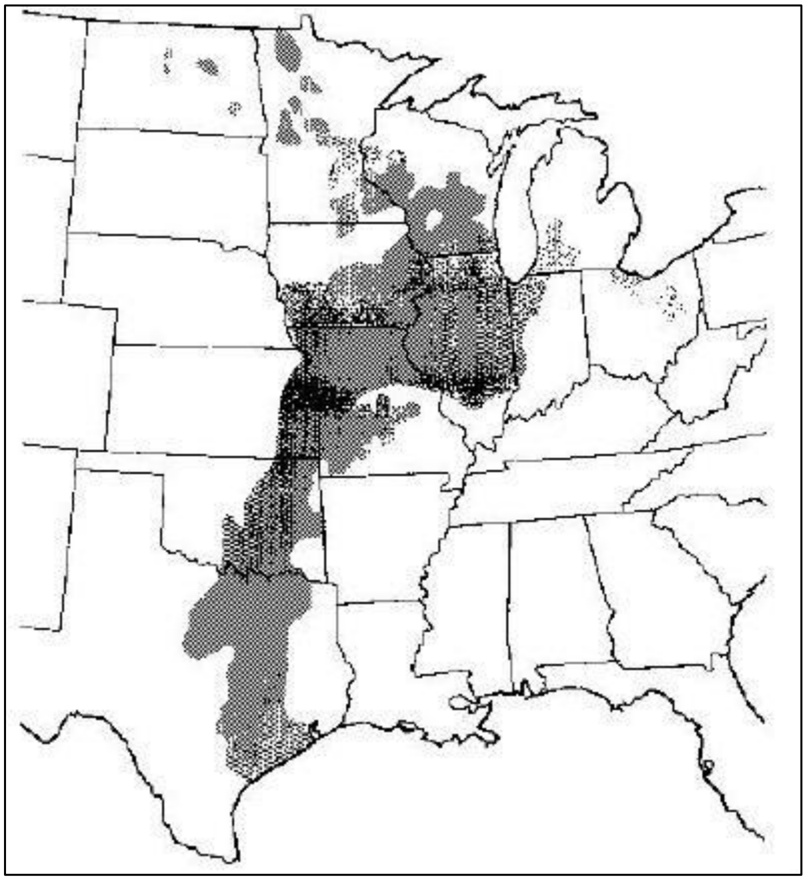


Figure 2-1. Estimated pre-settlement distribution of the midwestern oak savannas in the United States (Nuzzo 1985).

Figure 2-2. Location of the primary study area at the Gus Engeling WMA in Anderson County Texas, used for avian and vegetation surveys during the breeding seasons of 2009, 2016, and 2017.

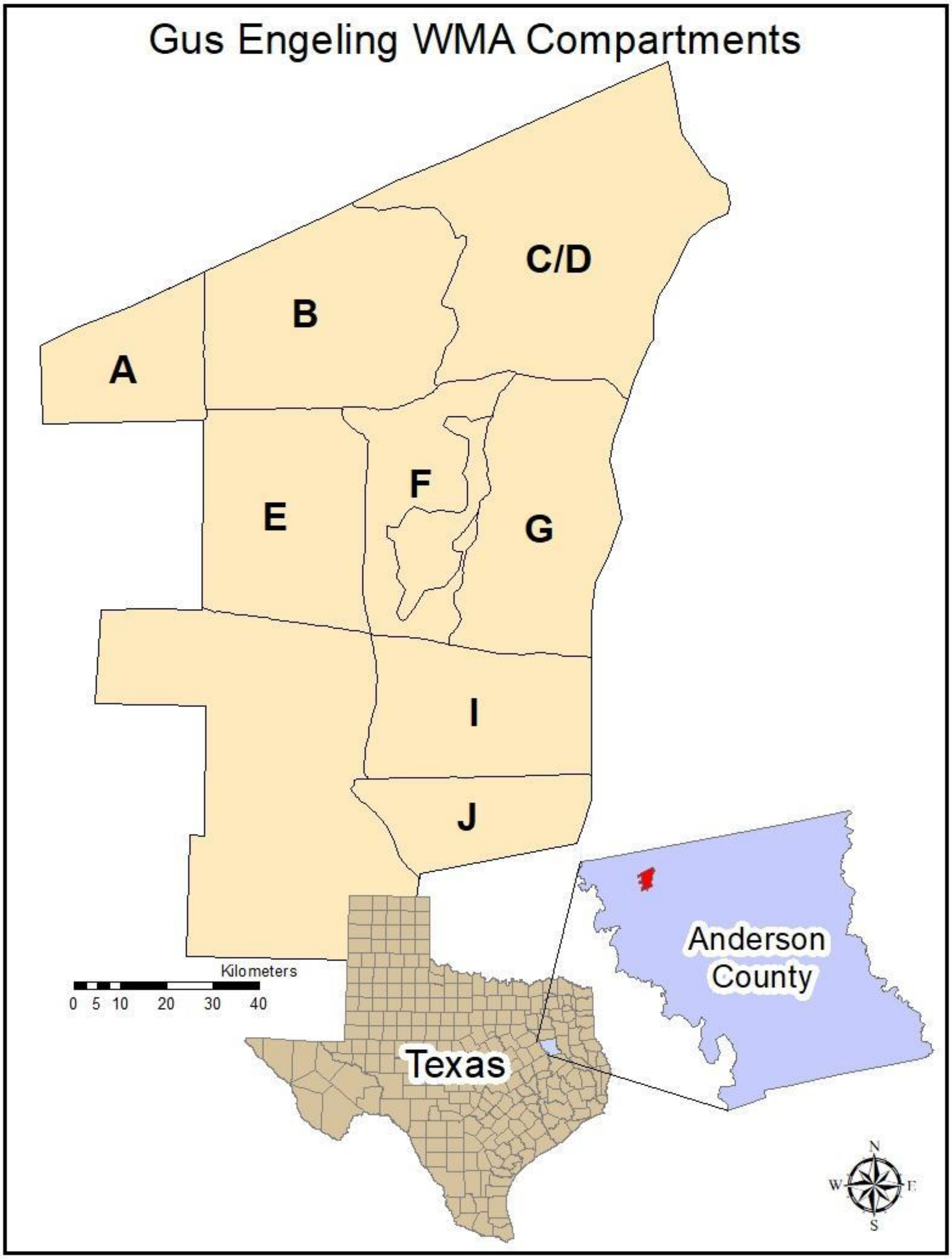


Figure 2-3. Northwest section of Gus Engeling Wildlife Management Area showing study compartments used for avian and vegetation surveys during the breeding seasons of 2009, 2016, and 2017.

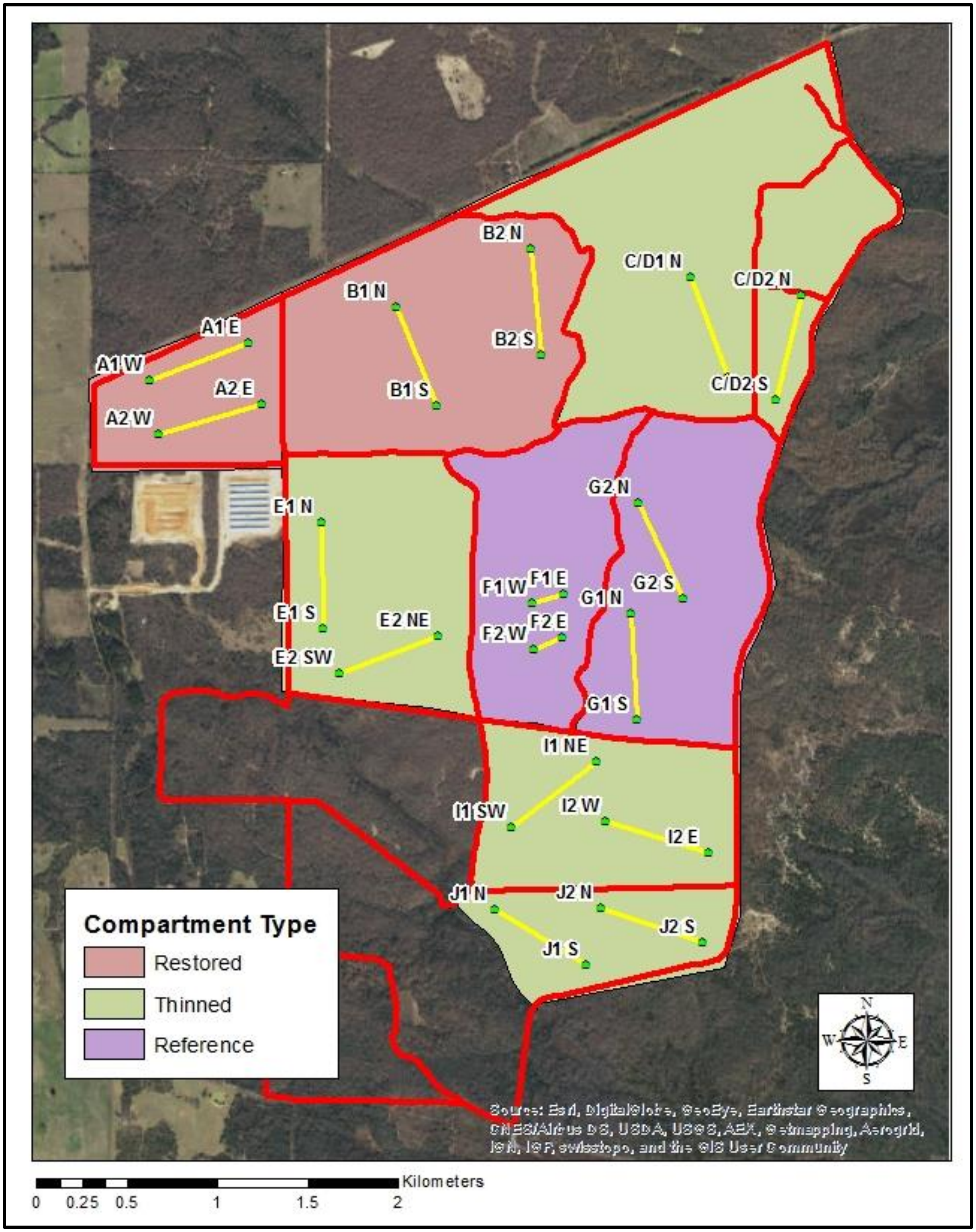


Figure 2-4. Northwest section of Gus Engeling Wildlife Management Area showing study compartments and line transect locations used for avian transect surveys during the breeding seasons of 2009, 2016, and 2017.

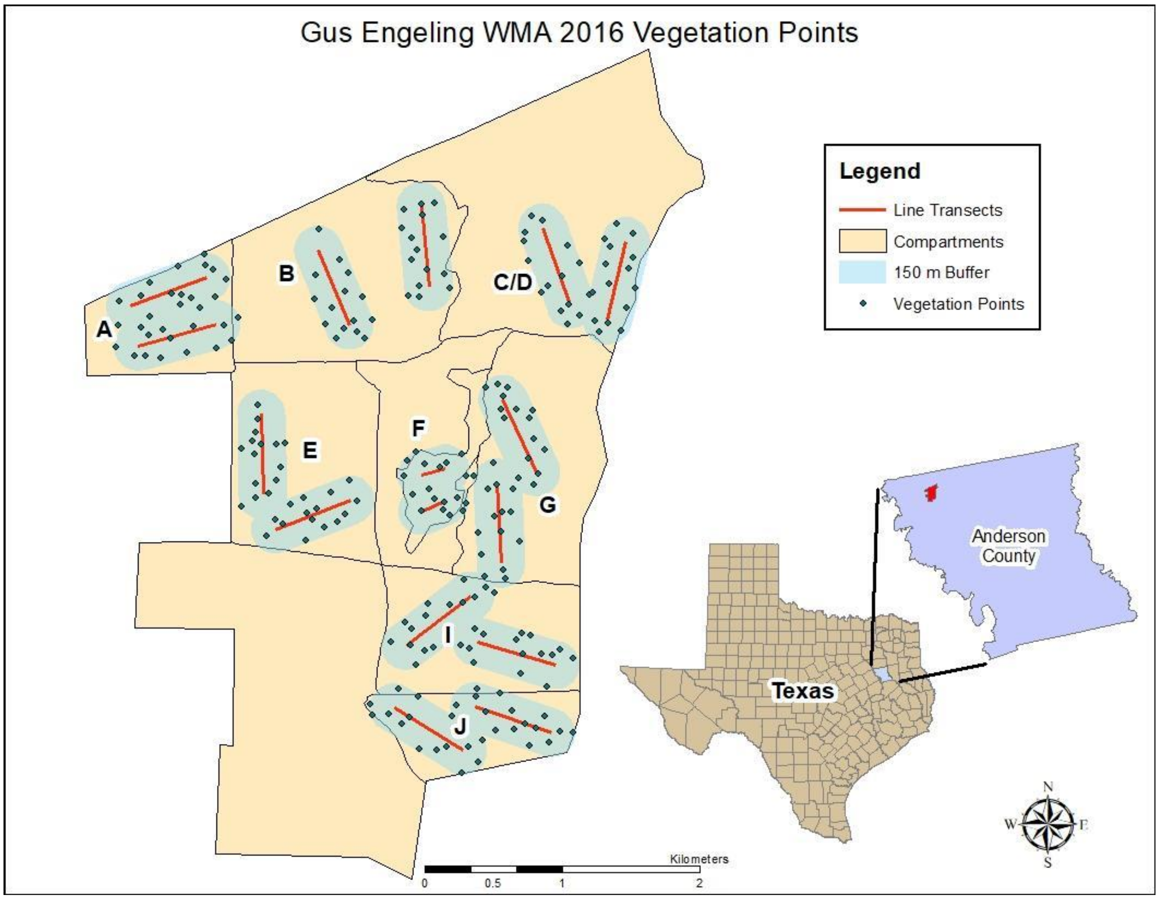


Figure 2-5. Northwest section of Gus Engeling Wildlife Management Area showing study compartments, line transect locations, and vegetation points used for avian transect surveys during the breeding seasons of 2009, 2016, and 2017.

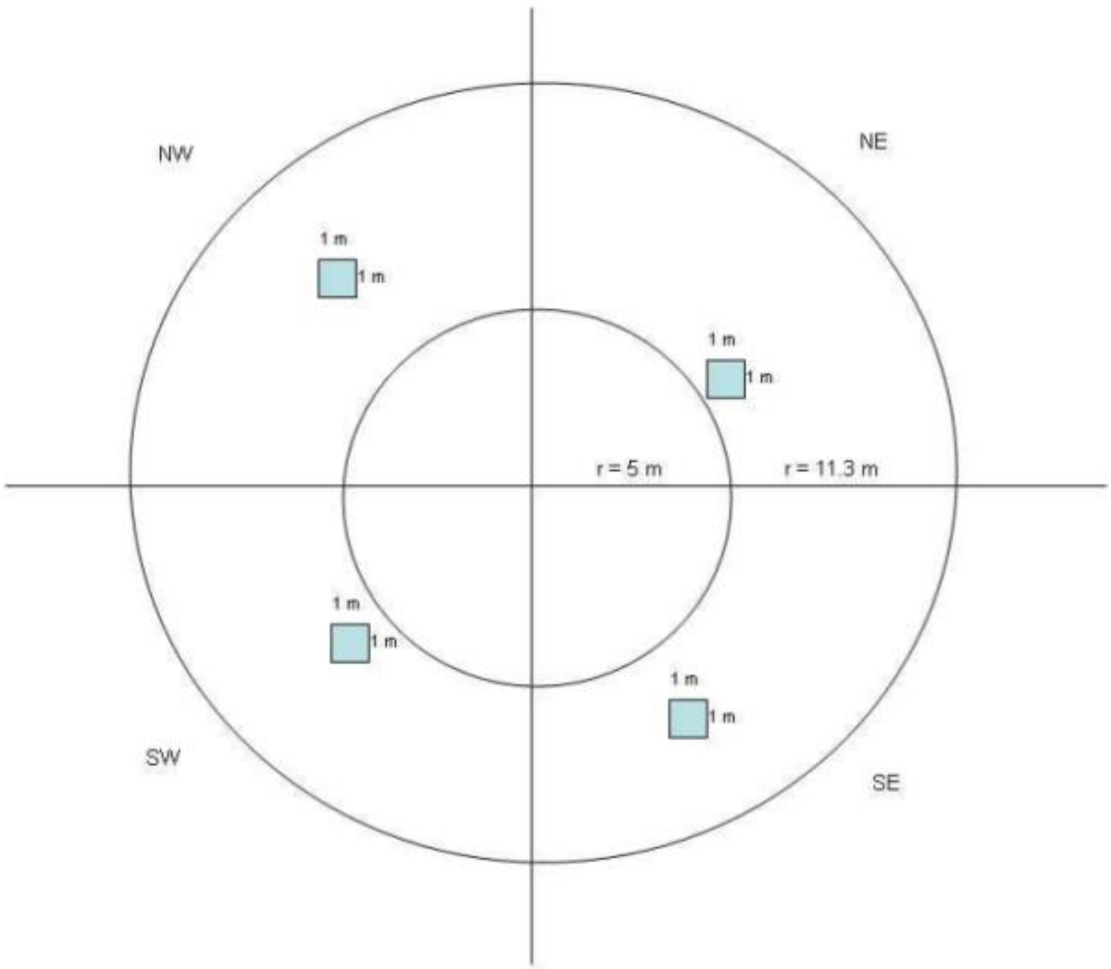


Figure 2-6. Plot arrangements for vegetation measurements used at points in study blocks at Gus Engeling Wildlife Management Area in Anderson County, Texas as presented in Comer and Lundberg (2011).

Figure 2-7. Avian species richness for various species groups compared among treatment types and years at Gus Engeling Wildlife Management Area in Anderson County, Texas during the breeding seasons of 2016 and 2017.

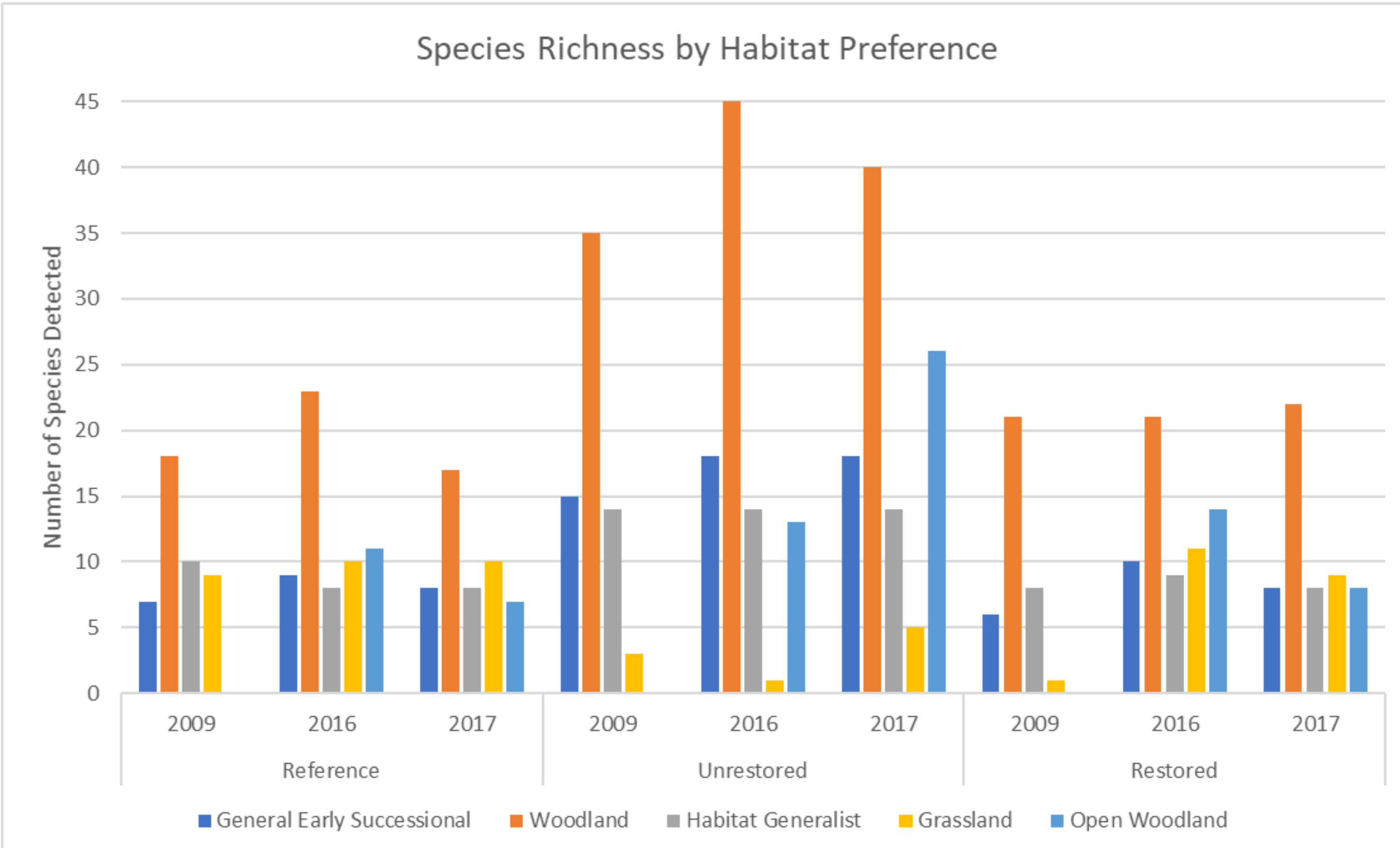
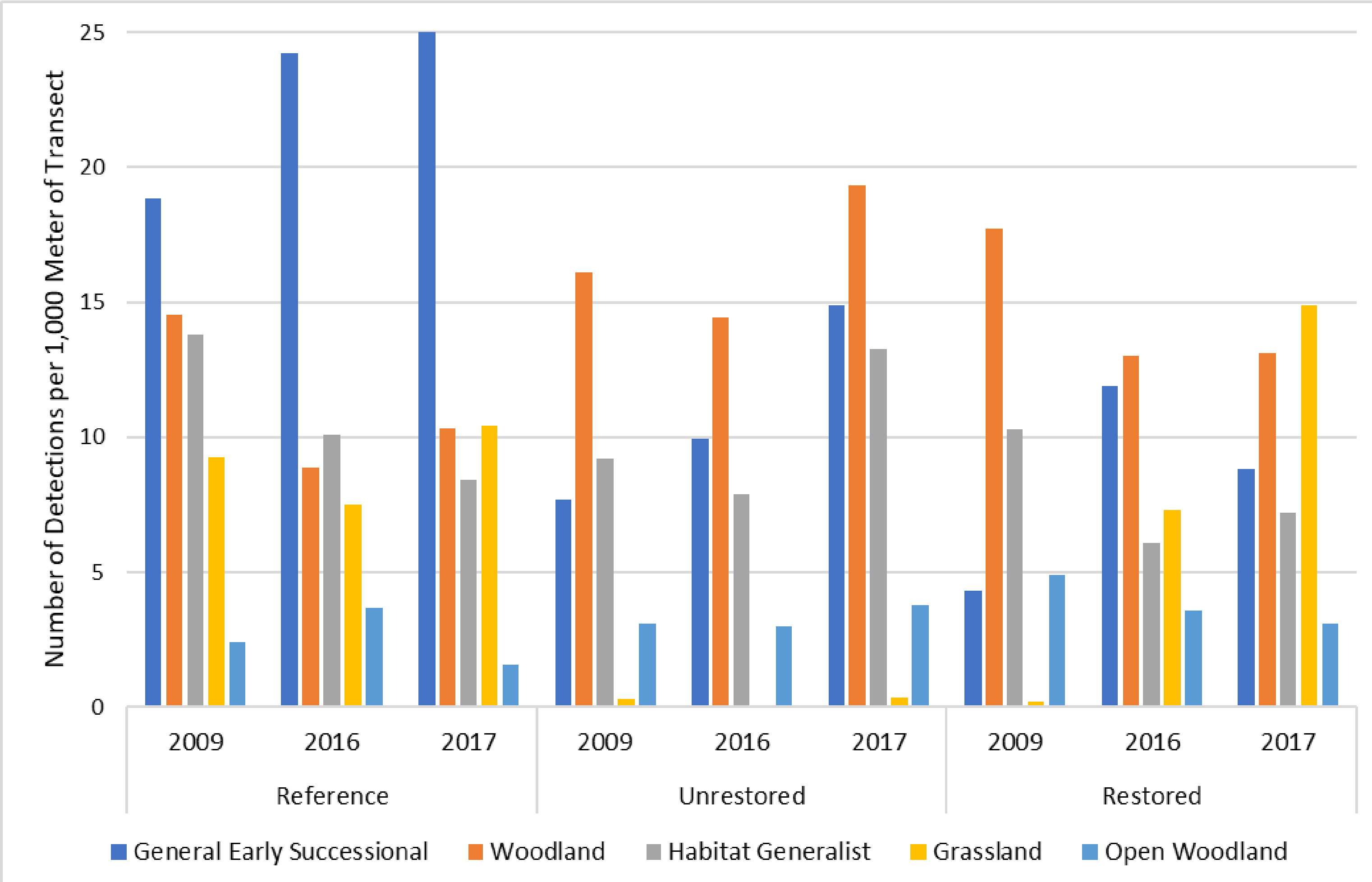


Figure 2-8. Number of detections per 1,000 meters of survey transect for various species groups compared among treatment types and years at Gus Engeling Wildlife Management Area in Anderson County, Texas during the breeding seasons of 2016 and 2017.



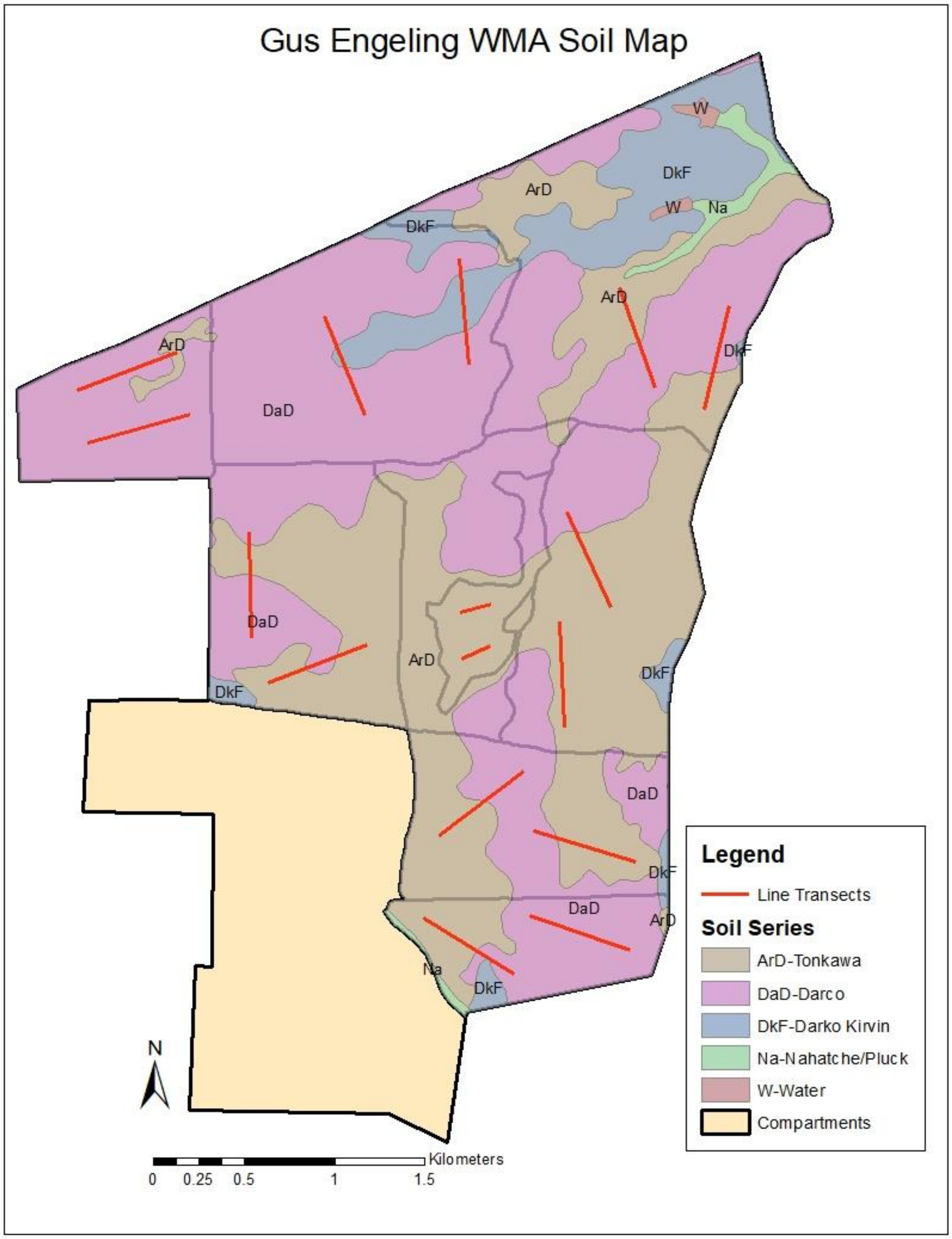


Figure 2-9. Soil types for study site at Gus Engeling Wildlife Management Area in Anderson County, Texas. Soil data obtained from National Resources Conservation Service.

Table 2-1. Mean understory cover percentages based on vegetation class, treatment, and year for vegetation surveys at Gus Engeling WMA, Anderson County, Texas in summer 2009 and 2016. Means followed by the same letter within the same row are not different following a significant (p-value <0.05) ANOVA result.

Vegetation Class	Reference		Unrestored		Restored	
	2009	2016	2009	2016	2009	2016
Bunchgrass	6.74 A	10.33 A	4.95 A	9.67 A	1.90 A	21.61 B
Forb	22.00 A	11.04 A	7.43 A	5.16 A	1.70 B	12.11 A
Grass/Sedge	13.17 A	5.09 B	13.47 A	8.13 B	27.59 A	5.04 B
Legume	6.75 A	7.54 A	3.14 A	3.51 A	2.71 A	0.75 A
Woody	6.62 B	11.84 A	6.73 A	19.24 A	11.81 A	7.02 A

Table 2-2. Means and standard deviations for basal area (m^2/ha), tree density (trees per hectare), and canopy cover (decimal percent) based on treatment and year at Gus Engeling WMA, Anderson County, Texas, in summer 2009 and 2016. Letters in each set of rows for each variable that are the same are not different following a significant (p-value <0.05) ANOVA result.

Variable	Year	Reference		Unrestored		Restored	
		Average	Std Dev	Avg	Std Dev	Avg	Std Dev
Basal Area	**2009**	8.05B	2.8991	26.48A	6.1424	36.90A	9.1924
	2016	3.74B	0.1273	8.26B	2.8072	3.70B	1.3011
Tree Density	**2009**	507.95AB	35.9917	385.55A	201.8923	83.15AB	35.4261
	2016	70.40AB	4.1012	150.23B	52.2536	65.00AB	9.4752
Canopy Cover	**2009**	0.83AB	0.0283	0.72AB	0.0938	0.39B	0.0495
	2016	0.18A	0.0636	0.39AB	0.1749	0.16A	0.0566

Table 2-3. Number of avian species detected in each year and treatment for Gus Engeling Wildlife Management Area in Anderson County, Texas during the breeding seasons of 2009 and 2016.

Year	Reference	Unrestored	Restored
2009	28	26	25
2016	36	33	41
2017	32	43	34

Table 2-4. Total species richness, number of avian species detected in each compartment and year for Gus Engeling Wildlife Management Area in Anderson County, Texas during the breeding seasons of 2009, 2016, and 2017.

Year	Compartment	General Early Successional	Woodland	Habitat Generalist	Grassland	Open Woodland
2009	A	3	9	4	0	0
	B	3	12	4	1	0
	C	4	9	4	1	0
	E	2	9	3	1	0
	F	3	9	5	5	0
	G	4	9	5	4	0
	I	5	9	4	0	0
	J	4	8	3	1	0
2016	A	5	10	5	7	9
	B	5	11	4	4	5
	C	5	11	3	0	2
	E	4	12	3	1	3
	F	4	12	4	5	6
	G	5	11	4	5	5
	I	5	10	5	0	4
	J	4	12	3	0	4
2017	A	4	12	4	5	4
	B	4	10	4	4	4
	C	6	12	4	1	8
	E	4	10	3	2	6
	F	4	8	4	6	3
	G	4	9	4	4	4
	I	4	7	4	1	5
	J	4	11	3	1	7

Table 2-5. Select avian species density estimates, standard error (SE), 95% confidence interval (CI), and detection probability (p) for each year at Gus Engeling Wildlife Management Area in Anderson County, Texas during the breeding seasons of 2016 and 2017. Density estimates and detection probabilities came from Program DISTANCE. Where detections were too low dashes were used to hold blank spaces.

Species	Year	Unrestored					Reference					Restored				
		Density	SE	95% CI		p	Density	SE	95% CI		p	Density	SE	95% CI		p
Blue-gray Gnatcatcher	2009	1.4261	0.2244	1.0374	1.9605	0.29	1.8689	1.0066	0.6373	5.4800	0.16	1.4400	0.3195	0.8981	2.3090	0.20
	2016	3.4076	0.4452	2.5992	4.4675	0.16	5.2338	3.1671	1.0614	25.8080	0.13	0.9869	0.4724	0.3151	3.0918	0.26
	2017	6.3976	0.6072	5.2706	7.7655	0.17	2.7696	0.7423	1.5058	5.0943	0.24	2.9723	0.5209	2.0473	4.3152	0.15
Brown-headed Cowbird	2009	0.7358	0.3376	0.2837	1.9086	0.18	1.4001	0.6948	0.3335	5.8770	0.53	-	-	-	-	-
	2016	0.5305	0.2063	0.2265	1.2423	0.38	3.6791	1.7940	0.9038	14.9760	0.35	1.1557	0.3645	0.5870	2.2754	0.33
	2017	0.5724	0.1136	0.3711	0.8830	0.56	1.2688	0.2309	0.8102	1.9870	0.62	-	-	-	-	-
Carolina Chickadee	2009	1.7449	0.2709	1.2665	2.4039	0.22	1.1565	0.5588	0.3534	3.7851	0.61	1.0189	0.5416	0.2800	3.7077	0.28
	2016	1.8624	0.3572	1.2488	2.7866	0.16	-	-	-	-	-	0.8793	0.3458	0.3148	2.4560	0.34
	2017	1.5784	0.4609	0.8314	2.9967	0.24	1.5109	0.4409	0.8219	2.7774	0.35	1.8139	0.7097	0.7375	4.4617	0.20
Dickcissel	2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2016	-	-	-	-	-	-	-	-	-	-	0.6881	0.2746	0.2404	1.9696	0.46
	2017	-	-	-	-	-	2.8957	2.3755	0.5938	14.1200	0.17	5.3918	1.2247	2.9547	9.8391	0.30
Indigo Bunting	2009	1.0772	0.5196	0.3743	3.1003	0.31	2.8334	1.3371	0.7885	10.1820	0.50	-	-	-	-	-
	2016	1.8169	0.4674	1.0222	3.2295	0.26	1.6635	0.4249	0.8732	3.1690	0.50	0.7109	0.3874	0.1604	3.1514	0.44
	2017	2.7990	0.5165	1.8748	4.1789	0.27	2.4784	0.5443	1.3223	4.6452	0.53	0.3969	0.1986	0.1025	1.5367	0.61
Northern Cardinal	2009	2.8704	0.2626	2.3862	3.4528	0.35	2.5794	1.9182	0.5622	11.8350	0.30	4.2510	1.1656	2.1407	8.4415	0.22
	2016	3.5833	0.4958	2.7028	4.7506	0.20	2.5437	0.8842	1.1596	5.5797	0.30	1.7671	0.9324	0.6292	4.9627	0.21
	2017	5.2660	0.8087	3.8213	7.2568	0.21	1.0464	0.3661	0.4543	2.4103	0.53	2.1670	0.5355	1.0832	4.3355	0.27
Painted Bunting	2009	1.7528	0.5044	0.9318	3.2972	0.28	6.8260	3.1896	1.9898	23.4170	0.25	2.3461	0.8348	1.1549	4.7659	0.16
	2016	2.2466	0.4010	1.5149	3.3319	0.22	9.0744	4.1739	2.3115	35.6240	0.29	2.7654	0.6519	1.4787	5.1719	0.32
	2017	2.9803	0.2874	2.4200	3.6703	0.30	10.2550	5.3933	2.1730	48.4000	0.30	1.9975	0.5369	0.9267	4.3055	0.37
Tufted Titmouse	2009	1.9691	0.2735	1.4907	2.6011	0.44	0.8132	0.2215	0.3471	1.9051	1.00	3.1959	0.7012	1.9640	5.2005	0.29
	2016	1.3716	0.2311	0.9636	1.9524	0.23	0.9300	0.4559	0.2544	3.3998	0.31	1.6671	0.6269	0.7283	3.8158	0.19
	2017	2.1173	0.6601	1.1118	4.0322	0.17	0.2153	0.1665	0.0356	1.3022	0.92	3.2144	1.4200	1.1833	8.7313	0.12
Yellow-billed Cuckcoo	2009	1.4787	0.2247	1.0724	2.0389	0.30	1.0813	0.5078	0.3192	3.6631	0.45	2.1743	0.1785	1.8437	2.5640	0.32
	2016	0.5011	0.1203	0.3009	0.8344	0.40	-	-	-	-	-	0.9397	0.5408	0.2908	3.0363	0.18
	2017	0.3922	0.1200	0.2063	0.7457	0.56	-	-	-	-	-	1.4506	1.0079	0.3644	5.7750	0.15

Table 2-6. Mean select avian species number of detections per 1,000 meters of transect surveyed and standard deviations (SD) based on year and treatment at Gus Engeling Wildlife Management Area in Anderson County, Texas during the breeding seasons of 2016 and 2017. Detections followed by the same letter within the same row are not different following a significant (p-value <0.05) ANOVA result comparing treatments in a certain year. Letters

Species	Year	Unrestored		Reference		Restored		F-score	P-value
		Mean	SD	Mean	SD	Mean	SD		
Blue Grosbeak	**2009**	0.00 A(A)	0.0000	0.00 A(A)	0.0000	0.00 A(A)	0.0000		
	2016	0.05 A(A)	0.1000	0.87 A(A)	0.6576	0.30 A(A)	0.4243	3.63	0.0151
	2017	0.30 A(A)	0.2582	0.62 A(A)	0.2546	0.70 A(A)	0.4243		
Carolina Wren	**2009**	1.50 A(A)	0.8083	2.58 A(A)	1.3859	2.90 A(A)	0.7071		
	2016	1.40 A(A)	0.3266	0.32 B(A)	0.1697	0.50 AB(A)	0.4243	4.86	0.0042
	2017	0.70 A(A)	0.3464	0.30 A(A)	0.4243	0.90 A(A)	0.7071		
Eastern Kingbird	**2009**	0.15 A(A)	0.3000	1.98 A(A)	2.2345	0.20 A(A)	0.2828		
	2016	0.00 A(A)	0.0000	0.62 B(A)	0.2546	1.20 C(A)	0.2828	2.21	0.0882
	2017	0.15 A(A)	0.1915	0.67 A(A)	0.9405	0.20 A(A)	0.2828		
Great-crested Flycatcher	**2009**	0.00 A(A)	0.0000	0.00 A(A)	0.0000	0.00 A(A)	0.0000		
	2016	0.95 A(B)	0.6807	1.59 A(B)	0.2687	0.80 A(B)	0.2828	5.75	0.0018
	2017	0.55 A(AB)	0.3000	0.20 A(A)	0.2828	0.10 A(AB)	0.1414		
Scissor-tailed Flycatcher	**2009**	0.00 A(A)	0.0000	6.06 A(A)	7.1488	0.00 A(A)	0.0000		
	2016	0.00 A(A)	0.0000	7.26 B(A)	5.4518	2.50 AB(B)	0.4243	3.69	0.0141
	2017	0.10 A(A)	0.2000	7.44 B(A)	4.5750	1.90 AB(AB)	0.7071		
Summer Tanager	**2009**	2.25 A(A)	1.0116	2.72 A(A)	2.4324	2.90 A(A)	1.2728		
	2016	2.30 A(A)	0.5774	1.15 A(A)	0.3606	2.50 A(A)	0.1414	1.24	0.3441
	2017	2.85 A(A)	0.2517	1.45 B(A)	0.7849	1.30 B(A)	0.4243		

Table 2-7. Species richness measured at Gus Engeling Wildlife Management Area in Anderson County, Texas during the breeding seasons of 2016 and 2017 separated by treatment type, year, and avian species habitat preference.

Treatment	Year	General Early Successional	Woodland	Habitat Generalist	Grassland	Open Woodland
Reference	2009	7	18	10	9	0
	2016	9	23	8	10	11
	2017	8	17	8	10	7
Unrestored	2009	15	35	14	3	0
	2016	18	45	14	1	13
	2017	18	40	14	5	26
Restored	2009	6	21	8	1	0
	2016	10	21	9	11	14
	2017	8	22	8	9	8

CHAPTER III

AVIAN BREEDING SUCCESS AND NEST SITE SELECTION IN RESTORED POST OAK SAVANNA IN EASTERN TEXAS

ABSTRACT

During the last three decades, many grassland bird populations in North America have seen declines, primarily due to the extensive loss and degradation of grassland breeding habitat. Oak (*Quercus* spp.) savanna vegetation types are among the most degraded grassland types in North America that have declined to <1% of their original distribution. Historically, natural disturbances such as periodic fire, grazing, and drought maintained oak savannas, but these have been reduced or eliminated, resulting in woody encroachment and habitat degradation. Oak savannas are known for their open, park-like appearance, with large scattered oaks and a well-defined herbaceous-dominated understory.

Grassland breeding birds are highly susceptible to habitat fragmentation due to effects on nest success and reproductive rates. Grassland obligates nesting in the Texas region of the post oak savanna include Bachman's sparrow (*Peucaea aestivalis*), lark sparrow (*Chondestes grammacus*), and dickcissel (*Spiza americana*). In this study, I quantified avian reproductive success and nest site characteristics for target bird species in restored post oak savannas at the Gus Engeling Wildlife Management Area (GEWMA). I also searched reference savanna communities and adjacent, unrestored areas for comparative purposes.

The 2010 restoration at GEWMA was at least partially successful, reflected in the presence and breeding of typical grassland obligate species following restoration. Dickcissels were the most abundant grassland obligate

nests (N=38), while lark sparrow and Bachman's sparrow had minimum nests (N=2 and N=0). Overall the daily survival rate (DSR) for this study (0.91) was similar to another study in Texas (0.90). Most dickcissel nests were detected in the restored compartments, only one was discovered in the reference compartments. Dickcissels need tall dense grass to breed and the reference compartments had a sparser herbaceous layer than the restored compartments. For painted buntings, the study site was on the far western end of the breeding range. The DSR of my study (0.82) was lower than both a study completed in Southcentral Louisiana (0.94) and South Carolina (0.89). While the raw nest success for painted buntings increased by 16%, from 2009-10 to 2016-17, it is important to explore the possibility of an ecological sink.

Similar to other studies, I did not find many differences between habitat structure at nest and paired sites or successful and unsuccessful nests. For both dickcissels and painted buntings the distance to nearest maintained road negatively affected nesting success. This is supported by other studies indicating that the proximity to roads was the best-supported model for influencing nest success. While there were factors that negatively affected nesting success, the effects were mild and overall DSR was similar to other studies for grassland obligate species. Restoration efforts overall were successful based on the presence and acceptable breeding success of grassland obligate species at GEWMA.

INTRODUCTION

During the last three decades, many grassland bird populations in North America have seen more dramatic and extensive declines than those documented in other North American birds (Herkert et al. 2003). The primary reason for this decline appears to be the extensive loss and degradation of grassland breeding habitat (Herkert et al. 2003). These changes include loss of both true grassland communities (e.g. tall grass and mixed grass prairies) and grass-dominated communities with a significant woody component (e.g., savannas, glades, and open woodlands).

Oak (*Quercus* spp.) savannas types are among the most degraded grassland types in North America. These savannas once covered 46 million hectares (ha) of the Midwestern United States, extending from southern Wisconsin southward into Iowa, Illinois, Missouri, and across parts of eastern Kansas, Oklahoma, and Texas; now less than 1% remains (Fig. 3-1; Temple 1998, Lorimer 2001). The park-like appearance of North American oak savannas suggests that the ecosystem is transitional between the deciduous forests to the east and the expansive prairies to the west (Temple 1998). The structure of oak savannas includes a spatially variable canopy cover from 10-70% that is dominated by fire resistant oak species such as bur oak (*Quercus macrocarpa*) or post oak (Quercus stellata). This is paired with a well-developed, herbaceous ground layer dominated by diverse fire-adapted grasses and forbs (Brawn et al. 2001, Berger & Keyser 2013). Oak savanna distribution can be linked to fire, grazing, and drought that reverse or slow the closure of the canopy (Harrington & Kathol 2008). Fire also plays a significant role in keeping the park-like structure of oak savannas, eliminating woody regrowth.

Associated wildlife populations have experienced long-term declines that reflect loss of high-quality savanna communities (Brawn et al. 2001). For example, 70% of disturbance-dependent bird species in the United States have experienced declines (Hunter et al. 2001, Sauer et al. 2014). Most are associated with early successional habitats and can be found in grasslands, oak savannas, and open forest communities (Hunter et al. 2001). Metrics used to monitor oak savanna status and restoration include breeding bird diversity and richness or occupancy by target species. An additional metric includes nesting success to determine if restoration meets conservation goals of producing a productive site.

Post oak savanna restoration projects have taken place at the Gus Engeling Wildlife Management Area located in Anderson County Texas. Prior to a 2010 restoration project, a pre-restoration project was initiated to monitor the progress and success of the restoration by determining the baseline conditions for avian occupancy and nesting success. We collected bird abundance and occupancy data 7 years later to assess restoration success (see Chapter 2).

However, it was also important to monitor reproductive success of bird species that were in two categories: grassland/savanna obligate species that are indicative of a truly successful restoration and generalist early-successional species that would be present in both restored savanna and other shrub or grass-dominated communities.

Generalist early-successional species often occupy recently disturbed sites, and based on initial occupancy surveys were more abundant. The two target species used were indigo bunting (*Passerina cyanea*) and painted bunting (*Passerina ciris*) based on the abundance at the site and baseline work done in 2009. Indigo buntings are familiar songbirds whose breeding grounds range across most of eastern North America (Kopachena & Crist 2000). Painted buntings typically replace the indigo buntings in central and west Texas; however, there is a large area of sympatry, including the post oak savanna region of Texas (Kopachena & Crist 2000). Both indigo buntings and painted buntings prefer habitats with a high edge-to-area ratio and tend to perch on edges between open and wooded habitats to sing and defend territories. The two species occupy similar habitats based on the vegetation structure and size of openings, but indigo buntings tend to prefer communities dominated by woody vegetation, while painted buntings prefer open habitats with small clusters of trees and shrubs or woody regeneration (Kopachena & Crist 2000). Indigo buntings are general early successional bird species; however, they can tolerate taller vegetation and trees better than other species, as long as it is not dense (Conner et al. 1983).

Grassland obligates nesting in the Texas region of the post oak savanna include Bachman's sparrow (*Peucaea aestivalis*), lark sparrow (*Chondestes grammacus*), and dickcissel (*Spiza americana*). Based on initial occupancy surveys, dickcissel was the most abundant species and we chose it as our target grassland obligate. The dickcissel is a common breeding bird of North American grasslands from central and south Texas north to the Dakotas. Dickcissels are dependent on grassland habitats for breeding but have had to adjust to habitat changes as grasslands and savanna communities have been converted to agriculture and other land uses. While dickcissels can breed in altered habitats (i.e. agricultural fields), few studies compared the breeding success in non-native monocultures to restored native grasslands. Lituma (2012) compared the nesting success and abundance of dickcissels on exotic and native grasslands in the Blackland Prairie ecoregion of east-central Texas and observed no difference in abundance between the different grass types and that dickcissels were choosing nest sites that reflected available vegetation structure. This vegetation structure included grasslands with 90-100% ground cover and moderate to tall grass (25-150 cm; Temple 2002).

In this study, I quantified avian reproductive success and nest site characteristics for target bird species in restored post oak savannas in Eastern

Texas. I also searched reference savanna communities and adjacent, unrestored areas for comparative purposes. I searched for nests during the breeding seasons (May—July) of 2016 and 2017. My expectations were that if oak savanna restoration efforts have achieved the desired outcome, I would see successful breeding of birds typical of oak savannas, such as dickcissel and painted bunting.

METHODOLOGY

Study Site

The study was conducted at the Gus Engeling Wildlife Management Area (GEWMA), a state-owned post oak savanna research and demonstration area located in Anderson County, Texas (Fig. 3-2). GEWMA is an isolated post oak savanna surrounded by coastal bermudagrass (*Cynodon dactylon*) pastures, second growth forests, and other degraded vegetation communities. We conducted our study on the northwest section, which is approximately 1,000 ha broken into nine compartments, eight of which were used for this nesting study (Fig. 3-3). The northwest section of the GEWMA was chosen in 2007 for a savanna restoration project, primarily because of the soil and vegetative cover on this portion of the area should support oak savannas, and is comprised mostly of Darco fine sand soils and Tonkawa fine sands that are somewhat excessively drained, have low water storage availability.

The eight compartments in the northwest section of GEWMA comprised three different types or treatments: reference, restored, and unrestored. Two compartments (F and G) represented reference compartments of 62 ha and 112 ha, respectively. These compartments have been consistently maintained using prescribed fire, herbicide, and mechanical treatments (i.e. mowing, mulching, tree removal) for more than 50 years, and have mature scattered trees with a mean basal area of 3.7 m^2 /ha and mean canopy cover of 18% that allowed a well-developed herbaceous layer to develop (see Chapter 2), of 10% bunchgrasses, 11% forbs, 5% grass/sedge, 7% legume and 12% woody. These compartments served as reference areas for desired oak savanna conditions at the site.

Compartments A and B were restored to post oak savanna conditions in 2010 and are 57 ha and 136 ha, respectively. Pre-2010 lack of disturbance has resulted in a woodland/forest structure, with dense mature trees in the overstory and an understory dominated by woody regeneration, resulting in a mean basal area was 36.9 m^2 /ha with a canopy cover of 39%. A timber harvest was completed in these compartments in 2010 to remove woody overstory and reduce canopy cover, followed by regular herbicide and prescribed fire treatments to control woody regeneration and encourage an herbaceous understory. These compartments contain mature scattered trees with a basal area of 3.7 m^2 /ha and a canopy cover of 16%. The herbaceous understory is comprised of mostly bunchgrasses with a 28% ground coverage.

The other six compartments ranged in size from 53—200 ha. These unrestored compartments are similar to pre-restoration conditions in the restored compartments with a basal area of 8.3 m^2 /ha and a canopy cover of 39%. The understory lacks the desired herbaceous layer and instead contains 19.2% woody regeneration ground cover.

Nest Searching and Monitoring

To document breeding status and monitor nesting success of target species, I searched each compartment from early May to late July for approximately the same amount of time each week on a scheduled rotation (Fletcher & Koford 2002). I located nests using visual cues: carrying nesting material, carrying food, distraction calls, and distraction displays (Martin & Geupel 1993). I monitored nests every 2-4 days until nest fate was determined. For each, I recorded the species, number of eggs, number of eggs hatched, estimated hatch date, estimated fledge date, and number of fledged young, as well as any adult activity around the nest.

Nests were considered successful differently based on the analyses run. I considered nests successful if they fledged at least one chick regardless of species, even if the nest was parasitized, for nest site selection analyses (Rodewald 2004). For Mayfield nest success analyses, a nest was considered successful if it fledged at least one of its own chicks. After nest fate was categorized (e.g., successful or unsuccessful and predated or abandoned), I measured vegetation structural characteristics that may influence nest site selection and nest success at the nest site and at a randomly chosen paired site.

Paired sites were approximately 25 meters away at a random azimuth, and plot center was chosen to be structurally similar to the nest substrate (e.g., sapling or bunch grass clump). I recorded the following measurements at each site: bird species, nest height (m) from the ground, substrate height (m), number of supporting branches, and diameter at breast height (dbh) for supporting woody plants, the vegetation circumference if non-woody (m), distance and species of nearest tree (m), and distance to road in meters (Martin et al.1997).

Nest site characteristics were measured within 11.3 meter radius circular plots centered on each site (Fig. 3-4). I identified all woody stems ≥8-cm dbh within the 11.3 m radius plot and used these measurements to determine trees per hectare (TPH). All woody stems <8-cm dbh and ≥50-cm tall within a smaller 5-m radius plot centered inside the larger plot were also measured and identified (Martin et al. 1997). Within each quadrant of the larger plot I used a randomly-located 1-m^2 quadrat to estimate percent herbaceous and woody ground cover. For each 1-m^2 quadrant, I recorded the five most dominant plant species based on six cover classes: 0-5%, 5-25%, 25-50%, 50-75%, 75-95%, and 95-100% (Daubenmire 1959). I estimated canopy cover using a spherical densiometer at each cardinal direction and obtained mean values (Lemmon 1957). I used ArcGIS 10.6.1 to measure the distance from the nest sites to the nearest road.

Statistical Analysis

I determined raw nest success (percent of nests fledging young) for each species, and to determine habitat selection preferences by breeding birds, compared the vegetation structure at nest sites and paired sites across all compartments and compared nest site characteristics of successful and unsuccessful nests. First data were tested for normality using the Shapiro-Wilks test and homogeneity using the Levene's test in Statistical Analysis System (SAS) v.9.2 ($\alpha = 0.05$). Count data was were transformed using square root and percent data was transformed using the arcsine when data did not meet the assumptions. Data were analyzed using the Kruskal-Wallis tests in SAS. Nest site characteristics included substrate height, DBH of the substrate, species of the nearest tree, distance to the nearest tree, distance to road, supporting branches, number of woody stems ≥ 8 cm, number of woody stems < 8cm, top 5 dominant herbaceous species, canopy cover, and vertical cover among 4 strata.

I examined daily nest survival using the Mayfield model, which accounts for nests being found at different stages of development by basing calculations on the daily survival rate (DSR, Mayfield 1975, Hensler & Nichols 1981, Hazler 2004). I also examined the influence of vegetation structural variables on nest survival using a Mayfield logistic regression approach (Aebischer 1999, Hazler 2004). This method allows for the addition of explanatory covariates on nest survival within the traditional Mayfield analysis framework. I used a step-wise information-theoretic approach to evaluate candidate models and I determined support for a model using the Akaike's Information Criterion corrected for small sample size (AIC_c). I considered models to be competitive if they were within 2 ΔAIC_c from the most supported model. Correlation were tested using a Spearman-Rho test using correlation coefficients of 0.7 to define highly correlated variables to prevent inclusion of highly correlated variables in the same model (Graham 2003).

I used the following covariates to construct a set of candidate models for each target species: dist. road (nest distance to nearest maintained road, m), nest height (height of nest above ground, m), height (height of nest substrate, m), woody cover (percentage of woody cover within an 11.3 m radius plot around the nest), bunchgrass cover (percentage of bunchgrass cover within an 11.3 m radius plot around the nest), canopy cover (percentage of canopy cover within an 11.3 m radius plot around the nest), vert3 visual obstruction (vertical nest strata cover percentage from 2-3 m), vert2 visual obstruction (vertical nest strata cover percentage from 1-2 m), vert1 visual obstruction (vertical nest strata cover percentage from 0-1 m), substrate (type of vegetation (grass/woody) in which a nest was located), and treatment (restored, unrestored, reference).

Among the painted bunting nests, highly correlated covariates were substrate height and vertical nest strata cover (3-4 m), nest height and vertical nest strata cover (3-4 m), canopy cover and distance to the nearest tree, distance to the nearest tree and the number of stems greater than 8 cm in diameter, nest height and substrate height, diameter at breast height (if in a shrub, woody regeneration or tree) and nest height, and diameter at breast height and substrate height. For dickcissels, they were substrate height and vertical nest strata cover (2-3 m), vertical nest strata cover (1-2 m) and vertical nest strata cover (2-3 m), and distance to the nearest tree and the number of stems greater than 8 cm in diameter.

For both species, I assumed that nests higher off the ground would have a higher chance of survival due to a lower probability of predation from cursorial predators. I evaluated the substrate type for each nest at the species level for painted buntings and at the family level (i.e. woody versus grass) for dickcissels. I considered the percentage of bunchgrass and woody vegetation cover, assuming that higher values of each would result in higher nest survival due to the increased search time for nests by potential predators. I considered upper vertical nest strata cover sections (1-4 m) because I predicted that higher values of each (which equate to screening cover) would result in higher nest survival.

Finally, I assumed that higher canopy cover values would increase nest survival because it would shield nests from aerial predators. I considered distance to nearest road and predicted the further the distance the better the chance of survival. For painted buntings, I also evaluated the effects of treatment (reference, restored, unrestored); I assumed nest survival would be relatively similar between the reference and restored treatment types and lower in the unrestored treatment type. There were no dickcissel nests in the unrestored area.

RESULTS

During the 2016 and 2017 breeding seasons I found 62 nests of the three target species (21 painted bunting, four indigo bunting, and 38 dickcissel; Fig. 3-5 & Fig. 3-6). I compared the raw nesting success to the nests found during the 2009-2010 survey seasons. During 2009 and 2010, there were a total of 20 nests detected: nine painted bunting nest and 11 indigo bunting nests. I found insufficient numbers of indigo bunting nests to derive meaningful estimates of daily nest survival; therefore, I only performed Mayfield logistic regression for painted buntings and dickcissels. Raw nest success for painted buntings increased from 0.22 in 2009-10 to 0.38 in 2016-17. In contrast, indigo bunting nest success decreased from 0.64 to 0.25 over the same time period. No dickcissel nests (and no dickcissels, see Chapter 2) were found at the site in 2009-10 but raw nest success was 0.21 in 2016-17 (Table 3-1). The most common cause of nest failure was predation with six out of 20 nests in 2009-10 and 39 out of 62 nests in 2016-17 (Table 3-1).

Nest-Site Selection

Painted bunting nests were commonly found in bluejack oak (*Quercus incana*), blackjack oak (*Q. marilandica*), and hickory (*Carya* spp.). There were 11 nests in the reference areas, one in the restored areas, and nine in the unrestored areas (Fig 3-5). When comparing nest site selection by fate, nests further from the road were significantly more successful (232 m) than unsuccessful nests (84 m; p=0.0024). Successful nests also had a higher percentage of legume, grass/sedge, and woody ground cover than unsuccessful nests (Table 3-2). Successful nest had a higher percentage of vertical nest strata cover at 3-4 m (62%) than paired sites (32%; P=0.0197; Table 3-2). Nest sites and paired sites for painted bunting were similar (Table 3-3).

All dickcissel nests were in the restored and reference compartments (Fig. 3-6). I found 20 nests in grass substrate and 18 in woody substrate such as post oak, hickory, bluejack oak, blackjack oak, mustang grape, spiderwort, and little bluestem, the majority located in little bluestem. When comparing nest site selection by fate, successful nests were further from the road (217 m) than unsuccessful nests (97 m; p=0.0052; Table 3-4). Successful nests also had a higher percentage of vertical nest strat cover at 0-1 m (99%) than unsuccessful nests (94%; P=0.0443; Table 3-4). Comparing nest sites to paired sites, nests in a woody substrate had a larger DBH (2.06 cm) than paired sites (1.33 cm; P=0.0081). Nest sites also has a higher percentage of vertical nest strata cover at 0-1 m (95%) and at 2-3 m (19%) than paired sites (92% and 7%; P=0.0010; P=0.0329; Table 3-5).

Mayfield Modeling

There was a high degree of uncertainty among the Mayfield models (Tables 3-6 and 3-7). I averaged DSR estimates for each competitive (<2 ΔAICc) model based on their AICc weight for painted buntings and dickcissels. For painted buntings, the top model was distance to road (β = 1.485, 95% CI: 0.563–2.407). The mean painted bunting DSR was 0.815 (95% CI: 0.637–0.917) and the total period survival was 0.014.

For dickcissels, the top models were the null model, distance to road (β = 0.002, 95% CI: -0.001–0.004), Vert2 visual obstruction (β = 0.005, 95% CI: -0.002–0.011), bunchgrass cover (β = 0.008, 95% CI: -0.003–0.019), Vert1 visual obstruction (β = 0.013, 95% CI: -0.005–0.031), Vert3 visual obstruction (β = -0.006, 95% CI: -0.015–0.003), nest height (β = 0.594, 95% CI: -0.453–1.640), and canopy cover (β = -0.123, 95% CI: -0.043–0.018). Although several variables related to nest cover and visual obstruction appeared in the models, all of the confidence intervals for β included zero, suggesting that the measure effects were weak. The mean dickcissel DSR was 0.907 (95% CI: 0.775–0.960) and the total period survival was 0.135.

DISCUSSION

Determining the nesting success of native birds by evaluating nest site selection and survival on target species can help evaluate the quality and accomplishment of restoration efforts. Dickcissels are grassland birds whose populations declined drastically from 1966 to 2014 as the North American Breeding Bird Survey estimated a 26% decline. Due to males needing an elevated perch to sing during the breeding season, the species can tolerate a higher number of trees and woody substrate than other grassland species (Winter 1999).

Studies in Texas and Oklahoma have shown dickcissels nesting in woody substrate more than herbaceous bunchgrass. Overmire (1962) found 69% and Dixon (2008) found 86% of dickcissels using woody substrate over herbaceous. This differs from my results with 47% of nests in woody substrate and 53% in herbaceous substrate. Even with the structural difference of woody and herbaceous substrate, the nest survival did not differ between the two. The few significant nesting site characteristics, percent legume cover, woody substrate DBH, and vertical nest strata cover 2-3 m, showed that nests tended to have more overhead cover. This could provide the protection needed to fledge young and provide places for males to perch and defend territories.

Comparing my dickcissel nest survival to other studies in both remnant native grasslands and restored grasslands, my DSR (0.91) was similar to what Lituma (2012) found in restored grasslands in Texas (0.90; Table 3-8). However, DSR was lower for my study than those in northern states (Iowa 0.96, Kansas 0.96, Missouri 0.94); this could be due to Texas being on the southern end of the breeding range, creating an earlier nesting period (Zimmerman 1982, Patterson & Best 1996, Basili 1997, Winter 1999). This supports the claim that the restoration efforts used at GEWMA have produced a habitat with acceptable nesting success for dickcissels.

When comparing my painted bunting nest survival on the far western end of the breeding range, my DSR (0.82) was lower than both a study completed in Southcentral Louisiana (0.94) and in South Carolina (0.89; Table 3-8; Vasseur & Leberg 2015, Garcia 2004). While the raw nest success for painted buntings increased by 16%, from 2009-10 to 2016-17, it is important to explore the possibility of an ecological trap. An ecological trap or sink is when an organism is drawn to a specific habitat that is surrounded by different habitats, making the fragmented habitat less suitable (Lituma et al. 2012). For example, GEWMA is surround mostly by agricultural hay fields or encroached land, with exception of one adjacent ranch. Concurrent with the lower DSR for painted buntings, the indigo bunting raw nest success decreased by 39% from 2009-10 to 2016-17. This could be the result of edge ratio and supports the premise that painted buntings are more suited for open habitats with small clusters of trees and shrubs versus indigo buntings (Kopachena & Crist 2000).

Similar to other studies, I did not find many differences between habitat structure at nest and paired sites or successful and unsuccessful nests (Novak 2001, Rodewald & Yahner 2001), suggesting that there is plentiful microhabitat available for nesting within restored treatments, with the number of maintained roads on the area being a negative factor. Each compartment had at least a maintained road as the boundary, with some having additional roads through the interiors. For both dickcissels and painted buntings the distance to nearest maintained road negatively affected nesting success, and other studies indicated that the proximity to roads was the best-supported model for influencing nest success (DeGregorio 2014, Dietz 2013). There are multiple ways that roads can affect nesting birds, including an increased chance of predation, habitat fragmentation, and increased stress by disturbances (DeGregorio 2014, Dietz 2013). Mammalian predators (i.e. coyote [*Canis latrans*] and striped skunk [*Mephitis mephitis*]) were observed using interior roads as corridors and avian predators (i.e. red-tailed hawk [*Buteo jamaicensis*]) were observed perching on trees along road edges.

Although I found only three dickcissel nests in 2016 and 35 nests in 2017; this could be due to searcher experience or yearly fluctuations in nesting rates. The restored compartments at GEWMA were burned in the winter of 2015, therefore the herbaceous layer was thinner in 2016 than in 2017, which I expected to negatively affect abundance and nesting rates of dickcissels. The number of years after a fire has been shown to not affected dickcissel nesting density, but to have a negative effect on nest success (Churchwell et al. 2008). While I was not able to compare nesting success between 2016 and 2017, I did see a lower density of dickcissels in the restored compartments during the season immediately following the prescribed fire (see Chapter 2). This could be another research aspect that could be explored and monitored to determine the fire return interval best for grassland breeding bird success.

While there were factors that negatively affected nesting success, the effects were mild and overall DSR was similar to other studies for grassland obligate species. Restoration efforts overall were successful based on the presence and acceptable breeding success of grassland obligate species at GEWMA. Further management of roads could improve the nesting success with some interior roads being grassed over to increase the amount of interior savanna and reducing the negative effects on nesting success. This study could provide a rough timeline for restoration efforts and to the time it takes for savanna obligates to occupy a restoration area.

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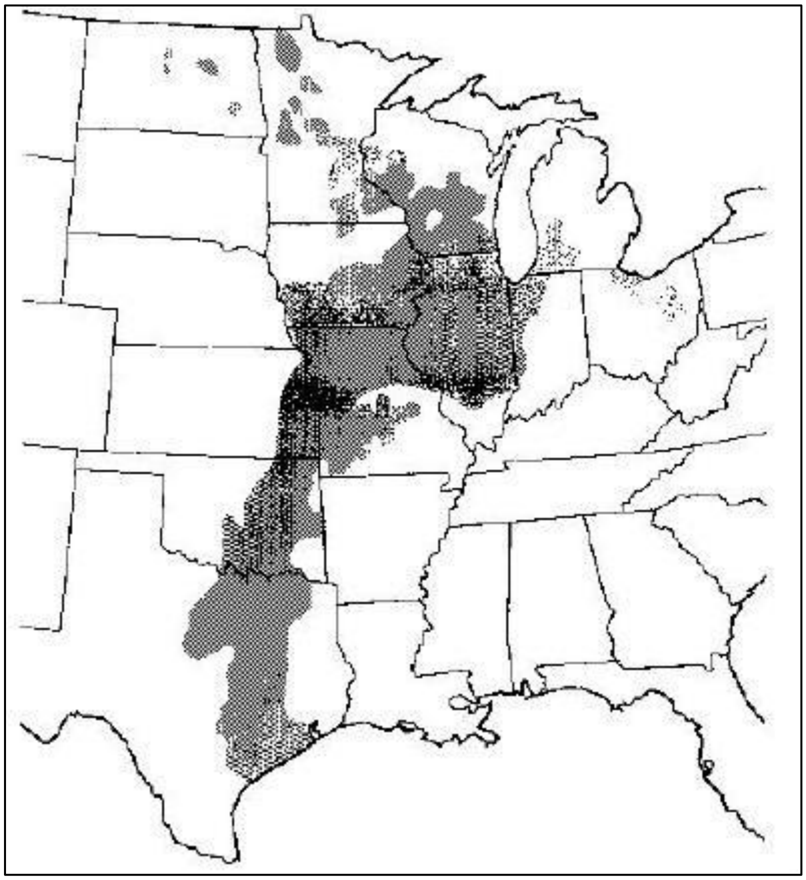

Figure 3-2. Estimated pre-settlement distribution of the midwestern oak savannas in the United States (Nuzzo 1985).

Figure 3-2. Location of the primary study area at the Gus Engeling Wildlife Management Area in Anderson County Texas, used for avian nesting surveys during the breeding seasons of 2009, 2016, and 2017.

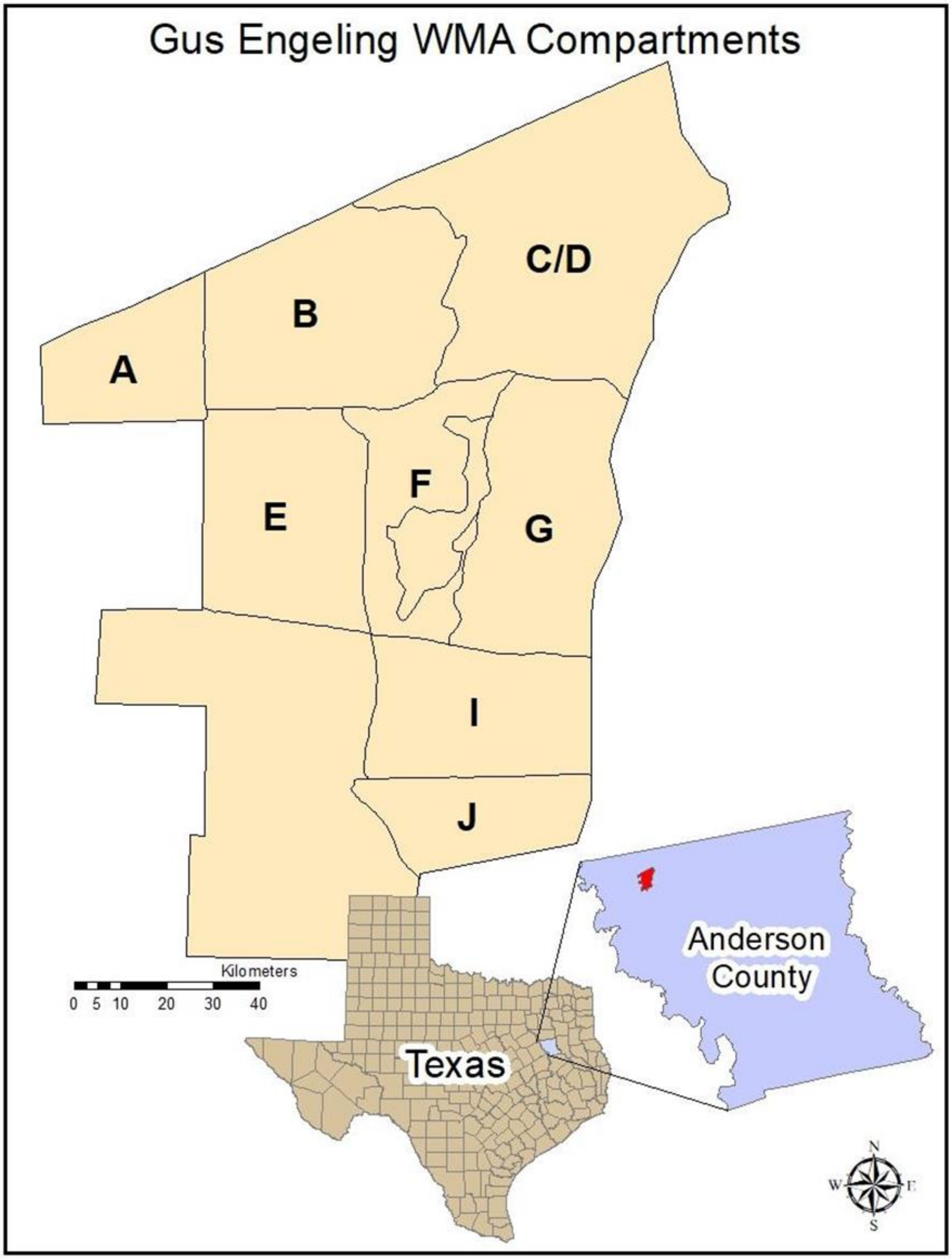

Figure 3-3. Northwest section of Gus Engeling Wildlife Management Area showing study compartments used for avian nesting surveys during the breeding seasons of 2009, 2016, and 2017.

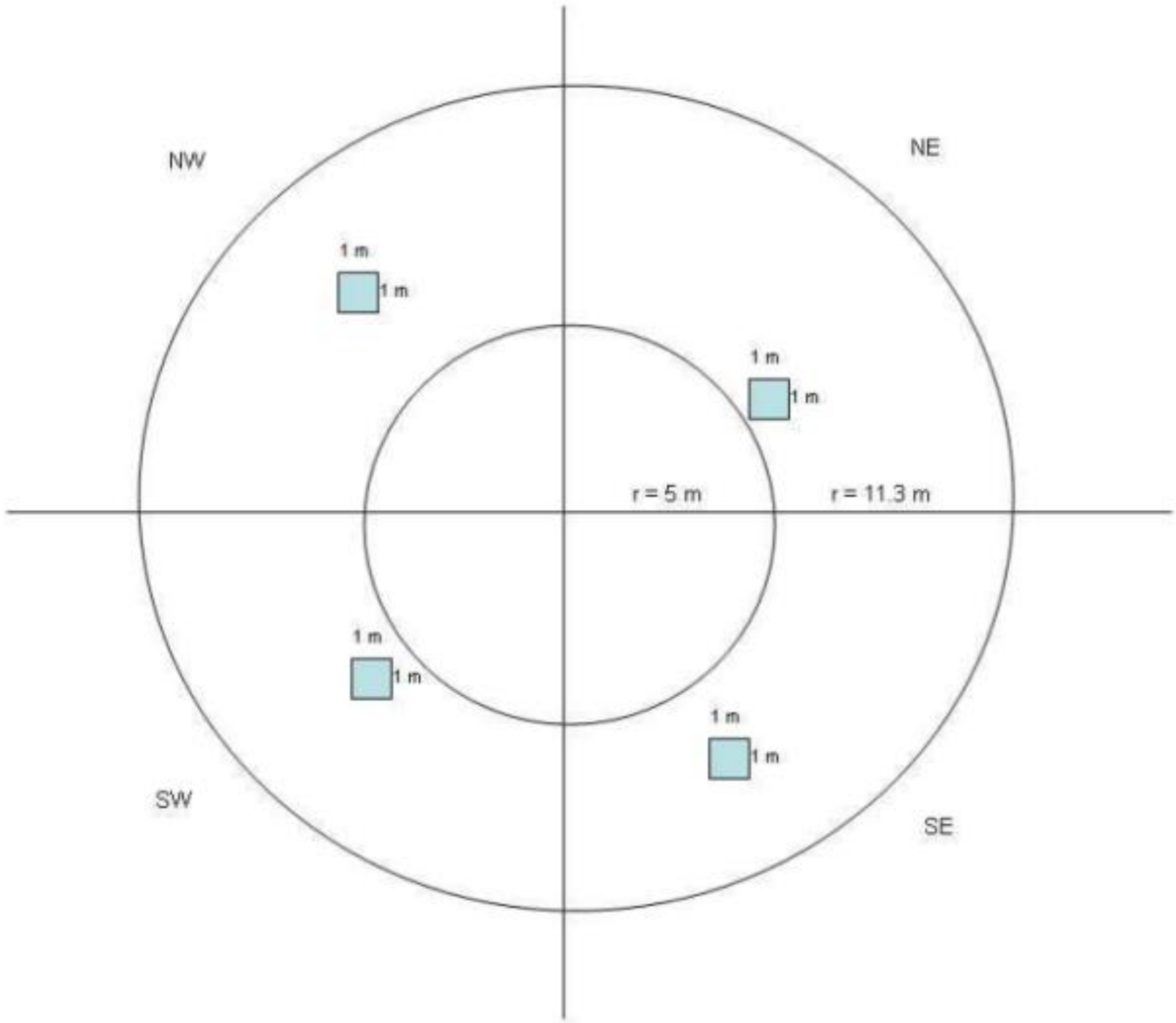

Figure 3-4. Diagram of plot arrangements for assessment of breeding bird nest site selection in restored and reference post oak savannah study blocks at Gus Engeling Wildlife Management Area in Anderson County, Texas as presented in Comer and Lundberg (2011). Plots will be centered on nest sites and nearby, random sites.

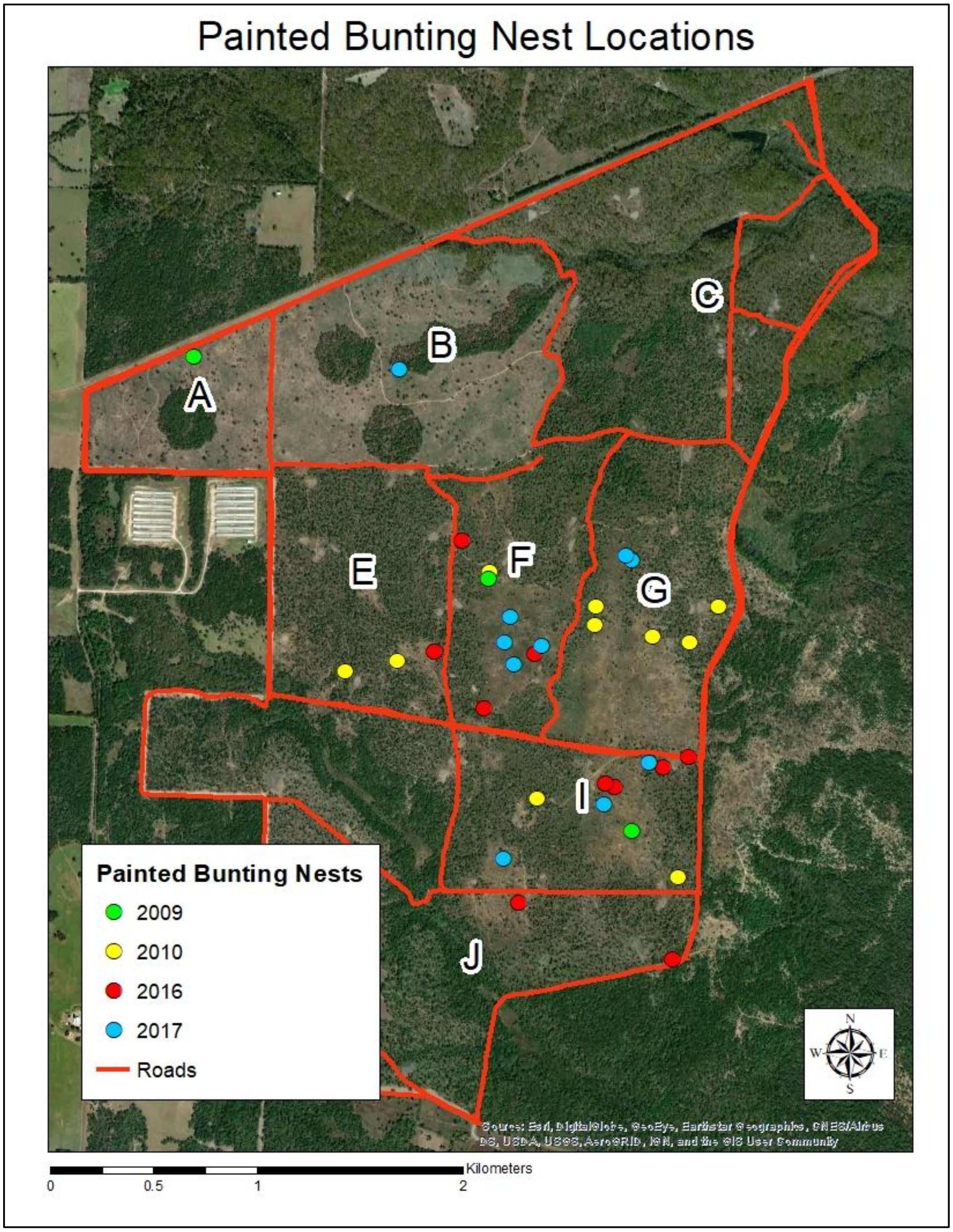

Figure 3-5. Northwest section of Gus Engeling Wildlife Management Area showing study compartments and painted bunting nests for the 2009-10 and 2016-17 breeding seasons.

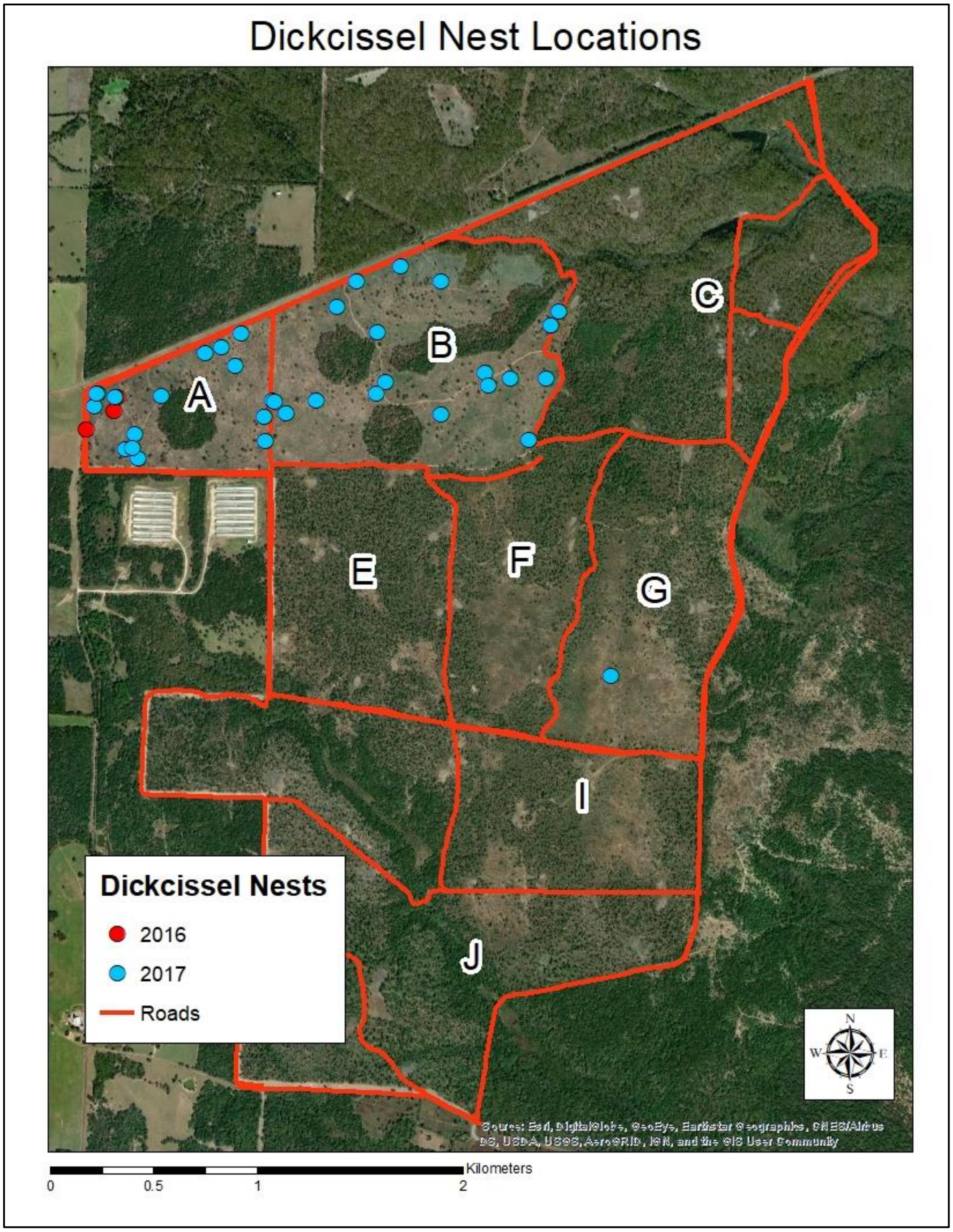

Figure 3-6. Northwest section of Gus Engeling Wildlife Management Area showing study compartments and dickcissel nests for the 2016-17 breeding seasons.

Table 3-1. Number of nests, nest fates, nest substrate, nest compartment types, and raw nest success for dickcissel, painted bunting, and indigo buntings during the 2009-10 and 2016-17 breeding season at Gus Engeling Wildlife Management Area located in Anderson County, Texas.

		Dickcissel		Painted Bunting		Indigo Bunting	
		2009-10	**2016-17**	**2009-10**	**2016-17**	**2009-10**	**2016-17**
Total Nest		0	38	9	21	11	4
Successful		0	8	2	8	7	1
Unsuccessful		0	30	7	13	4	3
	Abandoned	0	2	2	3	2	1
	Predated	0	27	4	10	2	2
	Unknown	0	1	1	0	0	0
Raw Nest Success (decimal %)		-	0.21	0.22	0.38	0.64	0.25
Nest Substrate							
	Tree	0	0	6	5	5	3
	Woody Regen.	0	18	3	16	6	1
	Bunchgrass	0	20	0	0	0	0
Compartment Type							
	Reference	0	1	5	11	5	2
	Restored	-	37	-	1	-	0
	Unrestored	0	0	4	9	6	2

Table 3-2. Nesting characteristics for painted bunting successful and unsuccessful nests at Gus Engeling Wildlife Management Area, 2016-2017. Results following Kruskal-Wallis tests. Alpha value = 0.05. Significant differences are shown by a (*) at end of row.

Nesting Characteristic	Successful Nests (n=8)			Unsuccessful Nests (n=13)			P-value	
	Median	Range		Median	Range			
Nest Height (m)	1.50	0.70	2.00	0.85	0.50	2.20	0.1564	
Nest Substrate Height (m)	2.50	1.00	3.00	2.10	0.70	4.00	0.5885	
DBH (cm)	3.15	1.50	4.00	2.90	0.70	5.30	0.9691	
Distance to Nearest Tree (m)	13.00	3.00	60.00	3.00	0.00	28.00	0.0700	
Distance to Nearest Road (m)	228.50	38.80	469.60	62.90	2.50	169.30	0.0047	*
Bunchgrass (%)	10.63	0.00	31.88	11.88	0.00	26.25	0.8558	
Legume (%)	8.13	0.00	22.50	0.63	0.00	13.13	0.0180	*
Grass/Sedge/Other (%)	11.25	1.25	18.13	3.75	0.63	26.25	0.0384	*
Forb (%)	19.69	1.88	43.13	15.63	0.00	60.00	0.7173	
Woody (%)	18.75	7.50	41.25	0.63	0.00	37.50	0.0447	*
Vertical Cover 0-1m (%)	55.00	23.75	91.25	68.75	10.00	92.50	0.4445	
Vertical Cover 1-2m (%)	37.50	6.25	97.50	55.00	16.25	95.00	0.1088	
Vertical Cover 2-3m (%)	52.75	10.00	97.50	45.00	12.50	80.00	0.6114	
Vertical Cover 3-4m (%)	75.00	2.50	80.00	23.75	0.00	90.00	0.0197	*
Canopy (%)	32.13	0.00	91.00	59.00	25.50	94.75	0.0948	

Table 3-3. Nesting characteristics for painted bunting nest and paired sites at Gus Engeling Wildlife Management Area, 2016-2017. Results following Kruskal-Wallis tests. Alpha value = 0.05.

Nesting Characteristic	Nest Site			Paired Site			P-value
	Median	Range		Median	Range		
Nest Substrate Height (m)	2.20	0.70	4.00	2.20	0.80	4.00	0.9892
DBH (cm)	3.00	0.70	5.30	2.60	1.10	5.10	0.6005
Distance to Nearest Tree (m)	7.00	0.00	60.00	6.00	0.00	30.00	0.3609
Bunchgrass (%)	11.88	0.00	31.88	11.25	0.00	37.50	0.3743
Legume (%)	1.88	0.00	22.50	0.63	0.00	11.88	0.3123
Grass/Sedge/Other (%)	8.13	0.63	26.25	5.00	0.00	17.50	0.4251
Forb (%)	16.25	0.00	60.00	16.88	0.63	56.25	0.6955
Woody (%)	8.13	0.00	41.25	9.34	0.00	28.75	0.5131
Vertical Cover 0-1m (%)	66.25	10.00	92.50	65.00	31.25	98.75	0.8037
Vertical Cover 1-2m (%)	51.25	6.25	97.50	52.50	6.25	90.00	0.6285
Vertical Cover 2-3m (%)	45.00	10.00	97.50	37.00	0.00	85.00	0.2448
Vertical Cover 3-4m (%)	43.75	0.00	90.00	15.00	0.00	93.75	0.1657
Canopy (%)	45.75	0.00	94.75	46.75	0.00	92.00	0.8920

Table 3-4. Nesting characteristics for dickcissel successful and unsuccessful nests at Gus Engeling Wildlife Management Area, 2016-2017. Results following Kruskal-Wallis tests. Alpha value = 0.05. Significant differences are shown by a (*) at end of each row.

Nesting Characteristic	Successful Nests (n=8)			Unsuccessful Nests (n=13)			P-value	
	Median	Range		Median	Range			
Nest Height (m)	0.52	0.35	0.70	0.40	0.95	0.44	0.1512	
Nest Substrate Height (m)	1.20	0.80	1.72	1.33	1.77	1.27	0.6667	
DBH (cm)	1.60	1.00	2.40	2.00	4.00	2.17	0.3896	
Grass Circumference (cm)	1.18	0.56	1.37	1.18	1.40	1.14	0.8487	
Distance to Nearest Tree (m)	19.00	4.00	43.00	23.50	50.00	24.38	0.2371	
Distance to Nearest Road (m)	256.85	59.50	306.10	59.95	400.50	96.94	0.0052	*
Bunchgrass (%)	48.44	11.25	65.00	40.00	73.75	37.96	0.4096	
Legume (%)	0.00	0.00	0.63	0.00	13.13	1.83	0.8154	
Grass/Sedge/Other (%)	0.63	0.00	5.63	1.25	13.13	3.63	0.3695	
Forb (%)	20.94	8.13	38.75	20.00	51.25	22.92	0.5904	
Woody (%)	6.25	0.00	18.75	5.00	50.00	9.08	0.9856	
Vertical Cover 0-1m (%)	100.00	95.00	100.00	97.50	100.00	94.33	0.0443	*
Vertical Cover 1-2m (%)	78.75	32.50	95.00	63.75	95.00	59.96	0.4202	
Vertical Cover 2-3m (%)	7.50	0.00	51.25	13.13	67.50	19.92	0.5361	
Vertical Cover 3-4m (%)	0.00	0.00	0.00	0.00	17.50	1.21	0.2228	
Canopy (%)	1.38	0.00	9.25	0.00	29.00	2.62	0.2189	

Table 3-5. Nesting characteristics for dickcissel nest and paired sites at Gus Engeling Wildlife Management Area, 2016-2017. Results following Kruskal-Wallis tests. Alpha value = 0.05. Significant differences are shown by a (*) at the end of each row.

Nesting Characteristic	Nest Site			Paired Site			P-value	
	Mean	Range		Median	Range			
Nest Substrate Height (m)	1.33	0.70	1.77	1.22	0.65	1.60	0.3405	
DBH (cm)	2.00	1.00	4.00	1.30	0.00	2.80	0.0081	*
Grass Circumference (cm)	1.18	0.56	1.40	1.19	0.80	1.40	0.8480	
Distance to Nearest Tree (m)	23.50	4.00	50.00	22.00	5.00	65.00	0.5536	
Bunchgrass (%)	43.44	4.38	73.75	33.43	0.00	79.38	0.2615	
Legume (%)	0.00	0.00	13.13	0.00	0.00	7.50	0.2287	
Grass/Sedge/Other (%)	1.25	0.00	13.13	0.63	0.00	44.38	0.0934	
Forb (%)	20.63	6.88	51.25	23.43	2.50	54.38	0.5026	
Woody (%)	5.00	0.00	50.00	3.75	0.00	32.50	0.5414	
Vertical Cover 0-1m (%)	97.50	51.25	100.00	93.13	72.50	100.00	0.0010	*
Vertical Cover 1-2m (%)	71.25	0.00	95.00	53.13	2.50	97.50	0.1292	
Vertical Cover 2-3m (%)	11.88	0.00	67.50	3.13	0.00	35.00	0.0329	*
Vertical Cover 3-4m (%)	0.00	0.00	17.50	0.00	0.00	1.25	0.0892	
Canopy (%)	0.00	0.00	29.00	0.00	0.00	20.25	0.5824	

Table 3-6. Model selection statistics for painted bunting nest survival at the Gus Engeling Wildlife Management Area 2016 - 2017. Competitive models were averaged to obtain survival statistics.

Model[a]	K[b]	AICc[c]	ΔAICc[d]	w[e]	Log Liklihood
Dist Road	2	64.69	0.00	0.55	-30.28
Height + Dist Road	3	66.79	2.10	0.19	-30.26
Height + Bunch	3	70.2	5.51	0.04	-31.97
Bunchgrass Cover	2	70.6	5.92	0.03	-33.24
Null	1	71.39	6.70	0.02	-34.67
Height + Treatment	4	71.72	7.03	0.02	-31.63
Nest Height	2	71.73	7.05	0.02	-33.80
Vert2 Visual Obstruction	2	71.96	7.28	0.01	-33.92
Height + Treatment + BUnchgrass	5	71.99	7.30	0.01	-30.66
Height*Bunchgrass Cover	4	72.16	7.47	0.01	-31.86
Treatment	3	72.33	7.64	0.01	-33.03
Woody Cover	2	72.37	7.68	0.01	-34.12
Canopy Cover	2	72.41	7.72	0.01	-34.14
Woody Cover + Vert2	3	73.09	8.40	0.01	-33.41
Bunchgrass + Treatment	4	73.2	8.51	0.01	-32.37
Height + Vert2	3	73.28	8.59	0.01	-33.51
Vert3 Visual Obstruction	2	73.41	8.72	0.01	-34.64
Vert1 Visual Obstruction	2	73.44	8.75	0.01	-34.65
Height + Woody	3	73.76	9.07	0.01	-33.75
Height + Canopy	3	73.82	9.13	0.01	-33.78
Height*Treatment	5	73.86	9.18	0.01	-31.59
Substrate (Species)	6	75.56	10.87	0.00	-31.30
Height*Woody Cover	4	75.57	10.88	0.00	-33.56
Global	14	86.25	21.56	0.00	-26.47

a Dist Road = nest distance to nearest maintained road in m, Nest Height = height of nest above ground (m), Vert2 Visual Obstruction = vertical nest strata cover percentage from 1-2m , Woody Cover = percentage of woody cover within an 11.3m radius plot around the nest, Bunchgrass Cover = percentage of bunchgrass cover within an 11.3m radius plot around the nest, Canopy Cover = percentage of canopy cover within an 11.3m radius plot around the nest, Vert3 Visual Obstruction = vertical nest strata cover percentage from 2-3m, Vert1 Visual Obstruction = vertical nest strata cover percentage from 0-1m, Substrate = the type of vegetation (grass/woody) in which a nest was located.

b K = no. of parameters.
c AICc = Akaike's Information Criterion corrected for small sample size.
d ΔAICc = AICc relative to the most parsimonious model.
e w = AICc model weight.

Table 3-7. Model selection statistics for dickcissel nest survival at the Gus Engeling Wildlife Management Area 2016 - 2017. Models were averaged into a single global model.

Model[a]	*K*[b]	AICc[c]	ΔAICc[d]	*w*[e]	Log Liklihood
Null	1	145.68	0	0.15	-71.83
Dist Road	2	147.12	1.43	0.07	-71.53
Vert2 Visual Obstruction	2	147.27	1.58	0.07	-71.6
Bunchgrass Cover	2	147.27	1.58	0.07	-71.6
Vert1 Visual Obstruction	2	147.28	1.59	0.07	-71.61
Vert3 Visual Obstruction	2	147.29	1.61	0.07	-71.61
Nest Height	2	147.42	1.74	0.06	-71.68
Canopy Cover	2	147.57	1.89	0.06	-71.75
Substrate (Species)	2	147.72	2.03	0.05	-71.83
Woody Cover	2	147.73	2.04	0.05	-71.83
Height + Dist Road	3	148.93	3.25	0.03	-71.4
Dist Road + Bunchgrass Cover	3	148.99	3.3	0.03	-71.43
Dist Road + Canopy Cover	3	149.07	3.38	0.03	-71.47
Height + Bunch	3	149.25	3.56	0.03	-71.56
Height + Vert2	3	149.25	3.56	0.03	-71.56
Woody Cover + Vert2	3	149.33	3.64	0.02	-71.6
Height + Canopy	3	149.39	3.71	0.02	-71.63
Height + Woody	3	149.49	3.8	0.02	-71.68
Height*Woody Cover	4	150.04	4.36	0.02	-70.91
Height*Bunchgrass Cover	4	150.29	4.61	0.02	-71.04
Dist Road + Canopy Cover + Vert2	4	150.77	5.08	0.01	-71.27
Dist Road + Vert2 + Bunchgrass Cover	4	150.89	5.21	0.01	-71.34
Bunchgrass Cover*Vert2	4	150.96	5.27	0.01	-71.37
Global	9	159.64	13.96	0	-70.31

a Dist Road = nest distance to nearest maintained road in m, Nest Height = height of nest above ground (m), Vert2 Visual Obstruction = vertical nest strata cover percentage from 1-2m , Woody Cover = percentage of woody cover within an 11.3m radius plot around the nest, Bunchgrass Cover = percentage of bunchgrass cover within an 11.3m radius plot around the nest, Canopy Cover = percentage of canopy cover within an 11.3m radius plot around the nest, Vert3 Visual Obstruction = vertical nest strata cover percentage from 2-3m Vert1 Visual Obstruction = vertical nest strata cover percentage from 0-1m, Substrate = the type of vegetation (grass/woody) in which a nest was located.

b *K* = no. of parameters.

c AICc = Akaike's Information Criterion corrected for small sample size.

d ΔAICc = AICc relative to the most parsimonious model.

e *w* = AICc model weight.

Table 3-8. Daily survival rate (DSR) and Mayfield survival for dickcissels and painted buntings between this study and other studies across their ranges.

Study	Location	Year	Dickcissel		Painted Bunting	
			DSR	Mayfield	DSR	Mayfield
This Study	Texas	2017	0.91	0.14	0.82	0.01
Vasseur & Leberg	Louisiana	2015	-	-	0.94	0.27
Garcia	South Carolina	2004	-	-	0.89	0.09
Lituma	Texas	2012	0.90	0.11	-	-
Zimmerman	Kansas	1982	0.96	0.42	-	-
Patterson & Best	Iowa	1996	0.96	0.42	-	-
Basili	Missouri	1997	0.94	0.27	-	-

APPENDIX

Appendix 2-1. Complete list of plant species detected in 2009 and 2016 based on compartments at Gus Engeling Wildlife Management Area.

Year	Family	Scientific Name	Common Name	Compartment							
				A	B	C	E	F	G	I	J
2009	Acanthaceae	*Ruellia spp.*	Wild Petunia					X	X		
	Agavaceae	*Yucca spp.*	Yucca			X		X			
	Amaranthaceae	*Froelichia gracilis*	Slender Snake-cotton	X		X	X	X	X	X	X
	Anacardiaceae	*Rhus aromatica*	Fragrant Sumac	X		X	X	X	X	X	X
	Anacardiaceae	*Toxicodendron radicans*	Poison Ivy	X		X	X	X	X	X	X
	Apocynaceae	*Trachelospermum difforme*	Climbing Dogbane				X	X	X	X	
	Aristolochiaceae	*Aristolochia reticulata*	Texas Dutchman's Pipe	X		X	X	X			X
	Asclepiadaceae	*Asclepias syriaca*	Milkweed	X				X			X
	Asteraceae	*Ambrosia psilostachya*	Western Ragweed	X		X	X	X	X	X	X
	Asteraceae	*Aster spp.*	Aster	X		X	X	X	X	X	X
	Asteraceae	*Rudbeckia hirta*	Black-eyed Susan					X			
	Asteraceae	*Solidago spp.*	Goldenrod			X		X	X	X	X
	Blachnaceae	*Woodwardia areolata*	Netted Chain Fern			X					
	Cactaceae	*Opuntia spp.*	Prickly Pear	X		X	X	X		X	X
	Capparaceae	*Polanisia erosa*	Large Clammyweed				X	X	X		
	Caprifoliaceae	*Lonicera japonica*	Japanese Honeysuckle	X							
	Caryophyllaceae	*Paronychia drummondii*	Drummond's Nailwort			X	X	X	X	X	X
	Cistaceae	*Helianthemum spp.*	Frostweed			X	X	X	X	X	X
	Clusiaceae	*Hypericum perforatum*	St. John's Wort			X	X		X	X	
	Commelinaceae	*Commelina spp.*	Dayflower	X		X	X	X	X	X	X
	Commelinaceae	*Tradescantia virginiana*	Spiderwort	X		X	X	X	X	X	X
	Cupressaceae	*Juniperus communis*	Juniper Leaf						X		
	Cyperaceae	*Carex spp.*	Sedge	X		X	X	X	X	X	X

Cyperaceae	*Cyperus spp.*	Flatsedge		X	X	X	X	X	X
Dennstaedtiaceae	*Pteridium gleditsch*	Bracken Fern		X					
Eriocaulaceae	*Syngonanthus spp.*	Hatpins		X					
Euphorbiaceae	*Chamaesyce spp.*	Sandmat	X	X	X	X	X	X	
Euphorbiaceae	*Cnidoscolus texanus*	Bullnettle	X	X	X		X	X	X
Euphorbiaceae	*Croton argyranthemus*	Silverleaf Croton		X	X	X	X	X	X
Euphorbiaceae	*Croton capitatus*	Woolly Croton				X		X	
Euphorbiaceae	*Croton glandulosus*	Tropic Croton			X	X	X	X	X
Euphorbiaceae	*Stillingia sylvatica*	Queen's-delight				X	X	X	X
Euphorbiaceae	*Tragia urticifolia*	Nettleleaf Noseburn	X	X	X	X	X	X	X
Fabaceae	*Baptisia nuttalliana*	Nuttall's Wild Indigo	X	X	X	X	X	X	
Fabaceae	*Centrosema spp.*	Butterfly Pea	X	X		X	X		X
Fabaceae	*Chamaecrista fasciculata*	Partridge Pea			X	X	X	X	X
Fabaceae	*Crotalaris sagittalis*	Arrohead Rattlebox		X				X	
Fabaceae	*Dalea spp.*	Prairie Clover		X	X	X			
Fabaceae	*Desmodium spp.*	Desmodium	X	X	X	X	X	X	X
Fabaceae	*Galactia spp.*	Milkpea	X	X	X	X	X	X	X
Fabaceae	*Indigofera miniata*	Scarlet Pea				X	X		
Fabaceae	*Lespedeza spp.*	Lespedeza	X	X	X	X	X	X	X
Fabaceae	*Mimosa microphylla*	Sensitive Briar		X					X
Fabaceae	*Strophostyles helvola*	Wild Bean				X			
Fabaceae	*Stylosanthes biflora*	Pencilflower		X	X	X	X	X	X
Fabaceae	*Tephrosia virginiana*	Goat's Rue	X	X	X	X	X	X	X
Juncaceae	*Juncus spp.*	Rush		X					
Krameriaceae	*Krameria lanceolata*	Trailing Krameria				X		X	
Lamiaceae	*Hedeoma drummondii*	Drummond's False Pennyroyal				X	X		
Lamiaceae	*Monarda punctata*	Spotted Beebalm(horsemint)		X	X	X	X	X	
Lamiaceae	*Pycnanthemum virginianum*	Mountainmint					X		

Lamiaceae	*Rhododon ciliatus*	Texas Sandmint						X		
Lamiaceae	*Scutellaria spp.*	Skullcap	X		X	X	X	X	X	X
Menispermaceae	*Cocculus carolinus*	Carolina Snailseed Vine					X	X	X	X
Molluginaceae	*Mollugo verticillata*	Green Carpetweed	X					X		X
Onagraceae	*Oenothera laciniata*	Cutleaf Evening Primerose					X	X		
Osmundaceae	*Osmunda regalis*	Royal Fern			X					
Oxalidaceae	*Oxalis spp.*	Wood Sorrel			X		X			
Passifloraceae	*Passiflora lutea*	Yellow Passionflower								X
Poaceae	*Andropogon ternarius*	Splitbeard Bluestem						X		
Poaceae	*Andropogon virginicus*	Broomsedge						X		
Poaceae	*Aristida spp.*	Threeawn			X	X	X	X		X
Poaceae	*Chasmanthium laxum*	Slender Woodoats			X					X
Poaceae	*Eragrostis spp.*	Lovegrass					X	X		
Poaceae	*Gymnopogon ambiguus*	Bearded Skeletongrass	X		X	X	X	X	X	X
Poaceae	*Panicum spp.*	Low Panic Grass	X		X	X	X	X	X	X
Poaceae	*Panicum spp.*	Panicum			X		X			X
Poaceae	*Paspalum spp.*	Paspalum	X			X	X	X	X	X
Poaceae	*Schizachyrium scoparium*	Little Bluestem	X		X	X	X	X	X	X
Poaceae	*Sorghastrum nutans*	Indiangrass				X	X	X		
Poaceae	*Sorghum halepense*	Johnsongrass			X		X			X
Poaceae	*Sporobolus junceus*	Pineywoods Dropseed				X	X	X	X	
Poaceae	*Triplasis purpurea*	Purple Sandgrass					X	X		
Polygonaceae	*Eriogonum spp.*	Buckwheat			X	X	X	X	X	
Polygonaceae	*Polygala polygama*	Racemed Milkwort					X			
Portulacaceae	*Phemeranthus parviflorus*	Sunbright					X		X	
Rhamnaceae	*Berchemia scandens*	Alabama Supplejack	X							X
Rosaceae	*Rubus spp.*	Rubus	X		X	X	X	X	X	X
Rubicaceae	*Diodia teres*	Poor-joe			X		X	X	X	X

	Rubicaceae	*Galium aparine*	Catchweed Bedstraw					X			
	Rubicaceae	*Galium pilosum*	Hairy Bedstraw	X		X	X	X	X	X	X
	Scrophulariaceae	*Penstemon murrayanus*	Scarlet Penstemon					X			
	Solanaceae	*Physalis angulata*	Cutleaf Groundcherry					X	X		
	Solanaceae	*Solanum spp.*	Nightshade	X		X	X	X	X	X	X
	Verbenaceae	*Verbena halei*	Texas Verbena				X	X	X		
	Violaceae	*Viola spp.*	Violet			X	X				
	Vitaceae	*Parthenocissus quinquefolia*	Virginia Creeper	X		X	X			X	X
2016	Agavaceae	*Yucca spp.*	Yucca								X
	Amaranthaceae	*Froelichia gracilis*	Slender Snake-cotton	X			X			X	
	Anacardiaceae	*Rhus aromatica*	Fragrant Sumac	X	X		X			X	
	Anacardiaceae	*Rhus copallinum*	Winged Sumac						X		
	Anacardiaceae	*Toxicodendron radicans*	Poison Ivy	X	X	X	X	X	X	X	X
	Aquifoliaceae	*Ilex vomitoria*	yaupon			X	X				X
	Asclepiadaceae	*Asclepias syriaca*	Milkweed						X		
	Asteraceae	*Ambrosia artemisiifloria*	Common Ragweed		X		X		X	X	
	Asteraceae	*Ambrosia psilostachya*	Western Ragweed	X	X		X	X	X	X	
	Asteraceae	*Aster spp.*	Aster	X	X		X			X	
	Asteraceae	*Cichorium intybus*	Chicory						X		
	Asteraceae	*Eupatorium capillifolium*	Dog Fennel	X	X					X	
	Asteraceae	*Helianthus annuus*	Sunflower	X	X	X	X	X	X	X	X
	Asteraceae	*Heterotheca subaxillaris*	Camphorweed	X	X			X	X	X	X
	Asteraceae	*Rudbeckia hirta*	Black-eyed Susan	X	X						
	Cactaceae	*Opuntia spp.*	Prickly Pear	X							
	Caprifoliaceae	*Lonicera sempervirens*	Coral Honeysuckle			X					X
	Clusiaceae	*Hypericum perforatum*	St. John's Wort			X					
	Commelinaceae	*Commelina spp.*	Dayflower	X	X	X		X		X	X

Commelinaceae	*Tradescantia virginiana*	Spiderwort								
Cornaceae	*Cornus florida*	flowering dogwood				X				X
Cyperaceae	*Carex spp.*	Sedge	X	X		X			X	
Cyperaceae	*Cyperus spp.*	Flatsedge	X	X	X	X			X	X
Dennstaedtiaceae	*Pteridium gleditsch*	Bracken Fern		X	X					
Ericaceae	*Vaccinium arboreum*	Tree Sparkleberry			X	X			X	X
Euphorbiaceae	*Cnidoscolus texanus*	Bullnettle	X							
Euphorbiaceae	*Croton argyranthemus*	Silverleaf Croton	X		X	X	X	X	X	X
Euphorbiaceae	*Croton capitatus*	Woolly Croton	X	X	X		X			
Euphorbiaceae	*Croton glandulosus*	Tropic Croton	X							
Euphorbiaceae	*Croton spp.*	Croton								X
Euphorbiaceae	*Croton texensis*	One-seed Croton	X							
Fabaceae	*Amorpha fruticosa*	Flase Indigo	X	X					X	
Fabaceae	*Chamaecrista fasciculata*	Partridge Pea		X						
Fabaceae	*Desmodium spp.*	Desmodium		X	X	X		X	X	
Fabaceae	*Galactia spp.*	Milkpea	X	X	X	X		X	X	X
Fabaceae	*Lespedeza spp.*	Lespedeza	X			X		X	X	
Fabaceae	*Mimosa microphylla*	Sensitive Briar	X	X						
Fabaceae	*Tephrosia virginiana*	Goat's Rue		X	X	X	X	X	X	X
Fabaceae		Legume								X
Fagaceae	*Quercus incana*	bluejack oak	X	X	X	X	X	X	X	X
Fagaceae	*Quercus marilandica*	Blackjack Oak			X	X	X	X	X	X
Fagaceae	*Quercus stellata*	Post Oak	X	X	X	X	X	X	X	X
Juglandaceae	*Carya spp.*	hickory	X	X	X	X	X	X	X	X
Lamiaceae	*Monarda punctata*	Spotted Beebalm(horsemint)	X	X	X	X	X	X	X	X
Lamiaceae	*Scutellaria spp.*	Skullcap	X			X			X	
Passifloraceae	*Passiflora lutea*	Yellow Passionflower	X							
Poaceae	*Andropogon gerardii*	Big Bluestem	X							

Poaceae	*Andropogon ternarius*	Splitbeard Bluestem	X	X	X	X			X	
Poaceae	*Avena sativa*	Wildland Oats	X							
Poaceae	*Chasmanthium laxum*	Slender Woodoats			X					
Poaceae	*Elymus virginicus*	Wildrye	X	X						
Poaceae	*Eragrostis spp.*	Lovegrass	X	X		X		X	X	X
Poaceae	*Panicum spp.*	Low Panic Grass	X	X	X	X	X	X	X	X
Poaceae	*Paspalum spp.*	Paspalum	X							
Poaceae	*Schizachyrium scoparium*	Little Bluestem	X	X	X	X	X	X	X	X
Poaceae	*Sorghastrum nutans*	Indian grass	X	X						
Poaceae		Grass					X	X		
Rosaceae	*Crataegus marshallii*	Parsley Hawthorn								
Rosaceae	*Prunus mexicana*	mexican plum								X
Rosaceae	*Rubus spp.*	Rubus	X	X	X	X	X	X	X	X
Rubicaceae	*Diodia teres*	Poor-joe	X		X	X	X	X	X	X
Smilacaceae	*Smilax spp.*	Greenbriar			X	X			X	X
Ulmaceae	*Ulmus spp.*	Elm								X
Verbenaceae	*Callicarpa americana*	American Beautyberry			X				X	X
Vitaceae	*Parthenocissus quinquefolia*	Virginia Creeper								X
Vitaceae	*Vitis spp.*	Grape	X	X	X	X		X	X	X

Appendix 2-1. Complete list of bird species detected at the Gus Engeling Wildlife Management Area (GEWMA) based on compartment and year.

Year	Family	Genus	Scientific Name	Common Name	Compartment							
					A	B	C	E	F	G	I	J
2009	Cardinalidae	*Cardinalis*	*Cardinalis cardinalis*	Northern Cardinal	X	X	X	X	X	X	X	X
		Passerina	*Passerina ciris*	Painted Bunting	X	X	X	X	X	X	X	X
		Passerina	*Passerina cyanea*	Indigo Bunting	X	X	X	X	X	X	X	X
		Spiza	*Spiza americana*	Dickcissel					X			
	Cathartidae	*Cathartes*	*Cathartes aura*	Turkey Vulture						X		
	Columbidae	*Zenaida*	*Zenaida macroura*	Mourning Dove	X	X	X		X	X	X	X
	Corvidae	*Corvus*	*Corvus brachyrhynchos*	American Crow	X	X	X	X	X	X	X	
		Cyanocitta	*Cyanocitta cristata*	Blue Jay				X				
	Cuculidae	*Coccyzus*	*Coccyzus americanus*	Yellow-billed Cuckoo	X	X	X	X	X	X	X	X
	Emberizidae	*Aimophila*	*Aimophila aestivalis*	Bachman's Sparrow					X	X		
	Falconidae	*Buteo*	*Buteo lineatus*	Red-shouldered Hawk						X		
	Icteridae	*Molothrus*	*Molothrus ater*	Brown-headed Cowbird		X	X		X	X	X	X
	Mimidae	*Mimus*	*Mimus polyglottos*	Northern Mockingbird					X	X		
		Toxostoma	*Toxostoma rufum*	Brown Thrasher							X	
	Odontophoridae	*Colinus*	*Colinus virginianus*	Northern Bobwhite				X	X	X		X
	Paridae	*Baeolophus*	*Baeolophus bicolor*	Tufted Titmouse	X	X	X	X	X	X	X	X
		Poecile	*Poecile carolinensis*	Carolina Chickadee	X	X	X	X	X	X	X	X
	Parulidae	*Dendroica*	*Dendroica dominica*	Yellow-throated Warbler					X	X		
		Geothlypis	*Geothlypis trichas*	Common Yellowthroat							X	
		Mniotilta	*Mniotilta varia*	Black-and-white Warbler	X	X	X	X				X
	Picidae	*Dryocopus*	*Dryocopus pileatus*	Pileated Woodpecker		X			X			
		Melanerpes	*Melanerpes carolinus*	Red-bellied Woodpecker	X							
		Picoides	*Picoides pubescens*	Downy Woodpecker	X	X		X				

		Picoides	*Picoides villosus*	Hairy Woodpecker		X						
	Polioptilidae	*Polioptila*	*Polioptila caerulea*	Blue-grey Gnatcatcher	X	X	X	X	X	X	X	X
	Regulidae	*Regulus*	*Regulus calendula*	Ruby-crowned Kinglet			X				X	X
	Sittidae	*Sitta*	*Sitta carolinensis*	White-breasted Nuthatch		X	X		X			
	Thraupidae	*Piranga*	*Piranga rubra*	Summer Tanager	X	X	X	X	X	X	X	X
	Trochilidae	*Archilochus*	*Archilochus colubris*	Ruby-throated Hummingbird		X						
	Troglodytidae	*Thryothorus*	*Thryothorus ludovicianus*	Carolina Wren	X	X	X	X	X	X	X	X
	Turdidae	*Sialia*	*Sialia sialis*	Eastern Bluebird						X		
	Tyrannidae	*Contopus*	*Contopus virens*	Eastern Wood-pewee		X		X	X	X	X	
		Empidonax	*Empidonax flaviventris*	Yellow-bellied Flycatcher						X		
		Sayornis	*Sayornis phoebe*	Eastern Phoebe	X	X	X		X	X	X	X
		Tyrannus	*Tyrannus forficatus*	Scissor-tailed Flycatcher					X	X		
		Tyrannus	*Tyrannus tyrannus*	Eastern Kingbird		X	X		X	X		
	Vireonidae	*Vireo*	*Vireo griseus*	White-eyed Vireo	X		X				X	X
		Vireo	*Vireo olivaceus*	Red-eyed Vireo	X	X	X	X			X	X
2016	Anatidae	*Aix*	*Aix sponsa*	Wood Duck		X						
		Dendrocygna	*Dendrocygna autumnalis*	Black-bellied Whistling Duck	X							
	Caprimulgidae	*Caprimulgus*	*Caprimulgus carolinensis*	Chuck-will's-widow								X
	Cardinalidae	*Cardinalis*	*Cardinalis cardinalis*	Northern Cardinal	X	X	X	X	X	X	X	X
		Guiraca	*Guiraca caerulea*	Blue Grosbeak	X				X	X	X	
		Passerina	*Passerina ciris*	Painted Bunting	X	X	X	X	X	X	X	X
		Passerina	*Passerina cyanea*	Indigo Bunting	X	X	X	X	X	X	X	X
		Spiza	*Spiza americana*	Dickcissel	X	X			X	X		
	Cathartidae	*Cathartes*	*Cathartes aura*	Turkey Vulture				X				
		Coragyps	*Coragyps atratus*	Black Vulture	X							
	Columbidae	*Zenaida*	*Zenaida macroura*	Mourning Dove	X	X	X	X	X	X	X	X
	Corvidae	*Corvus*	*Corvus brachyrhynchos*	American Crow							X	

	Cyanocitta	*Cyanocitta cristata*	Blue Jay						X		
Cuculidae	*Coccyzus*	*Coccyzus americanus*	Yellow-billed Cuckoo	X	X	X	X	X	X	X	X
Emberizidae	*Aimophila*	*Aimophila aestivalis*	Bachman's Sparrow	X				X	X		
	Chondestes	*Chondestes grammacus*	Lark Sparrow	X	X		X	X			
Falconidae	*Buteo*	*Buteo jamaicensis*	Red-tailed Hawk	X							
Fringillidae	*Carpodacus*	*Carpodacus mexicanus*	House Finch					X			
Icteridae	*Icterus*	*Icterus galbula*	Baltimore Oriole	X				X			X
	Icterus	*Icterus spurius*	Orchard Oriole	X	X			X	X		
	Molothrus	*Molothrus ater*	Brown-headed Cowbird	X	X	X	X	X	X	X	X
Mimidae	*Dumetella*	*Dumetella carolinensis*	Gray Catbird						X		X
	Mimus	*Mimus polyglottos*	Northern Mockingbird	X	X			X	X	X	
Odontophoridae	*Colinus*	*Colinus virginianus*	Northern Bobwhite	X					X		
Paridae	*Baeolophus*	*Baeolophus bicolor*	Tufted Titmouse	X	X	X	X	X	X	X	X
	Poecile	*Poecile carolinensis*	Carolina Chickadee	X	X	X	X	X	X	X	X
Parulidae	*Dendroica*	*Dendroica dominica*	Yellow-throated Warbler	X	X	X	X	X	X	X	X
	Icteria	*Icteria virens*	Yellow-breasted Chat	X		X		X	X	X	
	Mniotilta	*Mniotilta varia*	Black-and-white Warbler			X	X			X	X
	Oporornis	*Oporornis formosus*	Kentucky Warbler								X
Phasianidae	*Meleagris*	*Meleagris gallopavo*	Wild Turkey	X	X					X	
Picidae	*Colaptes*	*Colaptes auratus*	Northern Flicker		X						
	Dryocopus	*Dryocopus pileatus*	Pileated Woodpecker						X		X
	Melanerpes	*Melanerpes carolinus*	Red-bellied Woodpecker	X	X	X	X		X	X	
	Melanerpes	*Melanerpes erythrocephalus*	Red-headed Woodpecker	X							
	Picoides	*Picoides pubescens*	Downy Woodpecker	X	X	X	X		X	X	X
	Picoides	*Picoides villosus*	Hairy Woodpecker		X	X		X			
Polioptilidae	*Polioptila*	*Polioptila caerulea*	Blue-gray Gnatcatcher	X	X	X	X	X	X	X	X
Sittidae	*Sitta*	*Sitta carolinensis*	White-breasted Nuthatch	X	X	X	X				
Thraupidae	*Piranga*	*Piranga rubra*	Summer Tanager	X	X	X	X	X	X	X	X

	Trochilidae	*Archilochus*	*Archilochus colubris*	Ruby-throated Hummingbird	X				X			
	Troglodytidae	*Thryothorus*	*Thryothorus ludovicianus*	Carolina Wren	X	X	X	X	X	X	X	X
	Turdidae	*Sialia*	*Sialia sialis*	Eastern Bluebird	X	X						
	Tyrannidae	*Contopus*	*Contopus virens*	Eastern Wood-pewee	X	X		X	X		X	X
		Myiarchus	*Myiarchus crinitus*	Great Crested Flycatcher	X	X	X	X	X	X	X	X
		Sayornis	*Sayornis phoebe*	Eastern Phoebe	X	X		X	X	X	X	X
		Tyrannus	*Tyrannus forficatus*	Scissor-tailed Flycather	X	X			X	X		
		Tyrannus	*Tyrannus tyrannus*	Eastern Kingbird	X	X			X	X		
		Tyrannus	*Tyrannus verticalis*	Western Kingbird	X							
	Vireonidae	*Vireo*	*Vireo flavifrons*	Yellow-throated Vireo		X						
		Vireo	*Vireo griseus*	White-eyed Vireo			X	X		X	X	X
		Vireo	*Vireo olivaceus*	Red-eyed Vireo			X	X		X		X
2017	Anatidae	*Dendrocygna*	*Dendrocygna autumnalis*	Black-bellied Whistling Duck				X				
	Caprimulgidae	*Caprimulgus*	*Caprimulgus carolinensis*	Chuck-will's-widow			X					
	Cardinalidae	*Cardinalis*	*Cardinalis cardinalis*	Northern Cardinal	X	X	X	X	X	X	X	X
		Guiraca	*Guiraca caerulea*	Blue Grosbeak	X	X	X	X	X	X	X	
		Passerina	*Passerina ciris*	Painted Bunting	X	X	X	X	X	X	X	X
		Passerina	*Passerina cyanea*	Indigo Bunting	X	X	X	X	X	X	X	X
		Spiza	*Spiza americana*	Dickcissel	X	X		X	X	X		
	Cathartidae	*Cathartes*	*Cathartes aura*	Turkey Vulture				X				X
	Columbidae	*Zenaida*	*Zenaida macroura*	Mourning Dove	X	X	X	X	X	X	X	X
	Corvidae	*Corvus*	*Corvus brachyrhynchos*	American Crow			X		X			
		Cyanocitta	*Cyanocitta cristata*	Blue Jay	X							
	Cuculidae	*Coccyzus*	*Coccyzus americanus*	Yellow-billed Cuckoo	X	X	X	X	X	X	X	X
	Emberizidae	*Aimophila*	*Aimophila aestivalis*	Bachman's Sparrow					X	X		
		Chondestes	*Chondestes grammacus*	Lark Sparrow		X			X		X	
	Falconidae	*Buteo*	*Buteo jamaicensis*	Red-tailed Hawk	X			X				

Fringillidae	*Carpodacus*	*Carpodacus mexicanus*	House Finch	X			X	X	X	X	
Hirundinidae	*Hirundo*	*Hirundo rustica*	Barn Swallow	X							
Icteridae	*Icterus*	*Icterus galbula*	Baltimore Oriole			X				X	X
	Icterus	*Icterus spurius*	Orchard Oriole	X	X	X	X		X	X	X
	Molothrus	*Molothrus ater*	Brown-headed Cowbird	X	X	X	X	X	X	X	X
Mimidae	*Mimus*	*Mimus polyglottos*	Northern Mockingbird	X	X			X	X	X	
Paridae	*Baeolophus*	*Baeolophus bicolor*	Tufted Titmouse	X	X	X	X	X	X	X	X
	Poecile	*Poecile carolinensis*	Carolina Chickadee	X	X	X	X	X	X	X	X
Parulidae	*Dendroica*	*Dendroica dominica*	Yellow-throated Warbler	X	X	X	X	X	X	X	X
	Geothlypis	*Geothlypis trichas*	Common Yellowthroat			X			X		
	Icteria	*Icteria virens*	Yellow-breasted Chat			X					
Phasianidae	*Meleagris*	*Meleagris gallopavo*	Wild Turkey								X
Picidae	*Dryocopus*	*Dryocopus pileatus*	Pileated Woodpecker	X		X			X		X
	Melanerpes	*Melanerpes carolinus*	Red-bellied Woodpecker	X	X	X	X				X
	Picoides	*Picoides pubescens*	Downy Woodpecker	X	X	X	X	X	X	X	X
	Picoides	*Picoides villosus*	Hairy Woodpecker		X	X			X		
Polioptilidae	*Polioptila*	*Polioptila caerulea*	Blue-gray Gnatcatcher	X	X	X	X	X	X	X	X
Sittidae	*Sitta*	*Sitta carolinensis*	White-breasted Nuthatch	X	X		X				X
	Sitta	*Sitta pusilla*	Brown-headed Nuthatch	X							
Thraupidae	*Piranga*	*Piranga rubra*	Summer Tanager	X	X	X	X	X	X	X	X
Trochilidae	*Archilochus*	*Archilochus colubris*	Ruby-throated Hummingbird			X		X			X
Troglodytidae	*Thryothorus*	*Thryothorus ludovicianus*	Carolina Wren	X	X	X	X		X	X	X
Turdidae	*Hylocichla*	*Hylocichla mustelina*	Wood Thrush			X					
	Sialia	*Sialia sialis*	Eastern Bluebird	X	X			X		X	
Tyrannidae	*Contopus*	*Contopus virens*	Eastern Wood-pewee		X	X	X	X	X	X	X
	Myiarchus	*Myiarchus crinitus*	Great Crested Flycatcher		X	X	X		X	X	X
	Sayornis	*Sayornis phoebe*	Eastern Phoebe				X	X			
	Tyrannus	*Tyrannus forficatus*	Scissor-tailed Flycatcher	X	X	X		X	X		

	Tyrannus	*Tyrannus tyrannus*	Eastern Kingbird	X			X	X			X
	Tyrannus	*Tyrannus verticalis*	Western Kingbird	X	X			X	X		
Vireonidae	*Vireo*	*Vireo flavifrons*	Yellow-throated Vireo			X					
	Vireo	*Vireo griseus*	White-eyed Vireo			X	X				X
	Vireo	*Vireo olivaceus*	Red-eyed Vireo	X		X					X

VITA

After graduating in the top ten percent of Huntington High School's Class of 2012 in Huntington, Texas, Courtney (Williams) McInnerney entered Stephen F. Austin State University at Nacogdoches, Texas. She began SFASU in the fall of 2012 where she earned the degree of Bachelor of Science in Forestry with an emphasis in wildlife management in December 2015. She then began her graduate studies in January 2016 and received the degree of Master of Environmental Science in August 2018.

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