SUMMER AVIAN COMMUNITY STRUCTURE RESPONSE TO HABITAT AND LANDSCAPE VARIABLES AT MATADOR WILDLIFE MANAGEMENT AREA

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ABSTRACT

Birds are important components of natural ecosystems worldwide and aside from the many ecological services they provide they are also important in human recreation such as birding and hunting. Scientists have used surveys of bird species to monitor the health and functionality of several ecosystems. In North America, one of the most threatened ecosystems is the Great Plains. The prairie habitats within the Great Plains are threatened by numerous land use practices such as urbanization, tree planting by man, conversion to cropland, introduction of exotic grasses, over-grazing, fire control and subsequent woody encroachment. Reflecting the decline of North American grasslands is the decline in grassland bird populations. Knopf (1994) described grassland bird populations as showing the fastest, consistent, and widespread decline of any avian guild. During the summer of 2017 I investigated how the structure of bird communities respond to changes in environmental gradients in the Texas Rolling Plains ecoregion. I surveyed birds along line transects at Matador WMA in Cottle Co. Texas. Concurrent with these surveys I collected data on variables related to microhabitat, microclimate, and invertebrate abundance along each transect. I also processed habitat variables at the landscape scale from satellite imagery via GIS programming. I then performed a canonical correspondence analysis on our bird and environmental data to create an ordination biplot. My ordination organized the environmental gradients and species in a way to reveal distinct habitat types and associated bird species. Many bird species fell near the center of the ordination biplot which may indicate a blending of habitat use on the WMA for those species. I performed multiple linear regressions between the top 11 most frequently encountered species and all environmental variables, and between avian community level metrics and all environmental variables. Only five of the frequently-encountered species remained with significant relationships with environmental variables after the multiple linear regressions. For the community level metrics, total bird abundance, Modified Simpson's Index of Diversity, and species evenness were all significantly influenced by one or more environmental variables. My project, being conducted in northcentral Texas, lends insight to habitat use by a mixture of birds from both eastern and western North American avifaunae coexisting together. My ordination analysis also identifies key components within certain habitats which strongly correlate with certain avian species. Therefore, these environmental variables in particular greatly shape avian communities in the summer at Matador WMA. The information gained from my multivariate ordination and multiple linear regression analyses is useful to habitat managers and wildlife researchers concerned with both game and non-game bird species in the Texas Rolling Plains.

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INTRODUCTION

Birds are an important component of the North American fauna as predators (Steinmetz et al. 2003), prey (Perry et al. 2013, Murphy 1997), scavengers, (DeVault et al. 2003) herbivores (Ehrlich and Daily 1988), pollinators (Fenster and Dudash 2001), dispersers of plant and invertebrate propagules (Figuerola and Green 2002, Johnson and Webb 1989, McAtee 1947), vectors of diseases (Reed et al. 2003), and ecosystem engineers (Conner et al. 1997). In conservation biology, birds have been used as indicator species in monitoring biodiversity, the integrity of ecosystems, and the impacts of anthropomorphic disturbance (Gregory et al. 2003, Browder et al. 2002, and Robledano et al. 2010). Similarly, there have been numerous studies investigating the avian community structure response to changes in climate (Albright et al. 2010), landscape variables (Coppedge et al. 2001), and habitat variables (Roberts et al. 2012). As such, investigations in avian community structure can provide important information for the conservation and management of natural resources.

One such natural resource of conservation concern are prairie grasslands. From a global climate change perspective, prairie grassland conservation is important because these ecosystems act as carbon sinks, even surpassing forests with similar environmental characteristics (Seastedt and Knapp 1993). On the North American continent, some surveys suggest that native prairie range has decreased in area by 99.9% since European settlement (Samson and Knopf 1994). The loss of North America's native grasslands is because of the direct conversion into cropland and the degradation and fragmentation of remaining parcels of grassland (Johnson and Igl 2001). This degradation and fragmentation is caused by several factors including the destruction of grassland-associated wetlands (Dahl et al. 1991), introduction of exotic grasses (Vickery et al. 1995), overgrazing (Hamilton 1962), lack of fire, and subsequent woody encroachment (Van Auken 2009), urbanization (Williams et al. 2005), and the widespread planting of trees by man (Baer, 1989). The destruction of this ecosystem is alarming as its restoration would require many decades (Schramm 1990).

A major component of North America's native grasslands is the Great Plains, which stretches from Canada to Mexico, and from the foothills of the Rocky Mountains to western Indiana and Wisconsin (Samson and Knopf 1994). The Great Plains consists of 3 prairie types: tallgrass, mixed grass, and shortgrass. Tallgrass prairie, in particular, has experienced such dramatic loss that it has shrunk to about 4% of its pre-settlement land area, and has been described as having been altered to a greater degree than any other North American biome (Sampson and Knopf 1994). Kansas, Texas, and South

Dakota are the 3 states possessing the greatest remaining acreage of pre-settlement prairie (Askins et al. 2007).

Reflecting the decline of North American grasslands is the decline in grassland bird populations which utilize the grasslands as breeding and in some cases wintering habitat (Askins et al. 2007). The breeding bird survey, a roadside count-based survey conducted by volunteers, has been monitoring population trends in North American birds since 1966. The Breeding Bird Survey monitors 41 bird species recognized as grassland species, of which 21 species are recognized as obligate grassland species. These grassland bird species have been showing consistent downward trends (Sauer et al. 2013). In composite, the obligate grassland species populations have declined by 37.8% between 1968 and 2011 with 75% of obligates having negative trend estimates (Sauer et al. 2013). Knopf (1994) described grassland bird populations as showing the fastest, consistent, and widespread decline of any avian guild.

Because of the tight association of North American grasslands and its avian assemblages, researchers have attempted to demonstrate how birds can be used to assess grassland quality. Browder et al. (2002) suggested that assemblages of breeding grassland birds can be modeled as indicators of grassland condition. Their reasoning behind developing such a model was based on several qualities of avian species which make them good indicator species. Of these qualities was the fact that groups of birds can be used to develop associations with habitats that are predictive of the relative level of anthropogenic disturbance (Szaro 1986, Croonquist and Brooks 1991, Bradford et al. 1998, Canterbury et al. 2000). Because prairie grasslands and grassland birds are of conservation concern, and birds act as good indicator species, I wanted to investigate how bird communities responded to multiple habitat variables in the Texas Rolling Plains.

The Rolling Plains ecoregion of Texas is comprised of about 11 million ha in north-central portion of the state, of which two-thirds is utilized as cattle range (Jackson 1960). This ecoregion has been described a transition zone between shortgrass and mixed grass prairie in the southern Great Plains (Roberts et al. 2012). Although the original vegetation of this ecoregion consisted of open tall and mixed grass savannahs, honey mesquite (*Prosopis glandulosa*) is a common invader in all soils, while shinnery oak (*Quercus havardii*) and sand sage (*Artemisia filifolia*) can invade on sandy soils (Correll and Johnston 1979). Another woody plant encroaching in portions of the Texas Rolling Plains is redberry juniper (*Juniperus pinchotii*). These trees were originally found on rocky outcrops, canyons, and other areas with shallow limestone or gypsum soils where they were protected from grass fires (Ansley and Ueckert 1995). The encroachment of junipers in grasslands is concerning as it usually progresses toward a stable woody state of mature trees that requires a significant disturbance to shift succession in another direction (Ansley and Rasmussen 2005). One of the areas most affected by the encroachment of red berry juniper in Texas is Cottle County (Ansley and Ueckert 1995).

Texas Parks and Wildlife's Matador Wildlife Management Area (WMA) in Cottle County contains 11405.25 ha of land managed as a research and demonstration area, as well as for recreation, particularly public hunting. Nestled in the Texas Rolling Plains ecoregion, Matador WMA is a large parcel of land containing numerous habitats such as shinnery oak (*Quercus havardii*) rangeland, mesquite (*Prosopis glandulosa*) lowlands, breaks covered in a mix of red berry juniper and mesquite, and bottomland. Lack of management in the early history of the area resulted in brush encroachment, converting the property to denser shrubland habitats. Beginning in the early 2000s, intensive habitat management involving herbicide treatments, controlled burning, and mechanical brush manipulation is attempting to convert the dense shrubland habitats into the more historic open savannahs and prairies. Because these brush management practices have occurred in different combinations in a mosaic pattern, Matador WMA has a tremendous variety of different brush densities on the area. With its large acreage and diverse assortment of habitat types and plant communities I chose Matador WMA as a study site to investigate relations between avian community structure and habitat variables at the microhabitat, patch, and landscape scales.

METHODS

Transects

I sampled bird community structure via birding along 60 300-m line transects spread throughout Matador WMA (Figure 1). Each transect was birded once in this study and transect locations were selected in a way to maximize variation in habitat. This was done to ensure that we captured large gradients in our recorded environmental variables for our ordination analysis. These transects were set up as straight lines by shooting a bearing with a Silva Ranger mapping compass (Silva, Mariehallsvagen, Sweden). Each transect included a starting point, and 10 additional points, including the ending point, spaced evenly 30 m apart. GPS locations were recorded for each point along the transect for later reference. Transects were set up at least one day prior to the date of bird recording, and every point received a piece of flagging ribbon to aid in later navigation.

Birding procedure

To stay consistent in birding effort and skill, I was solely responsible for bird detection and identification throughout the duration of the study. Zeiss terra ED 8x42 mm binoculars (Zeiss International, Oberkochen, Germany) were used to observe birds while walking the transects. Only birds seen perched within or flushed from within my view were recorded. Therefore, birds seen flying through or flying over the transect without landing were not recorded. I was also following the protocols of distance sampling so that I could use this data for other analyses. Therefore, I was recording the distance between myself and any location that a bird was seen perching or flushing from. On a few occasions, large birds seen perched in the distance were not recorded as they were out of the range that my rangefinder could detect. The maximum distance for any bird record used in my analyses was for a perched Mississippi Kite which was 441 meters away. However, the rest of the recorded birds in this study were much closer when spotted, with the average distance 78.77 meters away. Each time a bird was detected, its species was recorded along with any behavioral notes. When available, a volunteer researcher followed the bird observer to assist in data recording. Aside from the microclimatic variables (see below), no other data were collected while birding was in progress. Birding began on May 31st, 2017 and lasted until August 17th, 2017. All birding was done between dawn (as soon as there was sufficient light for identification) and 12:00 noon.

The mid-day cut off time for birding was chosen for practicality and safety reasons as mid-day summer temperatures often reached dangerous levels.

Microclimatic variables

Every time a transect was walked for birds, microclimatic habitat variables were recorded at each of the 10 points with a Kestrel 3000 Portable Weather Station (Kestrel Meters, Boothwyn, Pennsylvania, USA). These variables included temperature, humidity, and wind speed. Each time I took measurements I activated the Kestrel for one minute and recorded the average measurement for all variables once the minute was up. In this way, all variables were measured once with the kestrel placed on the ground and once again with the Kestrel sitting on top of a 1.5-m tall pole. At each point along all transects I also used a Raytek MiniTemp infrared thermometer (Raytek, Wilmington, North Carolina, USA) to record ground surface temperature. For my analysis I averaged the 10 point measurements of each microclimatic variable to generate single transect specific microclimate values for analysis.

Vegetation surveys and visual obstruction variables

Vegetation surveys were taken at each of the 10 points along every transect. These surveys were either taken when the transect was initially set up or immediately after the transect was walked for birds, but never during bird recording. I used a Daubenmire frame (0.1 m^2; Daubenmire 1959), randomly thrown from each point to record vegetation characteristics. The frame usually landed within 5 feet of the point from which it was thrown. Within each frame I recorded percent litter, percent bare ground, percent forb cover, and percent grass cover. I also recorded species richness for forbs and grasses. At each point, I also took a measure of visual obstruction using a 1.5-m tall pole evenly divided into 3 alternating black and white sections. Each of these sections were further divided by black or white marks into 10 evenly spaced sections. To consistently measure visual obstruction with this pole, the observer's chin placed on a 3-foot tall measuring stick connected to the pole by a 5-m long rope. In this way, 4 measures of visual obstruction were taken from vantage points at right angles from each other. From these vantage points, the observer would estimate the percent of visual obstruction from each of the 3 sections of the pole: bottom, middle and top.

Arthropod sampling and processing

I sampled arthropods at each of the 10 points along every transect via sweep netting. When sweep netting, I walked 50 paces, in a perpendicular direction (to the left or right) from the transect randomly chosen at the time of sample collection. Because of time restraints, sweep-netting could not always take place on the day of birding the transects, but all sweep netting samples were collected within 3 days before or after the date of a bird survey. Samples collected from sweep netting were put into gallon sized plastic bags and stored in a freezer until processing.

When processing the sweep-net samples, I first separated the frozen arthropods from the vegetative debris. I sieved the contents of the sample using an E.H. Sargent & Co No. 10 sieve which had a mesh opening size of 2 mm (Sargent Welch, Rochester, New York, USA). The remaining contents were emptied onto dissecting trays where I separated all invertebrates from the remaining vegetative debris and returned the invertebrates to their bags for later identification. I identified each individual arthropod down to family using the taxonomy in Borror and DeLong (1971).

After enumerating families within each sweep sample, I used these raw counts to generate 10 abundance community metrics for each sweep sample. These metrics included total abundance of all arthropods, abundances of the 5 of the most encountered arthropod families (Acridid grasshoppers, Tettigoniid grasshoppers, Dictyopharid leafhoppers, Chrysomelid beetles, and Salticid spiders), Modified Simpson's Diversity Index, Shannon's Diversity Index, family evenness, and family richness.

I used the equation $1-\sum p_i^2$ to calculate the Modified Simpson's Diversity Index, where p_i is the proportion of the i^{th} family to the overall sample. I used the equation $-\sum p_i \ln p_i$ to calculate Shannon's Diversity Index, where p_i is as defined above. I used the equation H'/H_{max} to calculate family evenness, where H' = Shannon's Diversity Index and H_{max} in ln(family richness).

Landscape variables

I used 1-m resolution false color composite aerial photography from 2016 (available from Texas Natural Resource Information Systems; www.tnris.org) with Arcview 3.3 (Environmental Systems Research Institute, Redlands, California, USA) to develop a GIS to quantify habitat at the landscape and patch spatial scales around each transect. To do this, I first created a line of the transect pathway using the GPS coordinates for the beginning and ending of each transect. I then created a polygon encompassing 100-m buffer around each transect. While some recorded birds were located outside of this buffered zone, a 100-meter buffer was chosen for practicality purposes. I then overlaid each transect onto the aerial photography and then used on-screen digitizing to delineate patches into 4 habitat categories: bare ground, woody cover, herbaceous cover, and open water.

Following habitat delineation, I used the landscape program FRAGSTATS (McGarigal and Marks 1994) to compute landscape and patch metrics for each transect. I chose 7 landscape level FRAGSTATS variables and 19 habitat class level FRAGSTATS variables which I thought might be biologically significant for avian communities. Landscape level variables used in the analysis were total area, number of patches, mean patch size, patch size coefficient of variation, edge density, area weighted mean shape index, and Shannon's diversity index of patches (Table 1). Class specific level variables included total area, number of patches, mean patch size, patch size coefficient of variation, edge density, and area weighted mean shape index specific of each of the 3 primary habitat types (bare ground, herbaceous, woody), plus total area within the transect buffer for water (Table 2).

Ordination Analysis

I chose to investigate responses in avian communities across my experimental units via an ordination analysis. These types of exploratory analyses allow all species observations to be used, even the limited observations of rare species. Because of the large number of variables involved, I conducted a tiered analysis.I performed Canonical Correspondence Analyses (CCA; Ter Braak 1986) within CANOCO ver 4.5 to explore relationships with each transect representing an experimental unit, the habitat and landscape variables as the independent variables and the avian community structures as the dependent variables. I first calculated an ordination testing for correlation among 26 FRAGSTATS variables. I then conducted a second CCA that included microhabitat variables and variables obtained from invertebrate sampling. The combination of the 10 invertebrates variables and the 16 variables obtained from microclimate sampling, vegetation sampling, and visual obstruction brought the total of variables for this ordination to 26 as well.

I then conducted a combined model CCA that incorporated any environmental variable from the first 2 CCAs that significantly explained variation in the model at $p < 0.07$.

Multiple Linear Regression Analysis

In addition to the ordination analyses, I performed multiple linear regressions between the occurrence of 11 of the most frequently encountered bird species (i.e., species with >50 individuals) and the 3 groups of environmental variables (FRAGSTATS variables, microhabitat variables, and the variables associated with invertebrate abundances). I also regressed community metrics (Modified Simpson's Diversity, Shannon's Diversity, species richness, and species evenness) against the environmental variables. Because of multiple resampling, I used a Bonferroni correction (Zar 1998) to reduce the significance level of my p-value from 1.0 to 0.025 for this analysis.

RESULTS

I sampled 60 transects. However, 4 of these transects were in areas that had been disturbed by land management practices, such as grubbing, after aerial photography was taken. Thus, I could not determine accurate fragmentation statistics within the GIS for the samples, and they were excluded from the analysis. This left surveys on 56 transects being incorporated into the CCA.

Across all surveys of transects used in the analysis, I detected 1,458 birds (Table 3). Of these, 177 could not be determined reliably to species and were considered unknown (Table 3). These unknown birds were not used in the calculation of community metrics. This resulted in 1,281 birds of 48 species being used in the final analyses (Table 3). Lark Sparrows (*Chondestes grammacus*) were the most common species encountered, with 205 individuals (Table 3). Burrowing Owl (*Athene cunicularia*), Canyon Wren (*Catherpes mexicanus*), Dickcissel (*Spiza americana*), Great Blue Heron (*Ardea herodias*), Great Horned Owl (*Bubo virginianus*), Lesser Goldfinch (*Spinus psaltria*), Orchard Oriole (*Icterus spurius*), Vermilion Flycatcher (*Pyrocephalus obscurus*), and Western Meadowlark (*Sturnella neglecta*) were the least represented species with only 1 individual each (Table 3).

Ordination Analysis

The CCA for FRAGSTATS variables resulted in a total inertia of 4.976, and the sums of the first 4 axes explained 14.7, 27.9, 38.2, and 46.3% of the avian species-environmental relationship apparent in the model, respectively. Forward selection suggested landscape level mean patch size and edge density, plus class level woody vegetation edge density, mean patch size for bare ground, number of woody vegetation patches, total area of open water, and area weighted mean shape index were important in explaining patterns within bird communities at Matador WMA (Table 4). Thus, these variables were promoted for use in the combined model (Table 4).

The CCA for microhabitat and invertebrate variables resulted in a total inertia of 4.976, sums of the first 4 axes explained 13.2, 24.8, 35.6, and 43.6% of the avian species-environmental relationship apparent in the model, respectively. Forward selection suggested percent litter, Shannon's Diversity Index of invertebrate families, forb species richness, visual obstruction of the top zone, air temperature at 1.5 m, Acrididae abundance, and invertebrate family richness were important in explaining patterns within bird communities at Matador WMA (Table 5). Thus, these variables were promoted for use in the combined model (Table 5).

The CCA for the combined model resulted in a total inertia of 4.976, sums of the first 4 axes explained 17.6, 32.6, 44.7, and 54.6% of the avian species-environmental relationship apparent in the model, respectively. In this combined model, landscape level edge density, air temperature at 1.5 m, patch size coefficient of variation for woody vegetation, and visual obstruction of the top zone were no longer considered useful in explaining variation (Table 6). Thus, invertebrate family richness, percent litter, forb richness, number of patches of woody vegetation, landscape level mean patch size, edge density of woody vegetation, mean patch size of bare ground habitat, total area of open water habitat, invertebrate family richness, area weighted mean shape index, and Acridid abundance were considered to be the variables that I measured that were most useful in explaining variation in bird communities at Matador WMA (Table 6).

The biplot of my ordination axes 1 and 2 revealed some interesting correlations among bird species (Figure 2). the environmental variables chosen created environmental gradients which may be interpreted to represent riparian habitats in the top left section of the biplot, juniper breaks in the bottom left section of the biplot, open riparian woodlands in the top right corner, and mesquite savannah/shrub land on the bottom right corner. Although many bird species were placed in the center of the biplot, indicating no strong correlation with any of my chosen environmental gradients, some environmental variables seemed to have strong correlation with a few species. Because of the placement of many species in the center of the biplot, my ordination did not capture many distinct avian community guilds correlated with my environmental gradients. Rather, I see a blending of habitat use by numerous bird species. Therefore, the biplot suggests that many of these species may be acting as habitat generalists utilizing numerous habitats. Some birds, however, had strong associations with some habitat gradients. For instance, several species were clearly associated with riparian habitats.

Multiple Linear Regression: Combined Model

Abundances of Ash-throated Flycatchers (*Myiarchus cinerascens*), Bewick's Wrens (*Thryomanes bewickii*), Golden-fronted Woodpeckers (*Melanerpes aurifrons*), Lark Sparrows, Mississippi Kites (*Ictinia mississippiensis*), Northern Bobwhite (*Colinus virginianus*), Northern Cardinal (*Cardinalis cardinalis*), Northern Mockingbird (*Mimus *polyglottos*), Painted Bunting (*Passerina ciris*), and Scissor-tailed Flycatcher (*Tyrannus forficatus*) were sufficient to use in multiple regressions to explore the influences of FRAGSTATS, microhabitat variables, and invertebrate variables on these species individually.

The abundance of Ash-throated Flycatchers approached a significant positive relationship with visual obstruction in the bottom zone (P = 0.031), but no other variables were related to abundance of this species (P > 0.3490). Bewick's Wrens approached having a significant positive relationship with increasing visual obstruction in the top zone (P = 0.067), but no other variables were related to the abundance of this species (P > 0.200). Abundance of Golden-fronted Woodpeckers approached a positive significant relationship with species richness of forbs (P > 0.033), but not related to any other variable (P > 0.200). Lark Sparrow abundance increased with increasing ground surface temperature (P = 0.003), but were not related to the other variables examined (P > 0.822).

Northern Bobwhites increased with forb richness (P = 0.015), and approached a decrease with wind speed at ground level (P = 0.049), but were not related to the other variables (P > 0.200). Abundance of Northern Cardinals was not related to any variables I measured (P > 0.319). Northern Mockingbirds increased in abundance with increasing visual obstruction in the bottom zone (P = 0.003), but this species was not affected by the other variables I measured (P > 0.200). Scissor-tailed Flycatchers tended to have higher abundances in areas with higher species richness of grasses (P = 0.003), warmer air temperatures at 1.5 m (P = 0.021), and warmer ground surface temperatures (P = 0.017).

This species also approached a decrease with increasing wind speed at 1.5 m ($P = 0.120$), but was not related to the other variables measured ($P > 0.200$).

In terms of community level metrics, total bird abundance increased with increasing visual obstruction at both the middle ($P = 0.002$) and bottom ($P = 0.005$) zones, but was not related to the other variables ($P > 0.200$). Modified Simpson's Index of Diversity decreased with increasing ground surface temperature ($P = 0.005$), but was not related to any of the other variables I measured ($P > 0.200$). Species evenness decreased rapidly with increasing ground surface temperature ($P < 0.001$), but was not related to the other variables I measured ($P > 0.200$).

DISCUSSION

Avian species of the Texas Rolling Plains: A mix of peripheral species

From an avian ecology standpoint, the Rolling Plains ecoregion of Texas is an interesting region, partly because it contains no endemic avian species. Instead, its avifauna is derived from adjacent continental avifaunae of eastern, western and southwestern North America (Hamilton 1962). Hamilton (1962) described bird species occurring in the Mesquite Plains of Texas, including the region where my study took place, and categorized taxa by their wintering and breeding habitat, as well as if a species was "peripheral". Of the list Hamilton's (1962) peripheral species, I observed Blue Jay (*Cyanocitta cristata*), Common Grackle (*Quiscalus quiscula*), Dickcissel, and Eastern Kingbird (*Tyrannus tyrannus*) as "eastern" species, and Ladder-backed Woodpecker

(*Dryobates scalaris*), Golden-fronted Woodpecker, Black-crested Titmouse (*Baeolophus atricristatus*), Canyon Wren, Bullock's Oriole (*Icterus bullockii*), Lesser Goldfinch, Rufous-crowned Sparrow (*Aimophila ruficeps*), and Western Kingbird (*Tyrannus verticalis*) as "western" species.

I also recorded House Finch (*Haemorhous mexicanus*), a species that Hamilton (1962) categorized as a western "peripheral" species in 1962 as its range naturally extended to central Texas at that time (Oberholser 1974 as cited in Aldrich and Weske 1978). However, since the species introduction to Long Island, New York, in 1940 and it subsequent range expansion eastward to nearly cover the lower 48, it can no longer be considered a strictly western species to this day (Aldrich and Weske 1978). Also, because of recent northern expansions in their ranges (therefore not included on Hamilton's [1962] list of peripheral species), Vermilion Flycatcher and Pyrrhuloxia (*Cardinalis sinuatus*) were commonly seen on my study site and might best be considered "southern" peripheral species.

Another western species not included on Hamilton's (1962) list but currently with peripheral breeding range in north central Texas is the Ash-throated Flycatcher, which was seen on many of my transects. According to Lanyon (1963), the Ash-throated Flycatcher's breeding range extended from the southern tip of the central plateau of Mexico north to northern Oregon and west to central Texas fifty years ago. However, the species has been observed "with increasing frequency" east of the Mississippi River outside of the species breeding range or previously known wintering range (Murphy 1982). The species is now understood to be a vagrant visitor to the eastern United States during the fall and winter (Alderfer and Dunn 2014). The Northern Cardinal might also be considered an "eastern" peripheral species in the region, because the western boundary of its range loosely follows the western border of the Texas Panhandle.

Thus, 17 of the 48 (35%) species I documented on my transects could be considered in some way peripheral. This could suggest that the region contains a blend of mostly habitat generalists from surrounding ecoregions. If such a large proportion of species in my sample are truly habitat generalists, this may help explain why it was difficult for me to detect strong structuring in the avian community at Matador WMA in my CCA analyses.

However, for that very reason, the Rolling Plains of Texas provides valuable opportunities for research on avian niche overlap between closely related species existing together in the peripheries of their ranges. This would be particularly true here for the Eastern Kingbird and its congener the Western Kingbird, as well as the Northern Cardinal and its congener the Pyrrhuloxia. These species were seen on multiple transects (Northern Cardinals on 26 transects, Pyrrhuloxias only seen on 2 transects), and at times they were even observed interacting with each other on the same transects.

Eastern Kingbird and Western Kingbird

In the southern portion of the United States, the Eastern Kingbird's normal breeding range hits its western boundary in the Rolling Plains of Texas (Mackenzie and Sealy 1981). However, the species' breeding range extends from this region to the north and west all the way to Northwest Territories in Canada with the birds rarely occurring farther north and west into Alaska. In much of the western United States therefore, the Eastern Kingbird is sympatric with the Western Kingbird (Mackenzie and Sealy 1981). There have been several studies investigating the ecology of these 2 species where they coexist and the findings of these studies can shed some light on the results of this study.

Whithmore (1975) and James (1971) studied the species in Utah and Arkansas, respectively. While the 2 studies recorded several of the same species, only Western Kingbirds were recorded in the Utah study, where Eastern Kingbirds were rare, and only Eastern Kingbirds were recorded in the Arkansas study, where Western Kingbirds were not commonly found. Whithmore (1975) noted that the Western Kingbird's location in ordination space in his study was almost identical to the Eastern Kingbird's location in ordination space in James' (1971) study. This finding indicated that both geographical and ecological replacement was occurring for eastern and Western Kingbirds among the Utah and Arkansas study sites (Whithmore 1975).

My study occurs directly between the aforementioned Utah and Arkansas studies, and I documented both eastern and Western Kingbirds at Matador WMA. Therefore, my data provides insight from the intermediate zone between eastern and Western Kingbird dominance. In my ordination biplot, Eastern Kingbirds were positively associated with landscape area mean patch size and percent litter coverage in the Daubenmire frame. The species was also negatively associated with increasing numbers of woody patches, landscape level edge density, and the amount of woody edge. This suggests occupation of more open, grassland sites. Western Kingbirds in my ordination space fell out farther away from Eastern Kingbirds in the bottom right section of the biplot, an area which I consider to represent mesquite savannah/shrubland habitats. In other words, my data suggests there may be some habitat partitioning between these 2 species, with Western Kingbirds occupying shrubbier landscapes and Eastern Kingbirds occupying more prairie landscapes.

Northern Cardinal and Pyrrhuloxia

Gould (1961) studied territorial relationships between Northern Cardinals and Pyrrhuloxias at San Xavier Indian reservation, Pima County, Arizona, where both species bred and overwintered. Northern Cardinals only defended breeding territories against other Northern Cardinals, Pyrrhuloxias only defended breeding territories against other Pyrrhuloxias, and territories were established and maintained almost entirely by the males of both species. While the breeding territories would overlap with the territories of the opposite species, Gould (1961) noted that the species tended not to nest near each other. Gould (1961) speculated that this tendency may be a result of some form of competition as the species made similar nests, laid similar eggs, and utilized the same type of places to nest. Gould (1961) also found that both species required woodland patches as their territories for nest placement and Northern Cardinals appeared to require much more dense woodland than the Pyrrhuloxias. However, both species also preferred to include patches of open field within their nesting territories.

These findings are reflected in my ordination bi-plot of Axis 1 and Axis 2, where Northern Cardinals were positively associated with increasing numbers of woody habitat patches, landscape level edge density, and total amounts of woody edge. Pyrrhuloxias, while not being negatively associated with these variables, had a clearer alignment with the arrow coinciding with increasing cover at the highest level of the visual obstruction pole. This association may reflect one of Gould's (1961) observations where a pair of Pyrrhuloxias, but no Northern Cardinals, established a territory in an open mesquite patch. This open mesquite patch would tend to have greater visual obstruction higher off the ground relative to the lower levels sampled in my study because of the higher mesquite branches. Conversely, the denser woodland said by Gould (1961) to be preferred by Northern Cardinals in their territories, might have had more evenness in visual obstruction across the levels sampled in my study.

Therefore, the species preferences in nesting territory postulated by Gould (1961) supports patterns of habitat associations among Northern Cardinals and Pyrrhuloxia in my ordination bi-plot. While the 2 species were not negatively associated with each other or their associated habitat variables in my study, they did show greater association with certain characteristics related to woody vegetation. However, the species scores for Northern Cardinal and Pyrrhuloxia are quite close to each other within my ordination and this suggests minimal niche diversification between these species based upon the variables I assessed. This also suggests that other niches dimensions, such as diet, might be more important for niche diversification of these 2 similar species, than the habitat variables I explored.

Blue-gray Gnatcatcher (*Polioptila caerulea*)

There have been several studies investigating avian communities via ordination analysis. Whithmore (1975) investigated passerine bird communities in Utah and compared his results to James (1971) who conducted a similar study in Arkansas. In both studies, Blue-gray Gnatcatcher occurred near the center of the ordination biplots, indicating that the species is a habitat generalist utilizing a wide variety of habitats. While my study differed from these earlier studies in numerous ways including the method of obtaining data (sampling along transects vs. sampling circular plots around singing males), the location of Blue-gray Gnatcatchers in my ordination space was similar. On one occasion in my study it was somewhat surprising to find a Blue-gray Gnatcatcher perched in a small shrub in a relatively open area, and on another occasion the species was noted to be perched on salt cedar (*Tamarix* sp.), but my data generally support the ideal that Blue-gray Gnatcatchers act as habitat generalists at the scale I tried to assess relationships.

Open Grassland Species

My study reflected Greer et al. (2016) who found Western Meadowlarks to be negatively impacted by increasing amounts of wooded edge surrounding a grassland patch. Similarly, in my ordination I found Western Meadowlark to have a strong positive correlation with mean patch size and a strong negative relationship with the number of patches composed of woody vegetation, landscape level edge density, and total amount woody edge. Western Meadowlarks were only identified on 1 transect which ran through an open field. The GIS layer for this transect was mainly composed of large patches of herbaceous cover with only a few patches of woody vegetation within its 100-m buffer.

This was also the only transect where Burrowing Owls were documented, thus explaining the proximity between Burrowing Owl and Western Meadowlark in ordination space. This type of overlap is also the case for the Great Horned Owl and Vermilion

Flycatcher and the *Empidonax* flycatcher and Orchard Oriole in other areas of the ordination biplot.

The transect where Burrowing Owl and Western Meadowlark were observed ran through a predominately grass field, with only a few dead tree snags and one large living tree along the roadside. Loggerhead Shrike (*Lanius ludovicianus*), while also seen on other transects, were seen in highest number here as a family utilized the large living tree present near my transect as nesting habitat. This explains the placement of these species in positive association with increasing mean patch size in the landscape, as the transect contained nearly continuous herbaceous cover in the form of grass. This also explains the species' negative association with increasing number of woody patches, woody edge density and landscape edge density.

Another environmental gradient pointing in the same direction of increasing mean patch size in the landscape is increasing percent coverage of litter in the Daubenmire frames. This makes sense as the grassy transect on which these species were found contained much standing dead grass classified as litter. Therefore, with proper interpretation of the ordination biplot, the high spread of Burrowing Owl, Western Meadowlark and Loggerhead Shrike indicates these species' association with open habitats with large patches of herbaceous cover in the landscape rather than with the open cottonwood (*Populus deltoides*) woodlands which the other species in this section of the biplot are likely responding to.

Open Woodland Species

Other species in the same quadrant of the biplot, however, were seen on transects which included both large patches of herbaceous cover and with large trees either interspersed or occurring in nearly continuous patches of woody cover. Caution must be exercised in interpreting this section of the biplot. Some species in this section may be responding to this landscape variable of increasing mean patch size either as increasingly large patches of herbaceous cover, woody cover, or a mix of the two. Therefore, I would classify this section of the biplot as representing open savannah habitats, possibly occurring in floodplains with large patches of herbaceous cover in the landscape.

American Kestrel (*Falco sparverius*), Mississippi Kite, Red-headed Woodpeckers (*Melanerpes erythrocephalus*), and Blue Jays were observed utilizing both living and dead cottonwoods on transects running through these open woodlands. Red-tailed Hawk (*Buteo jamaicensis*) on the other hand may have been placed in this section of the ordination biplot responding to both increasing mean patch size of woody cover and herbaceous cover in the landscape. The 4 individual Red-tailed Hawks seen in my study were seen on 4 different transects. While 1 of these transect was in an area approaching the openness of the transect I document Burrowing Owl and Western Meadowlark transect, the other 3 transects where Red-tailed Hawks were found contained larger patches of woody vegetation.

American Kestrel

I recorded 22 individual American Kestrels occurring on 7 transects. Where they occurred, birds were typically seen in small groups as the average number seen at on a transect was 3.14 with a single individual seen on only 1 transect and a maximum of 5 individuals seen on another. My field notes suggest that these small groups may represent breeding pairs with their juvenile offspring. They were found in different habitats such as open fields with interspersed dead trees acting as hunting perches, to open cottonwood groves found in floodplains.

In my ordination analysis, this species, like the Red-tailed Hawk, Loggerhead Shrike, Blue Jay, Burrowing Owl, and Western Meadowlark were positively associated with landscape mean patch size and percent litter. Individual American Kestrels were often noted to be perching on either living or dead trees when encountered. Therefore, this species was associated with open habitats containing relatively tall trees and snags for perching sites and potential nesting sites. This finding in my study agrees with other literature on the species' ecology.

Johnsgard (1990) suggested the probable minimum habitat needs for the American Kestrel includes open terrain for hunting insects and small vertebrates, elevated perches, and the presence of tree or non-tree nest cavities. Furthermore, in an investigation of avian habitat use at multiple scales in Idaho, Saab (1999) found the American Kestrel to be more positively associated with open canopy and open sub-canopy habitats, herbaceous ground cover opposed to litter ground cover, and increasing bare ground opposed to willow sub-canopy. The species was also negatively associated with increasing birch (*Betula* sp.) density (Saab 1999).

On a landscape scale, Saab (1999) found the American Kestrel to be positively associated with decreasing distances between neighboring cottonwood patches, and natural landscapes opposed to agricultural landscapes. Saab (1991) speculated that this cavity-nesting species may be responding to limited and clustered suitable nesting trees within the cottonwood patches. My study's finding of this species' positive association with increasing litter contrasted with Saab (1999). However, this may be explained by my technique of evaluating litter cover. A transect running through an open field where these birds were once observed contained a thick cover of recently dead herbaceous top cover. While the herbaceous plants (mostly grasses) may have been alive underground, I categorized the dried top cover as litter. In addition, there may have been more cover of arboreal leaf litter on the transects running through the open cottonwood woodlands in the floodplains where American Kestrels were also found.

Red-headed Woodpecker and Blue Jay

Saab (1999) concluded in her study that an important management recommendation for riparian areas at the microhabitat scale is to manage for a relatively open cottonwood forest canopy which is characteristic of the woodlands created by natural flooding disturbances. In her study, Saab (1991) found this microhabitat to be the most important predictor of high species richness and the occurrence of several species. Similarly, my study found that not only American Kestrel to be associated with these open woodlands, but also Blue Jay and Red-headed Woodpecker. Both Gorman (2014) and Winkler et al. (1995) described Red-headed Woodpecker habitat as open and mature woodlands, including riparian woodlands with dead trees or snags and sparse undergrowth. In my study, the Red-headed Woodpecker was encountered on 2 transects. Five individuals occurred on a transect running through open cottonwood woodland and 2 individuals were seen on a transect running downhill through woody patches with multiple snags before ending in an open floodplain. The habitats of both transects fit the descriptions given by Gorman (2014) and Winkler et al. (1995) of riparian woodland habitats used by the species.

Blue Jays were also seen on only 2 transects in my study, each of these transects ran through a floodplain with an open woodland containing large cottonwood trees. In fact, 1 of these transects contained all 3 open woodland species highlighted here: Blue Jay, Red-headed Woodpecker, and a family of American Kestrels. Additionally, I did not document Blue Jays in any additional habitats while working on other wildlife research projects throughout the study season at Matador WMA. This suggests the importance of riparian woodland as habitat for this species within the habitat matrix found in the region.

Riparian Bird Assemblages

I have discussed above how my ordination biplot revealed habitat gradients representing open grassland and savannah habitats, which may or may not have been associated with riparian floodplains. However, my biplot also created an assemblage of habitat gradients collectively representing purer riparian habitats surrounding standing water (Figure 2). These gradients, advancing to the top left section of the biplot, included increasing invertebrate diversity, increasing invertebrate richness, increasing Acridid grasshopper abundance, and increasing area of open water. Of these, increasing area of open water had the longest arrow in the biplot, meaning it was the most important variable in explaining variation in my bird community dataset.

In contrast, the bottom right hand corner of my ordination biplot contained only one environmental gradient which indicated increasing temperature 1.5 m off the ground. While there were some bird species in this section of the biplot, no species was found directly opposite to the environmental gradient for water class area, which is found on the opposite section of the biplot. Placement of a species opposite of a gradient indicates negative association with the gradient and therefore, my ordination biplot highlights the importance of water in shaping bird communities. No bird species on my study responded negatively to the presence of open water, while some bird species were greatly associated with it and/or the habitat surrounding it. This finding in my study reflects Bohning-Gaese and Lemoine (2004) who stated species richness in bird communities in high latitudes is best predicted by measures of ambient temperatures while in low-latitude regions with high temperatures species richness is best predicted by water-related variables.

For my ordination's environmental gradients representing riparian habitat, one consideration must be made: water class area was represented by a man-made stock pond with a solar-powered mill on one transect. Water class area was otherwise represented in all my other transect buffers by the Middle Pease River. Although this transect with the stock pond had a starting point which was not far from the river, the transect ran away from the river into mesquite woodland habitat. Therefore, the habitat in this transects' buffer, although it did have a small area of permanent standing water, was probably not surrounded by the same quality riparian habitat found near the river. Similarly, as mentioned above, some birds may possibly be responding to standing water just outside of my transect buffers or possibly even by small water sources not detected in the aerial photography.

Looking at the placement of riparian species on the biplot it appears that these species are more closely grouped around the orientation of increasing water class area than they are grouped in the area directly opposite to the orientation of increasing ambient temperature. This suggests that these riparian birds were responding mainly to water class area or the other similarly oriented environmental gradients in the top left corner of the biplot. However, as ambient temperature 1.5 m above the ground appears in the final ordination biplot with a relatively long arrow, this variable was still important for explaining the variation in bird communities. The riparian birds may have been simultaneously responding positively to the gradients associated with water and negatively to increasing heat.

Tubbs (1980) identified 136 birds utilizing riparian communities in the Great Plains and categorized them as “year-round”, “breeding only”, or “winter only” residents. Traditionally these species were categorized as “woodland” or “limnic” birds. Therefore, Tubbs (1980) noted that although all species utilize riparian habitats, some may be less restricted to the riparian areas than others. The so-called obligate riparian nesting species included such birds as herons, egrets and the belted kingfisher (*Megaceryle alcyon*). My study did not encompass winter months and therefore I could only observe the bird species belonging Tubbs’ (1980) “year-round” and “breeding only” categories of riparian birds. The species associated with riparian habitats in my study included Green Heron (*Butorides virescens*), Great Blue Heron, Field Sparrow (*Spizella pusilla*), black-crested titmouse, Common Grackle, Red-winged Blackbird (*Agelaius phoeniceus*), and Killdeer (*Charadrius vociferus*). Black-crested titmouse was not identified as a riparian bird by Tubbs (1980) in his study, however its congener, the tufted titmouse (*Baeolophus bicolor*) was. I did see additional species in my study which would have been categorized as riparian bird species by Tubbs (1980), but they were more correlated with other environmental variables in my ordination. This agrees with Tubbs (1980) that some "riparian" species may be less restricted to riparian areas than others.

Only a small number of my transects contained standing water, but some transects contained dry creek beds with associated riparian woody vegetation in their buffered zones (e.g., the open cottonwood woodlands discussed above). This lends insight to species responses not only to standing water, but also to remaining riparian woody vegetation in the seasonal absence of water. However, as my transects only included a 100-m buffer on each side, it is quite possible that some of these bird species may have been responding to the presence of water occurring at greater distances from the transect line. Some of the species found along dry creek beds included Eastern Kingbird, Orchard Oriole, an *Empidonax* flycatcher species, American Kestrel, Blue Jay, and Mississippi Kite.

Standing Water

Red-winged Blackbird

I recorded 27 individual Red-winged Blackbirds occurring across 5 out of the 55 transects used in the ordination analysis. The ordination's resulting biplot of axis 1 and 2 placed Red-winged Blackbirds in the upper left corner directly aligned with the arrow for increasing total area of open water (Figure 2). The only other species in this ordination biplot with a stronger association with water was the Killdeer (Figure 2). My ordination's deep association of Red-winged Blackbird and water is in accordance with several other studies' findings. In an investigation of Conservation Reserve Program (CRP) fields as habitat for grassland birds, Johnson and Schwartz (1993) found Red-winged Blackbird densities had a strong positive association with water cover. Furthermore, Johnson and Schwartz (1983) recorded the conservation practices of each investigated field. This information suggested that Red-winged Blackbird density was highest in the conservation practices of permanent establishment of wildlife habitat and permanent establishment of introduced grasses and legumes. The conservation practices which had the lowest densities of Red-winged Blackbirds were the establishment of permanent native grasses, and already-established grasses.

Johnson and Schwartz (1993) also found this species to be negatively associated with grass and bare ground cover which suggested a higher association with forbs as it is consistent with the species' use of these plants for nesting, perching and food. I could not distinguish between grass cover and forb cover from the available imagery, and instead lumped these cover types as herbaceous cover in my ordination dataset of FRAGSTATS habitat variables. Regardless, the variables built around herbaceous cover in my study were not strong variables for explaining variation in the bird dataset and were not included in my final combined model. I did survey vegetation composition with Daubenmire frame along each transect, producing measures of percent grass cover, grass species richness, percent forb cover, and forb species richness. Of these cover types, increasing percent coverage of litter was the only variable which made it into my final combined ordination model. Therefore, I failed to detect any specific responses Red-winged Blackbirds may have demonstrated towards forb and grass cover in my ordination analysis.

However, it is worth noting that on 1 transect adult male Red-winged Blackbirds were seen utilizing thistle (*Cirsium* spp.) seeds for food. My ordination analysis did not contradict Johnson and Schwartz's (1993) result of a negative association between Red-winged Blackbird and bare ground. I did measure bare ground cover in the available imagery, and 2 FRAGSTATS variables built around bare ground were significant habitat variables accounting for variation in the bird dataset. These were mean patch size for bare ground and area weighted mean shape index for bare ground. Agreeing with Johnson and Schwartz (1993), my ordination detected no association among these bare-ground variables and Red-winged Blackbirds.

Killdeer

Across all species detected, Killdeer had the greatest correlation with water in my ordination. This species had a spread so far from the intersection of the main axis, that it is rivaled only by the spread exhibited by the Western Meadowlark and Burrowing Owl.

The strong association of this species with water in the landscape is not surprising because of its natural history. This species is known to inhabit numerous open habitats inland so long as these habitats are not too far from water (Farrand 1983).

Killdeer was 1 of 4 focal species in a study by Conway et al. (2005) on shorebird habitat use and nest-site selection in the Playa Lakes Region of Texas. Some of the study sites from this investigation were in counties neighboring the county of my own study site (Conway et al. 2005). Conway et. al. (2005) suggested that while the presence of water is essential for breeding shorebirds in the region, it cannot be used to exclusively identify suitable wetland habitats for breeding shorebirds. This was demonstrated in their study by the fact that the investigated man-made wetlands which contained standing water were not used as nesting sites by shorebirds at all (Conway et al. 2005).

Conway et al. (2005) suggested 3 requirements were necessary for nesting shorebirds in the playa lakes region of Texas: standing surface water shallow enough for foraging which lasts throughout the breeding and brood-rearing period, areas within the wetland which contain bare dry ground and dry ground with vegetation for nesting, and at least some vegetative cover. Killdeer specifically preferred nest sites on dry ground that was bare and dry ground with vegetation and avoided nesting in mudflats with vegetation and dry mudflats with vegetation (Conway et al. 2005). Conway et al. (2005) observed Killdeer nesting in wetland habitats which included saline lakes and playas, and were not observed nesting in riparian or man-made wetlands. Plissner et al. (2000) also demonstrated the importance of standing water bodies proximal to nesting Killdeers as they found that Killdeers nesting far from water bodies were generally observed at traveling greater distances from nests compared to birds which nested closer to shorelines.

On my study site the only suitable habitat available for nesting shorebirds such as Killdeer are riparian wetlands as there are no playas, saline lakes, or man-made wetlands. I did observe Killdeer chicks on the study site near concrete road crossings of the South Pease River which runs through the WMA. I observed no Killdeer chicks while birding on transects, and the only adults I saw were on transects situated along the river.

The goal of my ordination was not to investigate the suitability of breeding habitat for the avian species encountered, but rather to determine how habitat and landscape characteristics influence bird communities in the Texas Rolling Plains. Therefore, despite the high association of Killdeer with water and observations of Killdeer chicks on the study site, I cannot speak to the suitability of these habitats for breeding Killdeer in my study. My ordination results simply demonstrate that the environmental gradients representing riparian habitats, specifically water class area in the landscape, were important for Killdeer as a component of the summer avian community.

Great Blue Heron and Green Heron

I only observed 1 Great Blue Heron perched on 1 of my transects, although on 2 other transects the species was also seen flying in the distance. On 1 transect were the species was seen flying, I suspected that a small herd of wild hogs (*Sus scrofa*) flushed the bird while it was foraging near a creek. The single individual observed within one of my transects was seen hunting on the shore near a concrete road crossing on the river. In the earlier phase of my study period (early June), 3 Green Herons were recorded on 2 transects. They were all detected while they were perching conspicuously on top of trees along the river.

Field Sparrow

Only 3 Field Sparrows were encountered throughout my study and on 2 out of the 3 encounters the birds were identified by song in addition to sight. The small number of encounters in my study may explain why this species of open brushy woodlands (Alderfer and Dunn 2014) aligns with riparian habitat in my ordination biplot (Figure 2). The first transect that the species was seen on progressed toward the river at an angle. This transect started in an open recently burnt field near a dirt road and progressed into oldfield habitat with brushy shrub patches and tall grasses before terminating at the shore of the river at 300 m. The individual Field Sparrow recorded at this transect was identified by sight and sound as it was singing. It was on a bushy patch with fallen timber. A female Painted Bunting which was carrying nesting material was simultaneously encountered on this bushy patch when the Field Sparrow was sighted. Therefore, the riparian habitat surrounding the river in this case did provide seemingly appropriate breeding habitat for both the singing Field Sparrow and the nest-building Painted Bunting.

Black-crested Titmouse

The Black-crested Titmouse was another small songbird fitting into the cluster of riparian birds in my ordination biplot (Figure 2). I recorded 14 individual birds on 7 transects throughout my study. I observed this species in habitats consistent with the habitat description given by Alderfer and Dunn (2014) which included oak and other deciduous woodlands along watercourses, open tracts with scattered trees, and arid and scrubby habitats. My first encounter with this species occurred in early June on a transect parallel to the Middle Pease River on the property. On this encounter, I observed 2 individuals foraging in tall deciduous trees along the river. In this case the species of tree was not noted, but on other sightings throughout my study, Black-crested Titmice were noted to be perched in hackberry (*Celtis* sp.) and black willow (*Salix nigra*), a riparian tree species. This further demonstrates the importance of riparian woodland habitat for some avian species in the Texas Rolling Plains.

Common Grackle

I encountered 16 Common Grackles throughout my study occurring on 5 transects. These birds were often seen 2 or 3 at a time, and 1 transect accounted for 7 of the 16 individuals seen. I would observe this species perched in trees on transects near or parallel with the river. Alderfer and Dunn (2014) described this species as abundant and occurring in open and edge habitats, urban areas, agricultural lands, golf courses, swamps and marshes. The placement of this species in the riparian habitat section of my ordination biplot is not surprising. Even while working on separate projects on the WMA throughout the summer, I did not notice this species in areas far from the river.

Mourning Dove (*Zenaida macroura*)

The Mourning Dove is the most widespread North American gamebird (Grue et al. 1983). Its range extends from Alaska to southern Canada south across the contiguous United States and northern Central America (Alderich 1993, Tomlinson et al. 1994). Within this large distribution in North America this species nests in a wide variety of habitats (Sayre and Silvy 1993). Although the species most commonly nests in trees, the Mourning Dove may also nest on the ground if trees or shrubs are unavailable in a habitat (Eng 1986, Howe and Flake 1989, Soutiere and Bolen 1976). This species' adaptability in nesting and its widespread breeding range precludes describing habitat features with precision (Eng 1986). Despite this, Eng (1986) described the bird as being primarily an inhabitant of edge habitat between woodland and grassland.

In Texas, Grue et al. (1983) demonstrated that habitat variables correlated with Mourning Dove call counts differed between different ecological areas in the state. Grue et al. (1983) demonstrated that if 1 or more of the requisites of Mourning Dove survival and reproduction were limited, then the habitats or structural features that provided the limiting requisites were correlated with call counts. Furthermore, abundant habitat types in an ecological area which do not provide all requisites were negatively correlated with call counts (Grue et al. 1983). For example, while cropland was positively correlated to call counts in the Trans Pecos ecoregion of Texas, cropland was negatively correlated to call counts in the Texas High Plains (Grue et al. 1983). The abundance of woody vegetation for nesting and the scarcity of open areas for feeding made cropland a valuable resource for breeding Mourning Doves in the Trans Pecos ecoregion (Grue et al. 1983).

However, the abundance of cropland and scarcity of trees for nesting in the Texas High Plains led to a negative correlation between cropland and call counts in that region (Grue et al. 1983).

Grue et al. (1983) also investigated breeding habitat characteristics in the Texas Rolling Plains. Interestingly, the Texas Rolling Plains provided the highest average number of calling doves per transect within the 10 ecological areas of Texas. Grue et al. (1983) recorded call counts along state and federal Mourning Dove call count transects across Texas in the 10 different ecoregions in the state. Within the Texas Rolling Plains ecoregion, the researchers found that Mourning Dove call counts were positively correlated with parallel and intersecting shrub rows, powerlines intersecting the transects, permanent water sources, snags, livestock feeders, gravel pits, gravel road surfaces, deciduous parklands, mixed (riparian) woodlands with understory, and habitat dispersion and diversity along the transects (Grue et al. 1983). Conversely, dirt road surfaces, cropland and conifer parkland were negatively correlated with call counts in this ecoregion (Grue et al. 1983). Grue et al. (1983) suggested that riparian woodlands appeared to be important nesting habitat as they provided the only woody vegetation greater than 10 m in height in the ecoregion. They also noted that Mourning Doves appeared to prefer mesquite trees over juniper trees (Grue et al. 1983).

In my study, I recorded 88 individual Mourning Doves on 31 out of 60 transects. This species was seen on transects running through different habitats in my study site both far from and near the river. Despite this observed blending of habitat use by Mourning Doves, the species was still placed in the section of the biplot representing riparian habitats (Figure 2). Besides water class area in the landscape, the other environmental gradients in this section of the biplot are related to arthropod abundance or arthropod community metrics. As Mourning Doves feed chiefly on grains, seeds, and fruit (Alderfer and Dunn 2014) this species was probably not responding to arthropod prey represented by the arthropod abundance/community variables. The species' placement in the ordination biplot was also near the arrow representing visual obstruction on the top portion of the pole. The species may be responding to the presence of standing water and/or to other environmental variables associated to riparian areas which I did not measure; possibly tree height or woody species composition. Thus, while Mourning Doves were observed on many transects in different habitats, the ordination results agree with Grue et al. (1983) in highlighting the importance of riparian habitats for Mourning Doves in the Texas Rolling Plains.

While birding transects I flushed Mourning Doves from their nests on 3 separate occasions, and all nests were found in mesquite trees. On 28 June 2017 I discovered 1 nest on a transect running through primarily mesquite woodland on rolling hills. The next nest was discovered on 25 July 2017 on a transect running through rolling hills with juniper and mesquite. Finally, the last nest was discovered on my last day of birding, 17 August 2017, on a transect through rocky juniper breaks.

It is interesting that Mourning Dove nests I encountered were found in mesquite trees especially when the trees were notably short and open. Findings by Grue et al. (1983) may support my limited observations on Mourning Dove nests at Matador WMA, given that they found a negative relationship between coniferous parkland and Mourning

Dove call counts in the Texas Rolling Plains. Additionally, Grue et al. (1983) stated that while most woody vegetation in the Rolling Plains ecoregion appeared to be important as nesting substrate, Mourning Doves also appeared to prefer mesquite over juniper.

Northern Bobwhite

In my study, I observed 36 Northern Bobwhite across 15 transects. The two transects with the highest counts of Northern Bobwhites had 6 and 8 birds and these birds were seen all at once traveling in groups. All other transects had only 1 to 3 birds each. Often the birds were flushed as I walked the transect counting birds, but on a few occasions the birds were spotted in the distance or they flew in from other areas and landed within my view. Some of these birds were seen on transects in riparian areas near the river while others were seen on transects far from natural bodies of water. Still this species was grouped in with other riparian birds and habitat variables related to riparian habitat in my ordination.

One possible explanation for their alignment with this habitat in my study is that they are primarily responding to invertebrate prey. While other birds, such as the Green Heron, Great Blue Heron, and Killdeer, were aligned with the arrow for increasing water class area, Northern Bobwhite was more aligned with invertebrate richness and Shannon's diversity index for invertebrates in our ordination biplot (Figure 2). While Northern Bobwhite diets in the winter consists mostly of seeds, their diets in warmer months consists primarily of high-protein invertebrate prey (Eubanks and Dimmick 1974). Whitaker et al. (2000) demonstrated that riparian buffer zones contain higher densities of insect prey compared to surrounding habitats. Furthermore, Smith et al.

(2008) investigated avian use of different types of riparian buffer zones. Although seed production in buffer zones was less than ideal for quail forage, the vegetative structure at sites where Northern Bobwhite were seen provided essential cover and an indirect food source in the form of invertebrate prey for the Northern Bobwhites (Smith et al. 2008). Not only are invertebrates an important source of protein in adult Northern Bobwhite diets, they are essential in the diet of Northern Bobwhite chicks (Hurst 1972).

Lehmann (1984) noted that brooding habitat for Northern Bobwhites should consist of shade, open herbaceous cover, and green growing vegetation. Despite this, Palmer et. al (2001) demonstrated that indices of foraging values of habitat patches based on imprinted Northern Bobwhite chicks were more biologically relevant than estimates of arthropod abundance information gained from sweep-netting. Taylor et. al. (1999) investigated microhabitats selected by nesting and brood-rearing Northern Bobwhites using many of the same microhabitat variables focused on in my study, and found that the nesting and brood-rearing microhabitats selected by Northern Bobwhites varied in vegetative ground cover, height and structure. In general, my results are consistent with the idea that Northern Bobwhite benefit from a mosaic of habitat types and an abundance of invertebrates.

Microclimate Variables

My investigation on the shaping of avian communities incorporated numerous microclimate variables on the ground, 1.5 m above the ground, as well as ground surface temperature. I may have detected a greater importance of my microclimate variables, including ambient temperature, in my study if I had captured more variation in these measurements. Because of health risks associated in working in the mid-day summer heat, and because I observed bird activity to be lowest at that time, I opted to do my bird detecting from dawn until noon for all transects. Therefore, if I had birded the transects in the hotter hours of the days or at different times of year, I might have seen a greater negative association among certain bird species as they sheltered or changed habitat use in response to a more varied thermal regime.

From incidental observations made while working on other projects throughout the afternoon on the WMA, some common species seemed to remain conspicuous throughout these hotter hours. Of the species placed in the lower right hand corner of the biplot where the gradient of increasing temperature exists, the incidental observations indicate that these abundant "heat tolerant" species may include Western Kingbird, Northern Mockingbird, and Lark Sparrow (Figure 2). This statement is speculative, however as these incidental observations cannot be compared to observations made on the transects. Other species located in this section of the biplot, such as the Vermilion Flycatcher, Great Horned Owl, House Finch, and Dickcissel may occur there because of very low encounter rates in the study, with all of these species being documented as only 1-2 individuals in total (Figure 2).

Grasshopper Sampling

Wiens (1973) suggested arthropod prey items are very important in the diet of grassland birds during the breeding season, and performed a stomach content analysis on the dominant grassland bird species of his study sites: Horned larks (*Eremophila alpestris*), Eastern Meadowlark (*Sturnella magna*), Western Meadowlarks, Dickcissels, Lark Buntings (*Calamospiza melanocorys*), Grasshopper Sparrows (*Ammodramus savannarum*), and McCown's Longspurs (*Rhynchophanes mccownii*). The diets of these species were largely composed of seeds, Lepidoptera larvae, beetles, spiders and grasshoppers, with grass seeds (Poaceae), the beetle families Curculionidae, Carabidae, Cerambycidae, and Scarabidae, and the grasshopper family Acrididae being particularly important (Wiens 1973). Bock et al. (1992) utilized enclosures to eliminate bird predation as well as grasshopper immigration and emigration and demonstrated that bird predation clearly limited Acridid grasshopper numbers in an Arizona grassland.

Sampling invertebrate abundances has been a research technique for evaluating food availability and habitat quality for several avian species in many studies (McIntyre and Thompson 2003, Doxon and Carroll 2007, Brown et al. 2011). In a grassland ecosystem, Baldi and Kisbenedek (1997) the order Orthoptera is sensitive to environmental change, is present in almost every grassland and rangeland habitat, and can be sampled easily with the standardized method of sweep netting. As such, Baldi and Kisbenedek (1997) recommend the use of Othoptera, and grasshoppers in particular, as bioindicators of wildlife habitat quality.

Gardiner et al. (2005) also found that sweep netting was the most commonly used method for sampling orthopterans (used in 45.5% of the papers reviewed) and that the method has been used extensively in the United States, Canada, South America, and the Former Soviet Union. Although Gardiner et al. (2005) recognized that sweep netting does not provide an accurate assessment of frequency or density as it samples a hypothetical volume above the grass layer, the technique clearly has advantages for sampling relatively larger insects. Doxon et al. (2011) compared vacuum sampling and sweep netting sampling for invertebrates and suggested that vacuum sampling was more effective at collecting small invertebrates, such as flies, while sweep netting was more effective at collecting larger invertebrates such as grasshoppers and caterpillars. Therefore, Doxon et al. (2011) recommended that researchers should consider the types and sizes of invertebrates most likely to be consumed by their focal species prior to choosing a sampling method for invertebrates.

I did not have a focal avian species in this study and was instead investigating the entire avian community in multiple habitat types. Therefore, I utilized the widely-used and cost-effective sweep netting method in my study and I did not focus merely on grasshopper abundance. However, of the 106 arthropod families identified throughout my study, only 5 families were encountered frequently enough to use their individual abundances across all transects for my analyses: Acrididae, Tettigoniidae, Chrysomelidae, Dictyopharidae, and Salticidae. Analysis of these variables, plus community metrics, in my first ordination revealed the importance of invertebrate richness, Shannon’s Diversity Index, and acridid grasshopper abundance in explaining patterns in avian communities. Additionally, invertebrate richness, Shannon’s Diversity Index, and Acridid grasshopper abundance, were all correlated with water class area in the landscape surrounding my transects. This implies the importance of standing water and associated riparian areas habitats in supporting a diverse and abundant food supply for insect-eating birds. Furthermore, Acridid grasshopper abundance was the only family-specific abundance measurement retained in my final ordination, thus demonstrating the importance of these grasshoppers in shaping songbird communities at the microhabitat scale. This finding in my study therefore further validates the widely-used technique of sampling grasshopper relative abundance in ornithological and ecological studies.

Management Implications

Several bird species encountered in my study were often seen in groves with mature cottonwoods in floodplains or along dry creek beds. Some of these species were not seen in any other habitat on the WMA throughout the study period. Therefore, this habitat is likely very important for maintaining bird species richness, at least on a landscape scale, in the Texas Rolling Plains. This suggests that management should put a high priority on maintaining and rehabilitating such riparian corridors.

My results suggest Northern Bobwhite are strongly associated with invertebrate variables and environmental gradients related to riparian area. This finding lends insight to wildlife professionals managing this important game species in the Rolling Plains. It also further validates the technique of sweep-netting in studies evaluating habitat for Northern Bobwhite. My results also support the idea that habitat management for Northern Bobwhite requires a mosaic approach, with the species using grassland areas, but benefiting by some level of woody vegetation to meet resource needs. Likewise, my results suggest that conversion of shrublands entirely to grasslands would negatively impact species such as Mourning Dove that utilize grasslands, but benefit from woody species, particularly mesquite, for nesting.

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Table 1. Clarification of landscape level FRAGSTATS variables used to explore habitat associations of birds at Matador Wildlife Management Area, Cottle County, Texas, 2017.

Abbreviation	Term	Definition
LCA	Landscape Level Class Area	Total area in m^2 within the 100 m buffer for a transect regardless of habitat type
LNumP	Landscape Level Number of Patches	Total number of habitat patches within the 100 m buffer for a transect regardless of habitat type
LMPS	Landscape Level Mean Patch Size	Mean size of habitat patches within the 100 m buffer for a transect regardless of habitat type
LPSCoV	Landscape Level Patch Size Coefficient of Variation	Variation in the size of patches within the 100 m buffer for a transect regardless of habitat type
LED	Landscape Level Edge Density	The total amount of edge for habitat patches within the 100 m buffer for a transect (regardless of habitat type) divided total area of the buffer.
LAWMSI	Landscape Level Area Weighted Mean Shape Index	A measure of complexity of shape for habitat patches within the 100 m buffer for a transect regardless of the habitat type
LSDI	Landscape Level Shannon Diversity Index	A measure of diversity of patch size across all habitat types within the 100 m buffer for a transect regardless of habitat type

Table 2. Clarification of habitat specific/class level FRAGSTATS variables used to explore habitat associations of birds at Matador Wildlife Management Area, Cottle County, Texas, 2017.

Abbreviation	Term	Definition
BareCA	Class Area for the Bare Ground Habitat	Total area within the 100 m buffer for a transect for the bare ground habitat only
BareNumP	Number of Patches for the Bare Ground Habitat	Total number of habitat patches within the 100 m buffer for a transect for the bare ground habitat only
BareMPS	Mean Patch Size for the Bare Ground Habitat	Mean size of habitat patches within the 100 m buffer for a transect for the bare ground habitat only
BarePSCo	Patch Size Coefficient of Variation for the Bare Ground Habitat	Variation in the size of patches within the 100 m buffer for a transect for the bare ground habitat only
BareED	Edge Density for the Bare Ground Habitat	The total amount of edge for habitat patches within the 100 m buffer for a transect (for the bare ground habitat only) divided total area of the buffer.
BareAWMS	Area Weighted Mean Shape Index for the Bare Ground Habitat	A measure of complexity of shape for habitat patches within the 100 m buffer for a transect for the bare ground habitat only
HerbCA	Class Area for the Herbaceous Vegetation Habitat	Total area within the 100 m buffer for a transect for the herbaceous vegetation habitat only
HerbNumP	Number of Patches for the Herbaceous Vegetation Habitat	Total number of habitat patches within the 100 m buffer for a transect for the herbaceous vegetation habitat only

Table 2, con't. Clarification of habitat specific/class level FRAGSTATS variables used to explore habitat associations of birds at Matador Wildlife Management Area, Cottle County, Texas, 2017.

Abbreviation	Term	Definition
HerbMPS	Mean Patch Size for the Herbaceous Vegetation Habitat	Mean size of habitat patches within the 100 m buffer for a transect for the herbaceous vegetation habitat only
HerbPSCo	Patch Size Coefficient of Variation for the Herbaceous Vegetation Habitat	Variation in the size of patches within the 100 m buffer for a transect for the herbaceous vegetation habitat only
HerbED	Edge Density for the Herbaceous Vegetation Habitat	The total amount of edge for habitat patches within the 100 m buffer for a transect (for the herbaceous vegetation habitat only) divided total area of the buffer.
HerbAWMS	Area Weighted Mean Shape Index for the Herbaceous Vegetation Habitat	A measure of complexity of shape for habitat patches within the 100 m buffer for a transect for the herbaceous vegetation habitat only
WoodCA	Class Area for the Woody Vegetation Habitat	Total area within the 100 m buffer for a transect for the woody habitat only
WoodNumP	Number of Patches for the Woody Vegetation Habitat	Total number of habitat patches within the 100 m buffer for a transect for the woody vegetation habitat only
WoodMPS	Mean Patch Size for the Woody Vegetation Habitat	Mean size of habitat patches within the 100 m buffer for a transect for the woody vegetation habitat only
WoodPSCo	Patch Size Coefficient of Variation for the Woody Vegetation Habitat	Variation in the size of patches within the 100 m buffer for a transect for the woody vegetation habitat only

Table 2, con't. Clarification of habitat specific/class level FRAGSTATS variables used to explore habitat associations of birds at Matador Wildlife Management Area, Cottle County, Texas, 2017.

Abbreviation	Term	Definition
WoodED	Edge Density for the Woody Vegetation Habitat	The total amount of edge for habitat patches within the 100 m buffer for a transect (for the woody vegetation habitat only) divided total area of the buffer.
WoodAWMS	Area Weighted Mean Shape Index for the Woody Vegetation Habitat	A measure of complexity of shape for habitat patches within the 100 m buffer for a transect for the woody vegetation habitat only
WaterCA	Class Area for the Open Water Habitat	Total area within the 100 m buffer for a transect for the open water habitat only

Table 3. Total number of each avian species detected across all transects used to sample birds at Matador Wildlife Management Area, Cottle County, Texas, 2017.

Common Name	Zoological Name	Alpha Code	Total Number
Lark Sparrow	*Chondestes grammacus*	LASP	205
Northern Mockingbird	*Mimus polyglottos*	NOMO	137
Scissor-tailed Flycatcher	*Tyrannus forficatus*	STFL	85
Mourning Dove	*Zenaida macroura*	MODO	80
Golden-fronted Woodpecker	*Melanerpes aurifrons*	GFWO	70
Northern Bobwhite	*Colinus virginianus*	NOBO	66
Painted Bunting	*Passerina ciris*	PABU	64
Bewick’s Wren	*Thryomanes bewickii*	BEWR	63
Ash-throated Flycatcher	*Mylarchus cinearascens*	ATFL	55
Northern Cardinal	*Cardinalis cardinalis*	NOCA	52
Mississippi Kite	*Ictinia mississippiensis*	MIKI	50
Brown-headed Cowbird	*Molothrus ater*	BHCO	36
Bullock’s Oriole	*Icterus bullockii*	BUOR	36
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	26
Turkey Vulture	*Cathartes aura*	TUVU	23
American Kestrel	*Falco sparverius*	MAKE	21
Ladder-backed Woodpecker	*Picoides scalaris*	LBWO	21
Loggerhead Shrike	*Lanias ludovicianus*	LOSH	21

Table 3, con't. Total number of each avian species detected across all transects used to sample birds at Matador Wildlife Management Area, Cottle County, Texas, 2017.

Common Name	Zoological Name	Alpha Code	Total Number
Blue Grosbeak	*Passerina caerulea*	BLGR	17
Rufous-crowned Sparrow	*Aimophila ruficeps*	RCSP	17
Common Grackle	*Quiscalus quisculsa*	COGR	16
Cassin's Sparrow	*Peucaea cassinii*	CASP	15
Greater Roadrunner	*Geococcyx californianus*	GRRO	15
Black-crested Titmouse	*Baeolophus atricistatus*	BCTI	14
Eastern Kingbird	*Tyrannus tyrannus*	EAKI	9
Red-headed Woodpecker	*Melanerpes erythrocephalus*	RHWO	8
Yellow-billed Cuckoo	*Coccyzus americanus*	YBCU	8
Blue Jay	*Cyanocitta cristata*	BLJA	7
Blue-gray Gnatcatcher	*Polioptila caerulea*	BGGN	4
Killdeer	*Charadrius vociferus*	KILL	4
Western Kingbird	*Tyrannus verticalis*	WEKI	4
Yellow-shafted Flicker	*Colaptes auratus*	YSFL	6
Field Sparrow	*Spizella pusilla*	FISP	3
Green Heron	*Butorides virescens*	GRHE	3
Red-tailed Hawk	*Buteo jamaicensis*	RTHA	3
Eastern Phoebe	*Sayornis phoebe*	EAPH	2

Table 3, con't. Total number of each avian species detected across all transects used to sample birds at Matador Wildlife Management Area, Cottle County, Texas, 2017.

Common Name	Zoological Name	Alpha Code	Total Number
Empid Flycatcher	*Empidonax* sp.	EMPID	2
House Finch	*Haemorhous mexicanus*	HOFI	2
Pyrrhuloxia	*Cardinalis sinuatus*	PYRR	2
Burrowing Owl	*Athene cunicularia*	BUOW	1
Canyon Wren	*Catherpes mexicanus*	CAWR	1
Dickcissel	*Spiza americana*	DICK	1
Great Blue Heron	*Ardea herodias*	GBHE	1
Great Horned Owl	*Bubo virginianus*	GHOL	1
Lesser Goldfinch	*Spinus psaltria*	LEGO	1
Orchard Oriole	*Icterus spurius*	OROR	1
Vermilion Flycatcher	*Pyrocephalus rubinus*	VEFL	1
Western Meadowlark	*Sturnella neglacta*	WEME	1
Unknown			177
Total			1458
Total Used In Analysis			1281

Table 4. Significance of FRAGSTATS variables as determined by forward selection within a CCA for explaining patterns of avian communities at Matador Wildlife Management Area, Cottle County, Texas, 2017. Conclusion is in reference to whether or not the variable was retained for inclusion in a combined model.

Term	P-value	Conclusion
Landscape Level Mean Patch Size	0.005	retain
Landscape Level Edge Density	0.008	retain
Edge Density for the Woody Vegetation Habitat	0.009	retain
Mean Patch Size for the Bare Ground Habitat	0.017	retain
Number of Patches for the Woody Vegetation Habitat	0.034	retain
Class Area for the Open Water Habitat	0.037	retain
Area Weighted Mean Shape Index for the Bare Ground Habitat	0.044	retain
Patch Size Coefficient of Variation for the Woody Vegetation Habitat	0.049	retain
Class Area for the Herbaceous Vegetation Habitat	0.063	remove
Landscape Level Class Area	0.075	remove
Landscape Level Patch Size Coefficient of Variation	0.081	remove
Landscape Level Area Weighted Mean Shape Index	0.092	remove
Class Area for the Bare Ground Habitat	0.133	remove
Class Area for the Woody Vegetation Habitat	0.133	remove
Mean Patch Size for the Herbaceous Vegetation Habitat	0.167	remove

Table 4, con't. Significance of FRAGSTATS variables as determined by forward selection within a CCA for explaining patterns of avian communities at Matador Wildlife Management Area, Cottle County, Texas, 2017. Conclusion is in reference to whether or not the variable was retained for inclusion in a combined model.

Term	P-value	Conclusion
Number of Patches for the Herbaceous Vegetation Habitat	0.173	remove
Edge Density for the Bare Ground Habitat	0.191	remove
Patch Size Coefficient of Variation for the Herbaceous Vegetation Habitat	0.213	remove
Area Weighted Mean Shape Index for the Herbaceous Vegetation Habitat	0.223	remove
Landscape Level Shannon Diversity Index	0.302	remove
Patch Size Coefficient of Variation for the Bare Ground Habitat	0.311	remove
Area Weighted Mean Shape Index for the Woody Vegetation Habitat	0.312	remove
Edge Density for the Herbaceous Vegetation Habitat	0.326	remove
Mean Patch Size for the Woody Vegetation Habitat	0.339	remove
Landscape Level Number of Patches	0.346	remove
Number of Patches for the Bare Ground Habitat	0.575	remove

Table 5. Significance of microhabitat and invertebrate variables as determined by forward selection within a CCA for explaining patterns of avian communities at Matador Wildlife Management Area, Cottle County, Texas, 2017. Conclusion is in reference to whether or not the variable was retained for inclusion in a combined model.

Term	P-value	Conclusion
Percent Cover of Litter	0.010	retain
Shannon's Diversity Index for Insect Families	0.010	retain
Forb Species Richness	0.010	retain
Visual Obstruction in the Upper Zone	0.020	retain
Air Temperature at 1.5 m	0.049	retain
Acrididae Abundance	0.049	retain
Family Richness of Invertebrates	0.049	retain
Dictyopharidae Abundance	0.109	remove
Wind Speed at 1.5 m	0.119	remove
Visual Obstruction in the Lower Zone	0.129	remove
Family Evenness of Invertebrates	0.198	remove
Relative Humidity at Ground Level	0.218	remove
Ground Surface Temperature	0.297	remove
Percent Cover of Grass	0.307	remove
Tettigoniidae Abundance	0.327	remove

Table 5, con't. Significance of microhabitat and invertebrate variables as determined by forward selection within a CCA for explaining patterns of avian communities at Matador Wildlife Management Area, Cottle County, Texas, 2017. Conclusion is in reference to whether or not the variable was retained for inclusion in a combined model.

Term	P-value	Conclusion
Visual Obstruction at the Middle Zone	0.327	remove
Percent Bare Ground	0.337	remove
Chrysomelidae Abundance	0.347	remove
Percent Forb Cover	0.376	remove
Abundance of All Invertebrates	0.416	remove
Relative Humidity at 1.5 m	0.495	remove
Air Temperature at Ground Level	0.515	remove
Modified Simpson's Diversity Index for Invertebrate Families	0.535	remove
Species Richness of Grasses	0.654	remove
Windspeed at Ground Level	0.693	remove
Salticidae Abundance	0.871	remove

Table 6. Significance of FRAGSTATS, microhabitat, and invertebrate variables used in final combined model as determined by forward selection within a CCA for explaining patterns of avian communities at Matador Wildlife Management Area, Cottle County, Texas, 2017.

Term	P-value
Shannon's Diversity Index for Insect Families	0.003
Percent Cover of Litter	0.004
Forb Species Richness	0.004
Number of Patches for the Woody Vegetation Habitat	0.011
Landscape Level Mean Patch Size	0.011
Edge Density for the Woody Vegetation Habitat	0.013
Mean Patch Size for the Bare Ground Habitat	0.018
Class Area for the Open Water Habitat	0.031
Family Richness of Invertebrates	0.035
Area Weighted Mean Shape Index for Bare Ground Habitat	0.037
Acrididae Abundance	0.037
Visual Obstruction in the Upper Zone	0.087
Patch Size Coefficient of Variation for the Woody Vegetation Habitat	0.087
Air Temperature at 1.5 m	0.231
Landscape Level Edge Density	0.752

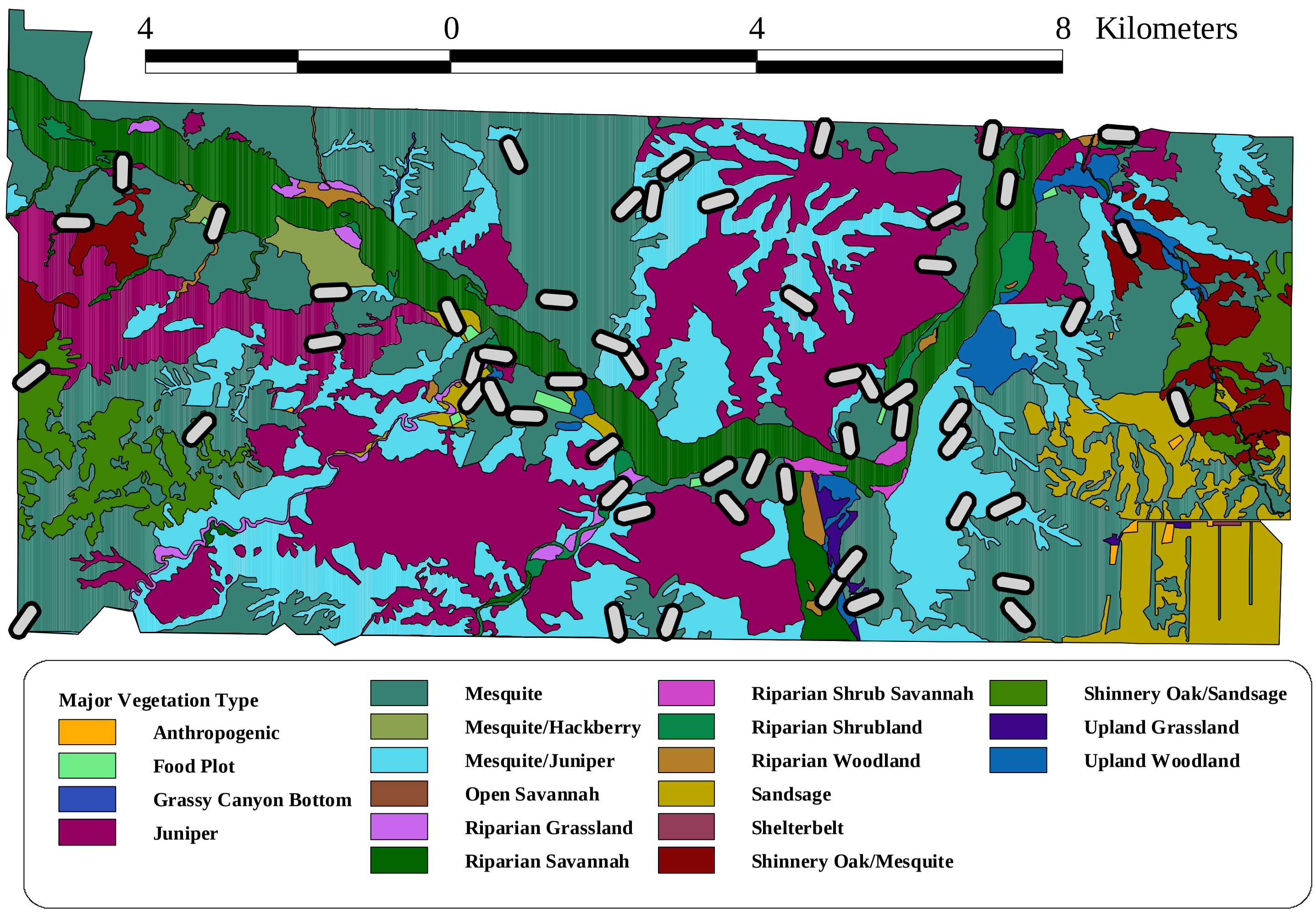

Figure 1. Locations of transects (100 m buffers represented by gray ovals with black borders) used to explore habitat associations of birds in relation to major vegetation types at Matador Wildlife Management Area, Cottle County, Texas.

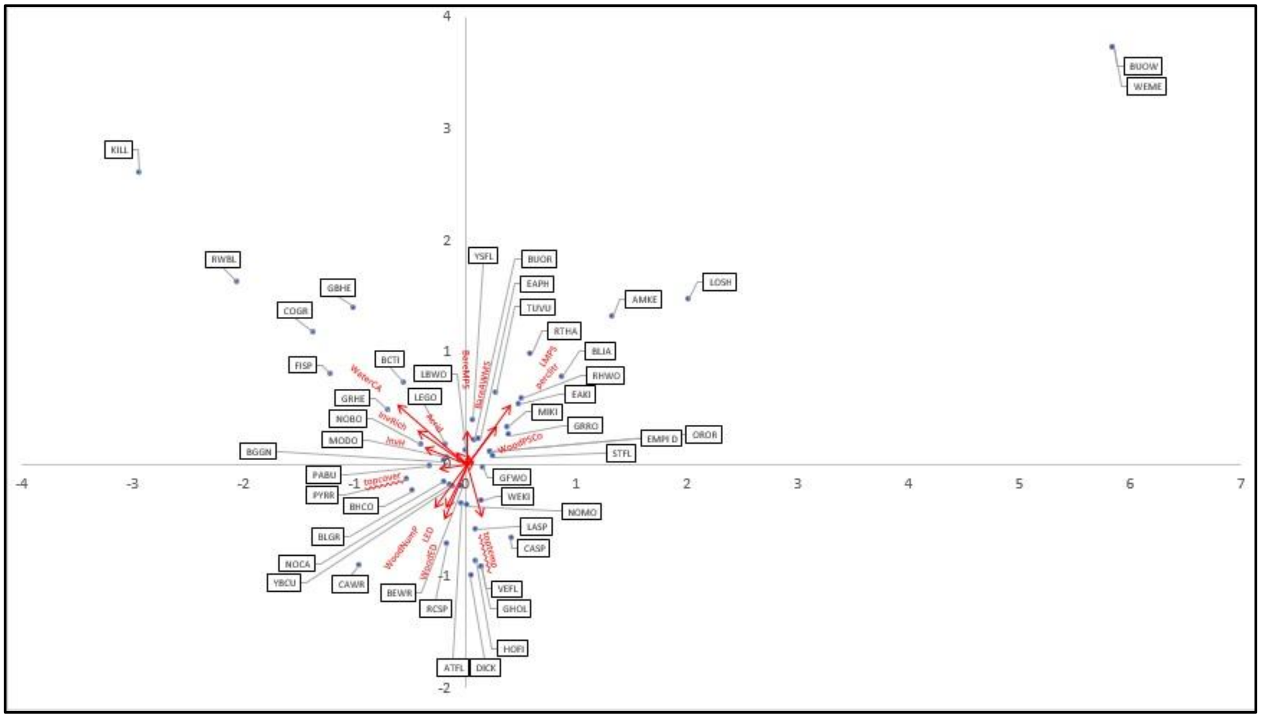

Figure 2. Canonical Correspondence Analysis biplot of species and environmental space for Axis 1 versus Axis 2 used to explore habitat associations of birds at Matador Wildlife Management Area, Cottle County, Texas, 2017. See tables 1-2 for explanation of variable abbreviations and table 3 for explanation of species alpha codes.