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BASELINE AVIAN AND VEGETATION COMMUNITIES ON POST OAK SAVANNAH RESTORATION AREAS

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INTRODUCTION

Oak (*Quercus*) Savannahs were once abundant in the Midwest United States, extending through portions of Minnesota, Iowa, Missouri, Illinois, Wisconsin, Michigan, Indiana, and Ohio, and southward through parts of Missouri, Kansas, Oklahoma, to the Texas Coast (Fig. 1). Definitions of savannah habitat vary; however, a typical oak savannah community consists of a widely spaced canopy (cover between10 and 70%) dominated by oak species and a well-developed grassy herbaceous layer (Nuzzo 1985). Vegetative heterogeneity is high because the community is dominated by graminoids in the open, high-sunlight areas and forbs and woody species in the low-light, forested mottes (small clumps of trees; Nuzzo 1985). Approximately 0.02% of the Midwest oak savannah exists today, and of this, <200 ha of oak savannah vegetation are in a pre-EuroAmerican settlement state (Fig. 1; Henderson 1995, Nuzzo 1985).

Wide-scale fragmentation of the natural oak savannah landscape began in the 1860s, following the passage of the Homestead Act (1862). This Act gave people free plots of undeveloped, federal land of up to 65 ha providing they built a house on it, dug a well, cultivated it, and lived on the land. As a result, large tracts of land were parceled, fenced, and converted for agricultural purposes and for cattle ranching (Knopf 1994). The converted pastureland has since been planted with exotic species such as Bermuda grass (*Cynodon dactylon*) and bahiagrass (*Paspalum notatum*), which are popular rangeland species favored by cattle (TPWD 2007b).

The Post Oak Savannah of Texas is the southernmost portion of the Oak Savannah ecoregion of the Midwest (Fig. 1). The Post Oak Savannah is a transition zone

from the Pineywoods of east Texas and the Blackland Prairie ecoregion to the west (TPWD 2007a). It is characterized by interspersed mottes of post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) and other hardwood species, surrounded by vegetation dominated by warm season grasses such as little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*) and switchgrass (*Panicum virgatum*; Nuzzo 1985, Samson and Knopf 1994, TPWD 2009). Mean annual rainfall in the Post Oak Savannah ranges between 90 and 115 cm. In upland sites, soils are characterized as light colored, extremely permeable sand and sandy loam, whereas gray-brown, moderately permeable clay and clay loam soils are associated with bottomland sites (TPWD 2007a).

Texas is divided into ten ecoregions based on similar ecosystems. The Post Oak Savannah ecoregion of Texas encompasses 31 counties (Fig. 2; TPWD 2007a). Approximately 10% of its original area remains in Texas (Samson and Knopf 1994). Currently, there are >4 million ha of non-native pastureland in Texas, which covers approximately 75% of the Texas Post Oak Savannah (Hays et al. 2005, Brennan 2007). Historically, Post Oak Savannah was maintained by 2 disturbance cycles: herbivory and fire (Henderson 1995, TPWD 2007a). Native grazers, mainly bison (*Bison bison*), maintained the Post Oak Savannah vegetation through occasional disturbance as a result of their nomadic grazing (TPWD 2007a). Fire was ignited either by lightning or anthropogenically by Native Americans. Prior to EuroAmerican settlement, Native Americans used prescribed fire to maintain grasslands and prevent woody overgrowth. They also used fire to attract bison post-burn to palatable early successional grasses and

forbs (Jurney et al. 2000). Fire by means of lightning ignition likely occurred during the dry season of mid- to late summer (Samson and Knopf 1994).

Drastic changes in the landscape result in changes in the wildlife community that resides there. There are 158 wildlife species classified as Species of Concern or State/Federally Threatened Species that occur in the Post Oak Savannah ecoregion of Texas (TPWD 2005). Of these, 110 are bird species, the greatest number of any taxon (TPWD 2005). Grassland-associated bird species have shown the most rapid decline in North America among avian species guilds, attributed primarily to habitat loss and degradation (Knopf 1994).

Grassland bird species also appear to be particularly sensitive to habitat fragmentation (Hunter et al. 2001). Both breeding and wintering grounds of songbirds have been affected by the changes in the Oak Savannah ecosystem (Hunter et al. 2001). Eight of 14 federally endangered disturbance-dependent bird species in North America are found in grassland, prairie, and savannah habitat, with patch size playing an important role in grassland bird distribution (Hunter et al. 2001). Some grassland bird species have been shown to exhibit lower reproductive success in highly fragmented habitats (Winter and Faaborg 1999, Winter et al. 2006).

Few studies have documented the success of restoration attempts in Post Oak Savannah systems, especially in regards to songbird ecology. Fire, herbicide, and mechanical treatments have been used in oak savannah restoration and have been shown to be effective in creating appropriate habitat structure (Brawn et al. 2001). Application

of prescribed fire, in particular, has been used to revive grassland bird species in some oak savannah ecosystems in the Midwest (Davis et al. 2000).

Gus Engeling Wildlife Management Area (GEWMA) is located in Tennessee Colony in Anderson County, TX (Fig. 2) and was purchased by Texas Parks and Wildlife Department (TPWD) between 1950-1960. Prior to purchase, GEWMA was used to raise livestock, mostly cattle. The area was established to serve as a research and demonstration site for the Post Oak Savannah ecoregion. Nearly 200 ha of the 4,450 ha are in the Post Oak Savannah restoration process and have been maintained in that state through application of prescribed fire and mechanical treatments over the past 35 years. Under the *Texas Comprehensive Wildlife Conservation Strategy*, native prairies and grasslands are listed as a habitat of high priority because they contain several rare species and species of conservation concern (TPWD 2005), such as the following high priority species: Northern bobwhite (*Colinus virginianus*), Eastern meadowlark (*Sturnella magna*), Bachman's sparrow (*Peucaea aestivalis*), and Henslow's sparrow (*Ammodramus henslowii*) (TPWD 2005). In 2007, TPWD initiated an effort to restore approximately 1,000 ha of grassland and savannah habitat on GEWMA that had been encroached by woody species. Woody overstory removal on the 1,000 ha is expected over the upcoming years. In order to monitor the progress and success of the restoration of the site to its native Post Oak Savannah habitat, a baseline condition of the site had to be established. Songbirds are a good indicator species of site quality because of their site specific preferences and sensitivity to habitat modifications. Avian diversity and abundance were measured in previously restored and encroached habitats to derive a

baseline community assessment and allow determination of the success of management practices (e.g. fire, herbicide, and timber harvest) on the Post Oak Savannah community.

OBJECTIVES

The goal of this study was to conduct a baseline assessment of vegetation and avian species composition and reproduction, specifically for grassland and early-successional songbirds, with the long-term goal of evaluating the success of current and future restoration effort success for Post Oak Savannah habitat at Gus Engeling Wildlife Management Area in eastern Texas. Specifically, our objectives included:

1. Establish a baseline, including species lists and structural characteristics for vegetation and avian communities, in the proposed post oak savannah restoration area at GEWMA.
2. Evaluate the potential for existing savannah habitats in Compartment F and Compartment G to serve as "desired conditions" for evaluation of the restoration efforts.
3. Quantify nest success and nest site selection of representative target bird species (painted buntings [*Passerina ciris*], indigo buntings [*Passerina cyanea*] and Bachman's Sparrows) at GEWMA.

METHODS

Study Site

The study was conducted in the northwest portion of GEWMA in Tennessee Colony, Texas. The GEWMA is a designated research and demonstration site for the Post Oak Savannah ecoregion. The northwest portion is approximately 1,000 ha of deep sandy soils ranging from fine sands (Tonkawa and Darco) and lilbert loamy fine sand, to Darco, Kirvin, and Tenaha soils. Within this area 11 compartments, separated by roads, exist. Of these, nine were used to form eight study blocks—six encroached blocks and two reference blocks (Fig. 3). The size of the reference blocks are 85 ha (Block F) and 112 ha (Block G) and have been exposed to one or more of the following: prescribed burns, herbicide, and mechanical treatments (i.e., disking, roller chopping, bush hogging, or mowing). They represent a desired condition for restoration of the encroached blocks at GEWMA. The encroached blocks range between 52 and 195 ha and have undergone a minimal amount of restoration treatment as compared to the reference blocks. Prescribed burns were conducted on both reference blocks during October 2005 and again in 2008 (one in summer and one in winter).

Winter and Breeding Season Bird Surveys

We used line-transect distance sampling to quantify winter and breeding bird community abundance, density, and composition in each block. Two 500-m transects were randomly assigned to each block using a random point generator and a random azimuth generator with the following restrictions: (1) each 500-m transect must be ≥100 m from the boundary (road) of the block to avoid edge effects and (2) all transects must

be ≥ 250 m from adjacent transects to ensure independence (Igl and Ballard 1999, Fritcher et al. 2004). Because its small size did not allow for 500 m transects, Block F had two 150-m transects. These transects were surveyed three times within each survey period to derive the same 500 m transect length (Fig. 3; Buckland et al. 2001).

Bi-weekly (every other week) bird surveys were performed on designated transects in winter from 15 December 2008 to 1 March 2009, and again from 15 December 2009 to 1 March 2010 and in the breeding season from 1 May to 15 July 2009 and 2010 (MacKenzie and Royle 2005). Each transect was surveyed five times per survey season to derive a detection history at each site for each species. All surveys were conducted at a constant speed of 1.0 km/hour. All birds detected were identified to species (or genus if we could not determine species). We also recorded the position along the transect at which the bird was detected, the bird's perpendicular distance from the transect (using an optical range finder), the time of detection, and the method of detection (visual, call, song etc.; Buckland et al. 2001, Buckland 2006). Surveys began 30 minutes before sunrise and continued until approximately 3.5 hours after sunrise (Igl and Ballard 1999, Thomas et al. 2002, Fritcher et al. 2004). Surveys were not performed during weather conditions that were likely to negatively affect bird activity or detectability (i.e., rain/snow, winds above 16 km/hr, and/or fog; Igl and Ballard 1999).

Nest Searches

Nest searches in the designated study blocks were performed during the songbird breeding season from 25 April to 15 July 2009 and 2010 (Winter and Faaborg 1999, Fletcher and Koford 2002). We located nests by conducting systematic nest searches

along previously designated survey transects as well as opportunistically while conducting other work. Systematic searches consisted of intensive transect searches through three separate 1-ha patches along each of the 16 survey transects (Winter et al. 2003). We located nests through the use of visual cues such as the transport of nesting materials, fecal sac removal, distraction displays and distraction calls. Nest searchers also looked for bird nests, individual birds carrying food back to a nest, and bird activity occurring at or near a nest. (Martin and Geupel 1993). Nest searchers (2-3) were positioned approximately 3 meters apart in a straight line and walked perpendicularly away from the transect for 50 m, turned, walked back 50 m towards the transect line, crossed the transect line, walked 50 m away from the transect line on the opposite side, turned, and walked back. This was repeated for 100 m along the transect line. Nest searchers then proceeded 100 m down the transect line and repeated the aforementioned steps for two more patches along the transect (Fig. 4; Winter et al. 2003, Albrecht and Klvaňa 2004). Once a nest was found, we recorded species for the nest based on the shape, composition, location and other characteristics of the nest, location of the nest in the substrate (if any), the egg characteristics (if egg(s) are present), and/or the species of the adult found on or near the nest (Harrison 1975, Baicich and Harrison 2005). The following information was recorded on a nest card at nest discovery: date, species, nest identification name, nesting substrate, height of the nest from the ground, the number of eggs or nestlings inside the nest, a brief description of the eggs or nestlings, if applicable, and a description of the parental activity, if applicable. The location of the nest was both

marked on a Garmin GPS and hand recorded. The closest woody shrub or tree was flagged 5 m north of the nest.

Nest Monitoring

All active nests were monitored every 3-4 days until nest fate was determined (Martin and Geupel 1993). We recorded the number of eggs, number of chicks hatched, hatch date, fledgling age, fledge date and how many fledged (if any) on each visit (Martin and Geupel 1993). Nests found in the canopy above eye level at heights ≤ 6 m were monitored using a telescoping pole with a mirror attached to it. Nests were classified as successful if they fledged at least one chick (Rodewald 2004). A failed nest was defined as a nest that was predated, abandoned, destroyed, found empty before the nestling period ended, or that fledged no chicks (Martin et al. 1997, Rodewald 2004). In most cases, fate could be determined based on nest structure and the immediate area around the nest—such as shell fragments on the ground or in the nest before the expected hatching date, holes in the nest, torn nests, etc. (Martin and Geupel 1993). Nests for which fate could not be determined (i.e., eggs were gone but we did not observe the fledglings or evidence of predation or other nest failure) were classified as uncertain (Manolis et al. 2000).

Vegetation Assessment

A vegetative community assessment of each study site was conducted to quantify plant species composition and structural vegetative characteristics on the northwest portion of GEWMA. Each compartment had 50 randomly placed plots, totaling 400 vegetation plots. Woody vegetation was measured using the line-intercept method (Knight 1978, Smeins and Slack 1982). A 25-m transect was established along a random

azimuth beginning at the randomly placed plot point (Fig. 5). We recorded woody plant species intercepting the vertical plane over the transect at 1-m intervals. Herbaceous ground cover was measured using 1-m^2 square plots placed adjacent to the transect on alternating sides at 5-m intervals (Fig. 5). We identified all plants to species or the finest taxonomic designation possible and recorded a cover class (1-6: 0-5%, 5-25%, 25-50%, 50-75%, 75-95%, and 95-100%) based on the Daubenmire canopy-coverage method (Daubenmire 1959). We used the point-centered-quarter method to quantify overstory vegetation (Smeins and Slack 1982). At the 5 m and 20 m points along the transect, we divided a variable radius plot into quadrants using the cardinal directions (Fig. 5). Within each quadrant, we recorded the species, DBH and distance of the nearest tree ≥ 5 cm DBH and ≤ 50 m away.

Nest Site and Paired Site

We also examined habitat characteristics around nest sites to determine factors influencing nest site selection for indigo buntings and painted buntings. Once nest fate was determined, we examined the characteristics of each nest site and a randomly chosen paired site approximately 25 m away. Paired sites were designated by traveling 25 m away from the nest site at a random azimuth. Plot center for the paired plot was a structurally similar plant to the nest plant (shrub or tree). For ground nests, the woody plant nearest to the nest was identified, with plot center located in relation to the woody plant. The plant used for plot center at the paired plot measured ± 5 cm measured

diameter at breast height (DBH) and ± 5 m total height of the nest substrate (Martin et al. 1997).

The following individual measurements and observations were recorded at the nest site: nest height (m) from the ground (0 for ground nests), species, height, and DBH (for woody plants) for the plant supporting the nest, the number of branches supporting an above-ground nest, distance from the trunk of the plant to the center of the nest (cm), horizontal distance of center of the nest to the nearest outer edge of the foliage (cm), distance to nearest tree and species of that tree (m), and distance to the nearest habitat edge (m) (if any) and distance to the nearest road (m; Martin et al. 1997).

We also characterized the vegetation structure and composition surrounding the nest location and the paired site using a nested plot design. An 11.3 m radius circle was measured and outer edges flagged with the nest or paired plant as the center point (Fig. 6). The circular plot was divided into quadrants using the cardinal directions. Within this circle, a smaller 5-m radius circular plot was also established (Fig. 6). All woody stems ≥8-cm dbh within the large circle were counted and identified to species. In the smaller 5-m radius circle, stems of all woody species <8-cm dbh and ≥50 cm tall were counted and identified to species (Martin et al. 1997). In each large quadrant, a 1-m^2 square quadrat was used to estimate herbaceous and woody ground cover (Fig. 6). The 5 most dominant plant species that fall within the square were recorded to species, as well as their cover classes (1-6; Daubenmire 1959).

A 0.5 m by 2 m cover board was used to measure vegetation density at various vertical strata. The board was set on the ground against the central tree facing each

cardinal direction centered at the nest location for nest sites, or at the plant center for paired sites. The percent coverage by vegetation of each vertical increment (0.5 m each for 4 total) was read from a distance of 5-m and recorded to the nearest 5% (Daubenmire 1959, Martin et al. 1997).

ANALYSIS AND RESULTS

Vegetation Characteristics

We used one-way analysis of variance to examine differences in vegetation structure (expressed as trees/ha, basal area, canopy coverage, and groundcover composition) among the 8 compartments (Table 1). We also performed Tukey's honestly significant difference tests to identify post-hoc differences among individual compartments and performed *a priori* one-degree-of-freedom tests to compare the encroached blocks (B, CD, E, I, J) to the reference blocks (F, G). Initiation of restoration efforts on additional compartments at GEWMA commenced in spring/summer 2010. In particular, vegetation surveys in block A occurred after the timber harvest was complete in most of this area. Therefore, we considered block A (2009) and block A (2010) separately in our evaluation of vegetation structure and did not include block A in the one-degree-of-freedom tests. Also, due to ongoing management activities at the GEWMA, including timber harvests and prescribed fires, we were unable to survey block J in 2009 and block B in 2010. For the remaining blocks, we combined the 2009 and 2010 data for analytical purposes.

Structural characteristics varied considerably among the various study blocks (Table 1). In general, blocks A (2009), B, CD, E, and J were the most "forested", with higher basal area and canopy coverage. The reference blocks and block A (2010) had the least forest cover, as expected. Block I was intermediate between the other groups—this block is technically not a restored savannah but has been subject to regular prescribed fire and has similar soil characteristics to the reference blocks. The one-degree-of-freedom

tests showed that the reference blocks had lower basal area, less canopy, more bare ground, more grass cover, and more forb cover than the encroached blocks ($P < 0.05$).

The overstory on all study blocks was dominated by 5 species: black hickory (*Carya texana*), post oak (*Quercus stellata*), sandjack oak (*Q. incana*), blackjack oak (*Q. marilandica*), and flowering dogwood (*Cornus florida*). According to the line-intercept surveys, the component species varied considerably among the various study blocks (Table 2). Post oak and black hickory were important on all sites, while sandjack oak was most important on the reference blocks and flowering dogwood was more important in the most forested blocks.

Based on the analysis of groundcover species in 1,740 1-m^2 square plots, we documented 138 plant species in 7 study blocks at GEWMA (study block B not included) in summer 2010. A complete list of these species with their occurrence by study block is provided in Appendix A. Species richness in the herbaceous layer was higher in the reference blocks (87-95) than in the encroached blocks (41-68; Figure 7). The long-term management of the reference blocks has apparently resulted in a unique set of herbaceous plants, including 30 species that were documented only in blocks F and/or G (Table 3). Study block CD also included portions of an herbaceous bog habitat; several wetland species (e.g., *Juncus effusus, Osmunda regalis, Syngonanthus flavidulus*) were documented only in this study block.

Avian Community

During the study period, we detected 66 species of birds at GEWMA (Table 4). Of these, 20 were detected only during the breeding season, 22 only during the winter season, and 24 were detected in both seasons. We detected several species identified as high or medium priority in the *Texas Comprehensive Wildlife Conservation Strategy*. During the breeding season, these included regular residents such as Bachman's sparrows, northern bobwhites, and painted buntings as well as occasional sightings like Kentucky warblers (*Oporornis formosus*), chuck-will's-widows (*Caprimulgus carolinensis*), and hairy woodpeckers (*Picoides villosus*). Wintering high priority species included northern harriers (*Circus cyaneus*) and Henslow's sparrows (*Ammodramus henslowii*). Complete lists of species detected by study block are provided in Appendix B. Species richness was similar across all the study blocks, varying from 31 (in block CD) to 42 (in block J; Fig. 8).

We compared summer and winter avian communities in the reference blocks (F and G) and encroached blocks (A, B, CD, E, I, and J) using the number of individuals detected during the five surveys in summer (Table 5) and winter (Table 6). Although detections are not directly proportional to abundance due to potential variation in detectability over time and among sites, we feel that they were a reasonable index to abundance of the various species in these habitats. Because there were more encroached than reference blocks, we expressed detections as the number detected per 1,000 m transect. To simplify interpretation of these results, we also restricted the analysis to species detected at least once in both survey years, and eliminated species that were flyovers or incidental sightings (e.g., American crows [*Corvus brachyrhynchos*], chuck-

wills-widows, turkey vultures [*Cathartes aura*]). We also grouped the species loosely by their preferred habitats for illustrative purposes: grassland species (e.g., savannah sparrow [*Passerculus sandwichensis*]), generalist early-successional species (e.g., indigo bunting), woodland species (e.g., eastern tufted titmouse [*Baeolophus bicolor*]), and habitat generalists (e.g., northern cardinal [*Cardinalis cardinalis*]).

We observed few individuals of grassland species during the breeding season; however, both species present--Bachman's sparrow and northern bobwhite--were detected at considerably greater frequency in reference blocks compared to encroached blocks. Early successional species such as painted and indigo buntings were relatively common throughout all compartments but were also detected at greater frequency in the reference blocks. Parasitic brown-headed cowbirds (*Molothrus ater*) were also more abundant on the reference blocks. White-eyed vireos (*Vireo griseus*) were an exception, as they were detected only in encroached blocks. Several woodland species were common in most study blocks. Somewhat surprisingly in light of significant differences in coarse habitat structure (basal area, tree density; see above), many of these species were detected at similar frequencies in the encroached and reference blocks (e.g., Carolina chickadee [*Poecile carolinensis*], blue-gray gnatcatcher [*Polioptila caerulea*], summer tanager [*Piranga rubra*]). Some species associated with more mature forests like red-eyed vireos (*Vireo olivaceous*), downy woodpeckers (*Picoides pubescens*), and black-and-white warblers (*Mniotilta varia*) tended to occur more frequently in the more heavily forested encroached blocks.

The wintering bird community was very different (Table 6). We observed an abundance of wintering sparrows, particularly in the reference blocks. The wintering sparrows were dominated by savannah and field (*Spizella pusilla*) sparrows; however, we observed at least 10 species of sparrows on the various study blocks during winter. Most of these were either limited to reference blocks or occurred at greater frequency in those blocks. Wintering species in the encroached blocks were mostly resident species, although some short-distance migrants such as dark-eyed juncos (*Junco hyemalis*) and hermit thrushes (*Catharus guttatus*) were detected only in these blocks.

Nesting Success and Ecology

Nest Success

During 25 April to 15 July 2009 and 2010, systematic and opportunistic nest searches were performed on 16 transects which were located on 8 blocks. In our analysis, we included nests that were known to be active—i.e. had at least one egg. Indigo bunting nests were located on 4 compartment blocks (3 encroached, 1 reference) with an overall nest density of 0.66 nests/100 ha. Painted bunting nests were located on 5 compartment blocks (3 encroached, 2 reference) with an overall nest density of 0.54 nests/100 ha (Fig. 9).

Five indigo bunting nests were located in 2009, and 6 in 2010, totaling 11 indigo bunting nests. Three painted bunting nests were located in 2009 and 6 in 2010, totaling 9 painted bunting nests. We combined the two sample years for each species for the analysis because we did not find a difference in nest success between the two years ($p >$

0.05). Raw nest success for indigo buntings and painted buntings was 64% and 22%, respectively. Indigo bunting nest success was similar on reference and encroached blocks with 60% and 67% success, respectively. However, painted bunting nest success was 40% on reference blocks and 0% on encroached blocks.

Known predation rates of nests were 50% for indigo bunting nests and 57.14% for painted bunting nests (Table 7). Nests were found destroyed, dumped on the ground or nests were found intact with eggs missing. The other unsuccessful nests were abandoned before a full clutch was laid and the female was never observed returning to the nest (Table 7).

During both seasons, only one indigo bunting nest was parasitized by brown-headed cowbirds (9.09%) and this nest successfully fledged all three indigo buntings and the single cowbird. We observed one painted bunting nest that was parasitized by brown-headed cowbirds (11.11%). This nest was then depredated and subsequently abandoned; the painted bunting egg was assumed to be eaten by a reptilian predator (the egg was missing and no shell fragments were found nearby). The brown-headed cowbird egg remained and the adult female never returned to the nest (Whitehead and Schweitzer 2000).

Nest Site Selection

We used one-way analysis of variance (ANOVA) to examine differences between nest site characteristics of indigo and painted buntings, between nest sites of each species and paired random sites, between nest sites in encroached and reference blocks, and between successful and unsuccessful nests of each species. Indigo buntings placed their

nests at an average height of 1.91 m (SE ± 0.43) in trees that were approximately 3.02 m (SE ± 0.49) tall (Table 8). Painted buntings placed their nests slightly higher at an average height of 2.41 m (SE ± 0.37, *P* = 0.3973) and in taller trees (4.74 m, SE ± 0.83, *P* = 0.0788). Average DBH (cm) of painted bunting nest substrate was higher compared to indigo bunting nest substrate DBH (*P* = 0.0724, Table 8). Indigo bunting nests were located closer to the stem of the substrate (*P* = 0.0568) with more branches supporting the nest (*P* = 0.0577).

Indigo buntings had an average herbaceous ground cover of approximately 25.91% (SE ± 2.55) grass cover (this category includes bunchgrasses, grasses, sedges, and rushes) and 31.61% (SE ± 8.75) forb cover (including legumes). Indigo bunting nest sites had an average of 60% (0-50 cm) (SE ± 7.71) vertical coverage and 31.09 (SE ±10.29) canopy cover (Table 8). Painted buntings had an average grass cover that was similar to indigo buntings, but a lower forb cover of 19.25% (SE ± 5.20, *P* = 0.2668), as well as lower vertical (0-50 cm) and canopy coverage (*P* = 0.6760, *P* = 0.7103, respectively, Table 8). Indigo buntings showed a preference to place their nests in black hickory trees (n = 6) whereas painted buntings showed a slight preference for post oak trees (n = 5) (X^2 = 9.3795, *P* = 0.0523).

There was no significant difference found in nest site selection between encroached and reference compartments for both indigo buntings and painted buntings (*P* > 0.05) for all parameters. Successful indigo bunting nests had higher grass, sedge, and rush cover around the nest site than unsuccessful nests (*P* = 0.041, Table 9). There was no single nest site variable which predicted success of painted bunting nests (*P* > 0.05);

however, successful painted bunting nests tended to be in thicker sites with more vertical cover (Table 10). Nest sites and paired sites were similar for all the habitat parameters measured ($P > 0.05$).

Using the Average Nearest Neighbor tool in ArcGIS 9.3, we conducted an analysis to determine if nest sites for each species were: 1.) clustered together, 2.) dispersed evenly throughout the study site, or 3.) dispersed randomly throughout the study site (Anderson 2006, Fisher et al. 2007). This analysis calculates a nearest neighbor index as a ratio of the observed average distance divided by the expected average distance between neighbors. An index <1 indicates clustering; an index >1 indicates even dispersal; and an index =1 indicates random dispersal. In 2009, bunting nests were evenly dispersed throughout the study site ($P < 0.0001$); however, bunting nests were randomly dispersed in 2010 ($P = 0.08$). We also combined the two study years, excluding compartments where <2 nests were identified. In this case, bunting nests were significantly clustered ($P = 0.046$).

CONCLUSIONS

We were able to document baseline conditions for both vegetation and avian (winter and breeding season) communities in the proposed restoration areas. Detailed species lists for herbaceous vegetation and bird communities are provided in Appendices A and B, respectively, and more detailed statistical evaluations of structural characteristics of the various compartments are presented above. These data can be used to evaluate changes in these communities in response to the ambitious restoration efforts

that are currently ongoing at GEWMA. The structural response in vegetation characteristics can already be seen in the changes to block A following the initiation of timber harvest in 2010.

Blocks F and G (and to a lesser extent block I) appear to be adequate to serve as references for future desired conditions for vegetation characteristics. We documented clear differences in vegetation structure and species composition for these blocks compared to the blocks targeted for restoration, including 30 herbaceous species that occurred only in these actively managed blocks. The structural characteristics and floristic composition can be used as targets for monitoring the success of the restoration efforts.

Avian communities also differed between the reference and encroached blocks, but it was not clear that the reference blocks have achieved the desired avian community for post oak savannah in Texas. The reference blocks clearly supported a much more numerous and diverse community of wintering grassland birds than the encroached blocks; however, several species of concern in the post oak savannah ecoregion were either not detected or were detected only rarely. These include Cassin's sparrows (*Peucaea cassinii*), field sparrows, grasshopper sparrows, Harris's sparrows (*Zonotrichia querula*), Henslow's sparrows, Sprague's pipits (*Anthus spragueii*), and others.

Although early successional generalists associated with oak savannahs such as indigo and painted buntings were common on the site during the breeding season, we did not see high numbers of grassland species that nest in Texas (e.g., Bachman's sparrow, dickcissel [*Spiza americana*], eastern meadowlark, northern bobwhite). While

Bachman's sparrow occurred regularly in the reference blocks, density appeared to be low compared to other studies of this species (Haggerty 1998, Tucker et al. 2004). Despite the presence of several singing male Bachman's sparrows during the breeding season, we were unable to locate any active nests, nor did we document the presence of mated pairs. We found one abandoned and apparently predated nest in 2009 in study block F.

Nest density for indigo buntings (0.66 nest /100 ha) at GEWMA fell well below the reported range of Gram et al. (2003) of ~2.5 – 22 nests/100 ha in an uneven-aged pine stand. Nest density for painted buntings (0.54 nests/100 ha) was also well below that found in previous studies (~22.22 nests/ ha; Whitehead et al. 2002). Indigo bunting nest success was higher than that reported in other studies (Table 11). In contrast, painted bunting success was lower than observed in other locations (Table 11). Predation rates were similar compared to previous studies for both indigo buntings and painted buntings (Wiens 1963, Best and Stauffer 1980, Barber 1993, Martin 1993). Brown-headed cowbird parasitism rates were low for both painted and indigo buntings in our study, with only 1 parasitized nest for each species (Best and Stauffer 1980, Barber 1993, Barber and Martin 1997, Burhans 1997, Burhans and Thompson 1998, Whitehead et al. 2002).

It is not clear why the successful maintenance of savannah habitat in blocks F and G has not attracted the typical suite of grassland and savannah species, despite the presence of savannah-like habitat for at least a decade. In particular, the low nest density of all three of our target species in these areas is difficult to explain. Nest sites and paired sites were similar to each other and to documented nest structure for indigo buntings and

painted buntings (Conner et al. 1983, Lowther et al. 1999), suggesting that the density of appropriate nesting substrate was not an important limiting factor in the areas where these species nested. Grass height and density was low compared to Bachman's sparrow nests in Florida; however, patch size may be an important factor in the low nesting density of target species. Optimal fragment size for grassland breeding birds has been estimated at ≥100 ha (Winter et al. 2006, Ribic et al 2009). The reference blocks of restored post oak savannah were 85 and 112 ha in size, and were surrounded by a landscape of woodlands mixed with pasture and developed lands. Areas of native grassland or savannah in the area were limited to small wildlife openings and fallow fields, mostly on other parts of the WMA. If patch size and isolation are contributing to low reproduction by the target species at the site, it is possible that the ongoing expansion of the savannah restoration areas will increase nesting density and success of savannah birds.

Further analysis to quantify the vegetation and other factors influencing occupancy by various grassland and savannah bird species will be provided in the M.S. thesis and/or refereed publications to be produced from this research. This will allow the isolation of specific vegetation characteristics that can be measured and targeted to increase use of the site by target avian species. Now that the first phase of restoration efforts is complete on portions of the formerly degraded post oak savannah, it will be interesting to examine the effects of these efforts on avian communities at the site.

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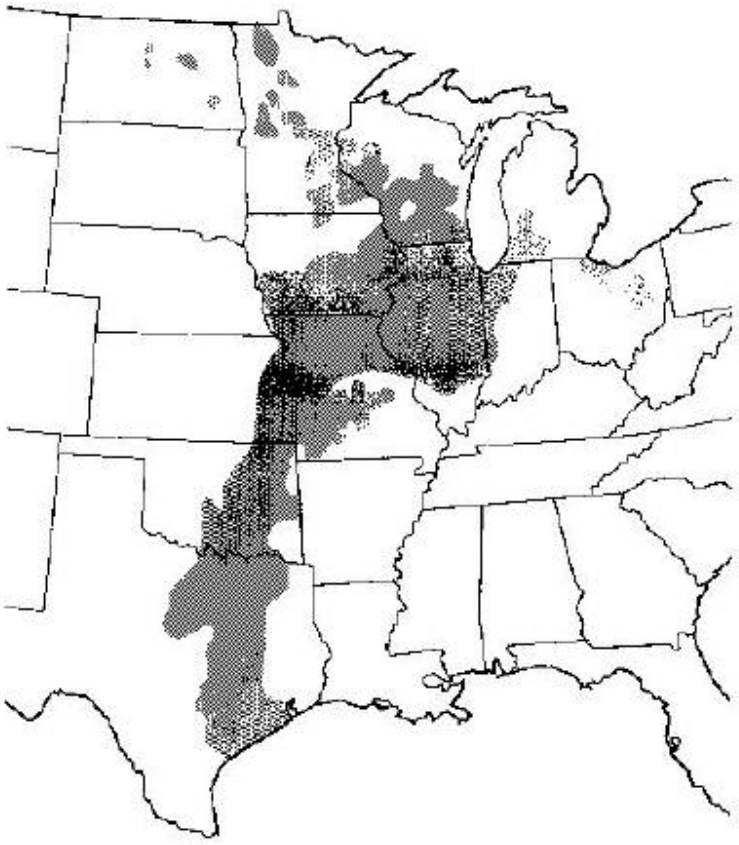

Figure 1. The presettlement distribution of Midwestern oak savannas and woodlands (Nuzzo 1985).

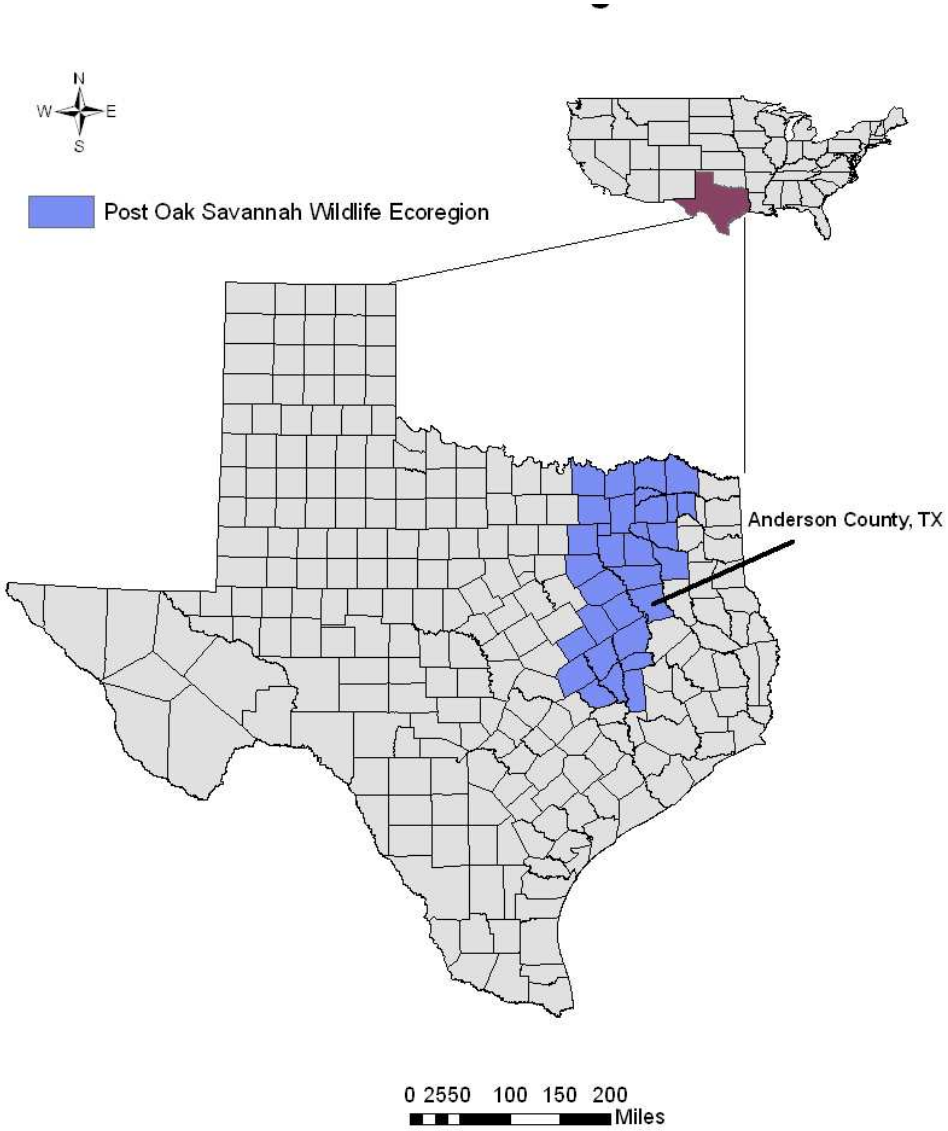

Figure 2. Location of the Gus Engeling Wildlife Management area in Anderson County, TX. The approximate boundaries of the Post Oak Savannah Ecoregion are indicated in blue.

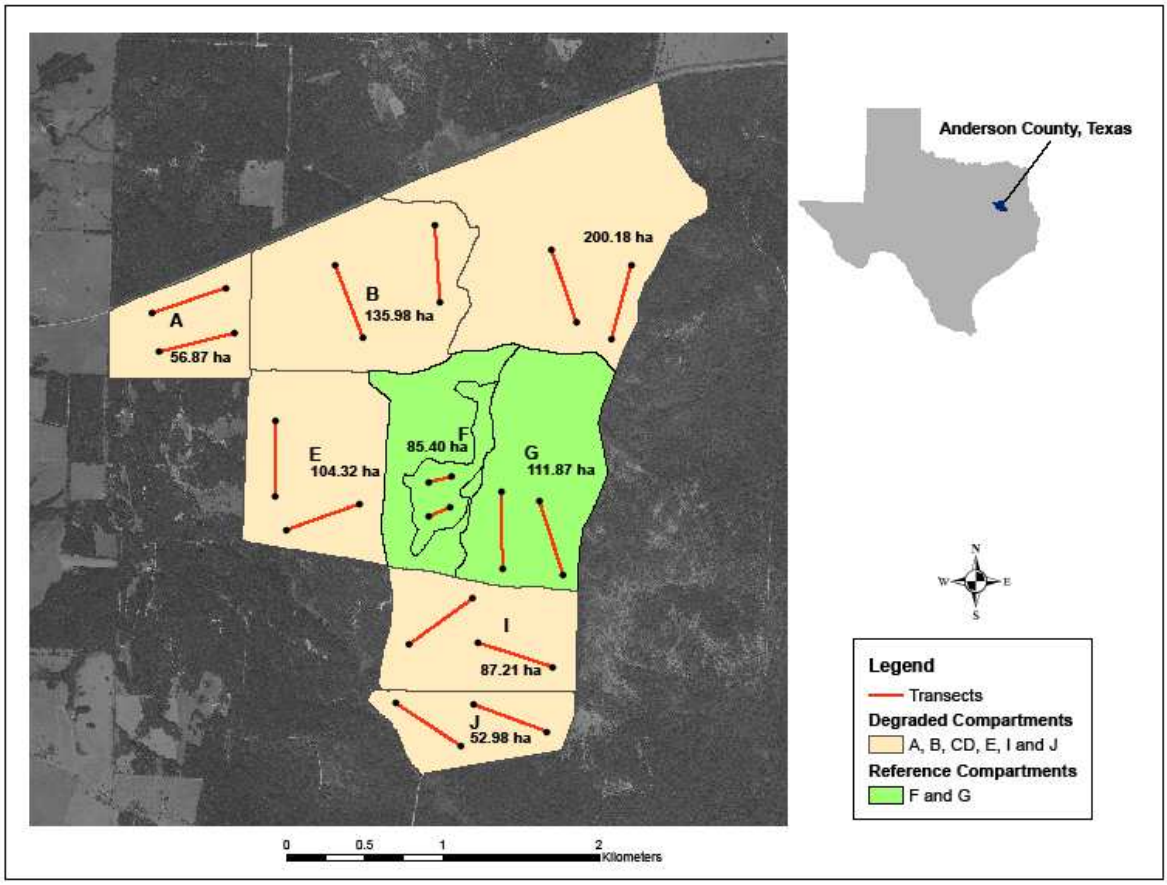

Figure 3. Study blocks used for avian and vegetation surveys at Gus Engeling Wildlife Management Area. The area of each block (ha) is provided and the locations of avian survey transects are indicated.

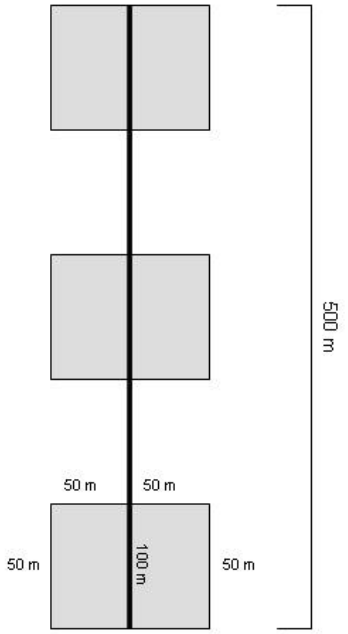

Figure 4. Diagram of the fixed area nest searches in 1-ha plots. Total area searched per transect = 3 ha.

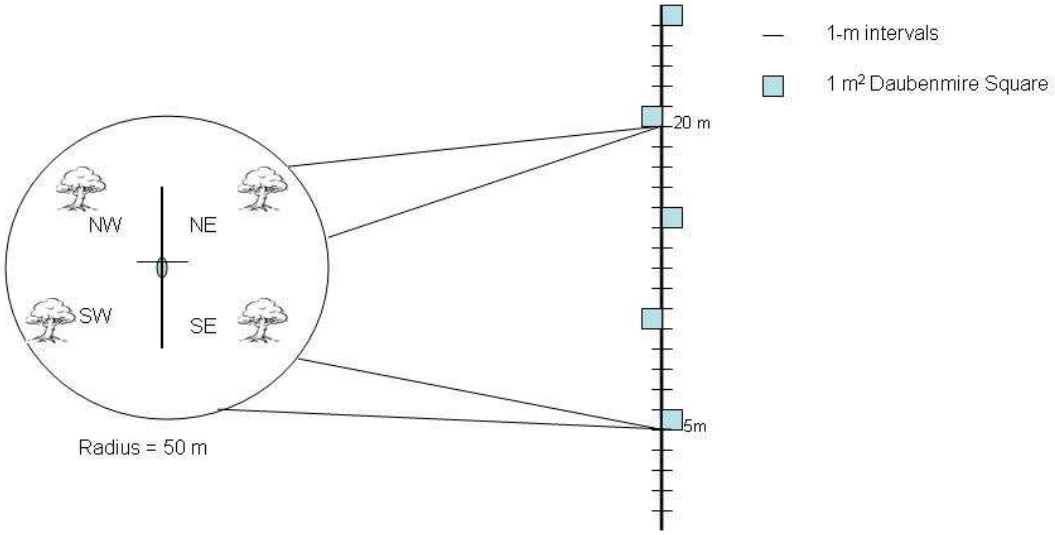

Figure 5. Plot arrangement used for vegetation surveys. The transect line is 25-m long, marked at 1-m intervals for line-intercept sampling. Herbaceous ground cover in a 1-m^2 square quadrat was measured at 5-m increments along the transect. At 5 m and 20 m, overstory vegetation was estimated using the point-centered-quarter method.

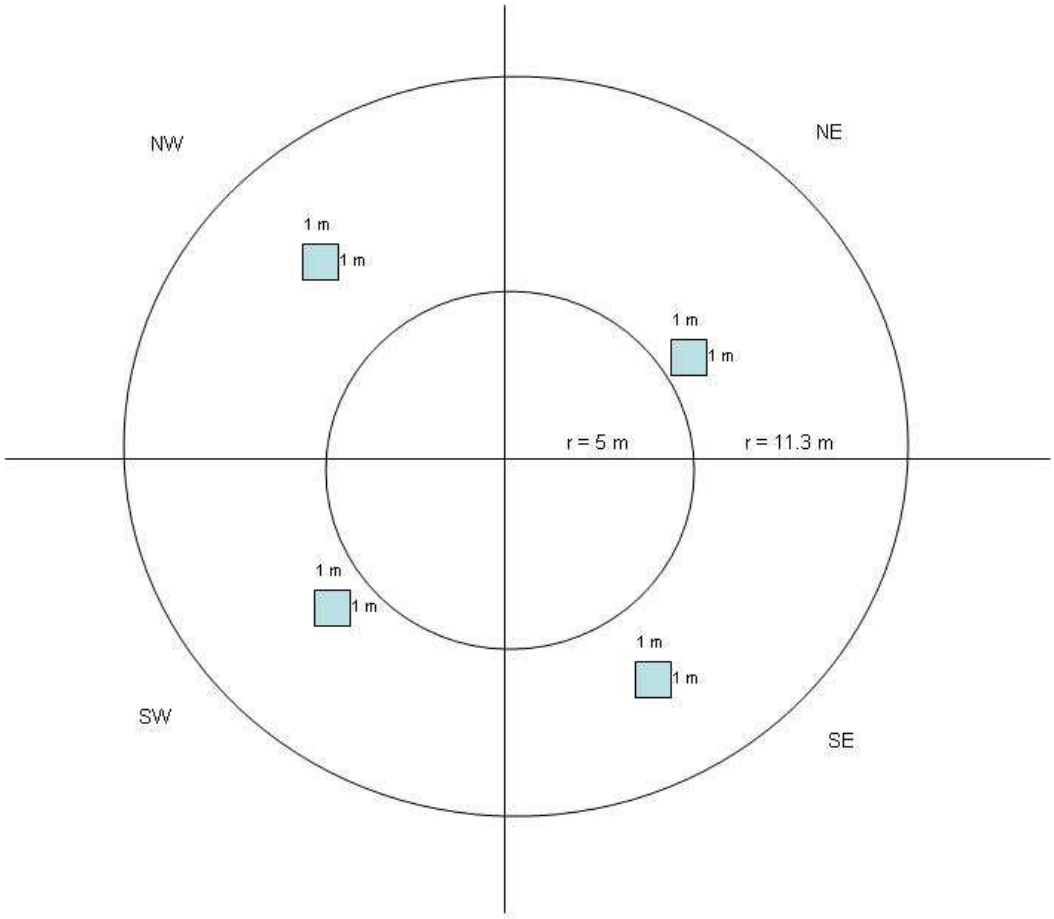

Figure 6. Plot arrangement used for habitat characterization at nest sites and paired random sites. Plot center was the nest for the nest site and the paired tree at the paired site.

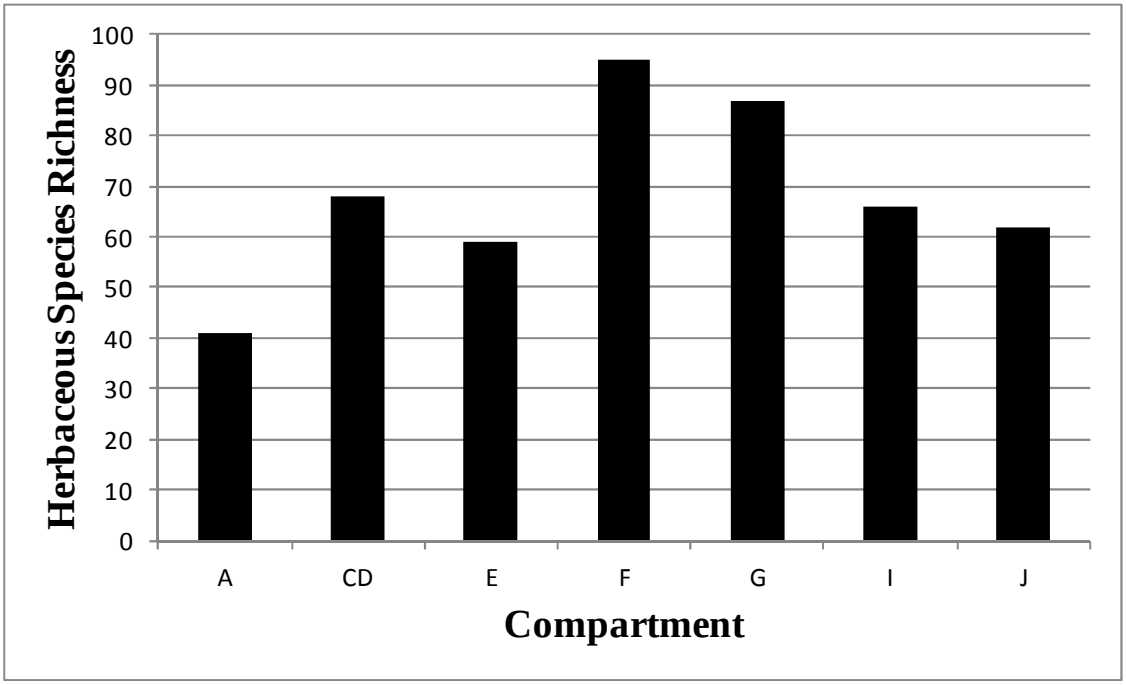

Figure 7. Species richness of herbaceous and other groundcover plant species measured in 1,740 $1m^2$ survey plots in 7 study blocks at GEWMA. Blocks F and G were the reference blocks.

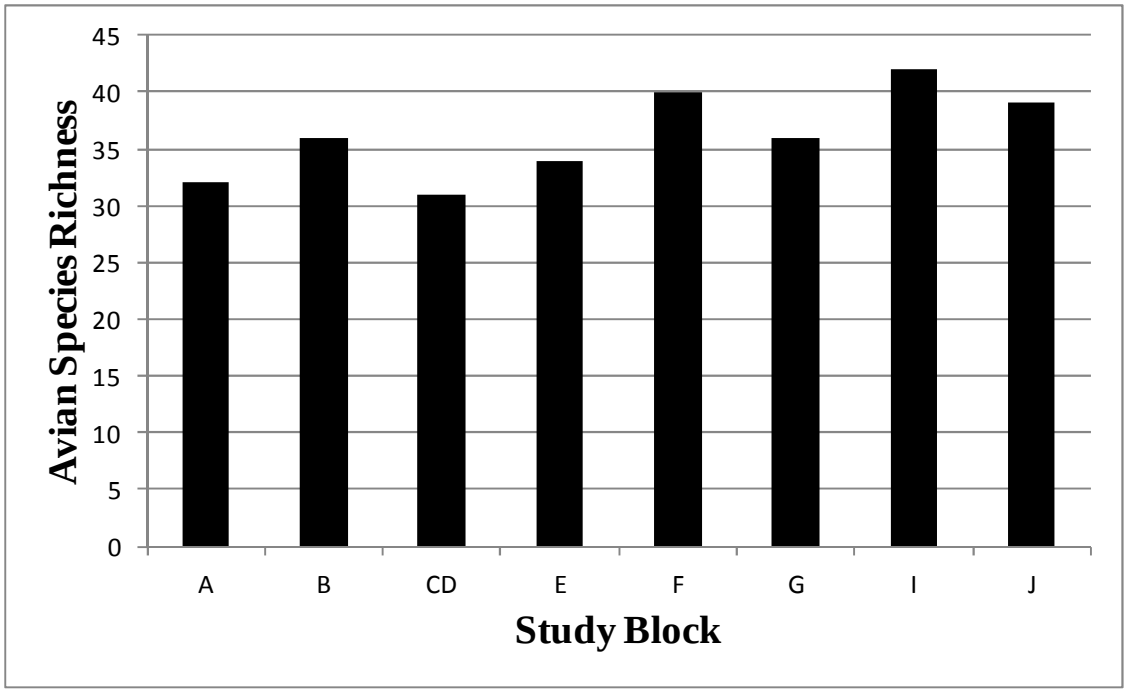

Figure 8. Combined breeding and wintering bird species richness observed in bird surveys (5 transects per season) at 8 blocks at GEWMA 2008-2010.

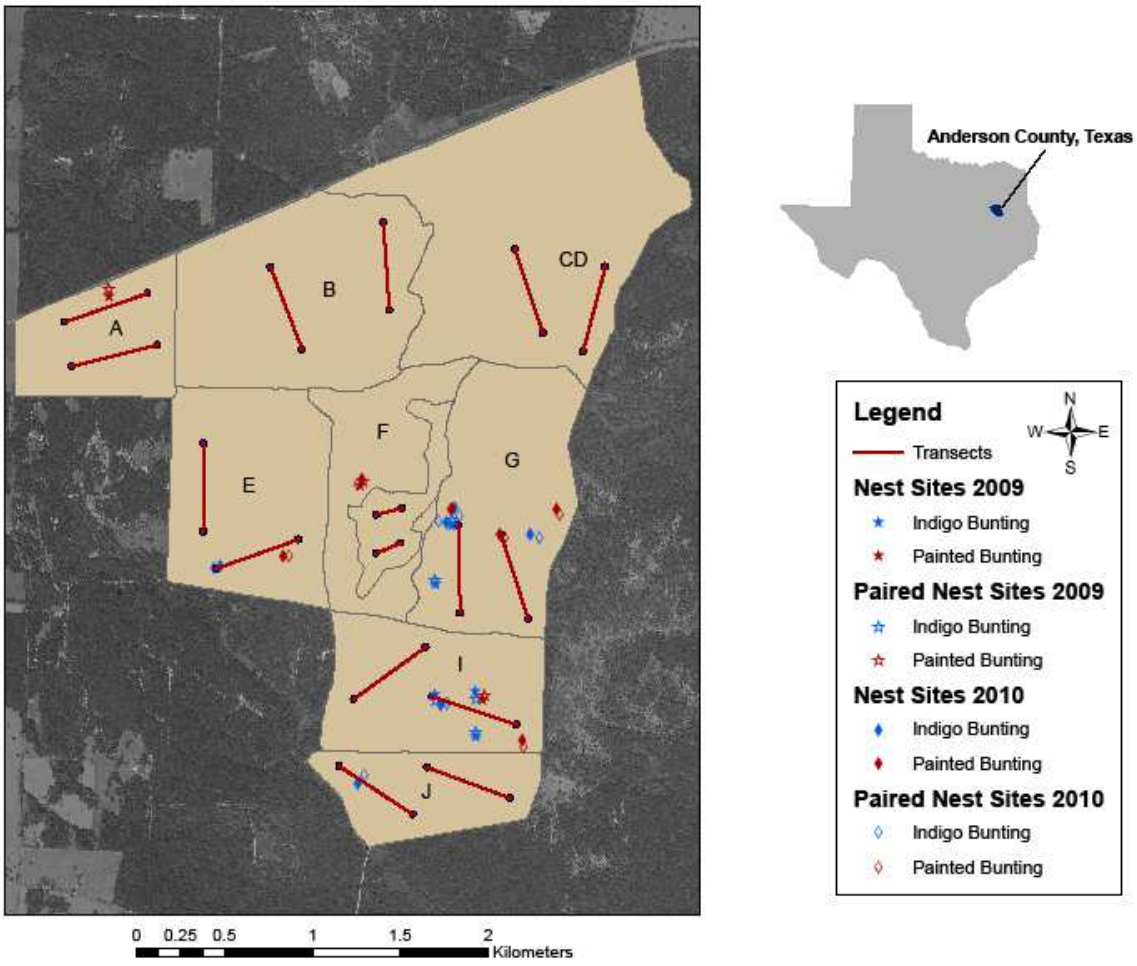

Figure 9. Locations of indigo and painted bunting nest and paired random sites surveyed during the breeding season, May-July 2009 and 2010 in 8 study blocks at GEWMA.

Table 1. Mean values and results of one-way ANOVAs (*F*-statistics and associated probability values) for vegetation structural characteristics in 8 study blocks at GEWMA, June-August 2009 and 2010. Values with the same letter within a row were not different according to Tukey's test. Block A is presented separately for the two study years because structure changed following timber harvest in 2010.

	Compartment										
Parameter	**A (2009)**	**A (2010)**	**B**	**CD**	**E**	**F**	**G**	**I**	**J**	***F***	***P***
Trees/ha	851	234	881	1,082	1,229	244	193	533	969	1.72	0.09
Basal area (m^2/ha)	30.4CD	8.3AB	43.4D	30.6D	30.6D	10.1AB	6.0A	17.65BC	27.1CD	16.99	<0.0001
Canopy coverage	0.85C	0.32A	0.81C	0.82C	0.76C	0.42A	0.35A	0.60B	0.70BC	53.65	<0.0001
Ground Cover											
% Bare ground	1.5C	26AB	NA	5.5C	3.5C	20C	46B	15C	36A	28.85	<0.0001
% Woody	14A	3.9CD	9.8AB	7.1BC	7.1BC	9.5B	4.4CD	6.6BC	2.3D	14.92	<0.0001
% Grass	20BCD	8.7D	43A	15CD	19BCD	31AB	26BC	24BCD	18BCD	6.03	<0.0001
% Forb	3.6C	4.0C	5.3C	9.1C	6C	25AB	30A	21B	7.3C	50.59	<0.0001

Table 2. Overstory percent canopy coverage by compartment for the 5 most common tree species in 8 study blocks at GEWMA, 2009-2010. Years are listed separately for Block A because of planned timber harvest that occurred in this block between years.

	A								
Species	**2009**	**2010**	**B**	**CD**	**E**	**F**	**G**	**I**	**J**
Carya texana	41	12	26	16	29	12	5.8	12	21
Cornus florida	4.5	1.4	5.0	11	8.3	<1	<1	<1	3.8
Quercus incana	7.0	3.8	4.1	12	14	15	20	25	11
Quercus marilandica	4.6	3.5	7.0	3.3	1.1	2.4	<1	2.6	<1
Quercus stellata	24	10	37	26	20	12	7	18	23
Other species	1.5	<1	1.9	14	3.6	<1	<1	1	11

Table 3. Herbaceous plant species detected only in reference study blocks at GEWMA, May-August 2010

	Compartment	
Species	**F**	**G**
Andropogon ternarius		X
Andropogon virginicus		X
Aristida purpurascens		X
Asclepias spp.	X	
Chrysopsis pilosa	X	X
Cyperus retroflexus		X
Desmodium veridiflorum		X
Dicanthelium aciculare		X
Eragrostis intermedia	X	
Eragrostis spectabilis	X	X
Euthamia leptocephala	X	X
Gaillardia aestivalis	X	X
Galium aparine	X	
Hedioma drummondii	X	X
Indigofera miniata	X	X
Lespedeza repens		X
Oenothera laciniata	X	X
Penstemon murrayanus	X	
Physalis angulata	X	X
Polygala polygama	X	
Polypremum procumbens		X
Pseudognaphalium obtusifolium	X	
Pycnanthemum spp.		X
Rhododon ciliatis		X
Ruellia caroliniensis	X	X
Rudbeckia hirta	X	
Ruellia humilis	X	X
Solidago petiolaris	X	X
Strophostyles spp.	X	
Triplasis purpurea	X	X

Table 4. List of species and bird banding lab 4-letter codes for birds detected by Season in 8 Study Blocks at GEWMA, 2008-2010.

Species	BBL Code	Season
American Crow	AMCR	Both
American Goldfinch	AMGO	Winter
American Robin	AMRO	Winter
American Woodcock	AMWO	Winter
Bachman's Sparrow	BACS	Both
Black-and-white Warbler	BAWW	Both
Blue-gray Gnatcatcher	BGGN	Both
Brown-headed Cowbird	BHCO	Both
Blue Grosbeak	BLGR	Summer
Blue Jay	BLJA	Both
Brown Creeper	BRCR	Winter
Brown Thrasher	BRTH	Summer
Carolina Chickadee	CACH	Both
Carolina Wren	CAWR	Both
Chipping Sparrow	CHSP	Winter
Common Yellowthroat	COYE	Summer
Chuck-Will's-Widow	CWWI	Summer
Dark-eyed Junco	DEJU	Winter
Dicksissel	DICK	Summer
Downy woodpecker	DOWO	Both
Eastern Bluebird	EABL	Both
Eastern Kingbird	EAKI	Both
Eastern Phoebe	EAPH	Both
Eastern Wood Peewee	EAWP	Both
Eastern Tufted Titmouse	ETTI	Both
Field Sparrow	FISP	Winter
Fox Sparrow	FOSP	Winter
Great Crested Flycatcher	GCFC	Summer
Golden-crowned Kinglet	GCKI	Winter
Grasshopper Sparrow	GRSP	Winter
Hairy Woodpecker	HAWO	Summer
Henslow's Sparrow	HESP	Winter
Hermit Thrush	HETH	Winter
Indigo Bunting	INBU	Summer
Kentucky Warbler	KEWA	Summer
Lincoln's Sparrow	LISP	Winter
Mourning Dove	MODO	Both
Northern Bobwhite	NOBO	Both
Northern Cardinal	NOCA	Both
Northern Flicker	NOFL	Winter
Northern Harrier	NOHA	Winter
Northern Mockingbird	NOMO	Both

Table 4. List of species and bird banding lab 4-letter codes for birds detected by Season in 8 Study Blocks at GEWMA, 2008-2010.

Species	BBL Code	Season
Painted Bunting	PABU	Summer
Pileated Woodpecker	PIWO	Both
Red-bellied Woodpecker	RBWO	Both
Ruby-crowned Kinglet	RCKI	Both
Red-eyed Vireo	REVI	Summer
Red-headed Woodpecker	RHWO	Both
Red-shouldered Hawk	RSHA	Summer
Ruby-throated Hummingbird	RTHU	Summer
Savannah Sparrow	SAVS	Winter
Song Sparrow	SOSP	Winter
Scissor-tailed flycatcher	STFL	Summer
Summer Tanager	SUTA	Summer
Turkey Vulture	TUVU	Both
Vesper Sparrow	VESP	Winter
White-breasted Nuthatch	WBNU	Both
White-eyed Vireo	WEVI	Both
Winter Wren	WIWR	Winter
White-throated Sparrow	WTSP	Winter
Yellow-billed Cuckoo	YBCU	Summer
Yellow-bellied Flycatcher	YBFL	Summer
Yellow-bellied Sapsucker	YBSA	Winter
Yellow-rumped Warbler	YRWA	Winter
Yellow-throated Vireo	YTVI	Summer
Yellow-throated Warbler	YTWA	Summer

Table 5. Number of detections per 1,000 m of survey transects for selected avian species during the breeding season, May-July 2009 and 2010, at reference and encroached study blocks at GEWMA.

	Encroached Compartments		**Reference Compartments**	
Species	**2009**	**2010**	**2009**	**2010**
Generalist Early-Successional Species				
Brown-headed cowbird	0.8	0.9	3.4	1.9
Indigo bunting	1.8	2.5	6.5	12
Painted bunting	3.2	3.9	7.9	14.2
White-eyed vireo	0.7	0.9	0	0
Habitat Generalists				
Carolina wren	2.0	1.3	1.6	1.2
Mourning dove	0.3	0.0	5.2	0.1
Northern cardinal	6.9	6.7	3.6	5.9
Grassland Species				
Bachman's sparrow	0.0	0.1	3.3	3
Northern bobwhite	0.1	0.0	1.4	1.1
Woodland Species				
Black-and-white warbler	0.3	0.3	0	0
Blue-gray gnatcatcher	2.6	3.0	1.5	4.7
Blue jay	0.0	0.0	0	0.1
Carolina chickadee	2.5	1.1	3.7	1.6
Downy woodpecker	0.1	0.4	0	0
Eastern phoebe	0.3	0.0	0.9	0.2
Eastern wood-pewee	0.1	0.0	0.9	0.1
Eastern tufted titmouse	6.2	4.7	4.4	3.2
Pileated woodpecker	0.0	0.1	0.1	0
Red-bellied woodpeceker	0.1	0.0	0	0
Red-eyed vireo	1.6	1.6	0	0.2
Summer tanager	2.4	2.7	1.5	5
White-breasted nuthatch	0.1	0.0	0.1	0.1
Yellow-billed cuckoo	3.7	1.7	2.1	2

Table 6. Number of detections per 1,000 m of survey transects for selected avian species during the winter season, Dec. 2008-March 2009 and Dec.2009-March 2010, at reference and encroached study blocks at GEWMA.

	Encroached Compartments		**Reference Compartments**	
Species	**2009**	**2010**	**2009**	**2010**
Generalist Early-Successional Species				
Brown-headed cowbird	0.47	0.07	0	0.1
Eastern bluebird	0.10	0.07	0.6	0
Northern flicker	0.33	0.43	0.4	0.3
White-throated sparrow	0.90	2.70	0.4	0.1
Yellow-rumped warbler	0.33	0.57	0	0
Habitat Generalists				
Carolina wren	0.80	2.07	0.2	0.9
Mourning dove	0.20	0.07	6.2	0
Northern cardinal	0.93	2.63	0.2	0.3
Northern mockingbird	0.00	0.00	0.2	0.1
Grassland Species				
Bachman's sparrow	0.03	0.00	0.2	0.1
Chipping sparrow	0.10	0.23	0.3	2.5
Field sparrow	1.83	0.27	4.5	12.7
Fox sparrow	0.00	0.00	0.5	0.1
Henslow's sparrow	0.00	0.00	0.2	0.5
Savannah sparrow	1.53	0.03	35.4	13
Unidentified sparrow	1.53	1.93	2.5	14.9
Woodland Species				
Blue-gray gnatcatcher	0.03	0.10	0	0
Blue jay	0.27	0.33	0	0
Carolina chickadee	1.23	3.77	2	1.2
Eastern phoebe	0.00	0.07	0.2	0.1
Dark-eyed junco	2.73	1.77	0	0
Downy woodpecker	0.20	0.27	0.2	0
Eastern tufted titmouse	4.77	5.53	4.5	2.1
Hermit thrush	0.13	0.20	0	0
Pileated woodpecker	0.03	0.10	0	0.1
Red-bellied woodpecker	0.27	0.17	0	0
Ruby-crowned kinglet	0.07	0.20	0	0.1

Table 7. Fates of indigo and painted bunting nest over 2 seasons (2009, 2010) at GEWMA. Nest Fate is indicated by an "S" for successful and a "U" for unsuccessful. The reason for an unsuccessful nest is given.

Season	Block	Clutch	Hatchlings	Fledged	Nest Fate	Reason
Indigo Bunting						
2010	E	-	3	3	S	-
2009	G	-	4	4	S	-
2009	G	4	4	4	S	-
2010	G	1	0	0	U	Abandoned
2010	G	4	4	0	U	Depredated[a]
2010	G	2	1	1	S	-
2009	I	-	4	0	U	Depredated[d]
2009	I	4	4	4	S	-
2009	I	4	4	4	S	-
2010	I	4	4	4	S	[b]-
2010	J	1	0	0	U	Abandoned
Painted Bunting						
2009	A	2	0	0	U	Environment[c]
2010	E	2	0	0	U	Parasitized[b], Depredated[a] Abandoned
2009	F	-	3	3	S	-
2010	F	1	0	0	U	Abandoned
2010	G	3	3	3	S	-
2010	G	1	0	0	U	Depredated[a]
2010	G	4	0	0	U	Depredated[a]
2009	I	1	0	0	U	Depredated[a]
2010	I	1	1	0	U	Abandoned

[a]Probable snake predation (eggs missing)

[b]Brown-headed cowbird egg in nest

[c]Nest damage by severe storm

[d]Probable mammalian predation, shell fragments present

Table 8. Means, standard errors, and P-values associated with one-way ANOVA comparing indigo and painted bunting nest sites at GEWMA, 2009-2010.

	Indigo bunting (n = 11)		Painted bunting (n = 9)		
Variable	Mean	S.E.	Mean	S.E.	*P*
Nest Height (m)	1.91	0.43	2.41	0.37	0.40
Nest Substrate Height (m)	3.02	0.49	4.74	0.83	0.08
DBH of Nest Substrate (cm)	3.24	0.74	5.58	1.00	0.07
# Branches Supporting Nest	2.36	0.20	1.89	0.45	0.06
Distance of Nest to Stem (m)	0.04	0.03	0.27	0.12	0.06
Distance of Nest to Edge of Tree (m)	1.25	0.89	0.45	0.08	0.43
Distance to Nearest Tree (m)	1.94	0.65	1.42	0.53	0.56
Distance to Habitat Edge (m)	88.72	15.07	87.06	20.08	0.95
# Stems ≥ 8-cm dbh	6.00	1.17	9.22	1.72	0.53
# Stems <8-cm dbh	27.73	5.85	32.33	9.05	0.33
Percent Bunchgrass	0.11	0.02	0.17	0.05	0.21
Percent Grass, Sedge, Rush	0.15	0.03	0.10	0.02	0.17
Percent Legume	0.09	0.04	0.05	0.02	0.38
Percent Forb (no legume)	0.22	0.07	0.14	0.04	0.33
Percent All Grass[a]	25.91	2.55	27.52	5.00	0.77
Percent All Forb[b]	31.61	8.75	19.25	5.20	0.27
Percent Vertical Cover (0-50 cm)	60.00	7.71	55.28	7.88	0.68
Percent Vertical Cover (50-100 cm)	40.36	8.05	28.22	6.91	0.28
Percent Vertical Cover (100-150 cm)	19.95	7.11	27.61	5.65	0.42
Percent Vertical Cover (150-200 cm)	15.61	7.08	23.14	5.85	0.44
Percent Canopy Cover	31.09	10.29	25.94	8.27	0.71

[a] Bunchgrasses are combined with grass, sedge, and rush category

[b] Legumes are combined with forbs category

Table 9. Means, standard errors (SE), and *p-values* for ANOVA comparing nest site habitat variables for successful and unsuccessful nests of indigo buntings at GEWMA, 2009-2010.

	Successful (n=7)		**Unsuccessful (n=4)**		
Variable	**Mean**	**S.E.**	**Mean**	**S.E.**	*P*
Nest Height (m)	2.05	0.66	1.65	0.34	0.67
Nest Substrate Height (m)	3.05	0.65	2.97	0.86	0.94
DBH of Nest Substrate (cm)	2.98	0.95	3.69	1.33	0.67
# Branches Supporting Nest	2.14	0.26	2.75	0.25	0.31
Distance of Nest to Stem (m)	0.01	0.01	0.09	0.09	0.30
Distance of Nest to Edge of Tree (m)	1.79	1.40	0.31	0.16	0.46
Distance to Nearest Tree (m)	1.68	0.91	2.39	0.95	0.63
Nest Substrate Distance to Habitat Edge (m)	96.07	21.40	75.87	19.82	0.55
# Stems ≥ 8-cm dbh	5.57	1.36	6.75	2.39	0.45
# Stems <8-cm dbh	36.00	7.04	13.25	5.51	0.36
Percent Bunchgrass	11	0.02	10	0.04	0.80
Percent Legume	13	0.06	4	0.02	0.31
Percent Grass, Sedge, Rush	11	0.02	22	0.05	0.04
Percent Forb	28	0.10	12	0.04	0.27
Percent Vertical Cover (0-50 cm)	66	0.10	50	0.13	0.37
Percent Vertical Cover (50-100 cm)	45	0.10	32	0.14	0.48
Percent Vertical Cover (100-150 cm)	24	0.10	13	0.07	0.50
Percent Vertical Cover (150-200 cm)	19	0.11	9	0.06	0.53
Percent Canopy Cover	30	0.14	33	0.16	0.87

Table 10. Means, standard errors (SE), and *p-values* for ANOVA comparing nest site habitat variables for successful and unsuccessful nests of painted buntings at GEWMA, 2009-2010.

	Successful (n=2)		Unsuccessful (n=7)		
Variable	**Mean**	**S.E.**	**Mean**	**S.E.**	***P***
Nest Height (m)	1.73	0.70	2.60	0.43	0.36
Nest Substrate Height (m)	3.95	2.15	4.97	0.96	0.64
DBH of Nest Substrate (cm)	3.04	1.54	6.30	1.11	0.19
# Branches Supporting Nest	1.00	0.00	2.14	0.55	0.56
Distance of Nest to Stem (m)	0.00	0.00	0.34	0.14	0.25
Distance of Nest to Edge of Tree (m)	0.24	0.06	0.52	0.09	0.15
Distance to Nearest Tree (m)	0.28	0.03	1.75	0.63	0.28
Distance to Habitat Edge (m)	71.51	4.72	91.51	25.99	0.71
# Stems ≥ 8-cm dbh	10	3.00	9.00	2.15	0.53
# Stems <8-cm dbh	49	29.00	27.57	9.14	0.34
Percent Bunchgrass	23	0.16	16	0.05	0.57
Percent Legume	7	0.05	5	0.02	0.72
Percent Grass, Sedge, Rush	7	0.03	11	0.02	0.26
Percent Forb	26	0.05	11	0.05	0.16
Percent Vertical Cover (0-50 cm)	81	0.05	48	0.08	0.07
Percent Vertical Cover (50-100 cm)	43	0.27	24	0.06	0.28
Percent Vertical Cover (100-150 cm)	33	0.16	26	0.06	0.63
Percent Vertical Cover (150-200 cm)	23	0.09	23	0.07	0.96
Percent Canopy Cover	28	0.28	25	0.09	0.92

Table 11. Literature values, including raw nest success and number of nests surveyed for nesting success of indigo and painted buntings.

Species	% Nest Success	n	Reference
Indigo bunting	**63.6**	**11**	**Current Study**
	56.7	30	Martin 1993
	36.4	22	Whitehead and Schweitzer 2000
	52.0	29	Burhans and Thompson 1998
	27.9		Barber et al. 2001
Painted bunting	**22.2**	9	**Current Study**
	38.2	828	Payne and Payne 1998
	17.7	17	Whitehead and Schweitzer 2000
	50.0		Wiens 1963
	66.6		Wiens 1963
	33.0		Wiens 1963

Table A1. Occurrence of plant species in 1 m^2 groundcover plots in 7 study blocks at GEWMA, May-August 2010. Study block B could not be surveyed due to ongoing timber harvest.

		Study Block						
Family/Species	**Common Name**	**A**	**CD**	**E**	**F**	**G**	**I**	**J**
Acanthaceae								
Ruellia caroliniensis	Carolina Wild Petunia				X	X		
Ruellia humilis	Wild Petunia				X	X		
Agavaceae								
Yucca louisianensis	Gulf Coast Yucca		X		X			
Amaranthaceae								
Froelichia gracilis	Slender Snake-cotton	X	X	X	X	X	X	X
Anacardiaceae								
Rhus aromatica	Fragrant/Aromatic Sumac	X	X	X	X	X	X	X
Toxicodendron radicans	Poison Ivy	X	X	X	X	X	X	X
Apocynaceae								
Trachelospermum difforme	Climbing Dogbane			X	X	X	X	
Aristiolochiaceae								
Aristolochia reticulata	Texas Dutchman's Pipe	X	X	X	X			X
Asclepiadaceae								
Asclepias spp.	Milkweed				X			
Asclepias tuberosa	Butterfly Milkweed	X						
Matelea gonocarpos	Angularfruit Milkvine							X
Asteraceae								
Ambrosia psilostachya	Western Ragweed	X	X	X	X	X	X	X
Aster spp.	Aster		X		X			
Berlandiera pumila	Soft Green-eyes	X		X	X	X	X	
Chrysopsis pilosa	Soft Golden-aster				X	X		
Conyza canadensis	Canadian Horseweed				X	X	X	
Coreopsis wrightii	Rock Tickseed		X	X	X	X	X	X
Croptilon divaricatum	Slender Scratch Daisy	X	X	X	X	X	X	X
Eupatorium compositfolium	Yankeeweed				X		X	X
Euthamia leptocephala	Bushy Goldentop				X	X		
Gaillardia aestivalis	Lanceleaf Blanketflower				X	X		
Helianthis debilis	Cucumber-leaf Sunflower		X		X	X	X	X
Lactuca canadensis	Tall Lettuce		X					
Liatris squarrosa	Scaly Blazing Star	X			X	X	X	X
Pityopsis graminifolia	Narrowleaf Silkgrass							X
Pseudognaphalium obtusifolium	Rabbittobacco				X			
Rudbeckia hirta	Black-eyed Susan				X			
Solidago odora	Anise-scented Goldenrod		X		X	X	X	X
Solidago petiolaris	Downy Ragged Goldenrod				X	X		
Symphyotrichum sericeum	Silky Aster						X	
Tetragonotheca ludoviciana	Louisiana Nerve-ray		X		X	X	X	X
Vernonia texana	Texas Ironweed	X	X	X	X	X	X	X
Blechnaceae								
Woodwardia areolata	Netted Chain Fern		X					
Buddlejaceae								
Polypremum procumbens	Juniper Leaf/Rustweed					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						

Table A1. Occurrence of plant species in 1 m^2 groundcover plots in 7 study blocks at GEWMA, May-August 2010. Study block B could not be surveyed due to ongoing timber harvest.

		Study Block						
Family/Species	**Common Name**	**A**	**CD**	**E**	**F**	**G**	**I**	**J**
Caryophyllaceae								
Paronychia drummondii	Drummond's Nailwort		X	X	X	X	X	X
Cistaceae								
Helianthemum rosmarinifolium	Rosemary Frostweed			X	X	X	X	X
Lechea tenuifolia	Narrowleaf Pinweed		X	X	X	X	X	X
Clusiaceae								
Hypericum crux-andrae	St. Peter's Wort		X					
Hypericum hypericoides	St. Andrew's Cross			X		X	X	
Commelineaceae								
Commelina erecta	Dayflower	X	X	X	X	X	X	X
Tradescantia reverchonii	Reverchon's Spiderwort	X	X	X	X	X	X	X
Cyperaceae								
Bulbostylis capillaris	Densetuft Hairsedge		X	X	X	X	X	X
Carex leavenworthii	Narrowleaf Sedge			X	X	X		
Carex spp.	Sedge		X					
Carex spp.	Sedge	X		X			X	
Cyperus echinatus	Globe Flatsedge						X	X
Cyperus retroflexus	Oneflower Flatsedge					X		
Cyperus retrorsus	Pine Barren Flatsedge		X		X	X	X	X
Cyperus spp.	Flatsedge			X	X		X	
Scleria triglomerata	Whip Nutrush	X	X	X	X	X	X	X
Dennstaedtiaceae								
Pteridium aquilinum	Bracken Fern		X					
Eriocaulaceae								
Syngonanthus flavidulus	Hatpins		X					
Euphorbiaceae								
Chamaesyce cordifolia	Heartleaf Sandmat		X		X	X	X	
Chamaesyce missurica	Prairie Sandmat			X	X	X		
Cnidoscolus texanus	Bullnettle	X	X	X		X	X	X
Croton argyranthemus	Silver Croton		X	X	X	X	X	X
Croton capitatus	Woolly Croton				X		X	
Croton glandulosus	Tropic Croton			X	X	X	X	X
Stillingia sylvatica	Queen's-delight				X	X	X	X
Tragia urticifolia	Nettleleaf Noseburn	X	X	X	X	X	X	X
Fabaceae								
Baptisia nuttalliana	Nuttall's Wild Indigo	X	X	X	X	X	X	
Censtrosema virginianum	Spurred Butterfly Pea	X			X	X		
Chamaechrista fasciculata	Showy Partridge Pea			X	X	X	X	X
Clitoria mariana	Butterfly Pea	X	X		X			X
Crotalaria sagitallis	Arrowlead Rattlebox		X				X	
Dalea phleoides	Slimspike Prairie Clover		X	X	X			
Desmodium laevigatum	Smooth Tick-trefoil	X	X	X		X	X	X
Desmodium obtusum	Stiff Tick-trefoil	X	X	X	X	X	X	X
Desmodium rotundifolium	Prostrate Tick-trefoil		X				X	X
Desmodium sessilifolium	Pine-barren Tick-trefoil	X	X	X	X	X	X	X
Desmodium veridiflorum	Velvetleaf Ticktrefoil					X		
Galactia regularis	Eastern Milkpea	X		X		X		
Galactia volubulis	Downy Milkpea	X	X	X	X	X	X	X
Indigofera miniata	Scarlet Pea				X	X		

Table A1. Occurrence of plant species in 1 m^2 groundcover plots in 7 study blocks at GEWMA, May-August 2010. Study block B could not be surveyed due to ongoing timber harvest.

		Study Block						
Family/Species	**Common Name**	**A**	**CD**	**E**	**F**	**G**	**I**	**J**
Lespedeza repens	Creeping Lespedeza					X		
Lespedeza stuevei	Tall Lespedeza	X	X	X	X	X	X	X
Mimosa microphylla	Sensitive Briar		X					X
Strophostyles spp.	Wild Bean				X			
Stylosanthes biflora	Sidebeak Pencilflower		X	X	X	X	X	X
Tephrosia spicata	Spiked Hoary Pea	X	X		X			
Tephrosia virginiana	Goat's Rue	X	X	X	X	X	X	X
Juncaceae								
Juncus effusus	Common/Soft Rush		X					
Juncus marginatus	Grassleaf Rush		X					
Juncus spp.	Rush							X
Krameriaceae								
Krameria lanceolata	Trailing Krameria				X		X	
Lamiaceae								
Hedioma drummondii	Drummond's False Pennyroyal				X	X		
Monarda punctata	Spotted Beebalm		X	X	X	X	X	
Pycnanthemum spp.	Mountainmint					X		
Rhododon ciliatis	Texas Sandmint					X		
Scutellaria parvula	Small 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 Primrose				X	X		
Osmundaceae								
Osmunda regalis	Royal Fern		X					
Oxalidaceae								
Oxalis stricta	Wood Sorrel		X		X			
Passifloraceae								
Passiflora lutea	Yellow Passionflower							X
Poaceae								
Andropogon spp.	Bluestem			X				
Andropogon ternarius	Splitbeard Bluestem					X		
Andropogon virginicus	Broomsedge Bluestem					X		
Aristida desmantha	Curly Threeawn				X	X		X
Aristida lanosa	Woollysheath Threeawn Grass			X	X	X		
Aristida purpurascens	Arrowfeather Threeawn Grass					X		
Aristida spp.	Threeawn grass			X	X	X		
Chasmanthium laxum	Slender Woodoats		X					X
Dicanthelium aciculare	Needleleaf Rosette Grass					X		
Dichanthelium dichotomum	Rosette Grass		X					
Dichanthelium oligosanthes	Scribner's Dicanthelium	X	X	X	X	X	X	X
Dichanthelium ovale	Fuzzy Dicanthelium	X	X	X	X	X	X	X
Dichanthelium scoparium	Hairy/Velvet Panicum		X					
Dichanthelium spp.	Low Panic Grass		X		X	X	X	X
Eragrostis intermedia	Plains Lovegrass				X			
Eragrostis spectabilis	Purple Lovegrass				X	X		
Gymnopogon ambiguus	Bearded Skeletongrass	X	X	X	X	X	X	X

Table A1. Occurrence of plant species in 1 m^2 groundcover plots in 7 study blocks at GEWMA, May-August 2010. Study block B could not be surveyed due to ongoing timber harvest.

		Study Block						
Family/Species	**Common Name**	**A**	**CD**	**E**	**F**	**G**	**I**	**J**
Panicum anceps	Beaked Panicgrass		X		X			X
Paspalum laeve	Field Paspalum			X	X	X	X	
Paspalum setaceum	Thin Paspalum	X		X	X	X	X	X
Schizachyrium scoparium	Little Bluestem	X	X	X	X	X	X	X
Sorghastrum elliottii	Slender Indiangrass			X	X	X		
Sorghum halepense	Johnsongrass		X		X			X
Sporobolus junceus	Pineywoods Dropseed			X	X	X	X	
Triplasis purpurea	Purple Sandgrass				X	X		
Polygalaceae								
Polygala polygama	Racemed Milkwort				X			
Eriogonum multiflorum	Heartsepal Buckwheat		X	X	X	X	X	
Portulacaceae								
Phemeranthus parviflorus	Sunbright				X		X	
Rhamnaceae								
Berchemia scandens	Alabama Supplejack	X						X
Rosaceae								
Rubus spp.	Blackberry/Dewberry	X	X	X	X	X	X	X
Rubiaceae								
Diodia teres	Poor-joe		X		X	X	X	X
Galium aparine	Catchweed Bedstraw				X			
Galium pilosum	Hairy Bedstraw	X	X	X	X	X	X	X
Scrophulariaceae								
Penstemon murrayanus	Scarlet Penstemon				X			
Solanaceae								
Physalis angulata	Cutleaf Groundcherry				X	X		
Physalis cinerescens	Beach Ground-cherry	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

Table B1. Bird species occurrence in each of 8 study blocks at GEWMA, from Dec.-Mar. 2008-2010 and May-July 2009-2010. An X indicates the species was detected at least once in that study block.

Species	**A**	**B**	**CD**	**E**	**F**	**G**	**I**	**J**
American Crow	X	X	X	X	X	X	X	X
American Goldfinch							X	
American Robin		X		X			X	X
American Woodcock			X					
Bachman's Sparrow					X	X	X	
Black-and-white Warbler	X	X	X	X			X	X
Blue-gray Gnatcatcher	X	X	X	X	X	X	X	X
Brown-headed Cowbird		X	X	X	X	X	X	X
Blue Grosbeak					X	X		
Blue Jay	X	X	X	X		X	X	X
Brown Creeper							X	
Brown Thrasher							X	
Carolina Chickadee	X	X	X	X	X	X	X	X
Carolina Wren	X	X	X	X	X	X	X	X
Chipping Sparrow					X		X	X
Common Yellowthroat							X	
Chuck-Will's-Widow							X	X
Dark-eyed Junco	X	X	X	X			X	X
Dicksissel					X			
Downy woodpecker	X	X	X	X	X	X	X	X
Eastern Bluebird	X	X			X	X	X	X
Eastern Kingbird		X	X		X	X		
Eastern Phoebe	X	X	X		X	X	X	X
Eastern Wood Peewee		X		X	X	X	X	
Eastern Tufted Titmouse	X	X	X	X	X	X	X	X
Field Sparrow		X			X	X	X	X
Fox Sparrow					X			
Great Crested Flycatcher	X			X	X	X	X	X
Golden-crowned Kinglet	X	X		X			X	
Grasshopper Sparrow			X					
Hairy Woodpecker		X						X
Henslow's Sparrow					X			
Hermit Thrush	X		X	X			X	X
Indigo Bunting	X	X	X	X	X	X	X	X
Kentucky Warbler								X
Lincoln's Sparrow					X	X	X	
Mourning Dove	X	X	X	X	X	X	X	X
Northern Bobwhite	X			X	X	X		X
Northern Cardinal	X	X	X	X	X	X	X	X
Northern Flicker	X	X	X	X	X	X	X	X
Northern Harrier		X						
Northern Mockingbird	X				X	X		
Painted Bunting	X	X	X	X	X	X	X	X
Pileated Woodpecker		X	X	X	X	X		X
Red-bellied Woodpecker	X	X		X			X	X
Ruby-crowned Kinglet	X	X	X	X		X	X	X
Red-eyed Vireo	X	X	X	X	X		X	X
Red-headed Woodpecker			X			X		

Table B1. Bird species occurrence in each of 8 study blocks at GEWMA, from Dec.-Mar. 2008-2010 and May-July 2009-2010. An X indicates the species was detected at least once in that study block.

Species	**A**	**B**	**CD**	**E**	**F**	**G**	**I**	**J**
Red-shouldered Hawk						X		
Ruby-throated Hummingbird	X	X		X	X		X	
Savannah Sparrow				X	X	X	X	X
Song Sparrow					X		X	
Scissor-tailed flycatcher					X	X		
Summer Tanager	X	X	X	X	X	X	X	X
Turkey Vulture						X		
Vesper Sparrow						X		
White-breasted Nuthatch		X	X	X	X			X
White-eyed Vireo	X	X	X	X	X		X	X
Winter Wren	X							
White-throated Sparrow	X	X	X	X	X		X	X
Yellow-billed Cuckoo	X	X	X	X	X	X	X	X
Yellow-bellied Flycatcher						X		
Yellow-bellied Sapsucker	X			X				X
Yellow-rumped Warbler	X	X	X	X				X
Yellow-throated Vireo		X	X		X		X	X
Yellow-throated Warbler					X	X		